Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)

FINAL

Thunder Basin Phase II Watershed Management Plan
Level I Watershed Study
Lance and Lightning Creek

Submitted to:
Wyoming Water Development Commission

Prepared by:
Olsson Associates

In Association With:
ESCO Associates, Inc.
Wester Wetstein Associates
Steady Stream Hydrology, Inc.

September 2011

FINAL

Thunder Basin Phase II Watershed Management Plan

Level I Watershed Study

Lance and Lightning Creek

WWDC Contract Number 05SC0294198

September 14, 2011

I hereby certify that this report was prepared by us or under our direct supervision and that we are duly Licensed Professional Geologists and Engineers under the laws of the State of Wyoming.

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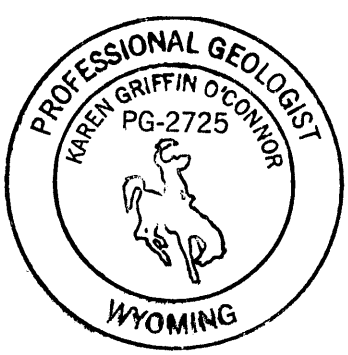

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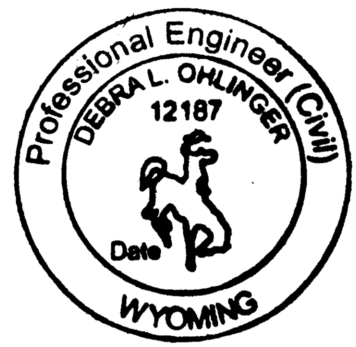


TABLE OF CONTENTS **PAGE**

Volume I

List of Figures

List of Photos

List of Tables

List of Appendices

Volume II

List of Maps

1.0 Introduction

Olsson Associates (Olsson) prepared the Thunder Basin Phase II, Lance and Lightning Creek (L&LC) Watershed Management Plan for the Wyoming Water Development Commission in accordance with Contract No. 055C0293618. The plan was prepared in association with ESCO Associates (ESCO) of Boulder, Colorado, Steady Stream Hydrology, Inc. of Sheridan, Wyoming, and Wester Westein & Associates of Laramie, Wyoming. The plan was prepared on behalf of the watershed landowners and the project sponsors including the Thunder Basin Grazing Association (TBGA), the Thunder Basin Grasslands Prairie Ecosystem Association (TBGPEA), and the two conservation districts that are represented in the Thunder Basin L&LC Watershed (Converse and Niobrara).

1.1 Purpose and Scope

The purpose of this Watershed Management Plan is to describe Thunder Basin L&LC watershed in its current condition, to suggest resolutions for any water related issues and provide insight into opportunities identified. Figure 1.1-1 provides a general location map and Map 1a-1e provides detailed watershed study boundaries with Township and Range information across the study area. As illustrated in Figure 1.1-1, the current study is directly south of a Level I study completed by the same team in 2009 (Olsson, 2009). Both Level I watershed studies include an extensive inventory and description of the watershed with scientific information on geology, hydrology, soils, climate, plant communities, wildlife habitat, infrastructure, and the geomorphic characteristics of the watershed stream system. The information gathered is intended to be used to develop proposed watershed improvements. Specific to this study, the project sponsors have requested an evaluation of surface and groundwater availability, the potential to develop upland livestock and wildlife water resources, and the potential to develop and enhance additional irrigation systems and water storage. Proposed projects are listed in the report and include cost estimates as well as information on project financing opportunities and project permitting considerations.

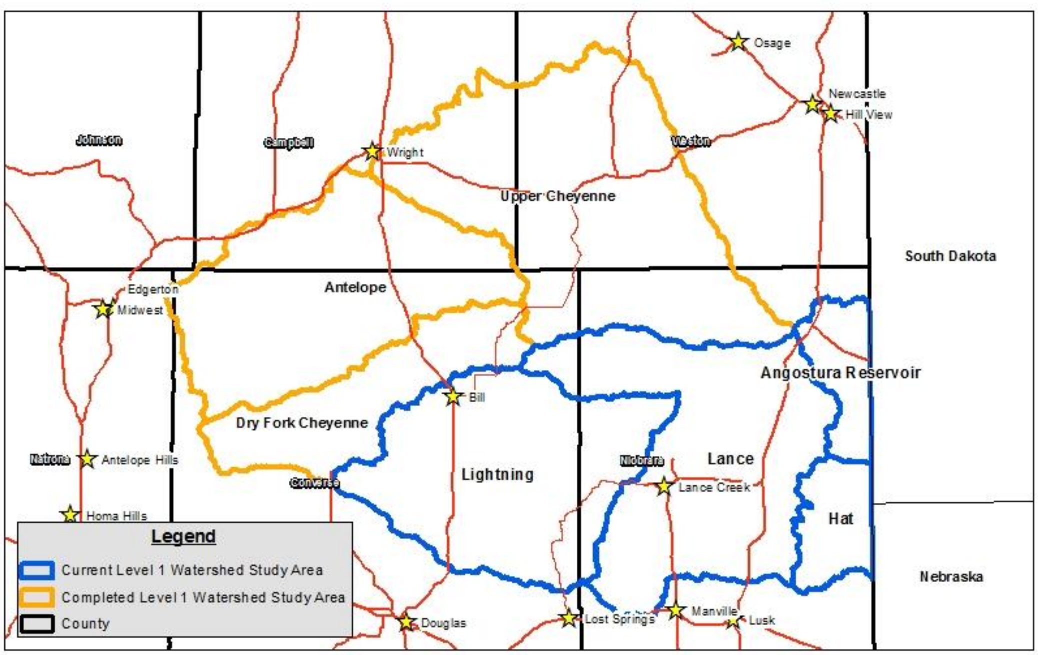


Figure 1.1-1 General Study Area Location Map of Thunder Basin and Thunder Basin L&LC Watershed Study Areas

1.2 Project Geographic Information System (GIS)

The information gathered as part of the Level I watershed study is compiled into a Geographic Information System (GIS) dataset. A list of the GIS layers developed for this project is provided in Data Summary 1.2-1 (In Appendix A). The GIS dataset is an electronic repository of the information gathered during the description and inventory phase of the project. With the GIS datasets, the user has the opportunity to overlay a series of maps to discern patterns and/or site proposed projects. The information includes mapped datasets on soil, geology, vegetation, wildlife, and infrastructure that is represented in a series of layers that can be "turned on" or "turned off" electronically. For the Thunder Basin L&LC project for example, the GIS maps were used by our hydrologists to differentiate the geomorphologic characteristics of the streams and to identify the potential impacts to wetlands and/or infrastructure at potential water storage sites.

Each map in this report contains a list of the data sources. The sources of information also are listed electronically in the metadata files for the layers. The major sources of data for the maps are as follows:

- Natural Resources Conservation Service (NRCS)
- U.S. Bureau of Land Management (BLM)
- U.S. Bureau of Reclamation
- U.S. Environmental Protection Agency (EPA)
- U.S. Department of Agriculture (USDA)
- U.S. Farm Service Agency (FSA)
- U.S. Forest Service (USFS)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Geological Survey (USGS)
- Wyoming Department of Environmental Quality (WDEQ)
- Wyoming Game and Fish Department (WGFD)
- Wyoming Geographic Information Science Center (WyGISC)
- Wyoming Oil and Gas Commission
- Wyoming State Engineer's Office (WSEO)
- Wyoming State Geological Survey (WSGS)
- Wyoming Water Development Commission (WWDC)

The information gathered for the Thunder Basin L&LC Watershed Study is presented in maps and datasets described throughout this report. The two-dimensional maps represent three-dimensional features and therefore the datasets were transformed using the Universal Transverse Mercator System (UTM), Zone 13 north. As specified in the contract, the GIS data is provided in electronic format using ArcGIS version 10.0 which is the current industry standard for GIS datasets.

1.3 Overview of Study Area Key Issues

Thunder Basin L&LC watershed lies in the northeast portion of Wyoming and includes Lance and Lightning Creeks which are the primary tributaries to the Cheyenne River System. The watershed is located in central and east Converse and central Niobrara counties (Maps 1a-1e, Study Area Location). The watershed encompasses approximately 1,572,390 acres of primarily grassland. The area has a robust livestock industry as well as mining and oil and gas development. For approximately ten years starting in 2000, the area has been abnormally dry and the drought conditions have exacerbated the need for additional water development and distribution.

The TBGA and TBGPEA, in conjunction with the two conservation districts (Converse and Niobrara), the BLM, NRCS, WWDC and other government agencies, have been promoting watershed improvement projects and best management practices across the area. With the extended drought conditions and the prospect of additional project support through the WWDC, the TBGA, TBGPEA, and the conservation districts decided to promote the completion of this Level I study in order to provide a comprehensive, multidisciplinary watershed management plan that will identify and begin to address the key issues facing the area. The intent was to produce a watershed management plan that would take into account the landowners' requests for future project improvements and also provide a comprehensive understanding of the current conditions of the watershed so that projects that will benefit a multitude of landowners and recreational visitors could be coordinated across the area.

In order to solicit landowner involvement and input, this project began with a series of bimonthly project meetings where information was solicited on specific project initiatives such as irrigation system upgrades, upland water development (wells), surface water storage, stream, rangeland enhancements as well as funding opportunities. Figure 1.3-1 depicts the project meeting information request forms sent to landowners across the project area. Responses from the request for information were compiled into a project database.

Thirty-nine, approximately 10 percent, of the landowners across Thunder Basin L&LC watershed responded to the request for information. Twenty-one landowners had no specific projects for evaluation; however, they asked to be kept informed of the project status. Three of the landowners had ranches outside of the watershed boundary. Based on their response, the WWDC and project sponsors decided to expand the areal extent of the project by including portions of Hat and Angostura Reservoir watersheds that are contiguous with Lance and Lightning Creek east to the South Dakota and Nebraska borders.

Of the remaining eighteen responses, four requested irrigation system evaluations, nine requested information on well development opportunities, eleven requested information on water storage sites and three were interested in stream and rangeland enhancements. Landowners that requested evaluation and granted site access were visited by the project team. Specific issues raised at project meetings, during the site visits, and in written responses included:

- *Irrigation Systems* – Less than 1 percent of Thunder Basin L&LC is irrigated and spreader dike systems are used as the standard for water distribution. There were several requests to upgrade spreader dike systems.
- *Groundwater Well Development* – Additional stock and wildlife water supplies are needed throughout the basin to enhance range conditions and habitat restoration. Solar wells were requested with pipelines, as needed, to encourage rotational grazing and reduce the distance cattle and wildlife must travel to water.
- *Water Storage Sites* – Most ranchers are interested in either rehabilitating existing small stock watering ponds or installing new small structures. There were a few ranchers that were interested in medium to large reservoirs, however, it was suggested that before any additional investigation be done on the larger structures that a water rights evaluation be completed.
- *Rangeland/Riparian Conservation* – Questions arose about what grasses would perform best in specific soil types with minimal precipitation and the increased frequency of grass fires.

With these specific key issues identified, the project team began a comprehensive evaluation of the watershed. The first stage of the study involved compiling a description and inventory of Thunder Basin L&LC watershed, as is described in the next section of this report.

Thunder Basin Watershed Improvement Study: Lightning and Lance Creeks

POTENTIAL PROJECT INFORMATION FORM

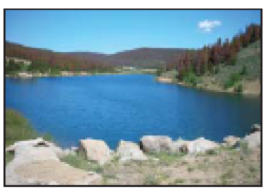
Name: ______________________________
Street Address: ______________________________
City/State/Zip: ______________________________
Location of property or allotment (township, range, section): ______________________________
Phone Number: ______________________________
E-mail Address: ______________________________

What is the best way to contact you? (please check) ___ mail ___ phone ___ e-mail

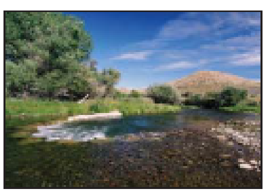
What improvement projects would you like to see evaluated as part of this watershed study?

Do you want an **irrigation system evaluation**? __ yes __ no
If so, do you have a project in mind? Please describe.

Do you want an **upland well development evaluation**? __ yes __ no
If so, do you have a project in mind? Please describe.



Do you want a **water storage evaluation**? __ yes __ no
If so, do you have a project in mind? Please describe.



Do you want a **stream/rangeland enhancement evaluation**? __ yes __ no
If so, do you have a project in mind? Please describe.

Other comments or ideas? (Please feel free to use the back of this form, if needed.)

Thank you for your comments!
Please return this form in the enveloped included by August 6, 2010.

July 2010

Figure 1.3-1 Landowner Request for Information Form

2.0 Watershed Description

The following section provides a description of the natural environmental features and resources of the Thunder Basin L&LC watershed. References are noted throughout the text and are listed in Section 9.0 to afford the reader sources of additional information on the specific topics discussed in this document.

2.1 Natural Environment

2.1.1 Basin Description

The Lightning and Lance Creek watersheds lie within the Powder River Basin, a geologic structural basin that is part of the Missouri Plateau of the Great Plains (Trimble, 1980). A structural basin is a geologic feature that is formed by rock strata dipping at various angles to a centralized area. The rock layers in the Powder River Basin were tilted from uplift of several structural features in the region, including the Big Horn Mountains and Casper Arch on the west, the Black Hills to the east, and the Hartville Uplift and Laramie Mountains to the south. To the north, the basin gently slopes upward towards the Miles City Arch, although the surface terrain in this area cannot be distinguished from the rest of the Missouri Plateau (Keefer, 1974). The region is characterized by rolling uplands dissected by tributaries of the Missouri River system. The Lightning and Lance Creek watersheds exist along the southern edge of the basin.

The study area watersheds consist of a dissected, rolling upland plain with low to moderate relief. The north to northeast oriented dissecting valleys originate along the southern edge of the study area in the uplands of the Hartville Uplift area. Buttes, mesas, hills, and ridges are present throughout the region, especially along the southern boundary of the Lightning watershed and throughout much of the southern and eastern portions of the Lance Creek watershed. Elevations range from 5,622 feet in the southwest area of the Lightning watershed to 3,693 feet in the far northeast corner of the Lance Creek watershed (Map 2, Ground Elevation Map). The present-day landforms have been shaped mostly by water action, even though modern-day precipitation is low and is greatly exceeded by evaporation. The incised drainages crossing the study area are mostly ephemeral or intermittent, and do not provide permanent sources of water along the entire drainage reaches. Runoff from surface precipitation can in places be augmented by groundwater-fed springs and seeps from shallow aquifers, particularly in the upper reaches of tributary drainages in the Lance Creek watershed (BLM, 2003).

2.1.2 Climate

2.1.2.1 Climate Overview

The climate of the Thunder Basin L&LC watershed can be classified as semiarid, steppe in the Kőppen climate classification system. The climate is influenced by several nearby and distant mountain ranges including the Absaroka and Wind River mountains approximately 200 miles to the west, the Bighorn Mountains approximately 75 miles to the northwest and the Laramie Mountains approximately 30 miles to the southwest. The Black Hills, about 50 miles to the northeast in western South Dakota, also influence the watershed. Moisture from the Pacific Ocean transported by westerly winds is primarily blocked by the Absaroka and Wind River mountains through autumn, winter and spring. During the summer months thunderstorms that develop on the eastern slope of the Bighorn and Laramie mountains can affect the watershed. During the winter months, Thunder Basin L&LC watershed is exposed to cold air masses that migrate down from western and central Canada. Periods of extreme cold air can persist for several days in the watershed. Down slope flow conditions, air moving from higher elevation to lower elevation from the Bighorn Mountains, Laramie Mountains, and Black Hills, can warm the air and reduce humidity levels.

2.1.2.2 Drought Conditions in Wyoming

The U.S Drought Monitor and the U.S. Drought Monitor maps for Wyoming use a scale referred to as the U.S. Monitor Intensity Scale. The scale is based on the combination of individual drought indices. The definition for each level of the scale, ranging from D0 to D4, is included on the U.S. Drought Monitor maps. In October 2010, most of the watershed was experiencing abnormally dry conditions, drought intensity D0. The October 2010 map identified the extreme western portion of the watershed as not experiencing drought conditions; however, caution should be used in interpreting drought conditions for specific points on the U.S. Drought Monitor map. The U.S. Drought Monitor maps are prepared across the entire country and specific locations can experience different drought conditions than identified on the generalized maps. Specific weather station data from Thunder Basin L&LC is provided in the next section. The 2010 U.S. Drought Monitor map (valid October 26, 2010) for Wyoming indicated moderate drought conditions in portions of Goshen and Laramie Counties in the southeast corner of Wyoming. Moderate drought conditions were identified in Sublette and Park Counties near the Absaroka and Wind River mountain ranges. Abnormally dry conditions existed for approximately half of Wyoming. According to the U.S. Climate Prediction Center, drought conditions were not found in the Thunder Basin L&LC watershed in 2011.

2.1.2.3 Weather Stations and Historic Precipitation Records

Map 3, Weather Stations, identifies seven weather stations within relative proximity to the area of interest in the Thunder Basin L&LC watershed. Of those, only the Redbird 1 NW weather station continues to operate. The time period covered by each weather station is listed next to each weather station in Table 2.1.2-1 (Western Regional Climate Center, 2010). Precipitation records for each of the listed weather stations can be found in Appendix B. The average monthly precipitation records, covering the years 1967 through 1978 for five of the seven stations, are listed in Figure 2.1.2-1. The average annual precipitation is 16 inches per year at the Redbird 1NW weather station. Historical records indicate mean annual snowfall from the seven weather station locations varies from 26.4 inches at the Lance Creek 3 WNW weather station to 73.3 inches at the Hat Creek 5E weather station. The period and extent of time covered for each weather station varies considerably and therefore it may be inaccurate to conclude that the range of mean annual snowfall values is due to spatial variation.

Table 2.1.2-1 – Precipitation Weather Stations Near Thunder Basin L&LC Watershed

Precipitation Station	Beginning Year	Ending Year
Bill	1948	1978
Hat Creek	1948	1967
Hat Creek 5 E	1967	1983
Keeline 3 W	1953	1987
Lance Creek 3 WNW	1962	1984
Redbird 1 NW	1948	Ongoing
Spencer 10 NE	1917	1974

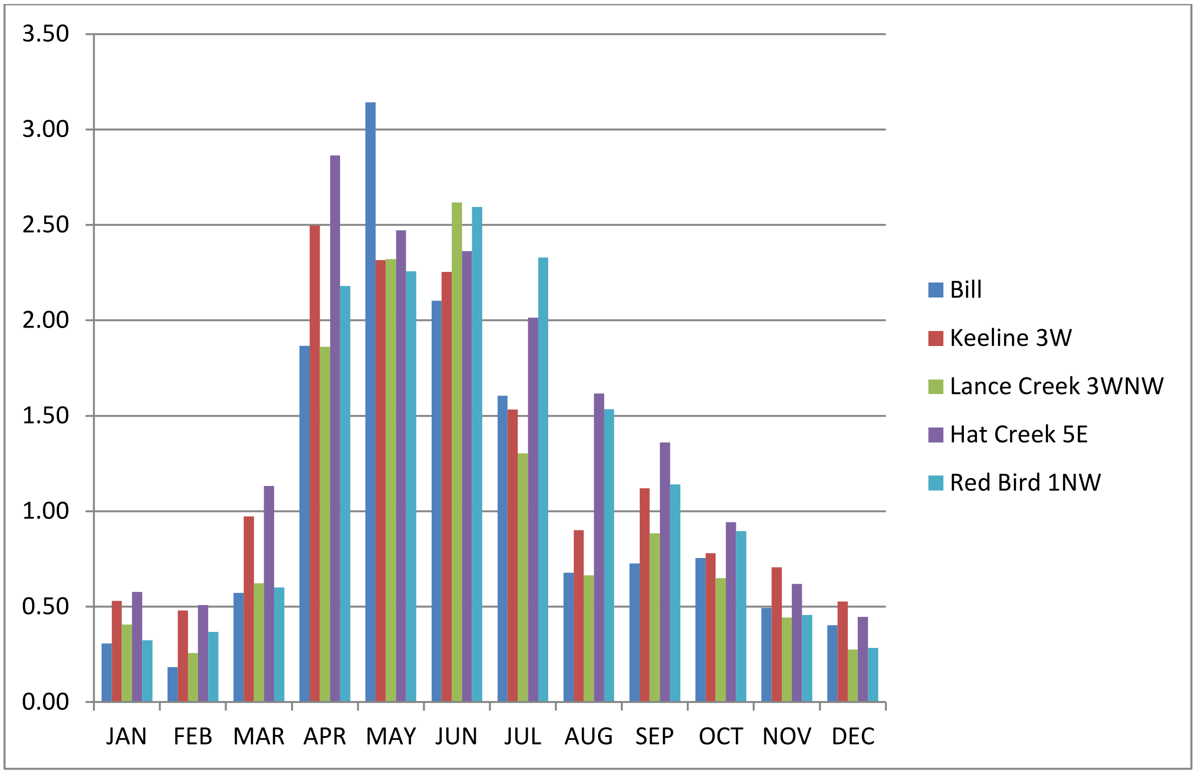


Figure 2.1.2-1 Average Monthly Precipitation (in inches) for Years 1967 through 1978

2.1.2.4 Precipitation Zones

Isohyetals of average annual precipitation for the entire state of Wyoming indicate the western portion of Thunder Basin L&LC watershed lies in a zone that receives less than 14 inches of precipitation per year. This is in contrast to the northwest part of the state where average annual rainfall is over 70 inches per year (Appendix B). This zonal average correlates well with annual average precipitation values indicated by the seven weather stations in the Thunder Basin L&LC watershed with Bill's average at 13.14 and Redbird at 15.92 inches of precipitation per year.

2.1.2.5 Temperature Climate

The Spencer 10 NE weather station climate dataset contains 58 years of climate data, the greatest amount of annual data of the seven weather stations in the watershed. Based on Spencer 10 NE climate data, the highest monthly mean maximum temperature occurs in July with a mean maximum monthly temperature near ninety degrees Fahrenheit (90° F). The lowest monthly mean minimum temperature occurs in January with a mean monthly temperature near five degrees Fahrenheit (5° F).

2.1.3 Vegetation and Land Cover

2.1.3.1 Overview

Based on precipitation records discussed in Section 2.1.2., the Thunder Basin L&LC area receives on average up to 16 inches of precipitation per year. Periodic declines in moisture delivery are responsible for conditions of moderate to severe vegetative stress, depending on how long the precipitation stays below average. Through periods of near average or greater moisture availability, mid-grasses are visually and physically dominant. Shortgrass cover, primarily blue grama (*Bouteloua gracilis*) is visually minimized during these times but upon return of severe moisture stress and the decline of mid-grass cover, the shortgrass cover can become visually dominant.

A representation of generalized vegetation conditions of Wyoming including the study area has been made using satellite spectral imaging data by the Wyoming Gap Analysis Program (www.wygisc.uwyo.edu/wbn/gap.html). This Land Cover/Vegetation map is presented in Map 4. A more detailed evaluation of potential natural vegetation and the dynamics of plant communities necessary to understand the way they exist on the ground are available by using the soils-based description of ecological sites that has been completed by the NRCS. Ecological sites of the project area are depicted on Map 5.

The bulk of upland vegetation is comprised of plant communities in which grasses are predominant, both biologically, and visually. These grasslands appear mostly in the form of mid-grass prairie in the eastern portion of the Study Area. In the uplands of the west and southwest portions, the grass component is joined by a substantial presence of big sagebrush (*Artemisia tridentata*, mostly subspecies *wyomingensis*). Shrub abundance varies both in responses to substrates and climate but also in response to range condition. Stress can encourage the establishment of shrubs as grass competition is lessened.

Based on current state and transition model information presented in the NRCS Ecological Site Descriptions (ESDs), most ecological sites of the Study Area can be expected to come to experience greater shrub cover as the effects of stress compound. It should be noted that ESDs for most of the study area are currently being revised to incorporate ongoing research into state descriptions and transition tipping points. This research suggests that grazing effects are likely not responsible for the presence of sagebrush in all cases. Extended drought is also an effective stressor. Some evidence also supports the view that sagebrush (and even abundant sagebrush) is a natural plant community component and not a vestige of stress, with abundance proportional to precipitation and snow cover (WGFD 2009). Ongoing research by TBGPEA supports this view as well.

Using a conceptual model of plant succession, the USFS found less than 10 percent of the nearby Thunder Basin National Grassland area (comprising approximately one-tenth of the study area) had proceeded to the oldest ("late seral") stage in which big sagebrush was highly abundant (USFS, 2007). Slightly more than one-third, on average, was in a less-developed intermediate stage with moderate shrub presence. Slightly more than one-half of the area was deemed to be in a relatively young stage, to intermediate stage, with comparatively little shrub presence. The latter areas may include areas from which sagebrush had been cleared by fires, with or without human involvement, or otherwise removed in cultivation or active range management. Regarding the latter, the history of homesteading and range improvement in the area has left scattered small areas of old or "go-back" fields that often after cultivation were planted to crested wheatgrass (*Agropyron cristatum*). Typically, these areas subsequently have been succeeded by native species, sometimes including big sagebrush.

Of the upland grassland and shrub-steppe vegetation, Thilenius et al, 1995 identifies the following major plant community associations:

- *Artemisia tridentata* (Wyoming big sage)/ *Bouteloua gracilis* (blue grama)/*Pascopyrum smithii* (western wheatgrass).
- *Artemisia tridentata* / *Pascopyrum smithii*

- *Bouteloua gracilis* – *Carex filifolia* (threadleaf sedge)
- *Hesperostipa comata* (needle-and-thread) - *Bouteloua gracilis*

Besides the species included in the above community names, grasses including Junegrass (*Koeleria macrantha*) and various bunch bluegrasses (now collectively referable to *Poa secunda*, with common names including Sandberg bluegrass, Canby bluegrass, big bluegrass, and alkali bluegrass), as well as the grass-likes threadleaf sedge (*Carex filifolia*) and needleleaf sedge (*Carex duriuscula*) are common. On sandier sites, silver sagebrush (*Artemisia cana*) and soapweed (*Yucca glauca*) may be common. Perennial forbs are numerous but not usually abundant and such species as scarlet globemallow (*Sphaeralcea coccinea*), American vetch (*Vicia americana*), scarlet gaura (*Gaura coccinea*), Hood's phlox (*Phlox hoodii*), and silverleaf scurfpea (*Psoralidium argophyllum*) are commonly present. Numerous annual plants are present, though highly variable in abundance depending on the moisture pattern of a given year. These plants include native species such as Indian plantain (*Plantago patagonica*), narrowleaf collomia (*Collomia linearis*), false pennyroyal (*Hedeoma hispida* and *H. drummondii*), and six-week fescue (*Vulpia octoflora*) in addition to non-native species such as alyssum (mostly *Alyssum desertorum*), Japanese brome (*Bromus arvensis*) and cheatgrass (downy brome, *Bromus tectorum*). The latter two species are winter annual plants that typically germinate in late summer and fall. They are often sufficiently abundant to compete with, and significantly reduce, the productivity of the native perennial species. This competitive advantage apparently is promoted by their early establishment and pre-emptive use of moisture and perhaps nutrient resources during the early growing season. Although palatable during early growing season, their presence in the plant community is regarded as a negative because of limited later season palatability, added fire hazard, and displacement of perennial plants.

Minor plant community components of the basin area include localized areas (Map 4, Land Cover/Vegetation) of ponderosa pine/bluebunch wheatgrass (*Pinus ponderosa / Pseudoroegneria spicata*) woodland underlain by sandy and rocky substrate (as well as salt-affected sites underlain by members of the Fort Union and Lance formations that support greasewood communities (*Sarcobatus vermiculatus*/ *Pascopyrum smithii - Bouteloua gracilis*) or desert sub-shrubs such as Gardner's saltbush (*Atriplex gardneri*) or birdsfoot sage (*Artemisia pedatifida*).

2.1.3.2 Targeted Vegetation

Vegetational components that have particular importance with respect to water resources of the Thunder Basin Water Management Area include the phreatophytic Russian olive (*Elaeagnus angustifolia*) and salt cedar (*Tamarix chinensis*), both of which are listed noxious weeds in Wyoming. These non-native shrubs / small trees are known to access stored moisture at great depth and to transpire large amounts, diminishing both groundwater availability and stream flows. Areas densely infested with salt cedar may be capable of removing from the soil (and transpired through leaves and stems) 2.1 cubic meters per square meter per year (Horton and Campbell 1974). This rate translates to approximately 6.9 acre feet per acre per year.

Salt cedar is capable of becoming established far from known populations and into areas with only the slightest moisture accumulation. The USFS (2007) states that salt cedar has recently begun to appear on the Cheyenne River as well as along some of its tributaries. The TBGA and TBGPEA have partnered with the National Wild Turkey Federation and Converse County Weed & Pest in an ongoing effort to control salt cedar and Russian olive on the Thunder Basin National Grassland.

Russian olive has been present in the basin for decades, having survived from early farmstead plantings as isolated trees. This plant in other western U.S. drainage basins has exhibited a period of benign presence followed by a rapid radiation, perhaps as a result of natural selection-based adjustment to the environmental particulars of the region. From available evidence, it would appear that a stage of rapid radiation has not begun in the study area.

If allowed to proceed, new establishment of stands of Russian olive and salt cedar can produce dense thickets. This can, in turn, increase phreatophytic depletion of massive amounts of shallow groundwater. Besides the loss of water, the dense thickets can be expected to shade out and out-compete previously existing riparian species, including the native cottonwoods (*Populus deltoides*) and willows (*Salix* spp.). Other noxious weeds present in the study area include leafy spurge (*Euphorbia esula*) and diffuse knapweed (*Centaurea diffusa*) in the Lightning Creek watershed (BLM, 2005) as well as occurrences of hoary cress (*Cardaria draba*), diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*Centaurea maculosa*), houndstongue (*Cynoglossum officinale*), leafy spurge (*Euphorbia esula*) and Scotch thistle (*Onopordum acanthium*) in Converse and Niobrara Counties documented between 2000 and 2011 (Rice 2011). The most abundant and the one most typical of moisture accumulation sites is Canada thistle (*Cirsium arvense*). To the extent that any of these noxious weeds displace diverse native plant communities to form extensive monocultures, they may not only diminish livestock and wildlife forage values, but they may negatively influence watershed function.

In addition, the distribution of cheatgrass and Japanese brome across the watershed is of concern. High prevalence of fine litter left by these plants can increase fire frequency and extent. Fires tend to enhance the spread of annual bromes in many circumstances.

2.1.4 Soils

Soil surveys have been completed throughout the Lightning and Lance Creek watersheds and are available online through the NRCS (http://SoilDataMart.nrcs.usda.gov/). Map 6 illustrates the STATSGO (STATe Soil GeOgraphic) Soil Survey as prepared by the NRCS and Table 2.1.4-1 lists the acreages associated with each soil type. Additionally, the SSURGO (Soil SURvey GeOgraphic) Soil Survey data is incorporated in the GIS dataset included electronically with this report. The SSURGO Soil Survey map is too detailed to show at the scale of the maps in this report.

As stated in the data description for the NRCS SSURGO Soil Survey map, the data set is a digital soil survey and generally is the most geographically detailed level of soil data developed by the National Cooperative Soil Survey. The information was prepared by digitizing maps, by compiling information onto a planimetric-correct base and digitizing, or by revising digitized maps using remotely sensed and other information. The data set consists of a detailed, field verified inventory of soils and miscellaneous areas that normally occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The SSURGO Soil Survey map depicts information about the kinds and distribution of soils on the landscape. The soil map and data used in the SSURGO product were prepared by soil scientists as part of the National Cooperative Soil Survey.

Both the STATSGO and SSURGO Soil survey interpretations predict soil behavior for specified soil uses and under specified soil management practices. For the purposes of this study, they assist the planning of broad categories of land use such as cropland, rangeland, and pastureland. Soil survey interpretations also help plan specific management practices that are applied to specific soils, such as irrigation of cropland, or equipment use. Soil interpretations use soil properties and qualities that directly influence a specified use of the soil. These properties and qualities include: (1) site features, such as slope gradient; (2) individual horizon features, such as particle size; and, (3) characteristics that pertain to soil as a whole, such as depth to a restrictive layer. Data Summary 2.1.4-1 (In Appendix A) lists the specific soil properties and qualities available on the soil associations and specifies the report containing the tabular data.

Table 2.1.4-1 Thunder Basin L&LC Watershed STATSGO Soil Types

Soil Type	Acres	Percent
Draknab-Clarkelen (s9067)	20,429	2%
Shingle-Hiland (s9073)	277,093	21%
Taluce-Shingle-Cushman (s8932)	200,864	15%
Tassel-Shingle-Rock outcrop (s9075)	348,638	26%
Samday-Pierre-Bone (s8913)	117,504	9%
Wibaux-Shingle-Rock outcrop (s9070)	7,239	1%
Ustic Torriorthents-Hiland-Bowbac (s9068)	43,163	3%
Ulm-Renohill (s9074)	48,375	4%
Savageton-Samday-Mitchell-Heldt-Cambria-Bahl (s8915)	202,039	15%
Trelona-Tassel-Rock outcrop-Dix-Busher (s4955)	31,794	2%
Vetal-Otero-Jayem (s8991)	21,804	2%
Vetal-Tassel-Sarben-Manter-Jayem-Busher (s4860)	20,738	2%
Wendover-Rock outcrop-Motoqua (s8989)	10	0%
Total Area	1,339,689	100%

As described in the Powder River Basin Oil and Gas Final Environmental Impact Statement, (BLM, 2003), soils within the study area watersheds have developed in residual material and alluvium in a climatic regime characterized by cold winters, warm summers, and low-to moderate precipitation. The upland soils are derived from both residual material (derived from flat-lying, interbedded sandstone, siltstone, and shale) and stream alluvium. Valley soils have developed in unconsolidated stream sediments including silt, sand, and gravel. Soils in the study area watershed are generally low in organic matter and are alkaline (Lowry et al. 1986). Textures range from clay loams to sandy loams with varying amounts of gravel or coarser materials. Slopes range from nearly level to very steep with deeper soils found in the less steeply sloped areas. These soils support little crop agriculture except in irrigated valleys of perennial streams. Across the Lightning and Lance Creek watersheds the predominant land use is rangeland and the vegetation developed on the soils is predominantly grass and shrubs, with limited areas of irrigated pastures along Lance Creek below its confluence with the Lightning Creek drainage.

2.1.5 Geology

The following five subsections (surficial units, bedrock units, structural features, slope stability, and seismotectonics) describe the overall geologic framework of the Lightning and Lance Creek watersheds.

2.1.5.1 Surficial Units

Map 7 illustrates the surficial geology of the Thunder Basin L&LC watershed. The surficial geology can generally be divided into three unique categories: 1) bedrock, residuum, and mined areas; 2) alluvial valley deposits; and 3) upland deposits. Aspects of each of these deposits as they relate to the watershed are described as follows.

The surficial geology map of the watershed demonstrates that the geologic materials at the land surface primarily consist of residuum, alluvial (water-transported) and eolian (wind-transported) deposits. Residuum refers to weathered debris eroded from underlying bedrock that remains in situ (little to no transport) and forms a veneer of sediment on bedrock surfaces. In many locations, residuum can be combined with eolian and alluvial deposits. Alluvium, found predominately in the watershed valleys, is comprised of sediment ranging in size from clay to gravel. The particle size and distribution of alluvium is dependent on the energy of the transport mechanism (river or stream) at the time of sediment deposition. Eolian deposits are fine-grained (silt to clay size) materials, transported and deposited by wind with relatively uniform grain size distribution due to separation from larger particles during transport.

The alluvial deposits mantling the watershed drainages are critical to the watershed since they can potentially be used to identify a location for groundwater development and in some areas, indicate a location with baseflow to surface drainages. The alluvium is typically coarser grained than eolian and residuum deposits and can include alluvial fans, alluvial terraces, and slopewash. Because of the coarser texture of deposits in alluvial settings, greater opportunity exists for infiltration and recharge of precipitation to the subsurface that creates alluvial aquifers. Five distinct southwest-northeast oriented alluvium-filled valleys cross and converge in the northeast corner of the Lightning watershed. Three well-defined alluvial valleys with axes approximately in a north south orientation cross the Lance Creek watershed and one additional east-west oriented alluvial valley drains the northwest corner of the Lance Creek watershed. Further discussion on these alluvial valley aquifers can be found in Section 2.1.6.1, alluvial aquifers.

Most of the upland areas in the Lightning watershed are comprised of residuum overlying shallow bedrock combined with eolian deposits, alluvium, and slopewash. In the Lance Creek watershed, the upland areas consist of residuum, slopewash, and colluvium especially in areas of steeper topography, such as the eastern edge of the study area paralleling US Highway 85 north of the town of Lusk.

Small zones of red clinker deposits can be found in the northwest corner of the Lance Creek watershed. Although not as extensive in the Lightning and Lance Creek watersheds as compared to areas to the north, clinker is a distinct geologic deposit worthy of description since it is found in the Lance Creek watershed and plays an important hydrologic role regionally in the Thunder Basin. As described in the Powder River Basin Environmental Impact Statement (BLM, 2003):

> *"Generally, clinker consists of fractured rock on a base of porous ash. Semipermeable clay frequently underlies clinker formations (Heffern and Coates, 1999). This structure allows clinker to absorb, store, and transfer large amounts of water. The quality of water from clinker aquifers is highly variable, but in general, Total Dissolved Solids (TDS) values are lower for older formations (Heffern and Coates, 1999). The irregular terrain of clinker formations provides a unique habitat for plant and animals species that would otherwise not survive on the treeless plain*

(Heffern and Coates, 1999). Clinker is not considered a valuable agricultural soil and has a very poor revegetation potential."

Clinker is resistant to erosion and is typically found on elevated, exposed surfaces within the watershed. Because of the capability to store and transport appreciable amounts of water, springs can sometimes be found in areas of exposed clinker. Further discussion on potential water resources in the mapped clinker areas of the Lance Creek watershed can be found in section 2.1.6.3, Springs. The remaining exposed bedrock and mined areas are described in Section 2.1.5.2, Bedrock Units.

2.1.5.2 Bedrock Units

Bedrock units ranging in age from Paleozoic to Tertiary time are present in the Thunder Basin L&LC watershed (Map 8, Bedrock Geology). The shallow bedrock formations that underlie surficial deposits or are exposed in outcrops have played an important role in soil formation and other geomorphic processes in the study area. Across the two watersheds, the bedrock units are youngest (Tertiary) on the west and southeast fringes of the study area, with the oldest formations (Cretaceous, Jurassic, and Paleozoic) exposed in the upland areas of the Lance Creek watershed. Within the Lightning and the northwest corner of the Lance Creek watersheds, the four shallow bedrock units from youngest to oldest (west to east) include:

- Tertiary Wasatch Formation
- Tertiary Fort Union Formation - Lebo member
- Tertiary Fort Union Formation - Tullock member
- Cretaceous Lance Formation

The Eocene age Wasatch Formation consists of fine- to coarse-grained, lenticular sandstone interbedded with shale and coal (Hodson, 1973). The sandstone units sandwiched between the thick coal beds are the primary aquifers of the Wasatch Formation. The formation can be up to 1,600 feet thick (HKM, 2002a).

The Fort Union Formation (Paleocene age) was deposited by northeast-flowing river systems consisting of braided and meandering streams in the basin center that were fed by alluvial fans associated with uplift of the margins of the Powder River Basin. The Fort Union ranges from 2,300 feet to 6,000 feet in thickness (Curry, 1971) and is subdivided into three members; 1) Tullock, 2) Lebo, and 3) Tongue River. The members consist of interbedded sandstones, siltstones, claystones, mudstones, carbonaceous shales and rare limestones. The Lebo and Tullock members have thin coal beds (Curry, 1971).

The Cretaceous Lance Formation is also continental in origin with sandstones, siltstones, and claystones. The Lance Formation ranges from 1,600 to 3,000 feet in thickness in the southern portion of the Powder River Basin (Feathers et al, 1981). The Lance Formation is stratigraphically below and older than the Wasatch and Fort Union Formations.

In the northern half of the Thunder Basin L&LC watershed, two older Cretaceous formations, the Fox Hills and the Pierre, join the Lance Formation as the primary bedrock units beneath the surficial deposits. The Fox Hills Formations, often termed the Fox Hills Sandstone, is near-shore marine in origin with intervals of shale that exists stratigraphically below the Lance Formation. The thickness of the Fox Hills Formation can approach 450 feet (USGS, 2005). The Pierre Formation, commonly known as the Pierre Shale, ranges from about 700 to over 3,000 feet thick and is composed of dark grey shale, bentonite, and minor amounts of sandstone. On the eastern side of the Lance Creek watershed, Pierre Shale thickness has been estimated at over 3,000 feet (Gill and Cobban, 1966).

Near the eastern boundary of the Thunder Basin L&LC watershed, older Cretaceous and Jurassic formations are exposed in a structural upwarp (anticline) of the bedrock. Exposures of the Cretaceous and Jurassic bedrock units are also found in isolated areas in the southern half of the Thunder Basin L&LC watershed. Included in these Cretaceous units are (from youngest to oldest) the Niobrara Formation, Carlile Shale, Greenhorn Formation, Belle Fourche Shale, Mowry Shale, Newcastle Sandstone, Skull Creek Shale, Fall River Formation, Fuson Shale, and the Lakota Formation. These formations are mostly marine and continental margin in origin and are comprised of shale, sandstone, siltstone, mudstone, limestone, marl, bentonite, and chalk. Exposed at the center of the anticline are the Jurassic-age Morrison (claystone, limestone, sandstone), Sundance (sandstone and shale), and Gypsum Spring (shale and gypsum) Formations (Love and others, 1987).

In the southern half of the Thunder Basin L&LC watershed, the shallow bedrock is comprised of the Tertiary-age Arikaree and White River Formations. The younger Arikaree Formation is composed of fine-grained sandstone with some lesser amounts of limestone, siltstone, and volcanic ash deposits. The Arikaree Formation can range in thickness from 0 to 600 feet. The older White River Formation is primarily claystone and siltstone with thin beds of volcanic ash deposits and limestone. Isolated intervals of poorly cemented sandstone can be found in some areas. White River Formation thickness can range from 0 to 500 feet in the study area (Love and others, 1987).

Along the southern edge of the Thunder Basin L&LC watershed boundary about six miles north of the town of Lusk, Paleozoic rocks are exposed along a topographic high called Sullivan Ridge. The Paleozoic rocks are part of the Guernsey and Hartville Formations, which are primarily limestone and dolomite units interbedded with sandstone and shale. Undifferentiated metamorphic rocks (meta-sedimentary and meta-volcanic) are also exposed along Sullivan Ridge.

2.1.5.3 Structural Features

Thunder Basin L&LC watershed lies within the Powder River Basin, a northwest-southeast trending structural basin that was filled with sediments of continental origin eroded and transported from the surrounding uplifted margins (Brown, 1993). The Powder River Basin formed approximately 60 million years ago (Glass and Blackstone, 1996) during the Laramide Orogeny, the mountain-building event that formed the Rocky Mountains. The margins of the basin are asymmetrical with the western margin closer to the axis than the eastern margin. Figure 2.1.5-1 shows a regional map of the basin and related structural features. Rock layers dip gently several degrees throughout much of the eastern two-thirds of the basin. However, layer dips steepen along the western margins of the Powder River Basin. A generalized geologic cross section across the Powder River Basin is shown in Figure 2.1.5-2. Note that this cross section is north of Thunder Basin L&LC watershed but is indicative of the structural features within the study area. The significance of the structural basin that defines this area of northeast Wyoming cannot be overstated. The tectonic events of the Laramide Orogeny affected the outcrop patterns which thus influenced soil development, aquifer characteristics, groundwater flow patterns, oil, gas, coal, and methane deposits, as well as the topographic relief of the region.

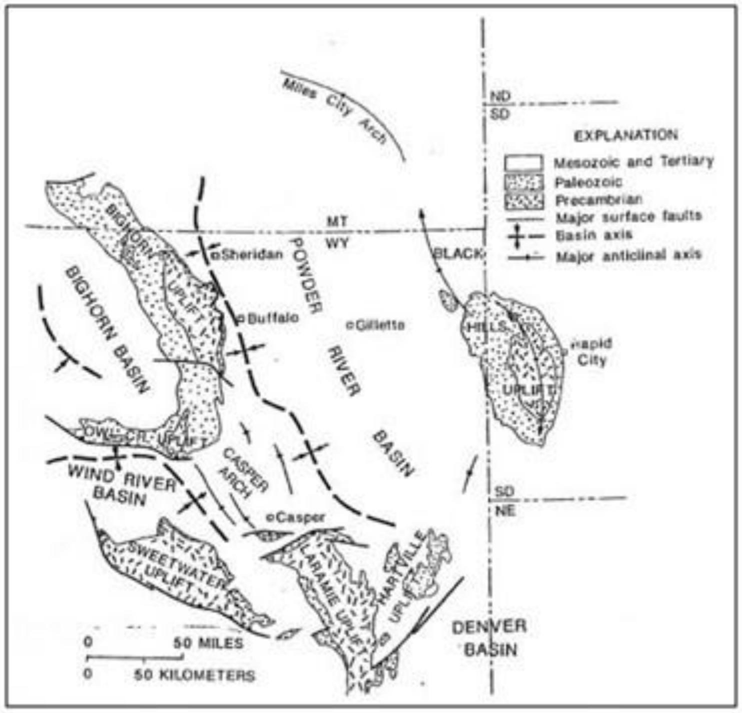


Figure 2.1.5-1 Structural features of the Powder River Basin and surrounding areas (Dolton et al., 1988).

The Thunder Basin L&LC watershed is flanked on the south and east by an extensive anticlinal structure known as the Hartville Uplift. This area of upwarp in the bedrock separates the Powder River Basin from the Denver Basin to the south. The anticline developed during the time of the Laramide Orogeny (late Cretaceous) and extends from the east flank of the Laramie Mountains northeast to the Black Hills uplift area of South Dakota. Direct observable evidence of the regional uplift can see on the eastern side of the Thunder Basin L&LC watershed where the Old Woman anticline exposes the upward tilting Cretaceous and Jurassic formations described in the Bedrock Units section (Sims and Day, 1999). At least three mapped faults cross the south central portion of the Thunder Basin L&LC watershed including the Lance Creek thrust fault that exhibits influence on the orientation of the Lance Creek alluvial valley (Johnson and Micale, 2008). The types of faults found in the study area can also exhibit influence on aquifer characteristics, and thus the potential for groundwater development in the watershed.

The present-day watersheds, oriented in the north-northeastward direction, were formed as runoff from the topographically higher regions flowed northward in post-uplift times.

2.1.5.4 Slope Stability

According to the WSGS, landslides (often termed *mass wasting*) occur when a slope becomes unstable. Rock falls, debris flows, slumps, and creep are all types of landslides. These processes can cause considerable damage: they can cover or destroy roads, carry mobilized houses downslope, and temporarily block rivers with unstable earthen dams, which can cause flash-flooding downstream when compromised. The WSGS has mapped more than 30,000 landslides in Wyoming, and maintains a database of these locations. Landslides of significant size or scale have not been mapped in the study area watersheds. Although not mapped, there are known landslides in both the Red Hills and Rochelle Hills just north of Thunder Basin L&LC.

A persistent landslide in the Rochelle Hills has permanently closed a section of Forest Service Road 933.

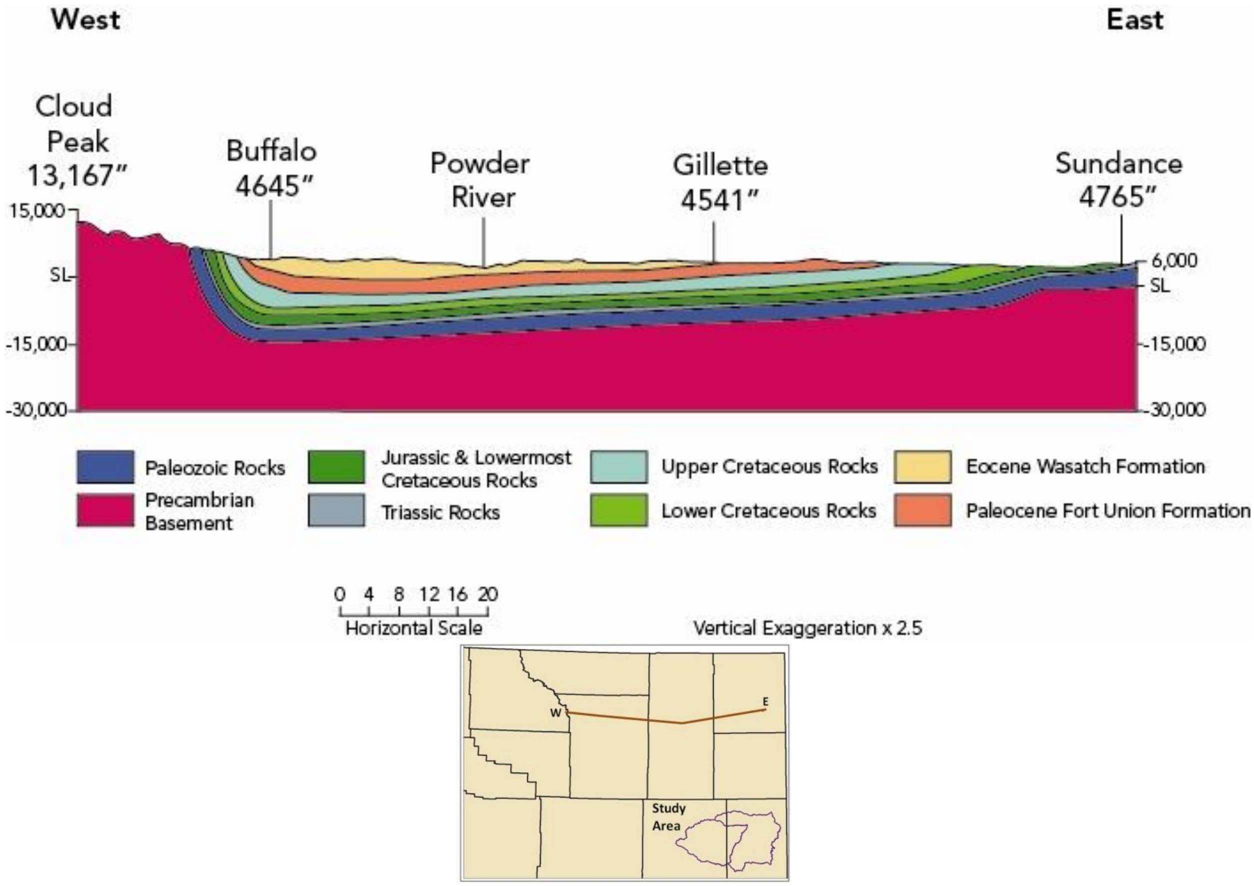


Figure 2.1.5-2 - Conceptual cross-section of the Powder River Basin from west to east. This cross-section is north of the Lightning & Lance Creek watersheds, but is indicative of the structural features within the study area (DeBruin et al., 2000).

The lack of WSGS mapped landslides within the study area does not relieve project sponsors from evaluating the hazards of slope instability on specific sites prior to project implementation. Small, localized slope failures can occur along the banks of active channels. Slope instability increases after material saturation following storm events when undercutting of stream banks is most intense. For this reason, watershed improvement projects should include site-specific geological hazard analyses, including an evaluation of the site's susceptibility to landslides.

2.1.5.5 Seismotectonics

According to the WSGS, earthquakes occur daily in Wyoming, but are rarely strong enough to be felt by humans. Most earthquakes occur in and around Yellowstone National Park in northwest corner of the state. However, earthquakes can and have occurred in eastern Wyoming. There have been 29 historic earthquakes recorded in Converse County with magnitudes of 3.0 or greater and eight greater than 3.0 in Niobrara County. According to the WSGS, the strongest measured earthquake within the region was a magnitude 5.5 event that occurred southwest of Casper on October 18, 1984. The earthquake was also felt in Montana, South Dakota, Nebraska, Kansas, Utah, and Colorado. Building damage was reported in the cities of Casper, Douglas, and Lusk (Case and Green, 2000). The WSGS has published seismology characteristics for the entire Thunder Basin L&LC watershed that are listed by county and are available on the WSGS website. Watershed improvement projects that involve significant disturbance or construction efforts should include site-specific geologic hazard analyses including a seismotectonic evaluation.

2.1.6 Groundwater

Groundwater in the Thunder Basin L&LC flows within the pore spaces of shallow alluvial sediments described in Section 2.1.5.1 (Surficial Units) and within the rock materials described in Section 2.1.5.2 (Bedrock Units) of this report. The following subsections provide more information on the quantity and quality of groundwater available in the two specific aquifer types, as well as from the springs that discharge groundwater to the surface. The physical properties such as hydraulic conductivity and transmissivity (measurable characteristics that describe how effectively aquifers can transmit water), as well as the chemical composition of the aquifer materials are important to establish so that productive wells with high water quality can be proposed for watershed improvement projects.

2.1.6.1 Alluvial Aquifers

Alluvial aquifers occur in the alluvial valleys located along the major drainages of the watersheds. Map 7 (Surficial Geology) illustrates the location of the alluvial deposits in the study area watersheds. Whitehead (1996) described the aquifer materials comprising the alluvial aquifers in the area as unconsolidated deposits of silt, sand, and gravel occurring in floodplains, stream terraces, and alluvial fans. The thickness of alluvial deposits is not known throughout the watersheds because of the inherent variability in alluvial depositional environments and the lack of geologic borehole information in parts of the watershed (Hodson et al. 1973). Wells (1982) reported that alluvial valley deposits in the Powder River basin are typically 30 feet in thickness, with a maximum measured thickness of 100 feet.

Presently, the number of alluvial versus bedrock wells within the study area watersheds is not known. However, estimates can be made based on well location, well completion depth, and well yield. Evaluation of well depth information from the WSEO for all wells identified within or bordering the alluvial valleys (Map 7, Surficial Geology) revealed that 98 of the 384 wells within the valleys have a depth of 75 feet or less. Well yields for these alluvial wells range from 1 to 370 gallons per minute (gpm). The highest yielding wells (300 gpm or greater) according the WSEO database are located in the Lance Creek alluvial valley in the north central portion of the Lance Creek watershed. In this area, the alluvial valley is wider than most of the tributary valleys in the study area, which increases the opportunity to receive recharge from precipitation. Well depths for these productive wells range from 37 to 68 feet.

Water quality of the aquifers within the Powder River Basin is described in Bartos and Ogle (2002) and Rice et al, (2000). The authors subdivide the primary aquifers as shallow (200 to 500 feet) to deep (500 feet or greater). The shallow groundwater system exhibited a chemically dynamic system with localized flow consisting of groundwater with a mixed composition of ions. The shallow system was described as containing calcium, magnesium, and lesser amounts of sodium cations (positively charged ions), and bicarbonate or sulfate as the dominant anions (negatively charged ions). The deep system is chemically static and exhibits regional flow patterns, with sodium and bicarbonate as its dominant ions. Additional information on the water quality aspects of the bedrock aquifers is described below.

2.1.6.2 Bedrock Aquifers

The bedrock aquifers underlying the study area have been studied and described by numerous authors. The bedrock aquifers are part of the Northern Great Plains aquifer system that has been described as "an extensive sequence of aquifers and confining units arranged in a stack of layers that may be discontinuous locally but that functions regionally as an aquifer system" (BLM, 2003). Confining units are geologic strata with low permeability, typically consisting of silt, clay, or shale that is bedded on top of or between more transmissive geologic materials (aquifers). Despite having permeabilities much lower than aquifers, confining units can store and slowly transmit water to aquifer formations. In the southern portion of the Powder River Basin, the aquifer system includes specifically the Tertiary aquifers exposed at the surface, as well as the deeper regional aquifers within older sedimentary rocks deposited through much of the Cretaceous Period and during the late Paleozoic Period. Data Summary 2.1.6-1 (Appendix A) contains information on the bedrock aquifers. For the purposes of this report, the following major aquifer systems will not be discussed because they do not occur within the study area watersheds or are too deep and would be too costly to complete and maintain for livestock/wildlife and irrigation purposes:

- Dakota Aquifer System (Newcastle, Fall River, and Lakota Formations) and other minor Cretaceous aquifers below the Lance and Fox Hills formations
- Madison Aquifer System (Madison and other Paleozoic carbonate formations)

The following summarizes information from Data Summary 2.1.6-1 (Appendix A) on the well yield, general water quality, and water supply uses for the remaining bedrock aquifers within the study area:

- The *Arikaree Formation* is the primary unit of what is termed by some authors as the Middle Tertiary aquifer system and is the primary bedrock aquifer only near the southern margin of the Lance Creek watershed. The formation has been observed to yield from 195 to over 700 gpm, with the potential to yield 1,000 gpm at optimal aquifer locations with proper well design. Observed total dissolved solid (TDS) levels range from 261 to 535 milligrams per liter (mg/l). Regionally, the Arikaree Formation serves public, industrial, domestic, irrigation and stock wells (Whitcomb, 1965). Each of these types of uses has been noted in WSEO well database records. Records from the WSEO do not explicitly indicate what formation wells are screened in, but even in the limited area of the Lance Creek watershed where the Arikaree Formation is present, 255 of the 304 (83%) of the known registered wells are completed between the depths of 50 and 500 feet, with the latter being the observed maximum thickness of the Arikaree Formation in Wyoming (HKM, 2002a).
- The *Wasatch Formation* underlies the western half of the Lance watershed and yields generally less than 15 gpm with higher yields (up to 500 gpm) possible in some locations. Some Wasatch wells flow under artesian conditions (HKM, 2002a). The TDS content ranges from less that 200 to greater than 8,000 mg/l (Hodson et al, 1973). Wells completed in the Wasatch Formation are used for municipal/public, domestic and stock water supplies.
- The *Fort Union Formation* underlies the eastern half of the Lightning watershed and the northwest corner of the Lance Creek watershed. The formation generally yields 1 to 60 gpm with higher yields observed along with considerable drawdown. Water quality is similar to the Wasatch Formation as these two units are often grouped into the Fort Union/Wasatch Aquifer System. Wells completed in the Fort Union Formation are used for municipal/public, domestic and stock water supplies.

- The *Lance Formation* is part of the Fox Hills/Lance Aquifer System and underlies the northern half of the Lance Creek watershed. The Lance Formation yields up to 300 gpm but with appreciable drawdowns. TDS content from the outcrops north of Niobrara County range from 1,500 mg/l to 3,000 mg/l, with fluoride enrichment characteristics and high sodium and radionuclide content in the specific areas especially near uranium deposits. Wells completed in the Lance Formation are used for municipal/public, domestic and stock water supplies.

2.1.6.3 Springs

Springs represent locations where the groundwater table intersects the land surface. In the Powder River Basin, this often occurs in association with clinker units. However, clinker is mapped in a very limited area of the Thunder Basin L&LC watershed. Where clinker does occur, the rock material acts as a sponge in absorption of snowmelt and precipitation, which then is stored and transmitted by the porous and permeable materials. Therefore, the amount of spring flow near clinker deposits is highly dependent on precipitation patterns and rates (Heffern and Coates, 1999). Landowners just north of the study area have noted that area springs have been dried up or experienced reduced flows during the extended regional drought.

Map 9 illustrates the locations of springs and seeps as mapped by the USGS. The map contains spring locations identified by both the National Hydrography Dataset (NHD) (Simley and Carswell, 2009) and from manual evaluation of USGS 1:24,000 topographic maps. From the two data sources, 18 springs were identified in the Lance Creek watershed and 8 in the Lightning watershed. Most of the Lance Creek watershed springs are found in the upland areas south-southeast of the town of Lance Creek. All but one of the springs identified in the Lightning watershed are located in the upland areas along the western and southern watershed boundaries. There are likely many more developed and undeveloped springs in the watershed that are not represented by the map, especially in the isolated area of clinker deposits in the northwest corner of the Lance Creek watershed. The NHD dataset identifies one spring along the watershed boundary in this area. Considering the hydrogeologic characteristics of the clinker deposits, especially in areas just north of the study area, it is possible that additional unmapped springs exist in this area. Additional mapping of springs throughout the study area would provide a more comprehensive understanding of the existing water resources in the Thunder Basin L&LC watershed.

2.1.7 Surface Water Hydrology

2.1.7.1 Hydrologic Regions and Stream Types

The Thunder Basin watershed is comprised of two main watersheds: the Lance Creek and Lightning Creek watersheds. The confluence of Lance Creek with the Cheyenne River is the downstream limit of these watersheds. In addition, a portion of the Angostura Reservoir watershed between the Lance Creek watershed and the eastern Wyoming state line were included in the study area (Map 1). Map 10, Watershed Hydrologic Features, shows a more detailed breakdown of watershed areas, along with their hydrologic unit codes (HUC). A listing of the hydrologic unit codes is included as Data Summary 2.1.7-1 in Appendix A.

The Lightning, Lance, and Hat watersheds lie within the Eastern Basins and Eastern Plains Region as designated by Miller (2003). This region, encompassing most of the study area, is characterized by semiarid grasslands. Annual peak flows are generally larger than the Central Basins and Northern Plains Region. Precipitation characteristics and the resulting variability in annual peak flows are similar in both of these regions.

The Angostura Reservoir watershed lies within the Central Basins and Northern Plains Region. This region includes the plains of northeastern Wyoming and Miller describes these areas as semiarid to arid, characterized by grasslands, shrublands, and some open woodlands. Measured annual peak flows are characterized by large year-to-year variability since annual peak flows generally are caused by localized convective rainstorms.

The U.S. Army Corps of Engineers (USACE) (2000) defines different stream regimes as follows:

- A **perennial stream** has flowing water year-round during a typical year. The water table is located above the streambed for most of the year. Groundwater is the primary source of water for stream flow. Runoff from rainfall is a supplemental source of water for stream flow.
- An **intermittent stream** has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow.
- An **ephemeral stream** has flowing water only during, and for a short duration after, precipitation events in a typical year. Ephemeral streambeds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow.

Based on the NHD dated December 31, 2005, within the study area, portions of fourteen streams are considered to be perennial. The larger tributaries are considered to be intermittent streams, and the remaining tributaries are considered to be ephemeral streams. Table 2.1.7-1 shows the classifications for perennial and intermittent streams.

2.1.7.2 Existing Lakes and Reservoirs

There are no natural lakes of significant size in the Thunder Basin L&LC watershed. Wetlands and small areas with water do occur in the watershed, as shown in Map 11, National Wetlands Inventory Map, and described in Section 6.3.2.

According to the National Inventory of Dams (NID), there are 62 dams within the study area. Map 12, National Inventory of Dams, shows the locations of the dams. The combined storage behind the identified dams is 13,483 acre-feet. The largest identified reservoir, Bradley, located on Bradley Gulch in Niobrara County, holds 644 acre-feet. The median reservoir size is 172 acre-feet. Dams that do not fall under the jurisdiction of the state engineer’s office are not included in the database.

The study area contains numerous small impoundments and stock watering ponds, which are shown in Map 13, Stock/Wildlife Ponds. Approximately 2,050 stock ponds are represented in the map. These stock ponds represent permitted ponds with uses identified as stock ponds.

2.1.7.3 Gaging/Sampling Stations

Map 14, Gaging Stations and Streamflow/Sampling Sites, shows surface water gaging stations and sampling locations, as well as lake/reservoir observation stations. Within the study area, there are no active and one historic USGS streamflow gaging station. There are four additional sites that have historic peak flow data and five observation sites. The gages are listed in Data

Table 2.1.7-1 Perennial[1] and Non-Perennial Intermittent Streams

Alkali Creek	Fitzsimmons Creek	Rat Creek
Alum Creek	Greasewood Creek	Rusty Creek
Antelope Creek	Harney Creek	Sage Creek
Bills Creek	Hon Creek	Sand Creek
Black Tail Creek	Horse Creek	S-Bar Creek
Bobcat Creek	Indian Creek	South Antelope Creek
Boggy Creek	Lance Creek	South Brush Creek
Bonsell Creek	Lightning Creek	South Cottonwood Creek
Box Creek	Little Boggy Creek	South Fork Box Creek
Bridge Creek	Little Cottonwood Creek	South Fork Moss Agate Creek
Brush Creek	Little Cow Creek	South Fork Walker Creek
Buck Creek	Little Lightning Creek	South Greasewood Creek
Bull Creek	Little Rat Creek	South Oat Creek
Cherry Creek	Middle Creek	South Prong South Antelope Creek
Cheyenne River	Mill Creek	Spring Branch Harney Creek
Chip Creek	Mule Creek	Spring Creek
Cottonwood Creek	North Antelope Creek	Stivers Creek
Cottonwood Prong	North Brush Creek	Swanski Creek
Cow Creek	North Cottonwood Creek	Tena Creek
Coyote Creek	North Fork Box Creek	Twentymile Creek
Deer Creek	North Fork Moss Agate Creek	Walker Creek
Dogie Creek	North Fork Wyatte Creek	West Bull Creek
Dry Creek	North Greasewood Creek	West Fork Twentymile Creek
Duell Creek	North Oat Creek	West Fork Walker Creek
East Alum Creek	Oat Creek	West Harney Creek
East Fork Buck Creek	Old Woman Creek	West Mule Creek
East Fork Twentymile Creek	Onemile Creek	Willow Creek
East Harney Creek	Owl Creek	Wyatte Creek
East Mule Creek	Piney Creek	Young Woman Creek
F F Creek	Plum Creek	

Note: Perennial streams are highlighted. It should be noted that only portions of the creeks are perennial, not the entire lengths. Non-highlighted streams are mostly ephemeral.

Summary 2.1.7-2 in Appendix A. Detailed information regarding these sites is available at http://waterdata.usgs.gov/wy/nwis/si.

USGS Gage 06378640, Lance Creek Tributary near Lance Creek, Wyoming, is on a tributary of Lance Creek near Highway 272. The reported drainage area is 1.2 square miles. The period of record for flow data is June 10, 1965 to September 8, 1973. Peak flow data for this gage can be found at the following Web site:
http://waterdata.usgs.gov/wy/nwis/inventory/?site_no=06378640&agency_cd=USGS&

USGS Gage 06379600, Box Creek near Bill, Wyoming, is located immediately downstream of Highway 59. The reported drainage area is 112 square miles. The period of record for flow data is June 9, 1957 to July 25, 1981. Peak flow data for this gage can be found at the following Web site:
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=06379600&agency_cd=USGS

USGS Gage 06382200, Pritchard Draw near Lance Creek, Wyoming, is approximately 8 miles upstream of the confluence with Lance Creek. The drainage area is reported to be 5.1 square miles. The period of record for flow data is 1964 to August 5, 1981. Peak flow data for this gage can be found at the following Web site:
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=06382200&agency_cd=USGS

USGS Gage 06385400, Cottonwood Creek at Hat Creek, Wyoming is approximately 14 miles north of Lusk, Wyoming. The reported overall drainage area is 14.5 square miles, with a contributing drainage area of 12.0 square miles. One peak flow is available for August 9, 1979. Peak flow data for this gage can be found at the following Web site: http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=06385400&agency_cd=USGS

USGS Gage 06386000, Lance Creek near Riverview, Wyoming, is located immediately upstream of its confluence with the Cheyenne River. The reported drainage area is 2,070 square miles. The period of record for flow data is May 1, 1948 to September 30, 1983. This gage is the only one in the area with daily and monthly streamflow data in addition to peak flow data. Streamflow, peak flow, and water quality data for this gage can be found at the following Web site:
http://waterdata.usgs.gov/wy/nwis/nwisman/?site_no=06386000&agency_cd=USGS

USGS Gages 06384000, 06384500, 06385000, 06385500, 06386200 are observation sites for which no data is available.

2.1.7.4 Stream Flow Characteristics

Most streams originating in the basins or plains areas of Wyoming are ephemeral or intermittent, flowing only as a result of local snowmelt or intense rainstorms. Intense localized convective rainstorms can produce most of the total flow for any given year in these watersheds (Miller, 2003). The only USGS stream gage with historic daily or monthly flow data is 06386000, Lance Creek near Riverview, Wyoming. As seen in Figure 2.1.7-1, the majority of flow occurs between April and September. Peak flow data shows that peaks most often occur in June. The streamflow distributions reflect snowmelt and early summer thunderstorm events. The four main stems (Lightning Creek, Lance Creek, Indian Creek, and Mule Creek) typically maintain perennial flow from groundwater and springs, as discussed in Section 2.1.8.3.

Figure 2.1.7-2 illustrates the mean annual discharge for Lance Creek at Riverview, WY. The record terminates in 1983 and as seen from the previous sections, the data for this area is very limited. In areas where future projects are being considered, it is recommended that additional stream gages be installed to better understand the streamflow characteristics and quantities. Adding stream gages will enable better estimates of potential watershed yield and timing of flows.

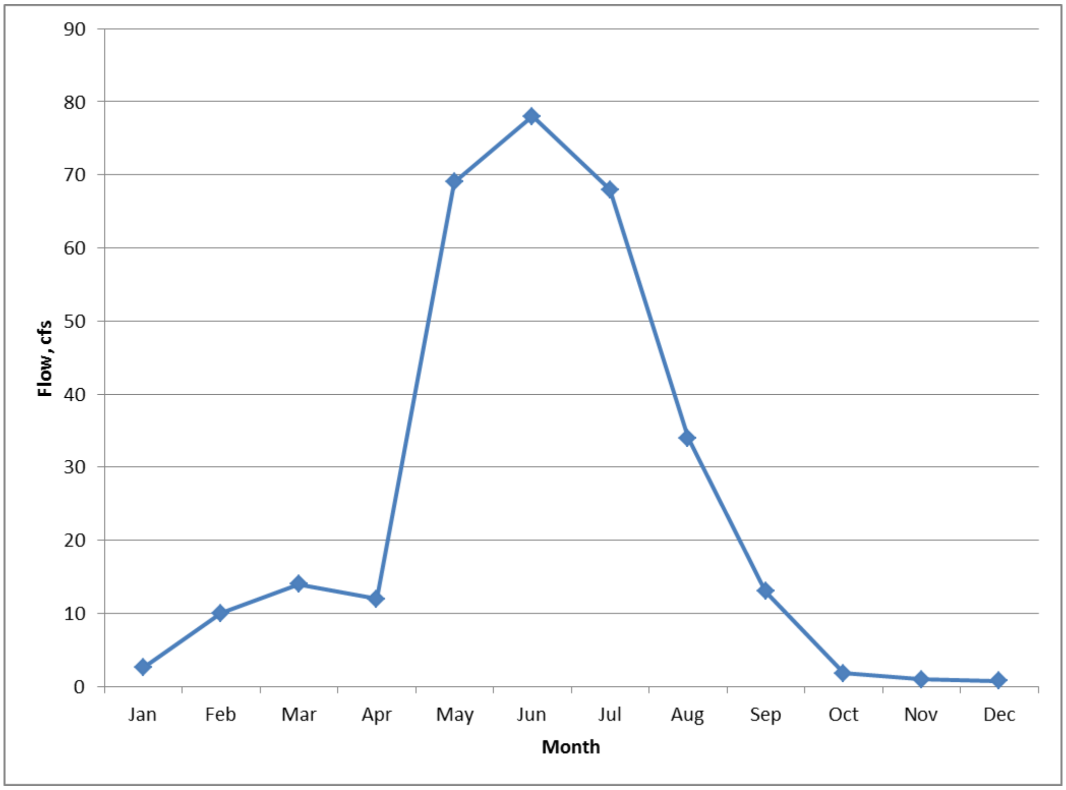


Figure 2.1.7-1 Average Flow per Month for Lance Creek near Riverview, Wyoming in cfs

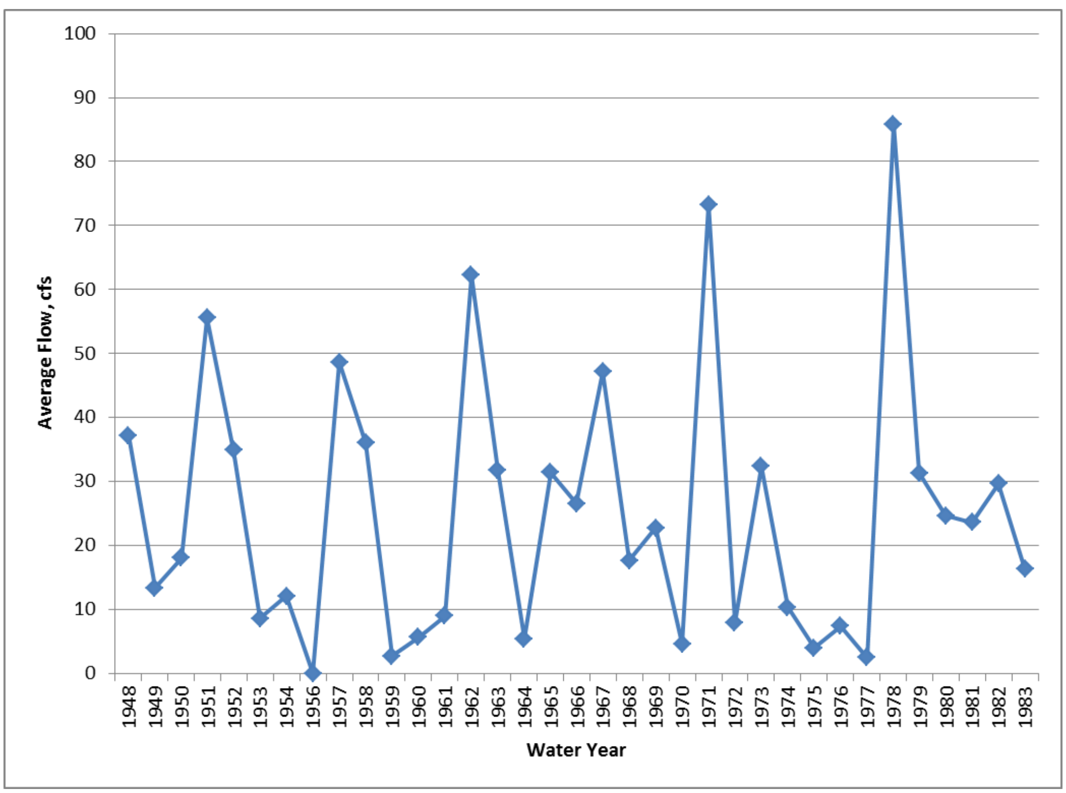


Figure 2.1.7-2 Mean Annual Discharge for Lance Creek near Riverview, Wyoming in cfs

2.1.8 Stream Geomorphology

The following section provides information on the stream geomorphology of Thunder Basin L&LC. Fluvial geomorphology is the study of how land is formed under the processes associated with running water. Over time, a natural stream channel at a given location establishes a cross section and planiform that reflect the quantity of water and the quantity and characteristics of sediment delivered to it from the drainage basin, as well as the imposed topography and local geologic conditions. Neither the water supplied (discharge) nor the quantity and distribution of sizes of the sediment load are delivered to the channel at a constant rate. All are subject to the variations of weather and climate, which dictate the magnitude, timing, and frequency of the range of flows and sediment, delivered to a given channel reach. Thus, the channel experiences varying sequences of low and high flows, depending on runoff from the drainage basin. Largely due to the varying runoff, the sediment supplied from the landscape and from sediments stored in, and adjacent to, the channel, varies as well (Emmett, Leopold, and Myrick, 1983).

Alluvial channels, like the ones in Thunder Basin L&LC, composed of sediments deposited by the river, are free to adjust their form, and to a lesser extent, their gradient. Because of this, over time, an alluvial river develops a cross section and shape reflecting the quantities of water and sediment and the sizes of sediment brought to it. While this form, in any given period responds to the variability of flow and sediment, observations of natural alluvial channels demonstrate that the channel, over time, develops a cross-sectional form reflecting an integration of these temporal variations. In general, channels have a cross-sectional area, width, and depth at bankfull discharge that is related to the range of flows capable of eroding and transporting the alluvial deposits constituting the channel boundaries. Bankfull discharge refers to the discharge when streamflow just begins to overtop into the floodplain. The floodplain is defined as a relatively flat depositional surface, adjacent to the channel and constructed by the river in the present hydrologic regimen.

A variety of terms have been used to characterize stream and rivers flowing in alluvium, while erosion and deposition may take place, the channel neither aggrades (raises) nor degrades (lowers) its mean bed over time. The time scale is important because channel behavior may vary over different time scales, and over very long periods of geologic time, stable equilibrium is not maintained as the landscape is denuded or reduced in elevation. This is clearly evident by the existence of terraces, which, by definition, are abandoned floodplains from previous hydrologic regimes.

It is commonly observed that many, if not most, alluvial rivers are subject to episodic floods; that is, the flow overtops the river banks and spills into the adjacent lands. Floodplains are formed by lateral movement of the channel and deposition of bars and by vertical accretion resulting from deposition of sediment by floods. To the extent that the adjacent land is the product of deposition by the existing river it is, by definition, a floodplain. The floodplain therefore is a flat area adjacent to the channel constructed by the river in the present hydrologic regimen. Deposits, and surfaces other than the floodplain, may exist on the valley floor. If they are alluvial, that is riverine in origin, they may constitute terraces (topographic surfaces) or terrace deposits laid down by the river under a different hydrologic regimen. Although there is some evidence to suggest that the bankfull stage, i.e., height of the floodplain, in many rivers corresponds to a discharge of constant frequency, for example, every one to two years (Wolman and Leopold, 1957; Emmett, 1975) variability is encountered among river sites in a given region and in different regions (Williams, 1978). Similarly, in some rivers, there is a close correspondence between flows during which much of the annual sediment load is transported (effective discharge) and the bankfull flow (Wolman and Miller, 1960).

Stream stability is morphologically defined as the ability of the stream to maintain, over time, its dimension, pattern, and profile, in such a manner that it is neither aggrading nor degrading and is able to transport without adverse consequence the flows and detritus of its watershed. Stable streams do, however, assume many combinations of dimension, pattern, profile, and materials within individual valley and geologic types. Due to the great diversity of these morphological features within rivers and streams, Rosgen (1994, 1996) developed a stream classification system by which to stratify and describe these various river types. The Rosgen Stream Classification System was utilized for this watershed study and is described in greater detail below.

2.1.8.1 Rosgen Classification System

The Rosgen Stream Classification System is a way of classifying and evaluating a stream system. The Rosgen system is widely accepted as the classification system of choice for watershed management activities. It is comprised of four levels, each being more detailed and site specific. Figure 2.1.8-1 shows the four inventory or assessment levels. Rosgen (2006) describes the following five objectives of this stream classification system:

- To predict a river's behavior from its appearance, based on documentation of similar response from similar types for imposed conditions;
- To stratify empirical hydraulic and sediment relations by stream type by state (condition) to minimize variance;
- To provide a mechanism to extrapolate site-specific morphological data;
- To describe physical stream relations to complement biological inventory and assist in establishing potential and departure states; and
- To provide a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines.

As part of the Thunder Basin L&LC Phase II watershed study a Level I Rosgen channel classification was completed. This basic level of stream classification is based on morphological characteristics that result from the integration of basin relief, landform, and valley morphology. This coarse-scale level uses dimension, pattern, and profile to make determinations. Level I criteria is typically determined from topographic maps, landform maps, and/or aerial topography. Table 2.1.8-1 shows the general stream type descriptions and delineative criteria for a Level I classification.

Disturbances to the channel, such as accelerated bank erosion or sediment supplies, can lead to channel changes and eventually stream type changes, as well. For example, there were evolutionary channel changes observed where an E-typed channel originally was functioning at a higher base level that, over time, converted to a C, Gc, F, and now is a C-type channel at a lower base level.

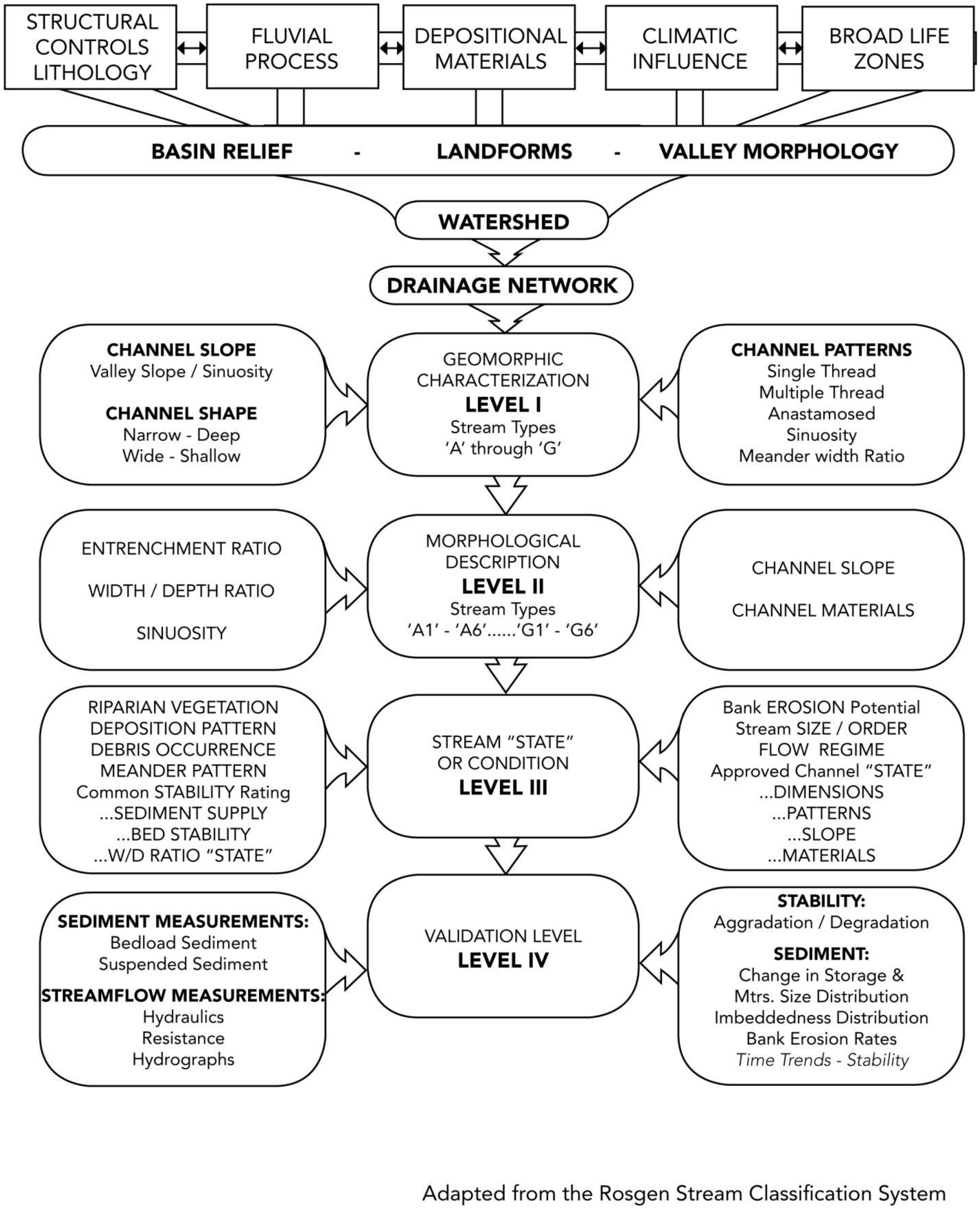


Figure 2.1.8-1 Rosgen Stream Classification System

Table 2.1.8-1 General Stream Type Descriptions

Stream Type	General Description	Entrench-ment Ratio	Width to Depth Ratio	Sinuosity	Slope	Landform/Soils/Features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>0.10	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	0.04 to 0.10	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	0.02 to 0.039	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 floodpolains.	>2.2	>12	>1.2	<0.02	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	<0.04	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	<0.005	Broad, low-gradient valleys with fine alluviium 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	<0.02	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	<0.02	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	0.02 to 0.039	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.

2.1.8.2 Level I Classification Methods

For the Thunder Basin L&LC Phase II Level I Watershed Study, a Level I Rosgen channel classification was completed for the entire watershed. This Level I classification is intended to provide a general summary of the channel types (A through G and NDC – no distinct channel) present within the watershed. The classification was completed utilizing topographic maps and aerial photography (Google Earth) and limited field visits.

Level I stream classification is a general characterization of the stream within the watershed and is intended to be preliminary in nature. This level of classification makes use of readily available published information and relies on the experience of the observer. The first four delineative criteria for classification levels I and II are the same, but vary greatly in the intensity of required data. Level II stream classification requires field measurements of the entrenchment ratio, width-to-depth ratio, slope, and sinuosity by establishment of a cross section and longitudinal profile.

The following sequence of analysis was used in the Level I Stream Channel Classification:

- Map and identify the origin and character of landforms
- Overlay the drainage systems of interest
- Locate the terrace elevations to differentiate Pleistocene, Holocene, and Modern depositional features.

1) Overlay the river system on the fluvial landscape to get the following:

   - General channel slope (steep/flat)
   - Channel bed features (step/pool or riffle/pool)
   - Estimate of channel shape (general width/depth ratios categories – less than 12; 12 to 40; and more than 40)
   - Pattern and profile to show floodplain extent
   - Plan view pattern (single or multiple channels)
   - Confinement (entrenchment slight, moderate, entrenched) or lateral containment (yes or no)

2) Delineation of Valley Types and Landforms

   - Landforms (alluvial fans, glacial and/or fluvial terraces, floodplains, hanging valleys)
   - Valley Types I through X (see Rosgen, 1996)

2.1.8.3 Level I Classification Results

The results of the Level I Rosgen Stream Classification are graphically displayed on Map 15, Major Streams with Rosgen Classification, and summarized on Data Summaries 2.1.8-1 – 2.1.8-3 (in Appendix A) and Figure 2.1.8-2 as follows:

- Data Summary 2.1.8-1 – Level I Rosgen Stream Channel Classification Reach ID's
- Data Summary 2.1.8-2 - Level I Rosgen Stream Channel Classification Reach Information (6 pages)
- Data Summary 2.1.8-3 - Level I Rosgen Stream Channel Classification Channel Type Statistics by Watershed.
- Figure 2.1.8-2 - Level I Rosgen Stream Channel Classification Type Percentage and Count by Watershed.

The majority of the streams within the Thunder Basin L&LC watershed are ephemeral or intermittent in nature. These streams are flashy and respond to temporary runoff events caused by snowmelt and precipitation events. Spring runoff events typically occur from March to April with early summer rains prolonging the stream flow into summer. Flows decrease and cease typically in mid to late summer only flowing in response to thunderstorm events. These flows vary with summer thunderstorms as well. The following subsections describe the results of the classification for each of the three watersheds.

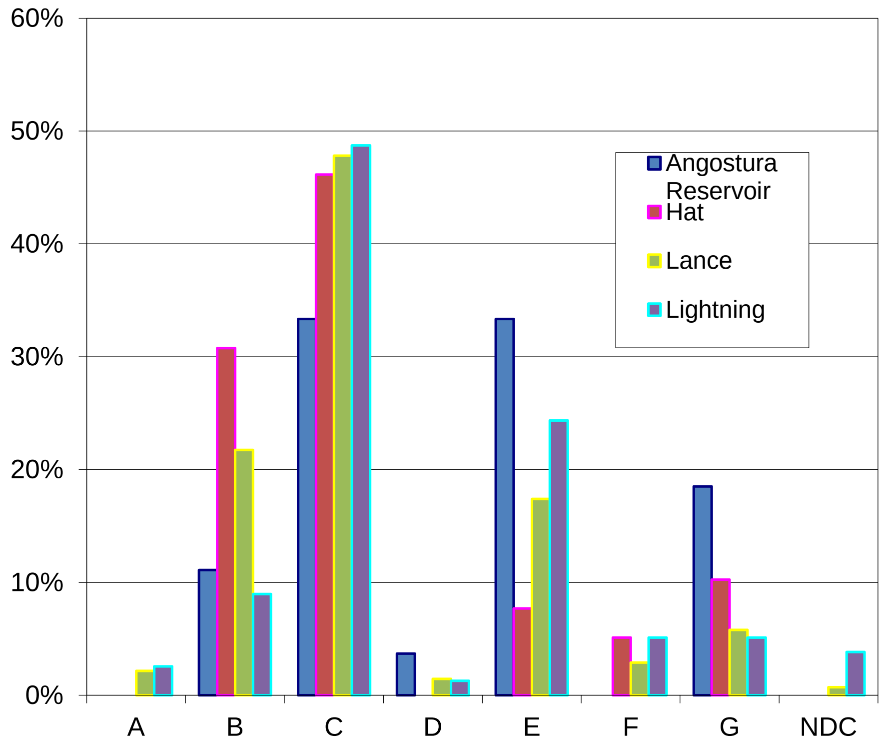


Figure 2.1.8-2 Level I Rosgen Stream Channel Classification Type Percentage by Watershed

Lance Creek Watershed

Within the Lance Creek Watershed there were 138 individual reaches assessed. Tributaries that were assessed included:

- Lance Creek
- Greasewood Creek
- Old Women Creek
- Coyote Creek
- Sage Creek
- Cottonwood Creek
- Spring Creek
- Chip Creek
- Alum Creek

- Young Women Creek
- North Branch Creek
- Black Tail Creek
- Antelope Creek
- Buck Creek
- Dogie Creek
- Bills Creek
- Sothman Draw
- Cow Creek
- Middle Creek
- Tena Creek
- Bull Creek
- Little Lightning Creek
- Rusty Creek
- Cherry Creek
- Buggy Creek
- Wyatte Creek
- 77 Creek

The Level I channel classification resulted in 2.2% A Type channels, 21.7% B Type channels, 47.8% C Type channels, 1.4% D Type channels, 17.4% E Type channels, 2.9% F Type channels, 5.8% G Type channels, and 0.7% with NDC.

As the percentages show, the three major channel types were B, C, and E types. The majority of the B channel types were found in the moderately steep gradient and moderately entrenched reaches of most of the tributaries located throughout the watershed. The C channel types primarily were found lower in the reaches where they displayed slightly wider valleys constructed from alluvial deposition having well developed floodplains. These channel reaches were also more sinuous than the B channel types. The majority of the E channel types were found in the lower reaches of Lance Creek. These channel types display a very wide channel bottom, with a low width to depth ratio and have relatively high sinuosities. The remaining A, D, F and G channel types were found within the watershed but in much smaller percentages.

Cow Creek at the bridge on Lance Creek Road was evaluated during a field visit. As shown in Photos 5 and 6 below, the channel is a C Type channel, single thread, meandering channel with terraces. The reach within the area where the photo is taken is L-Cow-7-C. These photos show a view looking downstream and upstream.

Photo 1 – Cow Creek at the Bridge on Lance Creek Road Looking Downstream (C Channel Type).

Photo 2 – Cow Creek at the Bridge on Lance Creek Road Looking Upstream (C Channel Type).

Lightning Creek Watershed

Within the Lightning Creek Watershed there were 77 individual reaches assessed. Tributaries that were assessed included:

- Lightning Creek
- Little Lightning Creek
- Box Creek
- Dry Creek
- Rat Creek
- Little Rat Creek
- Horse Creek
- Bobcat Creek
- Stivers Creek
- Piney Creek
- Deer Creek
- Twentymile Creek
- West Fork Twentymile Creek
- East Fork Twentymile Creek
- Cottonwood Creek
- Harney Creek
- West Harney Creek
- East Harney Creek
- Spring Branch
- Walker Creek
- Piney Creek
- Willow Creek

The Level I channel classification resulted in 2.6% A Type channels, 9.1% B Type channels, 48.7% C Type channels, 1.3% D Type channels, 24.4% E Type channels, 5.1% F Type channels, 5.1% G Type channels, and 3.8% with NDC .

As the percentages show, the three major channel types encountered within the Lightning Creek watershed were B, C, and E types. Once again, the B channel types were found in the moderately steep gradient and moderately entrenched reaches of several of the tributaries located throughout the watershed. The majority of the C channel types were found within the larger tributaries of the watershed (Lightning Creek, Box Creek, Dry Creek, and Walker Creek) where they also displayed slightly wider valleys with well-developed floodplains. The majority of the E channel types were found in the lower reaches of Lightning Creek. These channel types display a very wide valley bottom, with a low width to depth ratio and have relatively high sinuosities. The remaining A, D, F, G and NDC channel types were found within the watershed but in much smaller percentages.

Within the Phase I portion of this study, the Wyoming Department of Environmental Quality (WDEQ) completed a Level II Rosgen Stream Classification (Hargett, 2007). However, for the Phase II portion of the study, no level II comparison studies were available.

Photo 3 - Lightning Creek from bridge after significant runoff event. Sediment deposit on bank.

Photo 4 - Lightning Creek upstream at bridge.

Angostura Reservoir Watershed

Within the Angostura Reservoir Watershed there were 27 individual reaches assessed. Stream reaches that were not within the State of Wyoming were not assessed. Tributaries that were classified included:

- Bridge Creek
- Mule Creek
- Hen Creek
- Sage Creek
- North Fork Moss Agate Creek
- South Fork Moss Agate Creek
- Little Cottonwood Creek
- Cottonwood Creek

For that portion of the Angostura Reservoir Watershed within the state of Wyoming, 0 % of the channels were Rosgen Type A, 11.1 % were Type B, 33.3% were Type C, 3.7% were Type D, 33.3% were Type E, 0% were Type F, 18.5% were Type G, and 0% were areas of no defined channel (NDC). Within the Angostura Reservoir Watershed, B and C types were typically found along the valley bottoms and at the topographic break from the steep uplands onto the valley floor. C type channels are a single thread meandering channel with a well-developed floodplain which is typical of the main stems.

The Type G channels were observed in the upper reaches of the tributaries as expected. These steeper, more confined reaches are typically associated with Type A channels, however the Type G channels, or gullies, are typical as well in the upper reaches where the slope breaks and the head cut features are formed along the slopes with high erosion potential.

One reach with multiple channels was identified as a Type D channel. These areas were typically bounded by C or B types and typically occurred where there was previously a dam of some type (stock pond embankment, spreader dikes). The Type E channels were typically observed on broad flood plains where some extent of groundwater influence was likely. These E types are very narrow and deep with stable banks and vegetation with deep roots. These features typically develop in areas where groundwater is available for a longer duration during the growing season.

The “E” channel type was one of the more common types encountered within the Angostura Reservoir watershed. Typical “E” channel types have high channel sinuosity and are typical in the wide flat valley bottoms.

Hat Creek Watershed

Within the Hat Creek Watershed there were 39 individual reaches assessed. Stream reaches that were not within the State of Wyoming were not assessed. Tributaries that were classified included:

- Oat Creek
- Cottonwood Creek
- Brush Creek
- Indian Creek
- S Bar Creek

- Fitzsimmons Creek
- Duell Creek
- Plum Creek
- Middle Creek
- Swanski Creek
- Mill Creek
- Sage Creek
- Antelope Creek

For that portion of the Hat Creek Watershed within the state of Wyoming, 0 % of the channels were Rosgen Type A, 30.8 % were Type B, 46.2% were Type C, 0% were Type D, 7.7% were type E, 5.1% were Type F, 10.3% were Type G, and 0% were areas of no defined channel (NDC). As the percentages show the three major channel types were B, C, and G types. The majority of the B channel types were found in the steep upper reaches of the Hat Creek Breaks located in the southern portion of the watershed. The G channels were found in that transitional area between the steep B sections and the flatter valley bottoms where C channel types occurred. The remaining E and F channel types were found within the watershed but in much smaller percentages.

The "B" channel type was one of the more common types encountered within the Hat Creek watershed, especially near the Hat Creek Breaks. Typical "B" channel types have moderately steep to gently sloped terrain and low channel sinuosity with a limited floodplain. The "F" and "G" channel types were also encountered within the Hat Creek watershed.

2.2 Land Uses and Management Activities

2.2.1 Land Ownership

The Thunder Basin L&LC watershed Study Area is approximately 1,572,390 acres within the two counties of Converse and Niobrara. Niobrara County accounts for approximately 65% of the area and Converse County approximately 35%.

The majority of land in the Thunder Basin L&LC watershed is privately owned with the second largest landowner being the Federal Government. The distribution of land ownership is illustrated in Map 16 and listed in Table 2.2.1-1.

Table 2.2.1-1 Thunder Basin L&LC Watershed Land Ownership

Landowner		Acres*	Percentage of Total
Federal			
	Bankhead Jones	17,925	1
	Bureau of Land Management	88,543	6
	National Grasslands	28,723	2
Private		1,302,998	83
State		129,464	8

*0.01% or 188 acres of the study area were not accounted for in the Land Ownership database.

2.2.2 Range Conditions

The following data were obtained using GIS data for grazing allotments administered by the BLM in the Casper and Newcastle Districts. BLM grazing allotments encompass approximately 18 percent (~283,000 acres) of the land within the Study Area, which includes the Lance Creek, Lightning Creek, Hat Creek and Angostura Reservoir watersheds (see Map 17 – Grazing Allotments). The BLM allotment numbers and names are provided in Tables 2.2.2-1 and 2.2.2-2. The BLM-administered allotments typically include intermingled private, state, and federally-administered lands used for grazing and are not currently administered through grazing agreements with Grazing Associations. Under the Record of Decision and Approved Resource Management Plan for the Casper (BLM, 2007) and Newcastle (BLM, 2000, revised 2008) Districts, livestock grazing permittees are required to implement management actions (e.g., grazing systems, land treatments, and range improvements) appropriate to the allotment category (i.e., "C" – Custodial, "M" – Maintain, or "I" – Improve). 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.
- 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. Implementation of appropriate range management practices and/or improvements is carried out under an activity or implementation plan, including allotment management plans (AMPs). AMPs have been completed for the following allotments in the Study Area (BLM, 2009):

Table 2.2.2-1 - Listing of BLM Grazing Allotments – Casper BLM District

ALLOTMENT NAME	ALLOTMENT NUMBER	ACRES
BOWMAN DRAW	00376	31,950
BOX CREEK	10155	7,649
BOX CREEK 2	00247	4,542
BOX CREEK 3	00300	4,800
COLTER DRAW	00235	17,974

ALLOTMENT NAME	ALLOTMENT NUMBER	ACRES
CONVERSE 1	00243	6,242
COTTONWOOD CREEK	10418	6,755
EAST FK. TWENTYMI	00242	3,237
ETCHEMENDY	20224	2,106
FETTERMAN CREEK	10331	2,541
FLAT TOP	00231	484
HIGHLAND FLATS	00471	2,380
HIGHLAND FLATS 2	00482	930
HORNER	20513	1
HORSE CREEK	10317	1,268
LA PRELE CREEK 4	00452	2
LIGHTNING CREEK	10324	3,738
LITTLE LIGHTNING	20202	14,276
MIKES DRAW	10302	12,484
PRIVATE	-	12,309
RICE RESERVOIR	10314	12,499
SKUNK CREEK	00342	1,453
SMITH	10147	787
TWENTYMILE CREEK	00341	15,696
	00384	6,227
	00484	4,557
WALKER CREEK	00371	32,845
TOTAL		**209,731**

Table 2.2.2-2 - Listing of BLM Grazing Allotments – Newcastle BLM District

ALLOTMENT NAME	ALLOTMENT NUMBER	ACRES
ALUM CREEK	14002	1,109
ANTELOPE CREEK	14027	2,166
BADLAND DRAW	04067	314
BOGGY CREEK I	04084	1,406
BOWEN FLAT	04240	681
BREWSTER DRAW	04031	555
BRIDGE CREEK I	04160	760
BRIDGE CREEK II	04394	40
BRUSH CREEK I	04028	400
BUCK CREEK HILLS	04121	279
BUCK CREEK I	04348	400

ALLOTMENT NAME	ALLOTMENT NUMBER	ACRES
BUCK CREEK II	04153	40
BUCK CREEK NE33	04311	39
CALF DRAW	04302	1,133
CHARLIES DRAW I	04188	382
CHERRY CREEK	04316	571
CLAYTON DRAW I	04072	511
COUNTY ROAD S10	04112	119
COUNTY ROAD S22-2	04174	1,210
COUNTY ROAD S3	00728	62
COUNTY ROAD S3N	04161	47
COUNTY ROADS	04329	40
COW CREEK	04236	706
CROSS A	04152	276
DOG TOWN	04277	80
DOGIE CREEK	04346	971
DRY CREEK II	04273	41
EAGLE DRAW	04221	706
EAST FORK	04193	239
EAST MULE CREEK	04237	1,841
ELDRIGE DRAW	04029	2,816
FUNNY ROCK	04352	1,132
GOLDEN DRAW	04158	82
GREASEWOOD CREEK	04268	1,484
HARNEY HILLS	04192	45
HAT CREEK BREAKS	04327	111
	04380	118
HENRY DRAW	04392	203
HIGHWAY 18	04185	120
HIGHWAY 270 S33	04191	119
HORSESHOE CREEK	04163	41
INDIAN CREEK	04181	77
JACOBY DRAW	04282	874
JOLLY DRAW	04405	163
LANCE CREEK I	04148	993
LANCE CREEK II	00555	239
LANCE CREEK III	04397	40
LANCE CREEK IV	04118	22
LANCE CREEK NW	00724	25
LANCE CREEK V	04330	1,406

ALLOTMENT NAME	ALLOTMENT NUMBER	ACRES
LIGHTNING CREEK B	04249	634
LIGHTNING CREEK S	04168	2,751
	04356	2,799
LITTLE BOGGY CREE	04213	80
LITTLE COW CREEK	04200	1,093
LITTLE LIGHTNING	04132	120
MARCUS DRAW I	04402	688
MARCUS DRAW II	04041	3,419
MERCER DRAW	04396	4,909
MIDDLE CREEK	04175	2,163
MILL CREEK	04151	40
MULE CREEK	04145	39
MULE CREEK JUNCTI	04269	517
N LANCE CREEK	04043	2,802
OLD WOMAN CREEK I	04313	200
RHAY	04347	517
RUSTY CREEK	04111	343
SAGE CREEK III	04362	480
SAGE CREEK IV	04290	99
SAGE HEN	14022	40
SIMMS DRAW I	04189	354
SIMMS DRAW II	04115	123
SNYDER CREEK III	04289	300
SNYDER CRK DRAINA	14012	1,403
SOTHMAN DRAW	04371	41
SOUTH COTTONWOOD	04239	557
SPRING CREEK I	04314	233
SPRING CREEK II	04250	236
TELEPHONE DRAW	04122	992
TIMBER DRAW	04328	5,265
TWENTYMILE CREEK	04157	8,507
UPPER LIGHTNING	04331	367
WALKER CREEK	04345	1,333
WEST BULL CREEK I	04274	659
	14001	734
WHEATGRASS DRAW	04199	159
YOUNG WOMAN CREEK	14007	80
NA	-	840
TOTAL		**73,148**

The following data were obtained using GIS data for grazing allotments administered by the Forest GIS Coordinator, Medicine Bow - Routt National Forests and Thunder Basin National Grassland. U.S. Forest Service grazing allotments encompass approximately 7.5 percent (~118,000 acres) of the land within the Study Area (see Map 17 – Grazing Allotments). The allotment numbers and names are provided in Table 2.2.2-3. These grazing allotments listed below are administered by the Forest Service through grazing agreements with the Thunder Basin Grazing Association.

Table 2.2.2-3 - Listing of U.S. Forest Service Grazing Allotments

Allotment Name	Allotment Number	Acres
Alexander	09201	15,729
Downs	09206	7,509
Fiddleback	09231	4
Johnson	09216	4,567
Ketelson	09219	43,211
Lightning Creek	09277	3,716
Miller Hills	09233	2,375
Pellatz	09235	646
Reed	09238	558
Rothleutner	09246	108
Sadler	09248	6
Sheldon Draw	09245	4,991
Steinle	09253	599
Tena Creek	09244	5,158
Thomson	09259	6,848
Tillard	09227	14,890
Weiss	09261	4,032
Grand Total		**118,240**

Grazing agreements are grazing permits authorizing grazing associations to conduct specified amounts of grazing on National Forest System lands for a period of ten years or less and include provisions for the association to issue grazing permits to their members 36 C.F.R. §222.3(c)(1). The grazing associations are responsible for administering issued permits in conformance with the appropriate law and regulations, allotment management plans, and rules of management (USDA, 1997). The 2001 Medicine Bow National Forest Land and Resource Management Plan directs resource use on the Thunder Basin National Grassland. An Environmental Impact Statement addressing upland water development, among ther issues, was finalized and incorporated into the management plan in 2007. Guidelines (to be applied on a grassland-wide scale) for the management of livestock grazing to maintain or improve riparian/woody draw areas includes the following:

- Avoid season-long grazing and activities, such as feeding, salting, herding, or water developments, which concentrate livestock in riparian/woody draw areas.
- Control the timing, duration, and intensity of grazing in riparian areas to promote establishment and development of woody species.

The Environmental Impact Statement focused on areas within the Thunder Basin National Grassland, the Thunder Basin Analysis Area (USDA, 2007) to determine how existing resource conditions compare to the desired conditions outlined in the Thunder Basin National Grassland Land and Resource Management Plan (LRMP). The result would be the development of a management strategy to maintain or improve rangeland conditions which could be incorporated into individual AMPs. Area-wide design criteria established from the Environmental Impact Statements (EISs) include the following items that directly relate to this watershed study:

- Rotate livestock season of use in riparian areas to increase rush, sedge, shrub, and tree canopy cover.
- If the desired condition of a specific riparian area includes increasing willow cover or cottonwood density, livestock would be managed to improve riparian woody species.
- Manage livestock use through control of time/timing, and duration/frequency of use in riparian areas and wetlands to maintain or improve long-term stream health. Exclude livestock from riparian areas and wetlands that are not meeting or moving towards desired condition objectives where monitoring information shows continued livestock grazing would prevent attainment of those objectives. Grazing intensity or amount of forage utilization in uplands would be light to moderate in areas requiring an upward trend in vegetation, watershed, and/or soil health. Decrease livestock congregation in riparian areas and adjust livestock grazing distribution in areas of concern through appropriate analyzed management options.
- Keep stock tanks, salt supplements, and similar features out of the Water Influence Zone if practicable and out of riparian areas and wetlands always. Keep stock driveways out of water Influence Zone except to cross at designated points. Armor water gaps and designated stock crossings where needed and practicable.

State Grazing Leases. Most of the state lands within the Study Area 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. 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 an NRCS program follow the guidelines established in the plan of operations developed for the property and/or applicable NRCS technical guidelines as adapted for local conditions.

2.2.2.2 Ecological Site Descriptions

Practical potentials of grazing resources are best understood when landscape units with homogenous growing conditions such as precipitation, soils, slope, and geomorphic nature are identified and separated from each other. The USDA NRCS has accomplished this task for the Thunder Basin Phase II study area. These units known as Ecological Sites are included in the NRCS Electronic Field Office Technical Guides (eFOTGs) for Converse and Niobrara counties. These eFOTGs are available online at the following Web site:

http://www.nrcs.usda.gov/technical/efotg/

As mentioned earlier, the ESDs for most of the study area are currently being revised to incorporate on-going research into state descriptions and transition tipping points.

ESDs are grouped by precipitation zones; a total of 25 ecological sites are applicable for the Lance Creek, Lightning Creek, Hat Creek and Angostura Reservoir watersheds (Map 5, Ecological Sites). As an example, a copy of the most prevalent ESD for the these four watersheds (MLRA 58B, Site Type: Rangeland, Site Name: Loamy (Ly) 10 inches to 14 inches Northern Plains Precipitation Zone, 429,669 acres) is included in Appendix C – Ecological Site Description. The ESD addresses the full range of physiographic and climatic features, influencing water features, representative soil features, plant communities, wildlife interpretations, grazing interpretations, hydrology functions, recreational uses, and other information relevant to the site type. The GIS database developed for this Level I study and/or NRCS staff can assist in identifying the applicable ESDs to a given area. These ESDs can then be easily downloaded in .PDF format from the previously cited Web site. The 25 ecological sites occurring within the study area are summarized by acreage in Table 2.2.2-4.

Table 2.2.2-4 - Ecological Sites within the Thunder Basin L&LC Watershed

Ecological Site Name	Approximate Acreage
SANDS (15-17SP)	95
SUBIRRIGATED (10-14NP)	1,269
ROCK OUTCROP	1,778
WATER	1,856
LOAMY (15-17SP)	2,058
SHALLOW SANDY (15-17SP)	2,160
SHALLOW POROUS CLAY (10-14NP)	2,430
SALINE LOWLAND (10-14NP)	2,486
POROUS CLAY (10-14NP)	3,435
CLAYEY OVERFLOW (10-14NP)	4,172
LOAMY (12-17SP)	5,420
SANDS (10-14NP)	6,646
OVERFLOW (10-14NP)	15,298
DENSE CLAY (10-14NP)	22,522
SANDY (15-17SP)	25,305
SALINE UPLAND (10-14NP)	25,740
SHALLOW SANDY (10-14NP)	38,156
SHALLOW CLAYEY (10-14NP)	41,040
LOWLAND (10-14NP)	48,380
SANDY (12-17SP)	55,066
SHALE (10-14NP)	91,412
SANDY (10-14NP)	132,120
CLAYEY (10-14NP)	132,854
SHALLOW LOAMY (10-14NP)	228,212
VERY SHALLOW (10-14NP)	248,075
LOAMY (10-14NP)	429,669

The Thunder Basin L&LC watershed includes three precipitation zones: 10 inches to 14 inches; 12 inches to 17 inches; and 15 inches to 17 inches. These are shown in parentheses in the title of the ecological site. Ecological site descriptions can be used to compare what is growing on rangeland sites with what each is capable of supporting. Such comparison allows the relative health (ecological condition) of the range resource to be evaluated. Forage production of each site is closely related to the ecological condition of the site. Watershed values also are tied to the condition class. For example, areas with reduced ground cover have greater potential for limited infiltration and increased runoff; similarly, degraded sites may have soils with reduced organic content and consequently degraded soil structure, which likewise limits moisture infiltration and holding capacity.

Comparison of existing conditions to the historic “ideal” for a given ecological site facilitates a classification of range condition that expresses the degree to which the existing plant community reflects potential natural conditions. Four classes often have been used to make this categorization as follows: 76 percent to 100 percent; 51 percent to 75 percent; 26 percent to 50 percent; and 0 to 25 percent. In early years these categories were identified as excellent, good, fair and poor. More recently, the BLM has referred to these as seral, late seral, mid seral and early seral, respectively.

In the detailed analysis of range condition conducted by the U.S. Forest Service on the Thunder Basin National Grasslands (USDA, 2007), a similar evaluation of range condition using a seral stage model (Benkobi and Uresk 1996) was employed. A comparison was made of existing conditions to the desired conditions as set forth in the Thunder Basin Land and Resource Management Plan (USFS 2001). In the latter plan, it was not a given that all areas should ultimately come to qualify as late seral (the Benkobi and Uresk most advanced seral stage). Rather, a mix of seral stages with accompanying differences in species richness and structure among other things was targeted. Even though the goal of late seral was 10 percent to 25 percent, depending on the sub-area (and not 100 percent), the overall Thunder Basin Grassland rating was somewhat low (USDA, 2007). However, data for the vegetation analysis was collected from 2003 to 2005, during the drought, which may have negatively impacted the seral stage classifications. A more detailed analysis of range condition and specific range attributes can be found in USDA (2007).

2.2.2.3 Range Conditions

Distribution of water sources are critical to the implementation of a functional grazing management system. Evaluation of range condition can be used to identify areas that will benefit, over time, from a plan to adjust exposure to grazing to the benefit of more nutritious and productive species. However, such plans inevitably require that reliable livestock and wildlife water is available.

Fundamentals of science-based range management revolve around the health of individual range plants. The degree to which plants are allowed access to their basic needs determines their over-all well-being and their ability to produce useable forage. That useable forage is at once the sought-after product and the means by which future plant production is enabled. Above ground parts of range plants are the means by which carbohydrates are produced. Some amount of this production must be reserved to enable construction of new photosynthetic parts (leaves and stems) in future years. Removal of the capacity to produce these carbohydrates by defoliation has been proven to diminish the capacity of range plants to renew growth in future seasons. Hence, the objective of range management is the balancing of grazing use (defoliation) with the maintenance of the energy budget of the range plants. This balance is not usually possible to achieve by adjusting only the number of animals continuously present on a pasture. Rather the balance is struck by limiting the exposure to any defoliation and leaving the plants and their photosynthetic parts at rest for planned periods. Achieving this balance is complicated further by the fact that livestock are not the only grazers. Other grazers present in the study area include rabbits, prairie dogs, and big game such as antelope, deer, and elk. Rabbit and prairie dog populations are cyclical due to disease but when they are at normal levels, they can be significant consumers of vegetation. Big game populations can be controlled somewhat by hunting license quotas set by WGFD. However, protecting vegetation from defoliation from these grazers is much more difficult than for livestock. Length of rest from defoliation is important but the timing of the harvest is also highly influential in encouraging (or discouraging) long-term plant health.

In as much as creeks and drainage ways are often the location of what water is available, livestock pressure in these portions of the landscape is disproportionately great. With dispersal of livestock watering sources to uplands, not only are riparian areas relieved of grazing and trampling pressure, but little-used forage on remote uplands may be accessed by foraging animals.

Ultimately, improved health of perennial range plants yields greater ground cover and average overall height. This will tend to enhance snow-catch in winter and reduce surface water runoff during melt out and rain events. The latter tends to enhance soil moisture infiltration which feeds back to improved plant growth and more firmly controlled competitive advantage by these desirable plants, with resulting improved resistance to invasion of weeds. Enhanced soil moisture infiltration also increases the likelihood that moisture will pass through the soil and into groundwater and may support more continuous moisture supply to riparian and swale sites.

Range management in recent times has also come to incorporate concern with wildlife habitat conditions. While a heterogeneous landscape is necessary to meet the habitat needs of the diverse wildlife in the study area, high structure areas are generally the most difficult to achieve. Rested rangeland vegetation mosaics may enhance availability of forb buds, flowers, fruits and seeds highly sought after by many wildlife species, and greater plant height and cover in general offers improved habitat for native insect and arachnid populations that birds especially find necessary. The alternative water resource improvements presented in this report will achieve their highest and their most durable positive effects in conjunction with well-reasoned range management planning that directs and times livestock activities in accordance with range plant health.

2.2.3 Oil and Gas Production

Exploration and production of oil and natural gas has been commonplace in Wyoming for at least 125 years. Over this time, extraction of these commodities has become an important part of the Wyoming economy. Nationally, Wyoming ranked 8th in crude oil production in 2009 and 3rd in natural gas production in 2008 (U.S. EIA, 2010). Sublette County was the highest oil producer in 2009 at 7.94 million barrels with Campbell and Park Counties close behind with production volumes of 7.5 and 7.46 million barrels, respectively. Sublette County far outpaced other Wyoming counties in natural gas production in 2009 with a total volume of 1.2 billion cubic feet extracted (Wyoming Oil and Gas Conservation Commission).

Map 18 illustrates the distribution of oil and gas fields in the study area. The largest fields are situated primarily in the Lightning watershed, where approximately 160,000 acres have been designated as "High" potential areas for oil and gas according to the U.S. Department of

Interior's former Bureau of Mines (U.S. Bureau of Mines, 1990a). Smaller, more isolated oil and gas fields are found throughout much of the Lance Creek watershed, with the largest productive zones found near the town of Lance Creek. Data Summary 2.2.3-1 (Appendix A) lists the active oil and gas fields identified in Map 18. The locations of all active wells are available through the Wyoming Oil and Gas Conservation Commission.

Over the last decade (2000-2010), the Powder River Basin witnessed a substantial increase in the number of Coal Bed Methane (CBM) wells. According to the Final Environmental Impact Statement prepared to address the potential impacts of increased CBM development in the basin:

> *Development of oil and gas in the PRB (Powder River Basin) is generally classified into two categories: CBM and non-CBM. Development of CBM resources began in the mid-1980s. With advancements in technology, development and production of CBM has been increasing substantially since the mid-1990s. In contrast, production of non-CBM resources was relatively stable from 1986 through 1991, but has been declining sharply since (BLM, 2001). Overall, oil and gas development in the PRB, exclusive of CBM, is expected to decline slowly (BLM, 2001).*

A significant amount of water is produced during the CBM extraction process, with lesser amounts produced during conventional oil and gas primary production. Table 2.2.3-1 lists the amount of oil, gas, and water produced during oil and gas production in Wyoming with the two counties in the watersheds (Converse and Niobrara) highlighted for emphasis. These two counties alone account for about five percent of the total crude oil production in Wyoming in 2009 and just over one percent of the state's total natural gas production (http://wogcc.state.wy.us/cfdocs/2009_stats.htm). Although Converse and Niobrara Counties extend well beyond the boundaries of the watersheds, the data in Table 2.2.3-1 is useful for comparing orders of magnitude of oil, gas and water production in the state. Although over 18 million barrels of water (~2,381 ac-ft) were produced in 2009 in Converse and Niobrara Counties from extraction of oil and natural gas, the amount of water discharged to the land surface during CBM production within the study area is expected to be limited because CBM production is concentrated to the north of the Thunder Basin L&LC watershed. Water produced during conventional oil and gas extraction is normally unsuitable for livestock consumption and is generally re-injected, allowed to evaporate in surface disposal pits, or disposed of in other ways.

Although surface discharge of deep aquifer water currently occurs on a limited basis in the watersheds, some potential may exist for an increase in CBM production based on the mapped potential for coal deposits in the study area (Map 19). How the increase in CBM production has impacted groundwater and surface water supplies has been a topic of discussion for landowners north of the study area watersheds. The impact of this groundwater withdrawal and subsequent release of water during production of the CBM was not the focus of this study. Several recent publications have been prepared in order to address some of the significant issues related to increased CBM production. The most recent comprehensive document on this topic is the USGS Water Resources investigation report 02-0-4045, 2002.

Table 2.2.3-1 2009 Oil and Gas Production Summary

COUNTY	Wells	Total Year Oil/BBLS	% State Oil Total	Total Year Gas/MCF	% State Gas Total	Total Year Water/BBLS	% State Water Total
ALBANY	37	53,509	0.1	6,296	0	4,128,498	0.2
BIG HORN	457	1,877,419	3.7	2,634,990	0.1	167,562,752	7.3
CAMPBELL	13,468	7,498,711	14.6	142,106,355	5.6	398,841,184	17.3
CARBON	1,745	1,773,527	3.5	130,578,894	5.1	78,334,515	3.4
CONVERSE	960	1,874,627	3.7	8,304,798	0.3	6,075,325	0.3
CROOK	433	1,533,003	2.9	42,162	0.002	27,827,828	1.2
FREMONT	1,310	3,229,297	6.3	164,159,045	6.5	180,580,529	7.8
GOSHEN	2	0	0	104,404	0.004	384,068	0.02
HOT SPRINGS	701	2,891,363	5.6	441,685	0.017	223,321,297	9.7
JOHNSON	3,539	1,026,266	2.0	365,361,198	14.4	166,688,560	7.2
LARAMIE	103	345,263	0.7	100,918	0.004	1,170,824	0.1
LINCOLN	1,398	817,239	1.6	82,243,996	3.2	1,275,933	0.1
NATRONA	1,754	4,628,493	9.0	29,002,409	1.1	289,565,264	12.5
NIOBRARA	233	514,756	1.0	2,073,213	0.08	12,396,384	0.5
PARK	1,234	7,458,707	14.5	11,168,545	0.4	540,947,917	23.4
SHERIDAN	2,963	25,426	0.1	63,323,493	2.5	116,333,506	5.0
SUBLETTE	4,209	7,941,449	15.5	11,928,35232	47	24,762,030	1.1
SWEETWATER	3,069	5,122,918	10	23,093,4287	9.1	53,301,604	2.3
UINTA	408	1,101,775	2.1	10,662,8444	4.2	3,141,217	0.1
WASHAKIE	368	729,361	1.4	2,416,769	0.1	10,065,949	0.4
WESTON	1,176	908,556	1.8	1,861,184	0.07	3,884,540	0.2
County Totals	39,567	51,325,207		2,536,375,250		2,310,589,893	

Source: Wyoming Oil and Gas Conservation Commission (www.wogcc.state.wy.us)

2.2.4 Mining and Mineral Resources

The Powder River Basin is one of the most prolific coal-producing regions in the world. Much of the active mining in the Powder River Basin occurs just north of the study area in the Thunder Basin along the drainages of the Cheyenne River. In 2008, the Powder River Basin alone produced nearly 97 percent of Wyoming's extracted coal (452 million tons), an amount nearly three times that of West Virginia, the nation's second ranked coal producing state (U.S. EIA, 2008). Powder River Basin coal is highly sought because of its low-sulphur, sub-bituminous composition that requires little preparation for use as a power plant fuel. In addition to these qualities, Powder River Basin coal has high heat content. For example, coal from the Black Thunder mine has a heating value of 20.3 MJ/kg with an ash content of around 5 percent. The moisture content of some Powder River Basin coals increases reactivity potential to the extent that spontaneous combustion can be a problem if not properly managed. More detailed information on Wyoming coal production, including data on individual mines can be found online at http://www.wma-minelife.com/coal/coalfrm/coalfrm1.htm.

The nearest active coal mine to the study area is the Antelope Mine, about 16 miles north of the Lightning watershed boundary in northern Converse County. The Antelope Mine produced over 34 million tons of coal in 2009 (Wyoming Mining Association website). Although no active coal mines exist in the study area, data from the Wyoming Geographic Information Science Center indicates that nearly 40,000 acres of land, primarily in the Lightning watershed and the northwest corner of the Lance Creek watershed have "High" potential for coal production (Map 19). The remainder of the Lightning watershed and the northwest half of the Lance Creek watershed are designated as having "Moderate" potential for coal development. Little potential exists for coal development in the remainder of the Lance Creek watershed as the contact between the coal-bearing Tertiary formations and the older Lance Formation coincides roughly with the northeast-trending portion of the Lightning and Lance Creek watershed boundary.

2.2.5 Other Minerals

Map 20, Other Mine Sites and Mineral potential, delineates the locations of uranium, bentonite, limestone and other metal mining potential in the study area. Both the Lightning and Lance Creek watersheds contain isolated areas of potential uranium development (U.S. Bureau of Mines, 1990b). Potential deposits in the Lightning watershed can be found near the western watershed boundary in an area where the Wasatch Formation is mapped as the primary bedrock unit. Potential areas for uranium in the Lance Creek watershed can be found about 10 miles northeast of the town of Lance Creek in an area underlain by Cretaceous bedrock units. Currently, Cameco Resources, Inc. (formerly Power Resources) operates one active in-situ uranium mine, Highland, in the study area near the deposits in the far western extent of the Lightning watershed. Cameco Resources also operates another in-situ uranium mine just west of the Lightning watershed boundary in combination with the Highland mine (Wyoming Mining Association, 2010).

2.2.6 Transportation and Energy Infrastructure

The main transportation routes across Thunder Basin are illustrated in Map 21, Major Roads and Railroads. Highway 18-85 and Highway 59 are the main north/south routes with Highway 18-20 serving as the east/west route. Highway 270 provides a route north from Manville to Lance Creek (the heart of the study area) and east to Highway 18-85. Due to the high coal production rates to the north of the study area, the rail lines in the area have an extremely high volume of rail traffic. Maps 22 and 23, Major Pipelines, Major Electric Transmission Lines, respectively, provide information on the location of major pipelines and power lines in Thunder Basin L&LC watershed. Information on primary infrastructure such as dams and bridges will be used when siting water storage projects as discussed later in this report.

3.0 Watershed Inventory

3.1 Irrigation Inventory

3.1.1 Overview

The Thunder Basin L&LC watershed accounts for approximately 1,572,390 acres of land in northeast Wyoming. There are approximately 14,913 acres of irrigated land, or <0.1%. These few irrigated acres are vital to the ranchers in the area. The grasses that grow on the irrigated lands help sustain the rancher's cattle and livelihood. Local ranchers estimate that it takes 60acres of non-irrigated land to support one Animal Unit Equivalent (AUE). The irrigated acres supplement the rangeland forage supply for the cattle during difficult winter months and excessive drought conditions.

The following sections discuss the irrigated agriculture of Thunder Basin L&LC watershed including: the lands currently being irrigated; the current and potential future cropping pattern; and the irrigation methods used. It should be noted that evaluation of the potential for developing new irrigated lands was not included in the scope of this Level I study. This is not to say, however, that additional lands suitable for irrigation are not present in the watershed.

Irrigated Lands Mapping

Map 24 illustrates the distribution of irrigated land in Thunder Basin L&LC. Soil Surveys from the USDA and NRCS were used to create the map of the irrigated lands. The data from USDA and NRCS, show which areas of Thunder Basin L&LC watershed are best suited for irrigation based on soil type. Maps that show irrigated lands overlain on topographic maps were obtained from the University of Wyoming. Color infrared (CIR) satellite imagery from 2002 was used to identify irrigated lands on an individual basis. Almost all of the irrigated lands in the watershed are located in the overbanks and flanking terraces along the streams and rivers in Thunder Basin L&LC watershed.

The irrigated lands identified in the NE Wyoming Basin Plan study were digitally overlain on digital orthophoto quarter quadrangle (DOQQ) CIR photography flown in 2002 which is the latest available coverage suitable for this purpose. The red color on the CIR aerials indicates the presence of growing vegetation. When comparing the CIR aerials to the irrigated lands maps we could see where the vegetation was thriving and where it was sparse. When looking at the CIR aerials, it was interesting to note that many of the irrigated areas shown on the irrigated lands maps did not appear to be irrigated when looking at the CIR aerials. The smaller number of irrigated lands on the CIR aerials would suggest that due to severe drought conditions, fewer crops were being planted and/or the crops were not thriving.

Soil Irrigation Class

According to the USDA soil irrigation class map as illustrated in Map 25, the soils in the Thunder Basin L&LC watershed can be described as having severe limitations that reduce the choice of plants or require special conservation practices in order to achieve success with irrigation. Table 3.1.1-1 provides a summary of the soil irrigation class and percent of total acres that are mapped in the basin according to the classification scheme. As listed in Table 3.1.1-1, there are no Class I or II soils mapped in the watershed. Due to existing soil conditions, the variety of crops that can be effectively grown is limited to extremely hardy crops as shown in Table 3.1.1-2.

Table 3.1.1-1 Irrigation Class Distribution in Thunder Basin L&LC

Irrigation Capability	Abbreviated Description of Irrigation Capability Classification	Acres	Percent
Class I	Soils that have slight limitations that restrict their use.	0	0
Class II	Soils that have moderate limitations.	0	0
Class III	Soils that have severe limitations.	338,902	22
Class IV	Soils that have very severe limitations.	380,764	24
Class V	Soils that have other limitations.	1,533	0.1
Class VI	Soils that have severe limitations.	216,029	14
Class VII	Soils that have very severe limitations.	612,977	39
Class VIII	Soils and miscellaneous areas that have limitations	15,593	1
Water		1,856	0.1

Note: A full description of the irrigation class is provided on Map 25.

Cropping Patterns

According to 2002 USDA data, the only crop grown in the Lightning Creek and Hat Creek sub-basins is grass hay. The Lance Creek and Angostura Reservoir sub-basins are a little more diverse; with some alfalfa, grain, and corn in addition to the grass hay crop. Grass hay still accounts for 87% of the actively irrigated crops in the Thunder Basin L&LC watershed. Its lower water needs and ability to grow in poor soil conditions make grass hay the best crop for this region.

Table 3.1.1-2: Summary of Irrigated Crops in Thunder Basin L&LC

Sub-basin Name	HUC	Crop (acres)						Total Active
		Alfalfa	Grass	Grain	Corn	Idle	Total	
Lance Creek	10120103	790	6,309	114	48	801	8,062	7,261
Lightning Creek	10120101	0	2,211	0	0	643	2,854	2,211
Angostura Reservoir	10120106	877	2,860	127	53	288	4,205	3,917
Hat Creek	10120108	0	1,869	0	0	72	1,941	1,869
Total		**1,667**	**13,249**	**241**	**101**	**1,804**	**17,062**	**15,258**

Irrigation Methods

Crops in the study area are primarily irrigated using surface water. Surface water is the only source of water used in the irrigation of the Hat Creek and Angostura Reservoir watersheds.

Surface water accounts for 91% of agricultural irrigation in the Lance Creek watershed, with groundwater being used for 9% of irrigation. Surface water accounts for 80% of agricultural irrigation in the Lightning Creek watershed, with groundwater being used for 20% of irrigation.

Table 3.1.1-3: Primary Source of Irrigation Water in Thunder Basin L&LC

Sub-basin Name	HUC	Acres of Irrigated Land		
		Groundwater	Surface Water	Total
Lance Creek	10120104	667	7,395	8,062
Lightning Creek	10120105	469	2,385	2,854
Angostura Reservoir	10120106	0	4,204	4,204
Hat Creek	10120108	0	1,941	1,941
Total		**1,136**	**15,925**	**17,061**

Groundwater is used on approximately 7% of the irrigated land in the Thunder Basin L&LC watershed. Depth and availability make it difficult to extract large quantities of water from irrigation wells. There are only 4 wells in the entire Thunder Basin L&LC that yield more than 400 gpm. The few wells that can pump over 400 gpm are expensive to install and operate due to the depth from which the water must be extracted. Solar and wind powered wells typically observed across the Thunder Basin L&LC watershed are not potential irrigation well candidates. The typical flows obtained from either the solar or wind powered wells are in the range of 5-10 gpm and these flows are too small to consider them for irrigation use.

Flood irrigation is the most common form of irrigation in Thunder Basin L&LC watershed; it also happens to be one of the most cost efficient. With flood irrigation, expenses include the construction and maintenance of the diversion structures. Diversion structures can be expensive to build; however, they generally have a low maintenance costs. The drawback to using flood irrigation is that it is dependent on precipitation events that can be highly variable and unpredictable in the Thunder Basin L&LC watershed. Most flood irrigation systems in this region of Wyoming receive water directly from uncontrolled rivers and streams. Many rivers and streams in the watershed have little or no continuous flow; only after rainfall events do they have sizable flows. This makes flood irrigation difficult, as there isn't a reliable supply of water. Reservoirs offer more irrigation reliability as they contain the runoff from storm events and hold it to be used at a later date. With both reservoirs and the flood irrigation, sedimentation is also a significant issue to contend with. Sedimentation is discussed in more detail in Section 4.2.2.2.

3.1.2 Irrigation System Descriptions

Most, if not all, of the irrigation systems in Thunder Basin watershed are small, privately owned systems. Many of them are old, or dated systems with needed improvements and maintenance. These irrigation systems service areas ranging from a few acres to a couple hundred acres. The irrigation classifications are as follows:

A- Fully Irrigated Land (typically receives a full water supply.)

B- Partial Service Irrigation (typically receives a reduced water supply due to limited water availability or the inability to provide complete field coverage.)

C- Man Induced Sub-irrigation (beneficial use resulting from incidental irrigation such as ditch seepage to areas below a canal.)

S- Spreader Dike Irrigation (dikes constructed across ephemeral streams to spread infrequent flows over the land to increase beneficial use.)

H- Minor Beneficial Use (lands that receive some beneficial use on occasion such as lands served by kick-out ditches on ephemeral streams.)

E- Idle Irrigation (lands not currently receiving water, typically due to nonfunctional delivery systems.)

As listed in Table 3.1.2-1, less than 4% of the land in the Thunder Basin L&LC watershed is considered fully irrigated. During drought conditions this percentage will drop further. Most of the systems fall into the B, S, and H categories. These systems are supplied with water from ephemeral streams. They don't receive a full or steady supply of water.

Table 3.1.2-1: Summary of Irrigated Lands by Irrigation Classification (acres)

Sub-basin Name	HUC	Irrigation Classification							
		A (Full)	B (Partial)	C (Sub)	Total ABC	S (Spreader)	H (Minor)	E (Idle)	Total
Lance Creek	10120104	643	2,870	43	3,556	2,308	1,397	801	8,062
Lightning Creek	10120105	0	393	0	393	1096	722	643	2,854
Angostura Reservoir	10120106	0	1773	0	1,773	688	1455	288	4,204
Hat Creek	10120108	0	1442	0	1,442	46	381	72	1,941
Total		**643**	**6,478**	**43**	**7,164**	**4,138**	**3,955**	**1,804**	**17,061**

3.2 Groundwater Development Inventory

3.2.1 Groundwater Development Description

Based on the state engineer's July 2008 database, there are approximately 1,962 wells that are fully adjudicated/in good standing in the Thunder Basin L&LC watershed. The primary uses of the wells are listed in Table 3.2.1-1 and illustrated in Map 26, Groundwater Registered Wells Inventory Map. As listed in the table, stock wells are the most numerous water wells in the watershed.

Maps 27, Groundwater Registered Well Yield, and Map 28, Groundwater Registered Well Depth, illustrate the well yields and completion depths of the registered wells in Thunder Basin L&LC. This information is useful in reviewing additional opportunities to install wells. A more detailed geologic evaluation would be needed before a well construction project could be initiated, but information on well-depth and yield can provide preliminary information on the productivity and installation costs of proposed new wells.

Table 3.2.1-1 Registered Well Use in Thunder Basin L&LC

Well use	Registered Wells	Percentage of Total
Stock	1,173	60%
Other	453	23%
Domestic/Stock	205	10%
Domestic	94	5%
Industrial	37	2%
CBM	0	0%
Total	1,962	100%

3.3 Water Storage Site Inventory

Development of additional surface water storage opportunities within the Thunder Basin L&LC study area was a key objective of this Level I study. Providing additional water for irrigation and livestock/wildlife watering were the highest priorities for the study sponsors. Potential recreational opportunities and improvement of the riparian corridors also were important considerations. To create additional storage, both storage needs and potentially available water must be evaluated. The following sections discuss the potentially available and projected water shortages, existing reservoirs, and previous water storage investigations.

3.3.1 Surface Water Availability and Shortages

Information developed for the Northeast Wyoming River Basins Plan Final Report (HKM, 2002a) provided the basis for evaluating water availability and shortages as it related to proposed water storage projects in the Thunder Basin L&LC study area. The Northeast Wyoming River Basins Model consists of four water accounting spreadsheets that represent four sub-basins within the area. They are the Beaver Creek Model, the Belle Fourche Model, the Cheyenne River Model, and the Red Creek Model. The Cheyenne River model includes the main stem Cheyenne River, along with 17 tributaries. The models were developed as a planning tool for the state of Wyoming and local water users to determine where available flows might be available for future development.

The following paragraphs summarize the model development, as described in the technical memorandum documenting the Northeast Wyoming River Basins Plan Spreadsheet Model Development and Calibration (HKM 2002b).

The models are intended to simulate water use and availability under existing conditions. 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 1999 to identify the hydrological 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 the reaches in the Cheyenne River model, the dry years ranged from 73% to 98% lower than the normal years, with an average of 85% lower than normal. The wet years ranged from 63% to 706% higher than normal years, with an average of 312% higher than normal.

The models do not explicitly account for water rights, appropriations, or compact allocations nor is the model operated based on these legal constraints. Further, the model does not associate supplemental reservoir releases to the appropriate water users. However, by calibrating the models to historical streamflows at gaged locations, the models can be used to generally represent existing operations. Theoretical maximum diversion requirements were calculated using the mapped acreage of irrigated lands and consumptive irrigation requirements (CIR) were provided by the Consumptive Use and Consumptive Irrigation Requirements – Wyoming (Pochop et al., 1992.) The models were calibrated by adjusting the estimated actual diversions and diversion demands as well as irrigation efficiencies, duration of irrigation, and irrigation return flows.

To mathematically represent the Cheyenne River sub-basin, the river system was divided into reaches based primarily upon the location of major tributary confluences. Each reach then was subdivided by identifying a series of individual nodes representing diversions, reservoirs, tributary confluences, gages, or other significant water resources features. Figure 3.3.1-1, Model Nodes and Reaches Schematic, shows the model elements for the Cheyenne River portion of the Northeast Wyoming Basins model.

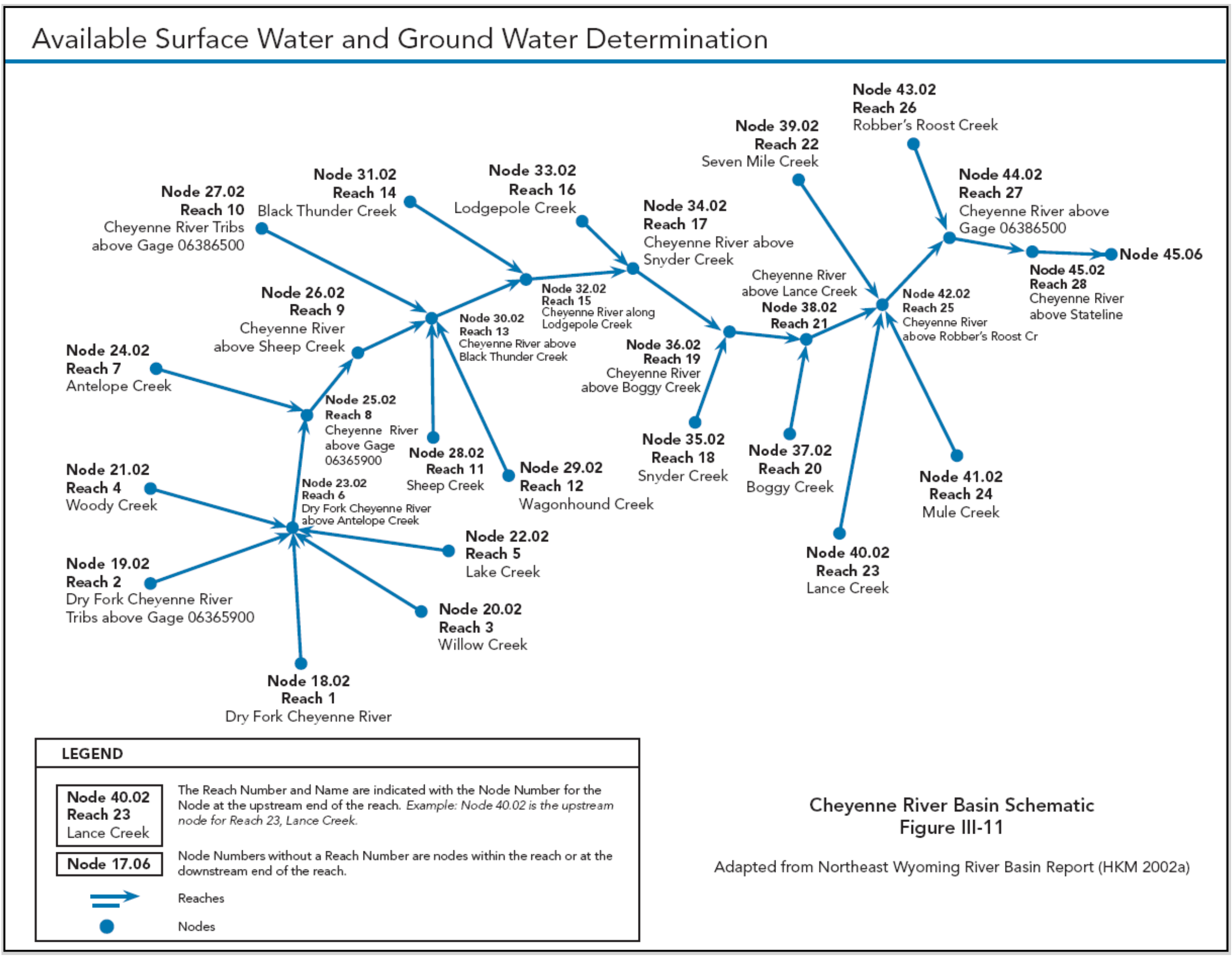


Figure 3.3.1-1 Cheyenne River Model Node Diagram (HKM, 2002a).

At each node, a water budget computation was completed to determine the amount of water that bypasses the node. At non-storage nodes, the difference between inflow, including upstream inflows, return flow, imports and basin gains, and outflows, including diversions, basin losses and exports, is the amount of flow available for the next node downstream. For storage nodes, an additional loss calculation for evaporation and the change in storage was evaluated. Also at storage nodes, any uncontrolled spill that occurs is added to the scheduled release to determine total outflow. Diverted amounts at diversion nodes are the minimum of demand (the full supply diversion at the structure) and physically available streamflow. The mass balance, or water budget calculations, is performed for all nodes in a reach.

"Available water" at a given reach terminus was defined as the minimum of the physically available flow at that point and the available flow at all downstream reaches (HKM, 2002c). Available flow was defined first at the most downstream point and then upstream availability was calculated in stream order. The calculations were made on a monthly basis, and annual water availability was computed as the sum of monthly values. Calculating the 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, since it reflects the constraints of downstream use on a monthly basis.

Tables III-16, III-17, and III-18 of the Northeast Basins report (HKM, 2002a) show the monthly and annual available water by model reach for the Cheyenne River basin. A summary showing the annual available water is depicted in Table 3.3.1-1. The annual available water in Lance Creek is 3,184 acre-feet, 18,323 acre-feet, and 44,909 acre-feet for the dry, normal, and wet hydrologic conditions, respectively. Mule Creek, downstream of Lance Creek but within the overall study area had water availability of 6 acre-feet, 33 acre-feet, and 80 acre-feet for the dry, normal, and wet years, respectively. These values represent the annual availability, as opposed to the sum of the monthly availability. Annual availability for normal year hydrologic conditions is shown in Map 29, Available Surface Water. The model indicated shortages in many of the reaches based on physically available water compared to demands on water. These reaches are highlighted in blue on Table 3.3.1-1.

The model has limitations, which should be considered when reviewing the model and its results. The most significant limitation is that the model does not account for diversions in accordance with Wyoming water law. Downstream senior rights are not given priority, which should result in an upstream junior right incurring a shortage. Though the model does not account for this occurrence, historical diversion data would reflect these actual operational conditions. If a Level II study of a particular storage project is to be undertaken, it is suggested that StateMod or similar model be developed so that water rights can be appropriately exercised and potential water availability can be more accurately estimated.

Table 3.3.1-1 Annual Available Flow Data for Cheyenne River Basin for Dry, Normal, and Wet Year Hydrologic Conditions (acre-feet) as reported in Northeast Wyoming River Basins Report (HKM, 2000a)

Reach	Reach Name	Dry Year	Normal Year	Wet Year
1	Dry Fork Cheyenne River	24	244	1,967
2	Dry Fork Cheyenne River Tribs above Gage 06365900	44	183	1,341
3	Willow Creek	60	225	704
4	Woody Creek	2	8	13
5	Lake Creek	18	68	213
6	Dry Fork Cheyenne River Tribs above Antelope Cr	164	860	4,501
7	Antelope Creek	534	2,837	21,427
8	Cheyenne River above Gage 06365900	705	3,696	25,968
9	Cheyenne River above Sheep Cr	707	6,341	37,321
10	Cheyenne River Tribs above Gage 06386500	69	399	1,980
11	Sheep Creek	1	8	19
12	Wagonhound Creek	3	17	60
13	Cheyenne River above Black Thunder Cr	1,007	7,074	39,624
14	Black Thunder Creek	358	5,120	16,078
15	Cheyenne River above Lodgepole Cr	1,482	12,193	55,745
16	Lodgepole Creek	9	480	1,268
17	Cheyenne River above Snyder Cr	1,491	12,674	57,013
18	Snyder Creek	14	187	474
19	Cheyenne River above Boggy Cr	1,511	12,861	57,500
20	Boggy Creek	4	34	122
21	Cheyenne River above Lance Creek	1,515	12,895	57,621
22	Seven Mile Creek	2	29	65
23	Lance Creek	3,184	18,323	44,909
24	Mule Creek	6	33	80
25	Cheyenne River above Robbers' Roost Cr	4,706	31,280	102,675
26	Robbers' Roost Creek	8	47	138
27	Cheyenne River above Gage 06386500	4,742	31,328	103,270
28	Cheyenne River above Stateline	4,911	31,434	103,362

(blue)	Model indicates shortage in reach
(green)	1,000 acre-feet or more available in normal year (reaches within study area)

The original study period for the Northeast Wyoming River Basins Model was 1970 to 1999. The model was updated to include 2000 through 2010. The analysis was done in two steps. Because there are no active stream gages in the watershed, the first step was to develop streamflows based on a reference gage, as described in the Northeast Wyoming River Basins Model Surface Water Hydrology Memorandum, Tasks 3A and 3B (HKM, 2002d), The first step was to extend the data. The reference stream gage used for the data extension was USGS Gage 06395000, Cheyenne River at Edgemont, South Dakota. This gage was used to develop data for USGS Gage 06386000, Lance Creek at Spencer near Riverview, Wyoming. The relationship between the two gages was described by the following regression equation:

$$y = 0.3049x + 820.91$$

where: x = annual flow (acre-feet) of Cheyenne River at Edgemont, South Dakota (Stn. 06395000)
y = annual flow (acre-feet) of Lance Creek near Riverview, Wyoming (Station 06386000)

The relationship had an R^2 value of 0.9253. The Lance Creek annual flow in acre-feet at Gage 06386000 was calculated from the reference gage. To determine the monthly flows, the monthly distribution that was developed for the original study period was used. Data Summary 3.3.1-1 (Appendix A) presents the annual and monthly flows, along with the monthly distribution for the entire period of 1970-2010.

Wet, normal, and dry years were previously defined as the highest 20% of years being wet years, the lowest 20% of years being dry years, and the remainder being normal years. The same criterion was applied to the new study period. Table 3.3.1-2 shows the resulting designation.

Table 3.3.1-2. Wet, Normal, and Dry Year Designation

Year	Annual Flow (ac-ft)	Designation		Year	Annual Flow (ac-ft)	Designation
1970	3361	Dry		1991	41370	Wet
1971	53510	Wet		1992	3689	Normal
1972	5702	Normal		1993	21600	Normal
1973	23567	Wet		1994	14734	Normal
1974	7530	Normal		1995	14050	Normal
1975	2904	Dry		1996	16715	Normal
1976	5331	Normal		1997	21913	Normal
1977	1819	Dry		1998	17355	Normal
1978	63214	Wet		1999	32791	Wet
1979	23004	Wet		2000	10409	Normal
1980	17607	Normal		2001	13158	Normal
1981	17303	Normal		2002	3616	Dry
1982	21457	Normal		2003	10288	Normal
1983	11748	Normal		2004	2835	Dry
1984	23540	Wet		2005	4491	Normal
1985	4733	Normal		2006	2603	Dry
1986	23134	Wet		2007	2808	Dry
1987	20413	Normal		2008	14876	Normal
1988	3481	Dry		2009	7362	Normal
1989	6028	Normal		2010	14979	Normal
1990	7801	Normal				

The averages of the flows for the wet, normal, and dry years were input into the Northeast Wyoming River Basin models. The resulting data for the available water for each of these three hydrologic conditions, however, did not make sense as compared to the previous modeling period reported in the Northeast Basins Report (HKM, 2002a.) The available water is a balance of the nodes shown in Figure 3.3.1-1 in which inputs are added and diversions are subtracted. Upon evaluation of the model inputs and outputs for the original Northeast Wyoming River Basins models, the same numbers that were shown in the report could not be replicated. Therefore, while the data was input into the model, updated water availability data was not generated. Upon discussion with the State, further investigation of the original models was not conducted.

3.3.2 Existing Reservoirs

As discussed in Section 2.1.7.2, Map 12, (National Inventory of Dams), shows the locations of the study area's 62 dams in the NID. The combined storage behind the identified dams is 13,483 acre-feet. The largest identified reservoir, Bradley, holds 644 acre-feet. The median reservoir size is 172 acre-feet. Dams that do not fall under the jurisdiction of the state engineer's office were not included in the database. Data Summary 3.3.2-1 (in Appendix A) lists the dams with select relevant information. Map 14, Stock/Wildlife Ponds, shows the location of 2,048 stock ponds in the study area.

3.3.3 Previous Storage Site Investigations

The Northeast Wyoming River Basins Plan (HKM, 2002a) did not identify any long-list future water use opportunities in the study area. Studies completed in 1939 and 1957 included potential water storage projects. The list of projects is in Table 3.3.3-1, along with available information about the project location and the source of the information. The intended storage for the structures varied in size from 40 acre-feet to 3,300 acre-feet. None of these projects were identified in the Northeast Wyoming River Basins Plan. Two structures identified in the Cheyenne River Basin Water Resource Study appear to have been constructed in the location identified in the study. The NID database shows that Middle No. 1 dam on Middle Cow Creek was constructed in 1962. The dam is listed as 17 feet high with 246 acre-feet of storage for the purpose of irrigation. The NID database also shows Wildcat No. 3 dam in the location identified in the study for Wildcat No. 2. Wildcat No. 3 was constructed in 1959. The dam is listed as 35 feet high with 176 acre-feet of storage for the purpose of irrigation. These dams were not visited as part of the study and, therefore, their current condition is not known.

Table 3.3.3-1 Previously Identified Potential Water Storage Projects

Project Name / Water Source	Section, Township & Range / County	Storage, acre-feet	Water Uses	Flaw
***Water Resources of the Missouri River Basin in Wyoming - Cheyenne River*[1]**				
Storrie No. 2 / Hot Creek	Sec 32, T 34 N, R 62 W / Niobrara	870	Agricultural	---[4]
# 77 Lance Creek	Sec 19, T 34 N, R 65 W / Niobrara	684	Agricultural	---
Witt No. 1 enl / So. Lightning Creek	Sec 21, T 35 N, R 70 W / Converse	3,273	Agricultural	---
***Cheyenne River Basin Water Resource Study*[2]**				
Bridge	Sec 24, T 39 N, R 62 W / Niobrara	200	Agricultural	---
Young Woman	Sec 3, T 35 N, R 63 W / Niobrara	1,497	Agricultural	---
Dry Draw	Sec 25, T 38 N, R 63 W / Niobrara	200	Agricultural	---
Dry Draw	Sec 26, T 38 N, R 63 W / Niobrara	100	Agricultural	---
Smyth Draw	Sec 15, T 38 N, R 63 W / Niobrara	40	Agricultural	---
Cow	Sec 20, T 38 N, R 65 W / Niobrara	1,000	Agricultural	---
Cow	Sec 14, T 38 N, R 66 W / Niobrara	1,000	Agricultural	---
Middle Cedar	Sec 2, T 37 N, R 66 W / Niobrara	100	Agricultural	---
Rat	Sec 35, T 38 N, R 69 W / Converse	50	Agricultural	---
Middle[5]	Sec 8, T 38 N, R 67 W / Converse	100	Agricultural	---
Wildcat No. 2[5]	Sec 2, T 36 N, R 65 W / Converse	150	Agricultural	---
***Northeast Wyoming River Basins Plan Final Report*[3]**				
None identified				

Notes: For notes 1-4, the report title is listed above and the following information provides / Level / Author / Date / Report Location

[1] Level 1 / State Engineer's Office / 1939 / WWDO and State Library

[2] Level 1 / Wyoming Natural Resources Board / 1957 / WWDO & WRDS

[3] Level 1 / HKM Engineering, Inc. / 2002

[4] Not available in document or unknown

[5] Water storage facility exists in identified location

3.4 Water Quality

3.4.1 Stream Classifications

Many of the streams in the Thunder Basin watershed have been classified for protection of one or more uses by the WDEQ. Streams within the study area have been classified as 2ABWW or 3B (WDEQ, 2001). The Water Quality Rules and Regulations, Chapter 1, Wyoming Surface Water Quality Standards defines these three classifications as follows:

> *"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 non-game fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses.

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."

Table 3.4-1 WDEQ Surface Water Classes and Use Designation

	Drinking water	Game Fish	Non-Game Fish	Fish Consumption	Other Aquatic Life	Recreation	Wildlife	Agriculture	Industry	Scenic Value
1*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3A	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3B	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3C	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4B	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4C	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

* Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the National Parks and Wilderness are Class 1, however, all do not support fisheries or other aquatic life uses (e.g. hot springs, ephemeral waters, wet meadows etc). For stormwaterpermitting, 401 Certification, and WQ assessment purposes, independently the actual uses on each particular water must be determined.

Table 3.4-1 defines the uses that are protected for all of the WDEQ surface water classifications. Map 30, WDEQ Stream Classifications, shows the stream classifications within the study area. Table 3.4-2 lists the streams and their classifications. There are differences between the GIS information obtained from the State and the WDEQ Surface Water Classification List (WDEQ, 2001). Map 30 shows the information obtained from the State's GIS database. In the Surface Water Classification List, Lance Creek was categorized as Class 2ABWW waters, for which designated protected uses include drinking water, warm-water game fisheries, non-game fisheries, fish consumption and all uses protected for Class 3B waters. According to the published state list, Lightning Creek is classified as 3B waters, for which designated protected uses include aquatic life other than fish, recreation, wildlife, agriculture, industry and scenic value.

Table 3.4-2 Thunder Basin L&LC Watershed Stream Classifications

Stream Name	WDEQ Classification			
	2AB	2ABWW	3B	4
Alum Creek			[shaded blue]	[shaded green]
Antelope			[shaded blue]	[shaded green]
Antelope Drain			[shaded blue]	[shaded green]
Bliss Creek		[shaded green]	[shaded blue]	
Box Creek			[shaded blue]	[shaded green]
Buck Creek			[shaded blue]	
Cow Creek			[shaded blue]	[shaded green]
Cow Gulch			[shaded blue]	
Dogie Creek			[shaded blue]	[shaded green]
Dry Creek			[shaded blue]	[shaded green]
East Fork Buck Creek			[shaded blue]	[shaded green]
Lance		[shaded blue]		
Lightning Creek			[shaded blue]	[shaded green]
Little Cow Creek			[shaded blue]	[shaded green]
Little Lightning Creek			[shaded blue]	[shaded green]
North Fork Box Creek			[shaded blue]	[shaded green]
Old Woman			[shaded blue]	
Poison Drain			[shaded blue]	
Sage Creek	[shaded blue]			
South Fork Box Creek			[shaded blue]	[shaded green]
Spring Creek			[shaded blue]	[shaded green]
Twentymile Creek			[shaded blue]	[shaded green]
Walker Creek			[shaded blue]	[shaded green]
Young Woman Creek			[shaded blue]	[shaded green]

Sources:

[shaded blue] Wyoming Surface Water Classification List, Water Quality Division Surface Water Standards, June 21, 2001

[shaded green] GIS

3.4.2 Water Quality Assessment

The Niobrara Conservation District has been conducting baseline stream sampling for a number of years at three different sites within the study area. The sites are located on Lightning, Lance, and Old Woman Creeks. The sampling site location maps provided by the district are included in Appendix D. The purpose of the monitoring was to build a baseline dataset that covered climatic changes over time, as well as to determine whether the streams were meeting the beneficial uses assigned by the Wyoming Department of Environmental Quality based on the stream classification.

Sampling data was obtained for the Lance Creek site for the period of July 1999 through June 2010. The sampling period obtained for Lightning Creek was August 1999 through August 2008, after which monitoring was discontinued. Old Woman Creek was sampled for the period of August 1999 through October 2007, after which monitoring was discontinued.

Limited water quality sampling data for the Thunder Basin L&LC watershed is also available from the USGS.

3.4.3 Suitability for Agricultural Use

Analysis of available water quality samples was conducted to gain a sense of whether the water is suitable for agricultural use, mainly irrigation and livestock watering. Water quality criteria were compiled from four sources to assess the suitability and is presented in Data Summary 3.4.3-1 (in Appendix A). It should be noted that the WDEQ criteria was obtained from Chapter eight of the Water Quality Rules and Regulations, which addresses standards for Wyoming groundwater. Chapter one, which addresses surface water standards, does not contain water quality standards for livestock or irrigation.

Water quality sampling data was obtained from the USGS Web site for the gages identified on Map 14, Gaging Stations and Streamflow/Sampling Sites. The gages are listed in Data Summary 2.1.7-2 (in Appendix A). Eleven of the gage locations had only one to three sample events, one gage had 14 sample events, and USGS Gage 06386000 had 127 sample events. Water quality data can be found for the gages at the following Website: http://nwis.waterdata.usgs.gov/wy/nwis/qwdata.

Data Summary 3.4.3-2 (in Appendix A) shows a summary of the sampling results. Ranges of results were typically shown for gage locations that had numerous samples, while the gages with only one or two samples show the results for the one or two samples, as appropriate. Values that exceeded the criteria listed in Data Summary 3.4.3-1 (in Appendix A) are highlighted in red. If results were reported as a “less than” value that was greater than the criteria, the results were highlighted in blue. It is possible that the criterion was exceeded, but not enough information was provided to be certain. For example, mercury was often reported as less than 1.0 µg/L, but the criteria is 0.05 µg/L, less than the value reported. It is not known whether the criterion was exceeded. Sodium absorption ratio (SAR) data was not available for any of the UGSS samples.

The water quality criteria exceeded most often were sulfate, specific conductance, and manganese. Exceeding the criteria does not necessarily indicate that water is unsuitable for livestock watering or agriculture. It does suggest that livestock and less tolerant plants might not be as productive as they would be with lower levels of the constituent. The Niobrara Conservation District reported that high SAR water is known to have caused adverse effects in the Cheyenne River basin.

Data Summary 3.4.3-3 (in Appendix A) presents a summary of the Niobrara Conservation District baseline sampling results. The values that exceeded the criteria listed in Data Summary 3.4.3-1 are highlighted in red. The water quality criteria most often exceeded were specific conductance, turbidity, total phosphorous, and sulfates.

3.4.4 Waters Requiring TMDLs

The Wyoming Water Quality Assessment and Impaired Waters List (2010 Integrated 305(b) and 303(d) Report does not show any of the streams in the study area to be water bodies for which Total Maximum Daily Load (TMDL) determinations have been completed or are needed.

3.4.5 WYPDES Permitted Discharges

Data obtained from the WDEQ/WCD shows that there are 41 Wyoming Pollutant Discharge Elimination System (WYPDES) permitted discharges in the study area. They are all oil treatment permits. The locations of the outfalls are shown in Map 31, WYPDES Permitted Discharges.

3.4.6 Thunder Basin L&LC Wetland Functions

Wetlands can provide many functions, including wildlife habitat, flood flow alteration, erosion control, sediment capture, nutrient transformation, groundwater recharge/discharge, habitat for rare species, and recreational opportunities. An individual wetland may provide some but not all of these functions, depending on variables such as size, hydrologic regime, location in the landscape, connectivity to other wetlands, and surrounding land use. Thus for the Thunder Basin L&LC watershed, it is only possible to generalize about wetland functions, and not discuss the functions of individual wetlands.

The location of the Thunder Basin L&LC watershed wetlands were mapped as part of the National Inventory of Wetlands (Map 11). The watershed primarily contains three general categories of wetlands:

- Riparian wetlands adjacent to stream channels
- Seep wetlands in areas where groundwater reaches the surface
- Wetlands associated with small impoundments such as cattle ponds

The functions most likely to be provided by each type of wetland are discussed below.

Riparian Wetlands. These wetlands are located along drainages throughout the watershed. Depending on their size and whether the stream is ephemeral, intermittent, or perennial, these wetlands are most likely to provide the functions of wildlife habitat, flood flow alteration, and streambank erosion control. Some of these wetlands may occur in cut-off oxbows of streams. Wetlands adjacent to streams can serve as corridors for movement of terrestrial wildlife, and particularly if they are associated with permanent bodies of water, serve as cover and food sources for aquatic organisms. Thus, they may provide recreational opportunities for hunting and fishing. In addition, wetlands adjacent to streams provide storage for out-of-bank flood flows. In these areas, flood waters will be slowed, and the lower flood velocity combined with the vegetative cover are likely to reduce erosion in and adjacent to stream channels. Wetlands along perennial streams will have a more diverse plant community, and may provide habitat for rare species.

Seep Wetlands. These wetlands develop in places where groundwater intersects with the land surface for at least part of the year. The wetlands in these areas may have a hydrologic regime that is temporary or relatively permanent. Depending on the season of the year and the duration of seepage, these wetlands may provide the functions of recharging or discharging groundwater, or both. Recharging groundwater may be important for maintaining the water table and thus supplying wells, while discharging groundwater may be important for maintain the headwaters of streams, particularly perennial streams. Wetlands maintained by seeping groundwater are often quite diverse due to their relative hydrologic stability compared to wetlands maintained exclusively by surface runoff, and thus also may provide habitat for rare species.

Impoundment Wetlands. These wetlands are associated with small ponds, such as those created for cattle. These ponds may be on-line (in other words, impoundments of a channel) or off-line in which case the water may be maintained by pumping water. Depending on the size of the pond, the depth of the water, and the source of the water, the wetland may be a fringe around the margins or may be more extensive. In either case, the impounded basin allows for water to be detained for longer periods of time than is the case for most riparian or seep wetlands. Thus these wetlands can provide the function of improving water quality by trapping sediment and removing and transforming nutrients. In addition, they can provide a water source for wildlife during times when surface water is otherwise scarce. Even a small pond with a fringe wetland may provide resting habitat for migrating waterfowl. Impacts to these wetland systems can limit plant diversity or suitable habitat for rare species.

4.0 Watershed Management and Rehabilitation Plan

The following subsections provide details on the proposed watershed improvement projects. The projects are subdivided into irrigation improvements, surface water storage and wildlife/livestock watering opportunities and other management practice improvements.

4.1 Irrigation Systems

Based on the responses from the landowners across Thunder Basin L&LC, for the Level I Watershed Study, we evaluated three landowner irrigation systems. Irrigation systems inventoried include:

- Bruegger's Property
- Kruse's Property
- Jensen's Property

Rehabilitation plans have been proposed for each of the ranches inventoried. The rehabilitation plans give the owners an idea of what needs to be done to make these irrigation systems function properly and efficiently.

The alternatives were based upon information obtained from project meetings and the evaluation of field inventory data. These alternatives provide the owners an overall assessment of conditions associated with the irrigation ditches, spreader dikes, and the associated hydraulic structures. They are not all-inclusive as the entire extent of each irrigation system was not examined. Additionally, evaluating water rights for the diversions was not part of the scope of this study.

For the purposes of this Level I investigation, the rehabilitation plans offer potential solutions to the primary issues and problems associated with each system. The irrigators can use these plans as a "resource or wish list" from which they can select projects for future Small Water Project Program or Water Development Program Level II investigations and ultimately Level III design and construction, if they desire to follow through with WWDC funding. Alternatively, this information also will support application for NRCS and/or other funding, as appropriate.

The rehabilitation plans focus on:

- Rehabilitation/replacement of existing structures
- Enhanced delivery of water
- Reduction in annual operation and maintenance costs
- Improvement in ditch management and efficiency
- Economic practicality
- Physical feasibility

4.1.2 Ditch Rehabilitation Plans

Based upon the results of the field inventories, rehabilitation cost estimates were developed and are presented in Table 4.1.2-1 – Irrigation System Rehabilitation Plans. This table includes the general description of the improvements and the estimated cost of construction.

Table 4.1.2-1 Irrigation System Rehabilitation Plans

Project Number	Ranch Name	Description	Units	Quantity	Unit Cost	Total Cost
1	Bruegger	Construct spreader dikes	Foot	300	$30/ft	$9,000
2	Jensen	Install centrifugal pump	Each	1	10,000	$10,000
3	Kruse	Improve berms on N side of Lightning Creek for hay fields	Foot	600	$10/ft	$6,000

4.1.2.1 Bruegger Ranch

The Brueggers's have several irrigation systems in place. Some of the key systems we looked at include: spreader dikes at Field 1 and the dam along Cow Creek Road (Map 34a). Rehabilitation and expansion of the spreader dikes at Field 1 would increase the area served by the dikes. It is estimated that with an addition of 200 linear feet to the spreader dikes, more water could be stored, and an additional area of 5.5 acres could be irrigated. Sediment removal from the dam along Cow Creek Road are discussed in Section 4.2.3.1.

4.1.2.2 Jensen Ranch

Jensen's Ranch is south of Lance Creek on the north side of the creek (Map 34e). They are looking at irrigating a field on the south end of his property. The Lance Creek runs along the south and west side of the field to be irrigated. The creek has been cutting back significantly. The cut backs are causing high banks to form on the south end of Jensen's property. This is making it difficult to utilize the water in the creek. The two options evaluated included cutting a ditch through the field or setting up a centrifugal pump to take water from Lance Creek over to the field they are interested in irrigating. The second option is the most cost effective. The plan would be to construct a small pumping basin on the south end of the property and pump the water onto the fields. The pump should be set up so that it is on wheels so that it can be moved if necessary.

4.1.2.3 Kruse Ranch

Kruse's Ranch has well established hay fields adjacent to Lightning Creek (Map 34h). Over the years, they have built berms along the north side of Lightning Creek. This allows runoff from rainfall events to flood the hay fields before draining into the creek. There are some low areas in the berms that will need to be addressed. The proposed improvement includes 600 linear feet of berm improvements.

4.2 Surface Water Storage

4.2.1 Alternative Concepts for New Surface Water Storage

Due to the large study area, it was necessary to develop screening criteria and methods to identify locations where water would be available and needed. Four main surface water storage concepts were developed based on known needs and shortages, potential water availability, and property owner requests. They are described below. The evaluations are described in Sections 4.2.2-4.2.5.

Account III Multipurpose Storage (see Section 4.2.2) – Reservoirs that would meet the requirements for WWDC Account III funding were first investigated. New reservoirs would need to provide at least 2,000 acre-feet of storage to qualify for the funding mechanism. Expansion of existing reservoirs must provide an additional 1,000 acre-feet of storage to qualify for the funding. The primary function of the reservoirs would be to provide supplemental irrigation water for irrigated lands that could be served through gravity delivery of water. The storage sites would need to be located far enough downstream of the headwaters to be able to capture the necessary amount of available flow. Secondary functions of the reservoirs would be to provide water in an "environmental account" to release for streamflow enhancement at critical times of the year, and as a seasonal fishery and/or for recreation.

Property Owner Storage Evaluation Requests (see Section 4.2.3) – Through the public information process, property owners and stakeholders were asked for input regarding storage evaluations on their properties. These requests were evaluated.

Livestock / Wildlife Storage **(**see Section 4.2.3) – As a rule of thumb, cattle will graze up to a mile from a water source. Using this criterion, an analysis of the watershed was conducted to identify locations where additional water storage for livestock watering could be beneficial.

Supplemental Storage at Existing Breached Dam Locations (see Section 4.2.5) – The watershed was searched to locate breached dam locations as potential water storage locations. Locations where dams once existed served a useful purpose at some point in time and may have an existing water right allocation. Rehabilitating a breached dam may be more extensive than constructing a new water storage dam, but permitting can be easier. These water storage sites would be used for supplemental irrigation of nearby irrigated lands and/or livestock and wildlife watering.

4.2.2 Potential Account III Sites

4.2.2.1 Overview

To qualify for WWDC Account III funding, a new surface-water storage project must provide a minimum of 2,000 acre-feet of storage and an expansion of an existing surface water storage site must provide an additional 1,000 acre-feet of storage. This section describes the process used to locate the structures and their conceptual design. The conceptual designs were based on information gathered and developed through the various tasks of this project.

4.2.2.2 Alternative Reservoir Locations and Sizing

New water storage dams were located to capture as much of the available flow as possible and far enough downstream within the watershed that the available flow would be 2,000 acre-feet annually for a normal hydrologic year. Other factors in the potential locations of the storage sites included topography, geology, proximity to irrigated lands, environmental impacts, and upstream/downstream constraints, including mines, highways, buildings, and other infrastructure. Water storage sites were developed in four locations, two on Lightning Creek, one at the confluence of Lance and Lightning Creeks, and one on Old Woman Creek.

It should be noted that the sites were identified using available water data from the Northeast Wyoming River Basins model, which does not include a detailed accounting of diversions in accordance with Wyoming water law. For example, downstream senior rights are not given priority, which should result in an upstream junior right incurring a shortage. If a Level II study of a particular storage project is to be undertaken, it is recommended that StateMod or similar model be developed so that water rights can be appropriately analyzed.

Concentrations of salts and other constituents can increase due to evaporation of water within storage reservoirs. The effects of accumulation of salts and other water constituents on the watershed should be investigated if one of the storage site projects were to advance to the next level of study.

For expansion of existing reservoirs, each of the 62 dams identified in the National Inventory of Dams (NID) and shown in Map 12, National Inventory of Dams, was evaluated to determine whether each dam has enough watershed area to yield a minimum of 1,000 acre-feet of available water based on a unit available water during the normal year of 8.7 acre-feet per square mile. In order to generate 1,000 acre-feet of water, a minimum of 114 square miles of watershed must be present. The contributing watershed would actually need to be larger since the dams have existing storage. None of the dams had close to 100 square miles of watershed area. Expansion of an existing reservoir to qualify for Account III funding is not an option in the Thunder Basin L&LC watershed.

The four sites identified as viable sites for new water storage dams are shown in Map 32. Data Summary 4.2.2-2 (in Appendix A) presents a comprehensive summary of design parameters related to the four dam locations, as well as a wide array of relevant information collected and developed throughout the course of the project. Maps 33a-33d show the four locations with the dam centerlines and limits of storage volumes.

Each dam site was designed to have an environmental account (EA) pool, which has a 50-year sedimentation life, and irrigation storage. The four sites have an average useful life of 57 years. The initial goal was to provide useful life of at least 100 years, however, an estimation of the potential sedimentation rates indicated that a dam that would be able to store 100 years of sediment accumulation plus water would not be reasonable.

Sedimentation was estimated from Figure 27 of *Sediment Sources and Drainage Basin Characteristic in Upper Cheyenne River Basin* (Hadley and Schumm, 1961). It is included in this report as Figure 4.2.2-1, Sediment Yield in the Lance Creek Basin. The U.S. Bureau of Reclamation has conducted sedimentation surveys on a number of its reservoirs. Reports obtained from the following Web site were reviewed. Annual sedimentation rates tended to be higher than those reported in Hadley and Schumm.
http://www.usbr.gov/pmts/sediment/projects/ReservoirSurveys/index.html

Elevation and stage-storage information for each location was developed using USGS topographic maps with 20-foot contour intervals. Detailed topographic information will be needed if further analysis of dam sites is desired. The NRCS' Reservoir Operations Study Computer Program (RESOP) was used to estimate reservoir levels on a monthly basis. RESOP utilizes stage-storage relationships, monthly available flows, monthly average precipitation, monthly average evaporation, estimates of seepage, and beneficial use.

The EA pool volume was determined from the lowest average monthly water level determined with the RESOP model. Irrigation storage for each site was determined by modeling the reservoirs with and without irrigation. The initial estimate of irrigation was half of the volume of the lowest month's permanent pool. The volume of water available for irrigation was spread between May and August and the water available models were iterated to use the difference between the EA and the available water. The total storage was based on the RESOP analysis, which maximized the storage at each site. Figure 4.2.2-2 illustrates the results of the analysis. The reservoir storage line takes into consideration monthly inflows of available water and precipitation and monthly outflows of irrigation water, evaporation, and seepage. Balancing the inputs and outputs, at Lightning Creek 1, the maximum storage available, assuming the sediment storage is full, would be approximately 17,600 acre-feet.

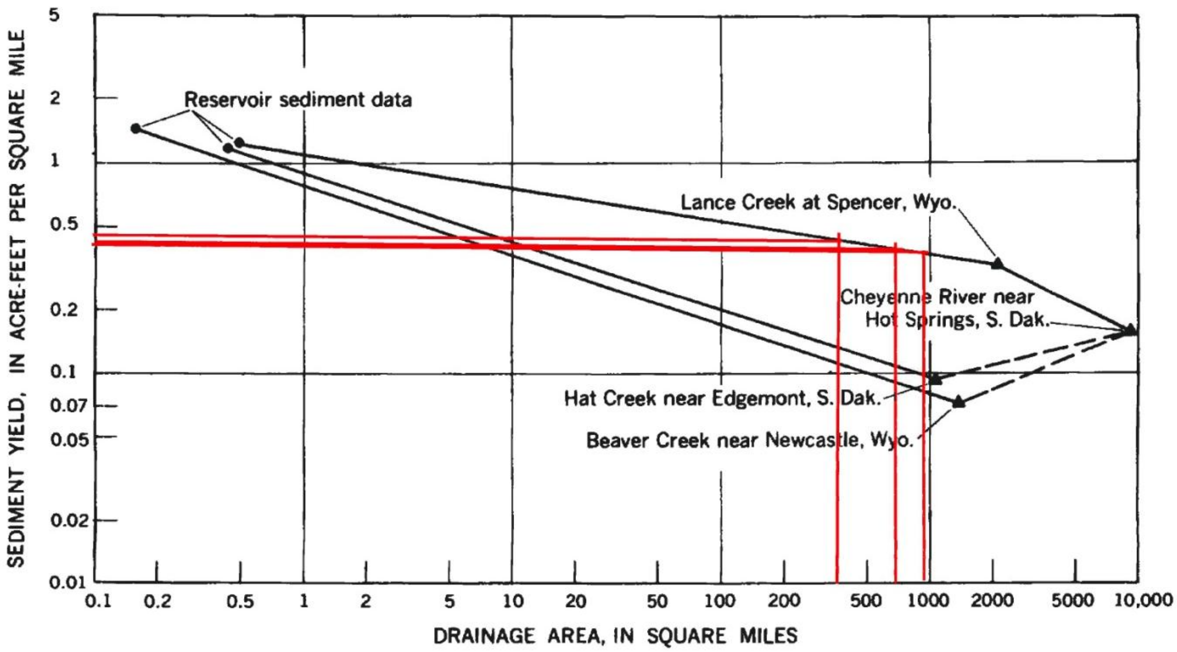


FIGURE 27.—Relations between sediment yield to 87 sediment-observation reservoirs and suspended sediment measured at gaging stations in the Cheyenne River basin.

Figure 4.2.2-1 Sediment Sources and Drainage Basin Characteristic in upper Cheyenne River Basin (Hadley and Schumm, 1961)

Over time, the environmental account will fill with sediment. As the sediment accumulates, the environmental account storage will decrease and the elevation of the irrigation storage pool will increase. The volume of the irrigation pool would be the same, but it would be stored at a higher elevation. At a point in the future if and when the entire reservoir is filled with sediment, the irrigation pool will no longer exist, either. Once the environmental account volume is filled with sediment, the irrigation storage pool will begin to fill with sediment and the volume available for irrigation will decrease. The water level management of each reservoir will change over time. After the design life of each reservoir is reached, it is anticipated that it could be full of sediment. It should be noted that a sediment capture rate of 100 percent was used. This rate might be overly conservative, but the sediment yield information greatly varied. Should a site advance to a Level II study, a more detailed analysis on sedimentation will be needed.

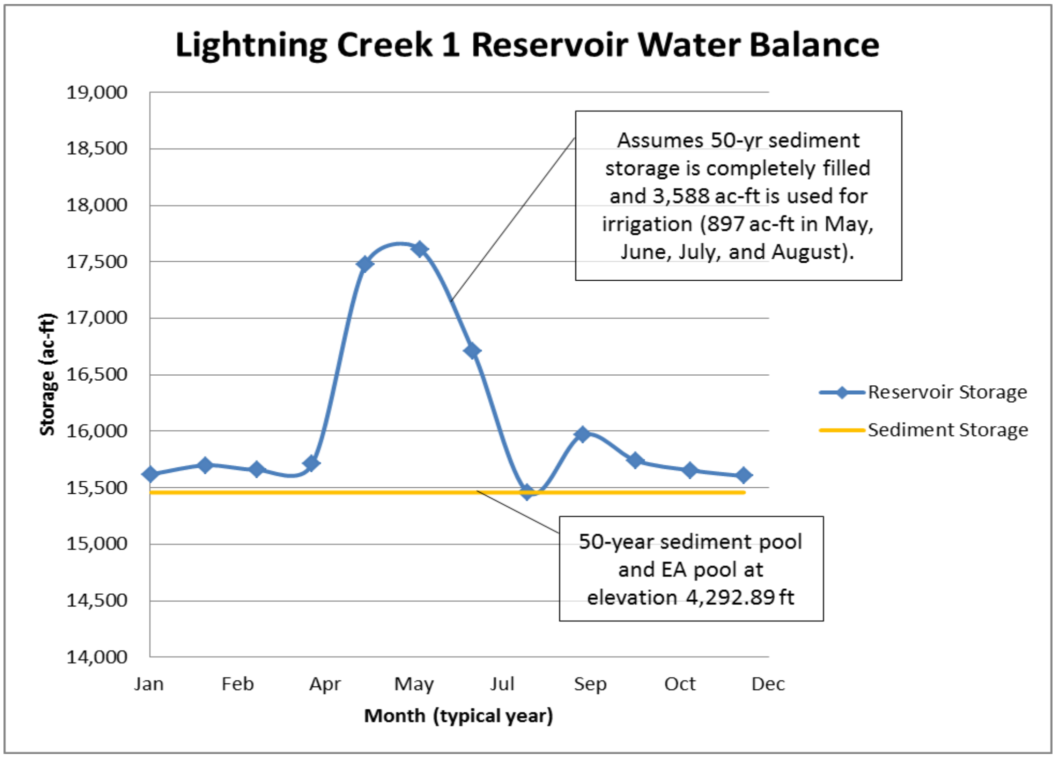


Figure 4.2.2-2 Example of RESOP Analysis

Table 4.2.2-2 summarizes the storage volumes and design life for each dam site. As illustrated in Figure 4.2.2-2, the EA pool and irrigation storage volumes are not simply additive. The EA pool, irrigation pool and 100-year water surface are shown on Maps 33a-33d.

Table 4.2.2-2 Summary of Potential Dam Site Storage and Design Life

Dam Site	EA Pool (acre feet)	Irrigation Storage (af)	Total Storage (af)	Sedimentation Rate (af/mi^2/yr)	50-Year Sedimentation Volume (af)	Total Storage Life (yr)
Lightning Creek 1	15,460	3,588	17,603	0.43	15,460	57
Lightning Creek 2	20,510	5,176	23,536	0.42	20,510	57
Lightning Creek and Tributaries	15,501	3,482	17,670	0.43	15,501	57
Old Woman Creek	8,458	1,622	9,557	0.45	8,458	57

4.2.2.3 Flood Hydrology and Spillway Sizing

A conceptual design of the dams, spillways, and outlet works was completed for the four potential dams. Each site was designed using the following typical criteria: earth dams with low level outlets, a 100-year flood control concrete spillway, an earth emergency spillway for one half of the Probable Maximum Flood (PMF), and a minimum design life of 50 years. The NRCS Water Resources Site Analysis Program (SITES 2005.1) was used to complete the conceptual design.

Conceptual Dam Safety Hazard Classification

According to the state engineer's office, the State of Wyoming does not explicitly define hazard classifications but does follow Federal Emergency Management Agency (FEMA) 333, *Federal Guidelines for Dam Safety* (FEMA, 1998). Three hazard classifications are defined in the document:

- *Low Hazard Potential:* Dams assigned the low hazard potential classification are those where failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner's property.
- *Significant Hazard Potential:* Dams assigned the significant hazard potential classification are those dams where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.
- *High Hazard Potential:* Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life.

Due to their locations and surroundings, it is thought that the four sites would be classified as significant or low hazard potential dams.

Inflow Design Flood and Probable Maximum Flood Determination

Because the State of Wyoming's Safety of Dams Program information does not specify the design criteria for different dam sizes and classifications, the State of Colorado Dam Safety Rules were used as a guideline for determining the Inflow Design Flood (IDF) that would be required for design of the dams and spillways. Based on their sizes, the dams would be classified as small dams. For the purposes of this study, they were all considered to be significant hazard dams. Each site was evaluated with an IDF equal to one-half of the PMF, in accordance with State of Colorado guidelines.

The level of study for this project does not warrant the in-depth analysis necessary to determine the most accurate PMF for each dam site; therefore, the PMF peak flows for each site were determined based on correlations of drainage area versus peak flows from previous studies of dam sites in Wyoming, South Dakota, Montana, and Nebraska. This information was compiled for the Cottonwood/Grass Creek Watershed Management Plan (SEH, 2007).

The original data included 35 sites ranging in drainage area sizes from 3.1 square miles to 19,650 square miles. Outliers were determined and removed from the data set, along with sites that did not reflect typical Wyoming sites. From the remaining sites, correlation factors for both the whole data set and ranges of drainage areas were determined. The subset for drainage areas ranging from 65 square miles (mi^2) to 4,300 mi^2 yielded a correlation factor (R^2) value of 0.91.The following regression equation was determined based on these 14 sites and was used to determine the PMF flow for each of the four potential dam sites:

$$Q_{PMF} = 91.669(DA) + 87{,}375$$

Where: Q_{PMF} = Peak PMF discharge in cubic feet per second (cfs)
DA = Drainage area in mi^2

The Q_{PMF} and IDF values determined for each of the four sites is summarized in Table 4.2.2-3. The information is also included in Data Summary 4.2.2-1 (in Appendix A).

Table 4.2.2-3 Inflow Design Floods and Volumes for Potential Dam Sites

Dam Site	Drainage Area (mi^2)	Q_{PMF} (cfs)	IDF (½ Q_{PMF}) (cfs)	V_{PMF} (acre-feet)
Lightning Creek 1	719	153,292	76,646	361,520
Lightning Creek 2	977	176,905	88,452	507,512
Lightning Creek and Tributaries	721	153,467	76,734	362,606
Old Woman Creek	376	121,833	60,917	167,017

The IDF values were used to calibrate the point rainfall input in the SITES 2005.1 program. It is important to note that should any of the potential dam sites be investigated further, a more detailed analysis of the IDF will be required.

IDF volumes were estimated using the same procedure for the same 14 dam sites. The following regression equation, which yielded an R^2 value of 0.82, was determined and used to determine IDF volumes for the four dam sites:

$$V_{PMF} = 567.77(DA) – 46,030$$

Where: V_{PMF} = PMF volume in acre-feet feet per second (cfs)
DA = Drainage area in mi^2

The V_{PMF} values determined for each of the four sites is summarized in Table 4.2.2-3. The information also is included in Table 4.2.2-2.

100-Year Flood Determination

The 100-year peak discharges were determined using USGS Water-Resources Investigations Report (WRIR) 03-4107 (Miller, 2003). The sites are primarily in Region 3. The equation that was used to determine the 100-year peak discharges is as follows:

Region 3: $Q_{100} = 127(DA^{0.432})(Soil^{2.05})$

Where: Q_{100} = 100-year peak discharge in cubic feet per second (cfs)
DA = Drainage area in mi^2
Soil = Mean basin soils hydrologic index

The time of concentration and runoff curve numbers were determined for each watershed and input into the SITES models developed for each dam site. The 100-year, 24-hour point rainfall values were obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2 maps. A weighted average of rainfall depths over the entire watershed for each site was determined. The weighted average rainfall values were put into the SITES models. The times of concentration and runoff curve numbers were adjusted to calibrate the models to the 100-year peak discharges estimated from WRIR 03-4107. The 100-year peak discharges and weighted 100-year, 24-hour point rainfall values are summarized in Table 4.2.2-4.

Table 4.2.2-4 100-Year Design Inflows and Related Parameters for Potential Dam Sites

Dam Site	Drainage Area (mi^2)	Soil Index from USGS WRIR 03-4107	Q_{100} (cfs) from USGS WRIR 03-4107	100-Year, 24-Hour Point Rainfall (in) from NOAA Atlas II
Lightning Creek 1	719	3.2	23,436	4.0
Lightning Creek 2	977	3.3	28,446	4.0
Lightning Creek and Tributaries	721	3.3	25,355	3.7
Old Woman Creek	376	3.3	18,881	3.9

4.2.2.4 Conceptual Dam and Appurtenances Design

Typical design parameters were applied to each dam site to complete the dam analysis. Each dam will have a low-level outlet pipe with a gate control to release irrigation flows. The conceptual 100-year flood control (principle) spillway was assumed to be a concrete chute with 7-foot foot vertical walls on each side. The length of the spillway was based on the elevation difference between the top of the (total) storage elevation and the valley flow-line elevation as determined from quadrangle topographic maps and a three horizontal to one vertical (3:1) slope between the top of the spillway and the valley floor elevations. The 100-year peak inflow was used to size the width of the spillway as determined by the following formula:

$$W = \frac{Q_{100}}{3H^{1.5}}$$

Where: W = Width of spillway in feet
Q_{100} = 100-year peak discharge in cfs
H = Height of spillway in feet

The earth embankments were assumed to have a top width of 14 feet with a 2 percent slope to the crown on either side. A 25-foot-wide wave berm is on the upstream side of the embankment, a 40-foot-wide berm is on the downstream side, and side slope ratios were assumed to be 3:1. The emergency spillway exit channels were assumed to be excavated out of native material. The lengths were determined by using a 3 percent slope from the emergency spillway crest to the flowline elevation. The bottom width and crest elevation were determined by iterations in SITES 2005.1 using the target IDF values. Typically, the materials excavated from the emergency spillway, if suitable, will be used in the construction of the embankment.

4.2.2.5 Discussion of Sites

Data Summary 4.2.2-2 (in Appendix A) presents a comprehensive summary of design parameters related to the four dam locations, as well as a wide array of relevant information collected and developed throughout the course of the project.

Lightning Creek 1: The layout of Lightning Creek 1 is shown in Map 33a. The dam would be approximately 2,850 feet long with a maximum height of 58 feet. The total volume of the Lightning Creek 1 dam site was estimated to be 17,603 acre-feet, with an irrigation volume of 3,588 acre-feet. The average depth of water would be 18 feet. The surface area at the principle spillway was estimated to be 1,006 acres. Annual evaporation was estimated to be 3,586 acre-feet. The design life was estimated to be 57 years. It is estimated that 14.4 acres of wetlands, primarily classified in the National Wetland Inventory as freshwater emergent wetlands, could be affected by construction of the dam. It could prove difficult to mitigate this area of wetlands. An actual wetland delineation would need to be conducted if a project were to advance to a more detailed study. The ratio at which the wetlands would need to be mitigated would be determined as part of the permitting process of the dam. Approximately 34 acres of irrigated lands would be inundated by the dam.

Some private landowner access roads would be inundated at the principle spillway elevation. A conceptual cost estimate for the Lightning Creek 1 dam site is included in Table 4.2.2-5. Annual operation and maintenance costs for all of the structures were estimated to be 0.75% of the construction cost, based on Nebraska NRCS recommendations. The annualized cost of the dam per acre-foot of irrigation water would be approximately $284.00.

Table 4.2.2-5 Conceptual-Level Cost Estimate - Lightning Creek 1 Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$2,020,000	1	$2,020,000
Permitting	LS	$240,000	1	$240,000
Wetland Mitigation at 1:1 ratio	AC	$8,000	14.4	$115,200
Legal Fees	LS	$80,000	1	$80,000
Acquisition of Right-of-Way	LS	$485,000	1	$485,000
Total Non-Construction Costs				**$2,940,200**
Mobilization	LS	$930,000	1	$930,000
Dam	CY	$10	1,344,000	$13,440,000
Principal Spillway	LS	$1,694,000	1	$1,694,000
Outlet Works	LS	$90,000	1	$90,000
Construction Cost Subtotal #1				**$16,154,000**
Engineering Costs = CCS#1 x 10%				$1,615,400
Subtotal #2				$17,769,400
Contingency = Subtotal #2 x 15%				$2,665,410
Construction Cost Total				**$23,375,010**
Project Cost Total				**$26,315,210**
Less Level II/Phase III Costs				$2,261,560
Project Cost Used in Ability to Pay Analysis				**$24,053,650**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$175,000**

Lightning Creek 2: The layout of Lightning Creek 2 is shown in Map 33b. This potential dam location is the largest of the four in terms of volume. The dam would be approximately 2,680 feet long with a maximum height of 67 feet. The total volume of the Lightning Creek 2 dam site was estimated to be 23,536 acre-feet, with an irrigation volume of 5,176 acre-feet. The average depth of water would be 19 feet. The surface area at the principle spillway was estimated to be 1,262 acres. Annual evaporation was estimated to be 4,477 acre-feet. The design life was estimated to be 57 years. It is estimated that 83.2 acres of wetlands could be affected by construction of the dam. The National Wetland Inventory classified the wetlands primarily as freshwater emergent wetlands with some freshwater forested/shrub wetlands. It could prove difficult to mitigate this area of wetlands, and is likely a fatal flaw of the site. An actual wetland delineation would need to be conducted if a project were to advance to a more detailed study.

The ratio at which the wetlands would need to be mitigated would be determined as part of the permitting process. Approximately 100 acres of irrigated lands would be inundated by the dam, another potential fatal flaw. Private access roads would be inundated at the principle spillway elevation. A conceptual cost estimate for the Lightning Creek 2 dam site is included in Table 4.2.2-6. The annualized cost of the dam per acre-foot of irrigation water would be approximately $293.00.

Table 4.2.2-6 Conceptual-Level Cost Estimate - Lightning Creek 2 Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$4,540,000	1	$4,540,000
Permitting	LS	$545,000	1	$545,000
Wetland Mitigation at 1:1 ratio	AC	$8,000	83.2	$665,600
Legal Fees	LS	$180,000	1	$180,000
Acquisition of Right-of-Way	LS	$1,090,000	1	$1,090,000
Total Non-Construction Costs				**$7,020,600**
Mobilization	LS	$2,090,000	1	$2,090,000
Dam	CY	$10	3,175,000	$31,750,000
Principal Spillway	LS	$2,373,000	1	$2,373,000
Outlet Works	LS	$100,000	1	$100,000
Construction Cost Subtotal #1				**$36,313,000**
Engineering Costs = CCS#1 x 10%				$3,631,300
Subtotal #2				$39,944,300
Contingency = Subtotal #2 x 15%				$5,991,645
Construction Cost Total				**$52,956,545**
Project Cost Total				**$59,977,145**
Less Level II/Phase III Costs				$5,083,820
Project Cost Used in Ability to Pay Analysis				**$54,893,325**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$400,000**

Lightning Creek and Tributaries: The layout of Lightning Creek and Tributaries is shown in Map 33c. It is located at the confluence of Lightning, Cow, and Lance Creeks. The dam would be approximately 4,390 feet long with a maximum height of 51 feet. The total volume of the Lightning Creek and Tributaries dam site was estimated to be 17,670 acre-feet, with an irrigation volume of 3,482 acre-feet. The average depth of water would be 17 feet. The surface area at the principle spillway was estimated to be 1,062 acres. Annual evaporation was estimated to be 3,737 acre-feet. The design life was estimated to be 57 years. It is estimated that 41.6 acres of wetlands could be affected by construction of the dam. The National Wetland Inventory classified the wetlands as mostly riverine with some freshwater emergent wetlands. It could prove difficult to mitigate this area of wetlands and could be a fatal flaw of the site. An actual wetland delineation would need to be conducted if a project were to advance to a more detailed study. The ratio at which the wetlands would need to be mitigated would be determined as part of the permitting process. Approximately 6 acres of irrigated lands would be inundated by the dam.

This dam site was evaluated considering that the Lightning Creek 1 dam site was in place. The drainage area upstream of Lightning Creek 1 was not included in the evaluation of this dam. Private access roads would be inundated at the principle spillway elevation. A school is located approximately 500 feet from the principle spillway water surface elevation, which could pose a safety hazard. More detailed mapping will be needed to ensure the school is outside of the 100-year floodplain if this alternative is evaluated further. A conceptual cost estimate for the Lightning Creek and Tributaries dam site is included in Table 4.2.2-7. The annualized cost of the dam per acre-foot of irrigation water would be approximately $119.00.

Table 4.2.2-7 Conceptual-Level Cost Estimate - Lightning Creek and Tributaries Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$2,680,000	1	$2,680,000
Permitting	LS	$320,000	1	$320,000
Wetland Mitigation at 1:1 ratio	AC	$8,000	41.6	$332,800
Legal Fees	LS	$110,000	1	$110,000
Acquisition of Right-of-Way	LS	$640,000	1	$640,000
Total Non-Construction Costs				**$4,082,800**
Mobilization	LS	$1,230,000	1	$1,230,000
Dam	CY	$10	1,849,000	$18,490,000
Principal Spillway	LS	$1,610,000	1	$1,610,000
Outlet Works	LS	$75,000	1	$75,000
Construction Cost Subtotal #1				**$21,405,000**
Engineering Costs = CCS#1 x 10%				$2,140,500
Subtotal #2				$23,545,500
Contingency = Subtotal #2 x 15%				$3,531,825
Construction Cost Total				**$31,160,125**
Project Cost Total				**$35,242,925**
Less Level II/Phase III Costs				$2,996,700
				$32,246,225
Project Cost Used in Ability to Pay Analysis				
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$235,000**

<u>Old Woman Creek</u>: The layout of the Old Woman Creek site is shown in Map 33d. The dam would be approximately 2,880 feet long with a maximum height of 51 feet. The total volume of the Lance Creek South Tributary dam site was estimated to be 9,557 acre-feet, with an irrigation volume of 1,622 acre-feet. The average depth of water would be 15 feet. The surface area at the principle spillway was estimated to be 621 acres. Annual evaporation was estimated to be 2,207 acre-feet. The design life was estimated to be 57 years. No wetlands or irrigated acres are predicted to be impacted by the dam. An actual wetland delineation would need to be conducted if a project were to advance to a more detailed study to ascertain whether they are present. Private access roads would be inundated at the principle spillway elevation, as well as several oil sites. A conceptual cost estimate for the Old Woman Creek dam site is included in

Table 4.2.2-8. The annualized cost of the dam per acre-foot of irrigation water would be approximately $156.00.

Table 4.2.2-8 Conceptual-Level Cost Estimate – Old Woman Creek Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$2,400,000	1	$2,400,000
Permitting	LS	$290,000	1	$290,000
Wetland Mitigation at 1:1 ratio	AC	$8,000	0.0	$0
Legal Fees	LS	$95,000	1	$95,000
Acquisition of Right-of-Way	LS	$575,000	1	$575,000
Total Non-Construction Costs				**$3,360,000**
Mobilization	LS	$1,100,000	1	$1,100,000
Dam	CY	$10	1,680,000	$16,800,000
Principal Spillway	LS	$1,204,000	1	$1,204,000
Outlet Works	LS	$75,000	1	$75,000
Construction Cost Subtotal #1				**$19,179,000**
Engineering Costs = CCS#1 x 10%				$1,917,900
Subtotal #2				$21,096,900
Contingency = Subtotal #2 x 15%				$3,164,535
Construction Cost Total				**$27,621,435**
Project Cost Total				**$30,981,435**
Less Level II/Phase III Costs				$2,685,060
Project Cost Used in Ability to Pay Analysis				**$28,296,375**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$210,000**

All of the sites have the potential for development of recreation based on their storage areas at the principle spillway. The reservoirs levels, however, would fluctuate throughout the year due to irrigation. Public access to most of the sites is marginal, as most lack public roads. The Lightning Creek and Tributaries site has the best potential access, with Cow Creek Road and Lance Creek Road crossing near the upstream end of the reservoir.

4.2.2.6 Locations of Dams Relative to Irrigated Lands

The locations of the storage sites were compared to nearby irrigated lands or potentially irrigable lands to make a general assessment of the water delivery system that would be needed. Irrigated lands are shown in Maps 33a-33d. Irrigated lands that could benefit from supplemental irrigation are approximately 2,000 feet downstream of Lightning Creek 1. Some irrigated lands, as discussed in Section 4.2.2.5, would be located within the footprint of the west arm of Lightning Creek1 and would likely be lost.

Of the four sites, Lightning Creek 2 shows the best potential for irrigation. Irrigated lands are located in close proximity to the west arm and immediately downstream of the dam. Similar to Lightning Creek 1, some irrigated lands are located within the footprint of the reservoir. Small areas of irrigated lands are located close to the southwest arm of the Lightning Creek and Tributaries site. An area of irrigated lands is located in the area of the west arm. More detailed topography is needed to determine whether they would actually be located within the footprint of the reservoir. Irrigated lands do not appear to be located in close proximity to the Old Woman Creek site. The nearest irrigated lands are approximately 3,900 feet downstream of the dam.

If any of the four Account III sites advances to a more detailed investigation, such as a Level II study, many issues will need to be addressed and questions answered. Following are a small number of these issues that will need to be evaluated:

- Refining estimates of the physical availability of water and the timing of water for irrigation.
- Water rights accounting to determine whether water is legally available at a given location and whether a project would cause injury to a water right holder, particularly a senior water right.
- Evaluation of the infrastructure needed to convey water from the reservoir to irrigated lands or potentially irrigable lands, including the amount of water needed to allow for diversion to a field or a spreader dike system.

4.2.2.7 Anticipated Geologic Conditions

The overall geologic conditions for the watershed were presented in Section 2.1.5. Maps 7 and 8 show the surficial and bedrock geology for the study area. In evaluating potential dam locations, the foremost concern from a geologic perspective was to avoid the clinker surficial geology, since it is unsuitable for a reservoir. Only a small area of clinker is present in the north central portion of the study area, far away from any of the potential Account III dam sites.

The Lightning Creek 1 site is underlain by Quaternary-age alluvium and colluvium. The Lightning Creek 2 site is underlain by Quaternary-age alluvium and colluvium on the west arm and the dam and by the Lance formation on the south arm. The Lightning Creek and Tributaries site is underlain by Quaternary-age alluvium and colluvium in the vicinity along the main drainageways and the Lance formation outside of the main drainageways. The Old Woman Creek site is also underlain by Quaternary-age alluvium and colluvium in the main channels and the Lance formation outside of them. Lance Formation consists primarily of shales, sandstones, and coal beds. Due to the general nature of the geologic mapping and the variability of conditions, site-specific studies must be conducted should one of the sites advance to a Level 2 study.

4.2.3 Property Owner Storage Evaluation Requests

During the course of the project, bi-monthly public meetings were held to solicit input from landowners within the study area. At the beginning of the project, landowners were sent information that included a potential project information form upon which irrigation system, upland well development, stream/rangeland enhancements, and water storage assessments could be requested. Table 4.2.3-1 summarizes the key information about the storage sites.

Table 4.2.3-1 Potential Surface Water Development Projects

Project Number	Ranch Name	Project Description	Estimated Cost
1	Bruegger	Pond rehabilitation – removal of sediment (maximum volume removed)	$4,500,000
2	Gunn Ranch	New dam and outlet structure	$24,300
3	Hales Draw	New dam and outlet structure	$92,600
4	Hammell	Relocation of existing dam plus outlet structure	$28,600
5	Kruse	Rebuild dam plus outlet structure	$97,100
6	Kruse	Pond rehabilitation – removal of sediment	$528,500
7	Kruse	New dam and outlet structure	$187,100
8	Lund	New dam on realigned road and outlet structure	$458,700
9	McCormack	New dam and outlet structure	$17,000
10	McCormack	New dam and outlet structure	$50,700
11	McCormack	New dam and outlet structure	$29,400
12	Nelson	New dam and outlet structure	$26,800
13	Snyder	New dam and outlet structure	$49,900
14	Swanson	New dam and outlet structure	$1,073,000

The following sections describe the surface water assessments that were requested, and the analyses conducted. Generally, the properties were evaluated for suitable storage locations. Evaluations were done based on available USGS topographic mapping. As such, the estimates of earthwork and volumes are approximate.

4.2.3.1 Bruegger Property

The Bruegger Ranch property is located adjacent to Cow Creek within the Lightning Creek watershed, in which the average unit available water yield for a normal year is 8.7 acre-feet per square mile, as shown in the Northeast Wyoming River Basins Report (HKM, 2002a). An existing water storage area is located immediately upstream of Cow Creek Road, as seen in Map 34a, Bruegger Ranch. The drainage area at the location is 2.6 square miles. During a normal water year, approximately 23 acre-feet of water could be anticipated.

The Brueggers reported that approximately 40 feet of sediment has accumulated over the years and that the headgate has been raised three times in the past 25 years to accommodate the sedimentation. They are interested in a project to remove the sediment. To determine the removal volume, the flowline of Cow Creek and road elevation of Cow Creek Road were estimated and the difference, 27 feet, was considered to be the maximum depth of sediment removal. The area of the pond was estimated to be approximately 13 acres. Assuming maximum depth of sediment at the outlet, tapering to no depth at the inlet, the full volume of sediment removal was estimated to be 180 acre-feet. This volume is approximately 2.5 times higher than the sedimentation rate predicted by the Hadley and Schumm method (Hadley and Schumm, 1961). A lesser volume could be removed to make the project more economically feasible, but the maximum volume was estimated to be conservative. If a project were to move forward, more detailed survey and determination of removal volume would be required.

4.2.3.2 Gunn Ranch Property

Gunn Ranch is located east of Lance Creek. Tributaries of Buck Creek flow through the property in the area where a storage evaluation was requested. A new storage area was proposed and can be seen in Map 34b, Gunn Ranch. An outlet structure would be installed in addition to the dam. At the location shown the drainage area is 0.3 square miles. The anticipated available water in a normal year would be 3 acre-feet. The pond area shown is three acres.

4.2.3.3 Hales Draw Ranch

The Hales Draw Ranch is located east of Lance Creek and the intersection of Highways 270 and 85. A tributary of Sage Creek, which is tributary to Lance Creek, flows through the ranch. Evaluation of a new storage area was requested, though a specific location was not indicated. A location was chosen to maximize the drainage area and provide suitable topography for a dam. The ranch and proposed storage area location are shown in Map 34c, Hales Draw Ranch. The drainage area for the dam would be 5.4 square miles. Available water in a normal year at that location could be expected to be 73 acre-feet. The volume of the storage area would be 78 acre-feet, and the surface area would be 13 acres. An outlet structure would be installed in addition to the dam.

4.2.3.4 Hammell Property

The Hammell Ranch is located in the northeast portion of the Thunder Basin L&LC watershed. An existing dam is located on the property, as seen in Map 34d, Hammell Ranch. The dam has been eroded and is in need of rehabilitation. After first evaluating rehabilitating the dam, relocating it approximately 1,600 feet upstream of its current location was investigated. The relocated dam would require less earthwork and would be significantly less expensive. In addition, the existing dam is close to the house and poses more of a potential flooding threat. An outlet structure would be installed in addition to the dam. It is estimated that the volume of the pond would be approximately 20 acre-feet. The drainage area upstream of the new location is 2.2 square miles and the pond surface area would be 2.2 acres. The available water for a normal year, based on the Lance Creek watershed, would be 19 acre-feet.

4.2.3.5 Kruse Property

The Kruse Ranch is located on a northern tributary of Lightning Creek. A dam was located on the property in the past, but has since eroded and washed out. A request to evaluate construction of a replacement dam was made, along with rehabilitating an existing dam and a new storage location. Spillways and outlet structures will be included with the new storage areas. Map 34h, Kruse Ranch, shows the ranch and the three proposed improvements.

- Replacing the dam is the highest priority. The drainage area at the location of the former dam is 1.9 square miles. The anticipated available water in a normal year would be 17 acre-feet. The dam would easily be able to store that volume.

- Removal of sediment from an existing structure was evaluated. It was estimated that approximately 12.8 acre-feet of sediment would require removal based on estimates of the road and channel flowline elevations. The drainage area to this structure is approximately 0.13 square miles, so the anticipated available water in a normal year is 1.1 acre-feet.

- A proposed new structure has a drainage area of 5.3 square miles, which would indicate available water during a normal year of 47 acre-feet. The volume behind the dam would store approximately 50 acre-feet. The surface area of the pond would be approximately 2.5 acres. A dam, outlet works, and spillway were included in the improvements.

4.2.3.6 Lund Property

The Lund Ranch is located southwest of Bill, in the far western portion of the watershed. Tributaries of Box Creek flow through the ranch. An existing water storage area is located immediately upstream of a road. A request was made to evaluate realigning the road and forming a new dam, raising the existing outlet pipe to provide additional storage. The ranch and pond location are shown in Map 34i, Lund Ranch. The drainage area of the pond is 1.9 square miles, which results in anticipated available water during the normal year of 17 acre-feet. With the realignment, the surface area of the pond would be approximately 9 acres. An outlet structure was included in the improvements.

4.2.3.7 McCormack Property

The Lone Crow Cattle Company Ranch is located near the northern boundary of the central portion of the watershed. Dogie Creek, which is tributary to Lightning Creek, flows through the ranch. A water storage evaluation was requested, but specific locations were not identified. Potential locations were determined based on maximizing the drainage area and suitable topography for a dam. Three potential locations were identified. The ranch and the potential storage locations are shown in Map 34j, McCormack Ranch. Table 4.2.3-2 summarizes the key information about the storage sites. Outlet structures are included in the proposed improvements.

Table 4.2.3-2 McCormack Property Potential Surface Water Storage Areas

STORAGE AREA	STORAGE SITE 1	STORAGE SITE 2	STORAGE SITE 3
Drainage area, square miles	0.4	2.6	0.6
Available water during normal year, acre-feet	3.3	22	4.9
Surface area, acres	1.0	2.8	2.1
Storage volume, acre-feet	5.0	28	17

4.2.3.8 Nelson Property

The Nelson property is located just east of Highway 270 approximately three miles south of the town of Lance Creek. Cherry Creek flows through the ranch. A storage evaluation for an east tributary of Cherry Creek was requested. A dam location was selected to capture most of the tributary drainage area. The drainage area to the dam would be 0.14 square mile, for which an estimated 1.2 acre-feet of water would be expected to be available during a normal year. The storage volume of the pond would be 3 acre-feet with a surface area of 0.5 acres. The ranch and proposed pond are shown in Map 34k, Nelson Ranch.

4.2.3.9 Snyder Property

The Snyder Ranch is located approximately five miles west of Highway 85. Tributaries to Little Alkali Creek flow through the ranch. A storage evaluation for the southeast portion of the property was requested as a catchment for stormwater or snowmelt. A dam location was selected based on maximizing the drainage area, which was 1.0 square mile. The available water during the normal year would be 9 acre-feet. The storage volume of the pond would be 11 acre-feet with a surface area of 1.4 acres. The ranch and the proposed pond are shown in Map 34n, Snyder Ranch.

4.2.3.10 Swanson Property

The Swanson Ranch is located near the northern boundary of the watershed. South Greasewood Creek flows through the property. An existing surface water pond is located on South Greasewood Creek. The dam is formed by a road. Evaluation of removal of accumulated sediment was requested to rehabilitate the structure. The landowner reported that the sediment has accumulated primarily 5 to 10 feet deep. If the pond were completely cleared out, the maximum depth could be in the range of 20-25 feet. To determine the removal volume, the 5 to 10 feet sediment depth was averaged and applied to the pond surface area of 3.5 acres. The full volume of sediment removal was estimated to be 26 acre-feet. A lesser volume could be removed if desired. The ranch and the proposed pond are shown in Map 34o, Swanson Ranch.

4.2.4 Livestock Watering Opportunities

Due to the large watershed, it was necessary to develop a screening method to determine where additional livestock watering is desirable or needed, in addition to the requests of property owners. As a rule of thumb, cattle will graze up to a mile from a water source. Map 35, Existing Livestock/Wildlife Watering Opportunities, shows the stock wells in the state engineer's office database and stock pond locations. Around each of these, circles with a 1-mile radius were drawn to indicate locations served by an existing water source. Areas outside of the circles indicate areas where additional water development could be useful. Areas not sufficiently served by an existing water source were evaluated for well development, as described in Section 4.4, and for rehabilitation of existing breached dams, as described below in Section 4.2.5.

4.2.5 Evaluation of Breached Dam Sites

A reconnaissance-level survey of the entire study area was conducted using aerial photography, topographic maps, and GIS surface water layers to identify locations where potential breached dams appeared to exist. Some of the dams are breached such that the former reservoir is empty, while others are apparently partially breached and still hold a smaller amount of water. Map 36, Breached Dam Location Map, shows the locations of the identified breached dams, which are listed in Data Summary 4.2.5-1 (in Appendix A).

The estimated surface area behind each breached dam was estimated. Assuming an average depth of 5 feet, an estimate was made of the volume of storage that could be gained. There are 290 potential breached dam locations. The median pond size was 0.7 acres and the median estimated volume was 3.6 acre-feet. The maximum pond size and volume were 20.1 acres and 6.7 acre-feet, respectively. The total estimated volume for all of the ponds was 1,946 acre-feet.

At the public meeting on March 24, 2011, the breached dam analysis was discussed. Attendees were asked whether any of the locations were desirable for rehabilitation. Other than storage evaluation requests described in Section 4.2.3, no feedback was received regarding which of the breached dam locations would be desirable to rehabilitate.

The breached dam locations were compared to the cattle ranges around the stock wells and stock ponds, as shown in Map 35, Existing Livestock/Wildlife Watering Opportunities. A total of 120 potential breached dams were shown to be outside of the circles that designated the ranges. These structures could be repaired to provide additional livestock / wildlife watering in areas not served by other water sources. Data Summary 4.2.5-2 (in Appendix A), shows the locations and estimated conceptual-level costs to repair the structures, which were based on a typical cost per acre-foot of water. Due to the lack of information on the structures and the number of them, it was not feasible to estimate If there is interest in rehabilitating any of these structures, site visits must be made to gain a better sense of the extent of necessary rehabilitation and a more refined estimate of needed work and a rehabilitation cost can be made. The locations of the breached dams are highlighted in Map 36.

4.3 Groundwater Development

Shallow groundwater development is a viable source of water for wildlife/livestock in Thunder Basin L&LC watershed. The information provided in Section 2.1.6 indicates that the shallow alluvial wells can produce up to 300 gpm, although the average flow ranges from 5 gpm to 10 gpm. Similarly, shallow bedrock wells completed in the Wasatch, Fort Union and Lance Formation can yield similar range of flow as the alluvial wells. Solar-powered well systems can be installed to pump water into either surface water ponds or storage tanks for livestock and wildlife watering. A lower-power pump would be desirable for use for this purpose. Based on the information on shallow well development in Thunder Basin, it is reasonable to assume the pump capacity at 5 gpm. The average annual hours of light in the area is approximately 4,400 hours (including cloud cover). The resulting annual pumping would be 3-4 acre-feet. To assess the viability of installing shallow wells at a particular location would require a site-specific evaluation by a groundwater professional and/or an experienced and capable well driller. Additionally, the locations of these systems would need to be identified by landowners to ensure that the locations are conducive to his or her range management practices.

4.4 Wildlife/Livestock Watering Opportunities

4.4.1 Existing/Planned/Proposed Watering Sites

The WWDC has been working with the Converse County Conservation District and members of the TBGA to develop new livestock/wildlife watering sites throughout Converse County. Map 37 illustrates locations of the recently completed and ongoing projects in the watershed. The projects included items such as well installation, pipeline, solar well pump, and stock tanks.

4.4.2 Alternative New Watering Opportunities

The following subsections include information on additional sites that could be developed in a similar manner through the Wyoming Water Development Small Water Project Program. These proposed projects were identified by landowners with the assistance of the TBGA sponsors through their attendance and involvement in the Thunder Basin Watershed Improvement project meetings. Each request was evaluated separately. Table 4.4.2-1 provides a list of the projects, the water source, types of proposed improvements and estimated costs. Other projects with similar parameters still exist throughout the watershed. The sites listed below provide a basis for evaluation upon which other sites could be assessed. For example, many of the SEO well sites listed on Map 27 are currently not producing. Along with the list of sites provided in Table 4.4.2-1, upland well developments would result in significant benefits to the watershed. Some benefits discussed with the ranch owners included:

- Healthy livestock with additional watering sites that minimize distance traveled per day to a clean water source
- Reduced soil erosion due to reduced distance livestock travel to water per day resulting in reduced sediment loading on streams
- Reduced impacts to sensitive riparian habitats
- Enhanced stream stability through stable vegetative cover
- Reduced expansion and establishment of non-native plants

Table 4.4.2-1 Upland Water Well Development Projects

Project Number	Ranch Name	Water Well	Solar Power	Pipeline Length (feet)	Pasture Fencing	Storage Tank	Stock Tanks	Site Prep	Estimated Cost
1	Greer	0	1	0	0	0	0	0	$6,500
2	Gunn	1	1	0	0	1	1	1	$22,500
3	Hales Draw	1	1	0	0	0	1	1	$12,660
4	Johnson North	0	0	13107	0	1	3	0	$44,214
5	Johnson South	1	1	10548	0	0	3	1	$41,996
6	Kremers A	1	1	3158	0	0	1	1	$20,236
7	Kremers B	0	0	15370	0	1	6	0	$42,760
8	Kremers C	1	1	1965	0	0	1	1	$17,850
9	Kremers D	0	1	13633	0	1	4	0	$45,386
10	Kremers E	0	1	9844	0	0	3	0	$31,408
11	Porter	1	1	0	0	1	1	1	$20,120
12	Robinson East	1	1	0	0	1	1	1	$44,900
13	Robinson West	1	1	0	0	1	1	1	$44,900
14	Robinson South	1	1	0	0	1	1	1	$44,900
15	Stoddard A	1	1	0	0	1	1	1	$44,900
16	Stoddard B	1	1	0	0	1	1	1	$44,900
17	Stoddard C	1	1	0	0	1	1	1	$44,900
18	Swanson	1	1	0	0	0	0	1	$12,460

4.4.2.1 Greer Ranch

The watershed improvement for Greer's Ranch includes converting a windmill located in Township 36 North, Range 64 West, Section 5, Southeast ¼, Southeast ¼ to a solar power well. The intent is to provide a consistent water supply for cattle to optimize range management in the area. By replacing the windmill with a solar power system, the water supply will be available whether there is wind or not. Conceptual cost estimates are presented in Table 4.4.2-1.

4.4.2.2 Gunn Ranch

The Olsson team met with Dwight and Shelly Krien of the Gunn Ranch to discuss their options for well development. The Gunn Ranch has very limited water supply from two wells on Highway 270 (Map 34b). The two wells are drilled to 60 foot depths and between the two wells they produce about 3 gallons per minute. They have about 15 miles of pipeline, 3 storage tanks and 14 stock tanks to distribute the water across their ranch. The three storage tank locations and capacity are as follows:

- 10,000 gallon in Section 34
- 10,000 gallon in Section 3
- 10,000 gallon from oil well discharge

They also have a well in the hayfield in Section 4 and another well in Section 7. The hayfield well is drilled to 200 foot depth. Water is at approximately 150 feet below ground surface. The yield is about 3 gallons per minute for a few minutes and then goes down to 3 quarts per minute. The water in the Section 7 well is bad and toxic to livestock.

They are interested in either water storage sites or new wells. They have had quite a bit of field investigation to look for water sources, but geologic faulting in the area makes predictions of water availability difficult on the property. A geophysical report indicated drilling to approximately 600 feet may yield a productive well although productive wells to the west of the Gunn Ranch in Section 17 are on the order of 150 feet in depth.

In summary, improvements to the Gunn Ranch to facilitate rotational grazing practices include installation of one new well with pipelines for water distribution and a tank for storage. Without additional geophysical investigations, our preliminary recommendation would be to drill test holes in Section 17, east of a producing well on the Walter property. If a good well location is identified, a new solar well could be installed. Without new water sources, another option may be additional piping and storage from the existing wells on highway 270.

4.4.2.3 Hales Draw Ranch

The watershed improvement for Hales Draw ranch includes an additional well in the northern pasture (Map 34c). By adding an additional water source, cattle grazing distribution can be improved and a grazing rotation can be considered. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.4.2.4 Johnson Ranch

The Olsson Team met with Mr. Frank Eathorne of the Johnson Ranch to discuss the options for upland water development opportunities. The improvements proposed for the Johnson Ranch include the addition of one new well, one large storage tank, six stock tanks and buried pipeline (Map 34f). There are two proposed projects on the Johnson Ranch, Johnson North and Johnson South. The two projects are based on improvements specifically targeted to the north and south pastures. With the installation of the strategically placed well and stock tanks, livestock could be rotated through a series of meadows which would benefit range management in the watershed. Several of the stock tanks are proposed along existing fencelines to allow for access by neighboring property owners/leasees. Based on existing well completion and yield information, conceptual cost estimates were developed for the Johnson North and Johnson South proposed improvements (Table 4.4.2-1).

4.4.2.5 Kremers Ranch

The Olsson team met with Justin and Ricky Kremers of Kremers Ranch to discuss watershed improvement projects. The Kremers are looking at increasing cattle production and rotational grazing by increasing the livestock and wildlife watering opportunities across their ranch. The improvements proposed include two new solar wells, upgrades of four existing windmills to solar power wells, 8.3 miles of pipeline, two new storage tanks and fourteen stock tanks (Map 34g). Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1. The projects were subdivided based on the location and pasture improvements into projects Kremers A through E. The intent of each of the projects (A-E) is to provide a consistent water supply for cattle to optimize range management in the area.

4.4.2.6 Porter Ranch

The Porter Ranch is 640 acres on the south end of the Lightning Creek watershed in Converse County (Map 34l). The water source for the property is a windmill built in the 1930s. The windmill broke in 2010 and they are interested in drilling a new solar well as a replacement.

They are planning to increase their cattle herd by 50-60 head once they have a more consistent water source. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.4.2.7 Robinson Ranch

The Olsson team met with Jay Butler of Robinson ranch to discuss watershed improvement projects. Mr. Butler would like to add some new wells along fence lines to maximize pasture rotation options for his ranch. He would like to install at least three wells:

- Between Section 28 and 21 on the new fence line. Target depth is 300-400 ft.
- Between two pastures in Section 22
- Section 12 to replace an old windmill well

He would also like to look at other viable well sites across the ranch to maximize rotational grazing and benefit wildlife. He would like to have overflow from the well flow into a pond for wildlife watering. He is also interested in learning more about the sage grouse program.

The watershed improvements proposed for Robinson Ranch include three new solar powered wells with storage and stock/wildlife watering tanks (Map 34m). The improvements include three specific projects including Robinson East, West, and Sough. By adding the proposed new wells and tanks, watering sources and locations will be increased thus allowing for optimized range management practices. Based on existing well completion and yield information, conceptual cost estimates for the east, west and south pastures are presented in Table 4.4.2-1. Additionally, information on the Sage Grouse Initiative was sent via email so that Mr. Butler could review the requirements for additional habitat and grazing management practices that could benefit Sage Grouse populations in the area.

4.4.2.8 Stoddard Ranch

The improvements on Stoddard's ranch include installation of three solar wells. The owners of the ranch would like to provide additional grazing opportunities for the cattle in areas that are currently dry. Based on existing well completion and yield information, conceptual cost estimates for three specific projects, Stoddard A, B, and C are presented in Table 4.4.2-1.

4.4.2.9 Swanson Ranch

The improvements on Swanson's buffalo ranch include installation of a solar power well (Map 34o). The owners of the ranch would like to provide additional grazing opportunities for the buffalo herd in areas that are currently dry. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.5 Other Management Practice Improvements

4.5.1 Grazing Management

Management of grazing use that enhances the extent and height of ground cover can be expected to enhance the retention of snow and rain in a manner that encourages greater infiltration into the soil surface. Improved vigor of prairie vegetation including riparian vegetation will reduce vulnerability to invasion by weeds in general including salt cedar and Russian olive.

Beyond the water budget benefits, successful grazing management marshals the proper balance of grazing intensity and duration on a site so that long-term yield of forage is maximized. Higher ground cover and biomass production positively influences wildlife habitat value, water course stability, as well as soil stability and water quality.

4.5.2 Salt Cedar and Russian Olive Treatment

According to the Thunder Basin Area Analysis FEIS, invasion of Russian olive and salt cedar has been confronted well in the basin, at least on public lands. Continued resistance to invasion however is likely to be required. This may take the form of manual removal preferably followed by chemical treatment of remaining stump or root stub surfaces with Garlon®, Roundup® or Rodeo®. For large infestations should they come to exist, the *Tamarix* leaf beetle (*Diorhabda elongata* ssp. *deserticola*) could be useful in diminishing the size of the problem, though as with most bio-control approaches it cannot be expected to eliminate salt cedar.

4.5.3 Noxious Weed Control

Other noxious weeds present in the study area include leafy spurge (*Euphorbia esula*) and diffuse knapweed (*Centaurea diffusa*) in the Lightning Creek watershed (BLM, 2005) as well as occurrences of hoary cress (*Cardaria draba*), diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*Centaurea maculosa*), houndstongue (*Cynoglossum officinale*), leafy spurge (*Euphorbia esula*) and Scotch thistle (*Onopordum acanthium*) in Converse and Niobrara Counties documented between 2000 and 2011 (Rice 2011). The most abundant and the one most typical of moisture accumulation sites is Canada thistle. Chemical control using systemic herbicides (for example Curtail®, Tordon® Milestone® or Transline®) is recommended at a time when translocation downward to the deep root mass can be accomplished (usually in the fall). Intensive, short term livestock grazing management can provide effective weed control.

Enhanced range condition tends to provide sufficient competitive pressure to limit the presence of annual bromes, however there has been a trend in northeast Wyoming for the plants to have a progressively higher average presence, even on sites that would be considered in good range condition. Chemical treatment of annual bromes with Matrix® and/or Plateau® can be effective. Again, intensive, short term livestock grazing management, particularly when bromes are most susceptible to grazing pressure, can provide effective control.

4.5.4 Grazing Management for Sage Grouse Habitat Improvement and Maintenance

Properly managed livestock grazing can support healthy rangeland conditions while also providing habitat for sage-grouse (Crawford et al. 2004). The Wyoming Game and Fish Department (WGFD) has developed livestock grazing guidelines with the main goal of encouraging healthy and vigorous plant communities for wildlife habitat (Bohne et al. 2007). Other grazing management practices to consider include the following:

1. Improve livestock distribution and forage use in upland areas by locating new water sources in areas where impact to critical sage-grouse habitat is minimized (Bohne et al. 2007).

2. Reduce concentration of livestock near water in good nesting and brood-rearing habitat to prevent reduced levels of residual cover or excessive trampling. (Bohne et al. 2007).

3. Making livestock fencing friendly to wildlife, e.g. using tags to mark barbwire fence making them more visible to wildlife reducing injury and mortality to sage grouse, prairie-chicken and other susceptible birds (USDA NRCS, 2011).

4. Retrofit existing watering facilities (troughs, tanks, etc.) to allow for escape of wildlife that become trapped while trying to drink (USDA NRCS, 2011).

5. Improve sagebrush understory vegetation using prescribed fire, mechanical treatments, interseeding with grasses and forbs, changes in grazing management, or a combination of these treatments (Miller and Eddleman, 2001).

Funding is available for some of these conservation practices including through the USDA Conservation Stewardship Program (CSP) which is part of the 2008 Farm Bill (USDA NRCS, 2011). Enhanced watershed function will ultimately provide ecological conditions that support habitat and whatever natural functions flora and fauna that can and will take advantage of the landscape within the watershed.

5.0 Cost Estimates

5.1 Irrigation System Cost Estimates

Costing for the recommended potential irrigation infrastructure rehabilitation measures is based on extensive prior experience by team member ACE in the planning, design, costing and construction oversight of similar project elements throughout Wyoming, including in the Cottonwood/Grass Creek watershed. These costs are included in Table 5.1-1. Table 5.2.1-1 provides a summary of the costs and then calculates an annual cost per acre serviced over 20 years.

Table 5.1-1 Annual Rehabilitation Costs

Project Number	Description	Acres Serviced	Revenue Per Acre	Rehabilitation Cost	Cost per Acre Served	Annual Cost per Acre
1	Improve berms along Creek	15	30	$6,000	$400	$20
2	Construct spreader dikes	5.5	30	$6,000	$1,636	$82
3	Install centrifugal pump	14	30	$10,000	$714	$82

5.2 Surface Water Storage Sites Cost Estimates

5.2.1 Cost Estimates for Account III Storage Sites

Tables 4.2.2-5 through 4.2.2-8 present the costs for the Lightning Creek 1, Lightning Creek 2, Lightning Creek and Tributaries, and Old Woman Creek sites. Table 5.2.1-1 presents a summary of the costs and calculates the cost on an annual basis per acre-foot of irrigation storage water. In order of least to most expensive based on this measure, the four sites would be ranked as follows: Lightning Creek 1, Lightning Creek and Tributaries, Lightning Creek 2, and Old Woman Creek. Annual operation and maintenance costs for the reservoirs is anticipated to be 0.75% of the construction cost.

Table 5.2.1-1 Potential Dam Sites Cost Summary

Dam Site	Irrigation Storage, ac-ft	Cost, $	Total Storage Life, years	Annual Cost/ac-ft of storage
Lightning Creek 1	3,588	$26,300,000	57	$129
Lightning Creek 2	5,176	$60,000,000	57	$203
Lightning Creek and Tributaries	3,482	$35,200,000	57	$177
Old Woman Creek	1,622	$31,000,000	57	$335

5.2.2 Cost Estimates for Rehabilitated Breached Dams

Table 4.2.3-1 shows the estimated conceptual level costs of repairing the breached dams. The costs were based on a typical cost per acre-foot of water. Site visits must be conducted and more detailed analysis of needed repairs done, if there is interest in rehabilitating any of these structures. The visits would provide a better sense of the scope of necessary repairs.

5.3 Cost Estimates for Groundwater Well Development/Wildlife/Livestock Watering

Table 4.4.2-1 shows the estimated conceptual level costs for groundwater well/ wildlife and livestock watering projects. The costs were based on similar project cost estimates for Small Water Project and personal communications with members of the TBGA. Site visits must be conducted and more detailed analysis of the site-specific hydrogeology will need to be completed before the projects are implemented. The evaluations will provide additional detail on well completion depths and well yield estimates.

5.3.1 Cost Estimates for Wetlands

Two areas are proposed for wetlands development. In both cases, the amount of water available will limit the extent of wetland which can be constructed. Note that the probable costs for these two wetland areas are not based on detailed plans, thus the specific footprint of the site is not known. In addition, the cost estimates do not include the cost of soil amendments or linings should the soils be judged unsuitable to maintain wetland hydrology conditions without modification.

The first proposed wetland area is on the Butler Ranch and is fed by a well that pumps approximately 5 gpm and feeds a cattle tank. The wetland will be created by overflow from the tank. The extent of wetland that can be maintained by this hydrology may range up to 0.25 acres.

Opinion of probable cost for this wetland:

- Stop-log outlet structure: $900
- Excavation and construction of berm (400 cu.yds. @ $10 per yard): $4,000
- Seeding with mix of native wetland species for 0.5 acres: $4,000
- Fencing (450 linear feet @ $2 per foot, plus corner posts): $1,000

Subtotal: $9,900
Contingencies (10%): $990
Design (10%): $990
TOTAL: $11,880

The second proposed wetland area is on Hammell Ranch and is a fringe wetland that will be maintained by an impoundment of an ephemeral creek. The impoundment is proposed to be located upstream of an existing silted-in pond. The wetland will be constructed in coordination with the construction of the new pond which would keep construction costs down. However, due to the small size of the pond, at most 0.1 acre of wetland is likely to develop.
Opinion of probable cost for this wetland:

- Excavation and grading of wetland area (100 cu.yds. @ $10 per yard): $1,000
- Seeding with mix of native wetland species for 0.1 acres: $2,000
- Fencing (800 linear feet @ $2 per foot, plus corner posts): $2,000

Subtotal: $5,000

Contingencies (10%): $500
Design (10%): $500
TOTAL: $6,000

5.4 Cost Estimates for Other Management Practice Improvements

5.4.1 Grazing Management

Costs of implementation of changes in grazing management other than livestock watering (addressed above) vary from comparatively small (salting, planning, moving herds between paddocks) to comparatively large when the need for additional fencing is involved.

5.4.2 Salt Cedar and Russian Olive Control

Estimates by Hart (2004) of the cost of saving water that would otherwise be lost to transpiration of salt cedar (by removing the salt cedar) ranged from $16 to $111 per acre-foot. This represents an extremely cost-effective approach to increase of available water in a range watershed.

5.4.3 Noxious Weed Control

Costs of chemical herbicide application are variable depending on scale of infestation, distances to be traveled, and fuel costs. Relative to control of Canada thistle, costs for the chemicals mentioned above range from $16 to $26 per acre not including application (Jacobs et al. 2006). At $14.60 per acre, a more cost effective noxious weed management tool is grazing management. Grazing management as a weed management tool is particularly beneficial and sustainable for this area and should be considered first when evaluating weed control management options.

5.4.4 Grazing Management for Sage Grouse Habitat Improvement and Maintenance

The costs associated with implementing changes in grazing management vary from comparatively small (moving herds between paddocks) to comparatively large when the need for additional fencing or water tanks are involved. The following are average costs to install conservation practices relating to grazing management for sage grouse habitat improvement and maintenance as provided by the Wyoming Environmental Quality Incentives Program (EQIP) and Montana NRCS Electronic Field Office Technical Guides (USDA Wyoming EQIP and NRCS Montana 2011).

Many of these costs do not including maintenance costs or offsets based on Environmental Quality Incentives Program (EQIP) payments from the USDA. In addition, some costs are accompanied by added benefits, for example, the benefit of higher utilization of formerly underutilized forage from the installation of cross-fencing (Knight et al 2011).

In addition, drill seeding costs, not including the seed and using a Rangeland (Laird-type) interseeder, are about $100 per acre plus mobilization costs (NRCS, 2011). Native forb and shrub seed can be costly, ranging from a few hundred dollars to a thousand dollars or more per acre depending on the seed mixture selected (David Buckner, personal communication, July 28, 2011).

Table 5.4.4-1 Costs of Conservation Practices Relating to Grazing Management for Sage Grouse Habitat Improvement and Maintenance

Conservation Practice	Initial Cost
Installing 3-5-strand barbed wire for cross-fencing.	$8,448/mile
Installing fencing visibility enhancement for sage grouse.	$950/mile
Using prescribed burning on non-forested land.	$12.60 per acre
Using of a rotational grazing system approved by NRCS designed to improve species of concern.	$3.40 per acre each year
Using rest rotational grazing system approved by NRCS designed to improve species of concern whereas minimum of 20 percent of the identified nesting habitat is rested each year (beginning no later than April 1 and extending through July 15 the following year as a minimum).	$13.35 per acre of rested pasture per year
Retrofitting existing tank with wildlife escape ramp.	$50.00 each per tank
Installing a new watering source (< 1,000 gallons).	$1,600.00

6.0 Permits

The following discussion presents the regulatory issues for the types of projects that have been identified in this report. The purpose of this analysis is to characterize the potential environmental permitting issues. This includes the identification of environmental documentation, permits, agency clearances and approvals, and agency requirements necessary for implementation of the proposed actions and alternatives. The WWDC has requested that there be a semblance of consistency between the different watershed studies. This section, therefore, will be structured similar to the report prepared by SEH, 2007 (SEH 2007).

The National Environmental Policy Act (NEPA) applies to any federal action and compliance is the responsibility of the lead federal agency. Other federal environmental regulations are regulated by the following federal agencies: EPA, BLM, USFS, USACE, and/or the USFWS and may apply to the potential projects described in this plan. The State of Wyoming agencies which may have approval requirements include, but are not limited to, the WDEQ, WSEO, State Historic Preservation Officer, and the Board of Land Commissioners through the Office of State Lands and Investments.

The following discussions are based upon various assumptions about the potential actions within the study area. These assumptions may change as project planning progresses from this Level I Study. Ultimately, the applicability of the individual federal and state permits, clearances and approvals will depend upon sites selected and the potential implications at each of those sites.

6.1 NEPA Compliance and Documentation

NEPA requires federal agencies to assess the possible environmental consequences of projects which they propose to undertake, fund, or approve. NEPA applies to any of the proposed actions for which the project site is located on federal land, federal funds may be used, and/or when formal federal agency actions are necessary for the project to move forward. One of the primary intentions of the NEPA process is to avoid, minimize, and mitigate adverse environmental consequences of federal actions. NEPA requires analysis and documentation of potential adverse and beneficial effects of a proposed action and alternatives and mandates an open public involvement process.

For this project, it is likely that either BLM and/or USFS would be the lead federal agency(s) charged with ensuring compliance with NEPA and related environmental statutes. The BLM would be lead for those projects on lands under their administration, and the USFS would be the lead for projects located on National Forest Service lands. Map 16 illustrates land ownership across the study area. The USACE would likely be the lead federal agency on private lands where wetlands may be impacted. These agencies also may work out a shared lead under a Memorandum of Understanding, if there are significant issues best led by both agencies for a given project.

6.1.1 NEPA for Major Reservoir Storage Projects

The following discussion characterizes the typical actions of the NEPA process applicable to a reservoir storage project. A separate discussion in Section 6.1.2 addresses other potential watershed rehabilitation or improvement projects.

Prepare a Purpose and Need Statement for the Project. Establishing a well-conceived statement of the Purpose and Need is one of the first steps in the NEPA process. The purpose and need for a project provides the basis for developing reasonable alternatives, establishes project objectives, and helps to define criteria for the alternative screening process, including the option of not doing the project at all (i.e., no action alternative). The Purpose and Need statement provides an overall or basic purpose for the potential action, which must be supported by some quantitative means. As project planning unfolds, additional needs may be revealed through stakeholder input, project constraints, or other factors.

Should the USACE be identified as the lead agency, the Purpose and Need must include a reference to finding the “least damaging practicable alternative.” This reference relates to the CWA Section 404 requirements that are under the jurisdiction of the USACE and is an important part of the NEPA process for a reservoir storage project. Additional details are provided in Section 6.2. The project sponsor, TBGA, other project participants, and the public all should be part of defining the Purpose and Need statement.

Develop Project Alternatives and NEPA Documentation Determination. The NEPA process requires analysis of both build and no-build (no action) alternatives that fully address the project’s purpose and need. The reasonable range of alternatives may include multiple “build” alternatives, including multiple locations, depending on the nature and extent of potential project impacts and level of NEPA documentation required.

For new reservoir storage projects, key issues associated with alternative development will or may include:

- Potential loss of wetland and riparian habitat from direct inundation by a new reservoir
- Potential impacts on threatened and endangered species;
- Potential impacts on fish and other aquatic species
- Potential impacts on other wildlife (e.g., sage grouse; big game)

Based on these issues, and the fact that some of the potential projects are as simple as wells (which should require no NEPA involvement on private lands) the potential projects will be Categorical Exclusions (CE) or Environmental Assessments (EA). An EA may or may not involve analysis of more than one build alternative and typically can be completed in less than 18 months. The outcome of an EA is either a Finding of No Significant Impact (FONSI) or a recommendation to prepare an EIS. If an EA is prepared, a possible outcome is a requirement for an EIS. This could occur as a result of “significant impact findings” or as a result of substantial public controversy over the project’s effects. Significant impacts should be identified early on in the EA effort, thus allowing the owner to move the project to a “least damaging alternative” location and avoid the potential for having an EA result in a requirement for an EIS. This decision should be reviewed during a Level II study to identify locations that would be best to avoid, from an environmental risk perspective.

Conduct a Proactive Public Involvement Program. The NEPA process begins with public and agency outreach, and provides the public the opportunity to comment on the proposed project’s impacts, potential mitigation measures, and the potential alternatives to be analyzed during the development of the required NEPA document. The public must be informed of the potential benefits and potential adverse impacts of the proposed project and alternatives. A pro-active public involvement program focuses on achieving public awareness and community interaction throughout the entire project development process. The public involvement process can influence alternative development, mitigation measures, the level of NEPA documentation to be prepared (EA or EIS), and the selection of the preferred alternative.

Collect and Analyze Environmental Baseline Data. It is important to carefully identify environmental constraints and considerations early and incorporate them into alternative development efforts as a means of avoiding and minimizing potential impacts. Early field investigations and agency consultation and coordination efforts help to focus this effort and streamline subsequent analysis methods, schedule needs, and budget requirements. Creating “self-mitigating” alternatives is highly advantageous and fully consistent with the intent of NEPA.

NEPA is an “umbrella” law that requires compliance with other federal, state, and local laws and regulations. Integrating the National Historic Preservation Act, Endangered Species Act, CWA and other compliance processes will reduce overall permitting time frames and costs, and streamline agency decision-making. These issues are discussed in Section 6.2.

Prepare the Draft and Final Environmental Impact Statement. The draft EIS would be prepared in two versions. A preliminary draft EIS would be prepared for internal review. The draft EIS would respond to comments on the preliminary draft EIS. The draft EIS would be circulated for public review and would be the subject of a public hearing. The final EIS would also be prepared in two versions. A preliminary final EIS would be prepared for internal review. The final EIS would respond to comments on the preliminary final EIS. The final EIS would be circulated for public review and would be the subject a public hearing. A Record of Decision (ROD) would be prepared to complete the NEPA process.

6.1.2 NEPA for Other Project Types

The level of NEPA documentation needed for projects other than major (non-stock pond) reservoir storage must be determined on a project-specific basis. For example, proposed new wildlife/livestock watering developments, including tank/pipeline systems that cross and/or serve federal or state rangeland 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 related to the discussion in Section 6.1 above.

BLM. Under current practice, NEPA evaluations and processes for both reservoir storage projects and other types of projects that may be proposed where BLM is the lead federal agency will be performed by BLM staff or qualified, independent third-party experts responsible to BLM. These experts may include specialists from other federal and/or state agencies working under Memorandum of Understanding, or other appropriate arrangements. Compliance with NEPA will be guided in large part by the Thunder Basin National Grassland Revised Land and Resource Management Plan and ROD (USFS, 2002), along with local land use plans, including the Converse County Land Use Plan (2003), the Converse County Conservation District Long Range and Natural Resource Management Program (2010), the Niobrara Conservation District Long Range Plan (2004), and any subsequent new or additional guidance and/or updates. All BLM-led NEPA-related processes and studies are administered by the lead BLM district staff (Newcastle or Casper staff), with assistance, as necessary and appropriate, from BLM state office staff. NEPA-related processes and studies are administered by the USFS Rocky Mountain Region for projects located on Medicine Bow-Routt National Forest-Thunder Basin Grasslands.

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. 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 and USFS, these plans will guide these agencies' NEPA process for any applicable proposed projects or improvements.

Watershed-Wide Environmental Analysis. Given the large number of planned and potential wildlife/livestock water development projects and the opportunity for larger-scale projects, it is recommended that serious consideration be given to the potential benefits of conducting a comprehensive "watershed-wide" environmental analysis for these and other potential water-resources related improvement projects. A key benefit of this approach would be to develop a single baseline characterization and impacts assessment of the relevant environmental issues associated with these types of projects. That approach is preferable to repeating the same assessments for many similar individual projects. A watershed-wide environmental analysis should substantially reduce the overall resources and time necessary to conduct the required environmental permitting (especially NEPA compliance) for individual projects. If necessary, the overall environmental analysis could be supplemented on a case-by-case basis for specific projects with particular issues.

6.2 Permitting/Clearances/Approvals

6.2.1 Dam and Reservoir Construction

Environmental resources are protected by a variety of state and federal regulations such as the CWA and the Endangered Species Act (ESA). Coordination with multiple agencies will be necessary to move forward with the dam and reservoir construction. Potential permits and/or agency contacts are explained in more detail below.

USACE Section 404 Permit. The USACE, through requirements contained in Section 404 of the CWA, regulates activities involving the discharge of dredged or fill material into waters of the United States. As such, any dam and reservoir storage project in the Thunder Basin watershed will need to address Section 404 permitting issues. Among other things, the proposed project must demonstrate that the least environmentally damaging practicable alternative (LEDPA) was selected to achieve the project's purpose. This is the alternative most likely to receive a permit.

Endangered Species Act (Section 7 Consultation). The lead agency would prepare a Biological Assessment (BA) to determine project effects on threatened and endangered plant and animal species listed or proposed for listing (candidate species) under the ESA (16 U.S.C. § 1531 et seq.). 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 destroy or adversely modify critical habitat. USFWS must approve the preparation of a BA to comply with the ESA in order to render its decision. If 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.

Fish and Wildlife Coordination Act. 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.

Migratory Bird Treaty Act. The Migratory Bird Treaty Act (MBTA) recommends avoiding construction activities in grassland, wetland, stream, and woodland habitats and bridges that may result in the taking of migratory birds, eggs, young, and/or active nests. In Wyoming, most migratory bird activity occurs during the period of April 1 to July 15.

The USFWS has indicated that if the proposed construction period is planned to occur during the primary nesting season, or at any other time that may result in taking the nests of migratory birds, a survey should be performed. The USFWS recommends that a qualified biologist conduct a field survey of the affected habitats and structures to evaluate the presence of nesting migratory birds during nesting season. The survey results should be maintained with the project files and made available to USFWS personnel upon request. The USFWS should be contacted immediately if active nests are identified within the construction area that cannot be avoided.

If construction of roadways falls within the primary nesting season, a survey of nesting birds will be conducted. As requested by the USFWS, a biologist will perform a field survey before construction activities to inspect the project construction corridor for nesting birds. The USFWS will be contacted if active nests are identified within the construction area and within a half-mile line of sight east and west from the construction area, that cannot be avoided. The results of the field survey for nesting birds, along with the information regarding the qualifications of person or persons performing the survey, will be documented and maintained on file for potential review.

Should active nests be observed that cannot be avoided until after the birds have fledged (left the nest), and if no practicable or reasonable avoidance alternatives are identified, then the contractor will complete a Federal Fish and Wildlife License/Permit Application Form 37 and submit it to the USFWS's Migratory Bird Program Office in Denver, Colorado. The contractor may proceed with work on the affected project activities following receipt of the approved permit from the USFWS.

Bald and Golden Eagle Protection Act. Although the bald eagle has been de-listed under the Endangered Species Act, bald eagles are still federally protected under the Bald and Golden Eagle Protection Act (BGEPA) of 1940. The BGEPA prohibits anyone, without a permit issued by the Secretary of the Interior, from the taking, possession and commerce of bald and/or golden eagles, including their parts, nests, or eggs. The definition of take includes pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb. Compliance with the BGEPA is part of the NEPA documentation.

Map 41, Raptor Nesting Areas shows several known nesting occurrences for both the bald and golden eagle in the Thunder Basin area. As with the MBTA, if construction falls within the primary eagle nesting season, a survey of eagle nesting sites should be conducted following guidelines set by the USFWS.

Laws Addressing Cultural Resources. Because federal approvals may be involved with the potential projects, a consideration of the impact on cultural resources must be undertaken (Section 106 consultation), as required under the NHPA)of 1966. Federal agencies will request a determination from the State of Wyoming Historic Preservation Office regarding the significance of cultural resources potentially affected by ground-disturbing activities.

In addition, consultation with relevant Native American groups concerning traditional cultural properties is required. Guidelines for evaluation of traditional cultural properties are contained in Bulletin 38 issued by the National Park Service.

Wyoming Board of Land Commissioners. The Wyoming Board of Land Commissioners, consisting of the five statewide elected officials, is responsible for regulating all activities on state lands, including granting of rights-of-way. This is accomplished through the Office of State Lands and Investments. Any project 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).

Wyoming State Engineer's Office Surface Water Storage Permit. The state engineer's office administers the water rights system of appropriation within the state. The applicant must obtain the necessary water rights permits from the State of Wyoming for the diversion and storage of the state's surface water.

Wyoming State Engineer's Office Permit to Construct/Dam Safety Review. The Wyoming Dam Safety Law (W.S. 41-3) requires that any persons, public company, government entity or private company who proposes to construct a 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 cubic feet of water per second (cfs), must obtain approval for construction of the dam or ditch from the state engineer's office. The approval by the state engineer's office of a dam's construction is contingent upon the office's review and approval of all dam plans and specifications, which must be prepared by a registered professional engineer licensed in Wyoming. Design, construction, and operation of jurisdictional dams must also comply with dam safety regulations promulgated pursuant to the Dam Safety Act. At present, these regulations are in final draft form and formal issuance is anticipated soon.

Wyoming State Engineer's Office Ditch Enlargement Permit. In addition to the permits and clearances that will be required for reservoir construction, if an enlargement to an existing ditch or storage facilities is needed, an enlargement filing with the state engineers office is required.

Even if physical enlargement of an existing ditch was found not be to required, the enlargement filing would be required as a legal formality of a water right requirement.

Wyoming Department of Environmental Quality – National Pollution Discharge Elimination System (NPDES) permit and Section 401 Certification. The federal CWA is administered in Wyoming by the WDEQ, Water Quality Division (WQD) and is consistent with the Wyoming Environmental Quality Act. The Section 401 Certification is the state's approval to ensure that the activities authorized under Section 404 meet state water quality standards and do not degrade water quality. Any discharge of pollutants into the broadly defined "waters of the state" requires application to and permit issuance by WQD in accord with WQD's Rules and Regulations. This body of regulations sets forth classification of surface and groundwater uses and establishes water quality standards (Wyoming Water Quality Standards). The WQD administers the NPDES permit system including stormwater permits and construction-related, short-term discharge permits.

Implementation of any of the action alternatives would require application for and compliance with the provisions of the statewide general NPDES Construction Storm Water Discharge Permit (WYR10-000). Construction activities associated with dam construction or enlargement often result in the requirement to temporarily discharge pumped water. These discharges are provided for in a general permit. Upon acceptance of the application by DEQ, the temporary discharge must comply with the terms of the general permit and any stipulations applied as a result of the application's review.

EPA has oversight responsibility for federal CWA delegated to and administered by the State WQD. EPA also may intervene to resolve interstate disputes where discharges of pollutants in an upstream state may affect water quality in a downstream state.

Mining Permit. A Wyoming mining permit is not required for development of an aggregate and/or borrow material source solely for use in construction of one of the various reservoir alternatives, and whose product is not for commercial sale. U.S. Army Corps of Engineers USACE – 404 Permitting. Any activities involving placement of fill or dredging of materials from jurisdictional waters of the United States requires permitting with the USACE.

Special Use Permits/Rights-of-Way/Easements. Special use permits, rights-of-way (ROW) or easements will be required wherever access across the lands of others (private, state or federal) is needed for construction and/or operation of the project facilities. These may be temporary (e.g., access to a temporary borrow area or quarry site to be closed and reclaimed; construction of a new haul road; etc.) or permanent (e.g., construction of a wildlife/livestock pipeline alignment). Usually privately owned lands that will be rendered permanently unavailable (such as the dam and reservoir footprint of a storage project) would be purchased unless the owner desires, and the sponsoring entity concurs, a permanent easement instead. Permanent use of BLM lands likely would be administered under a grant with an appropriate term issued under their ROW process; the USFS would use their equivalent special use process. An easement or ROW from the Wyoming Department of Transportation (WyDOT), and/or from Converse and/or Niobrara counties also may be required. The specific requirements for ROW, special use permits and easements vary widely and should be determined as part of the early stages of planning for a specific proposed project. This will help to avoid the potential for project delay, higher costs, or required changes in location/alignment or design during project development and implementation

Other. In addition to the above, there may be other permits and clearances required for a given dam and reservoir project. These might include permits typically required to be provided by the construction contractor (e.g., air quality permit; trash/slash burning permit; etc.).

6.2.2 Other Project Types

Permits, clearances and approvals for projects other than major dams and storage reservoirs will depend on the specific nature and location of the project. Various permits and clearances discussed above in Section 6.2.1 may also apply to other types of projects. 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 possibly redesign later during project implementation.

6.3 Environmental Considerations

6.3.1 General Habitat Description

The study area consists of a variety of habitats including mixed–grass prairie, ponderosa pine, sage brush, cactus, riparian habitats, open water, and local oil and gas operations. The animal and plant resources with an emphasis on those that are proposed, threatened or endangered, or candidate species are described in the following section. The ranges of three important game species (antelope, mule and whitetail deer) are illustrated on Maps 38-40. Although the species are not endangered, protection of their habitat is important to the hunters and wildlife enthusiasts of Thunder Basin L&LC.

6.3.2 Animal and Plant Resources

Proposed, Threatened and Endangered Species. The U.S. Fish and Wildlife Service indicates that the species listed in Table 6.3.2-1 have been identified in Niobrara and/or Converse Counties. It is important to note that they may not occur within the Thunder Basin L&LC part of the counties. However, if suitable habitat is present, there is a possibility that they may occur in the study area.

Table 6.3.2-1 – Thunder Basin Federal Threatened, Endangered and Proposed Species

Species	Scientific Name	Status	Habitat
Greater Sage-Grouse	*Centrocercus urophasianus*	Candidate	Sagebrush communities
Mountain Plover	*Charadrius montanus*	Proposed	Grasslands and prairie dog towns
Ute Ladies-Tresses	*Spiranthes diluvialis*	Threatened	Seasonally moist soils and wet meadows of drainages below 7,000 feet elevation
Blowout Penstemon	*Penstemon haydenii*	Endangered	Sand blowouts in dunes

Other Animal Species of Concern. The Wyoming Natural Diversity Database (WYNDD) (2007) identifies 29 species of concern within the two counties. The species are as follows:

Birds - Bald eagle (*Haliaeetus leucocephalus*), ferruginous hawk (*Buteo regalis*), long-billed curlew *(Numenius americanus),* yellow-billed cuckoo *(Coccyzus americanus),* burrowing owl *(Athene cunicularia),* short-eared owl *(Asio flammeus),* Lewis' woodpecker *(Melanerpes lewis),* Williamson's sapsucker *(Sphyrapicus thyroideus),* loggerhead shrike (*Lanius ludovicianus*), pygmy nuthatch (*Sitta pygmaea*), Virginia's warbler *(Vermivora virginiae),* sage sparrow *(Amphispiza belli),* Baird's sparrow *(Ammodramus bairdii),* McCown's longspur *(Calcarius mccownii),* chestnut-collared longspur *(Calcarius ornatus).*

Mammals - Hayden's shrew *(Sorex haydeni),* Townsend's big-eared bat *(Corynorhinus townsendii [Plecotus townsendii]),* black-tailed prairie dog (Large towns) *(Cynomys ludovicianus),* Preble's meadow jumping mouse *(Zapus hudsonius preblei),* swift fox *(Vulpes velox)*

Fish - Pearl dace [Northern dace] *(Margariscus margarita [Semotilus margarita]),* hornyhead chub *(Nocomis biguttatus),* finescale dace *(Phoxinus neogaeus)*

Amphibians – Boreal western toad (Southern Rocky Mountain population) *(Bufo boreas boreas (undescribed taxon)),* Northern leopard frog *(Rana pipiens)*

Reptiles - Northern many-lined skink *(Eumeces multivirgatus multivirgatus),* red-lipped prairie lizard [Orange-lipped plateau lizard] *(Sceloporus undulatus erythrocheilus),* Northern prairie lizard *(Sceloporus undulatus garmani),* smooth green snake (eastern and western) *(Liochlorophis vernalis [Lv. Vernalis, L.v. blanchardi; Opheodrys v. vernalis, O.v. blanchardi])*

Other Animal Species of Concern. The WYNDD (2007) identifies 40 species of potential concern. These species are as follows:

Birds - Black-crowned night-heron *(Nycticorax nycticorax),* common goldeneye *(Bucephala clangula),* golden eagle *(Aquila chrysaetos),* osprey *(Pandion haliaetus),* Merlin *(Falco columbarius),* Arctic peregrine falcon *(Falco peregrinus tundrius),* Virginia rail *(Rallus limicola),* Sandhill crane *(Grus Canadensis),* American avocet *(Recurvirostra americana),* Eastern bluebird *(Sialia sialis),* grasshopper sparrow *(Ammodramus savannarum),* Brewer's sparros *(Spizella breweri),* white-winged junco *(Junco hyemalis aikeni),* Northern bobwhite (Native populations) *(Colinus virginianus),* barn owl *(Tyto alba),* Eastern screech-owl *(Otus asio),* chimney swift *(Chaetura pelagica),* canyon wren *(Catherpes mexicanus)*, sage thrasher *(Oreoscoptes montanus),* red-eyed vireo *(Vireo olivaceous),* clay-colored sparrow *(Spizella pallida)*

Fish - Common shiner *(Luxilus cornutus),* Iowa darter *(Etheostoma exile)*

Amphibians – Tiger salamander *(Ambystoma tigrinum),* Great Plains toad *(Bufo cognatus)*

Reptiles - Western plains garter snake *(Thamnophis radix haydenii),* Eastern yellowbelly racer *(Coluber constrictor flaviventris)*, spiny softshell turtle *(Apalone spinfera [Trionyx spiniferus])*

Mammals - Dwarf shrew *(Sorex nanus),* hoary bat *(Lasiurus cinereus),* silver-haired bat *(Lasionycteris noctivagans),* Western small-footed myotis *(Myotis ciliolabrum [Myotis leibii]),* long-legged myotis *(Myotis volans),* long-eared myotis *(Myotis evotis),* Wyoming ground squirrel *(Spermophilus elegans),* olive-backed pocket mouse *(Perognathus fasciatus),* white-footed mouse *(Peromyscus leucopus),* common gray fox *(Urocyon cinereoargenteus),* plains (eastern) spotted skunk *(Spilogale putorius interruptua),* Bighorn sheep *(Ovis canadensis)*

Some of these species may occur in appropriate habitats within the study area. For example, some known raptor nesting areas are shown on Map 41, Raptor Nesting Areas and sage grouse leks are shown on Map 42, Sage Grouse Leks. Sage grouse are identified as a BLM sensitive species/species of concern and are designated by USFWS as a candidate for listing under the Endangered Species Act (ESA); therefore, the species merits special attention as discussed in some detail in the following paragraphs.

The greater sage grouse (*Centrocercus urophasianus*) is a species native to the area and is almost entirely dependent on open sagebrush plain. They are considered omnivores, eating insects, sagebrush and seeds; but are most reliant upon sagebrush for both cover from predators and for food. The greater sage grouse is listed as a sensitive species by the BLM, and a species of concern by WGFD. The BLM defines a sensitive species as a species that easily could become endangered or extinct in the state, including: (a) species under status review by the USFWS/National Marine and Fisheries Service; (b) species whose numbers are declining so rapidly that federal listing may become necessary; (c) species with typically small or fragmented populations; and, (d) species inhabiting specialized refugia or other unique habitats. WGFD lists the greater sage grouse as a species that is widely distributed, with 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. The sage grouse is not currently listed as a threatened or endangered species and does not receive any protections from the ESA; however, BLM and WGFD have developed restrictions/recommendations to help protect the sage grouse.

It is recommended that coordination with BLM and WGFD occur regarding any proposed or alternative project that has the potential to affect sage grouse habitat. Note that providing water to areas where water is limited may create a beneficial impact for sage grouse and should be considered when evaluating the net potential impacts to this species.

Rare Plant Species of Concern. The WYNDD has 20 known sensitive plant species of concern located in the study area: Slender false-foxglove (*Agalinis tenuifolia var. parviflora),* Laramie columbine *(Aquilegia laramiensis),* long-stalked racemose milkvetch *(Astragalus racemosus var. longisetus),* racemose milkvetch *(Astragalus racemosus var. racemosus),* dissected bahia *(Bahia dissecta),* hairy wood brome *(Bromus pubescens),* Sartwell's sedge *(Carex sartwellii var. sartwellii),* Wyoming dodder *(Cuscuta plattensis),* slim-leaf witchgrass *(Dichanthelium linearifolium), h*airy fimbry *(Fimbristylis puberula var. interior),* sidesaddle bladderpod *(Lesquerella arenosa var. argillosa)*, broad-leaved twayblade *(Listera convallarioides),* winged loosestrife *(Lythrum alatum var. alatum),* rosy palafoxia *(Palafoxia rosea var. macrolepis),* crown-seed fetid-marigold *(Pectis angustifolia var. angustifolia),* small-flowered fame-flower *(Phemeranthus parviflorus),* Rocky Mountain polypody *(Polypodium saximontanum),* nodding leafy bulrush *(Scirpus pendulus),* large bur-reed *(Sparganium eurycarpum),* Laramie false sagebrush *(Sphaeromeria simplex).* The potential exists for some of these species to occur within appropriate habitats within the project area. However, none of these species receive federal or state protection.

Big Game. The Thunder Basin watershed contains portions of crucial big game habitat for elk and pronghorn (see Map 43, Crucial Big Game Habitats) managed by the WGFD. The WGFD maps the seasonal ranges of the big game species and makes note of areas listed as crucial habitat.

Creating a dam/reservoir near critical habitat may have a positive effect on the area by providing additional water sources to the various wildlife species near the sites. Coordination with WGFD will need to occur to fully assess and evaluate potential impacts and mitigation measures for crucial big game habitat/parturition.

Fisheries. Map 30, WDEQ Stream Classifications, shows the different rivers and their associated tributaries within Thunder Basin. The map identifies the name of the rivers and tributaries within Thunder Basin, and these waterways are further classified by their respective stream classification. Two different classifications exist within the Thunder Basin study area (as described in Section 3.4.1.

Impacts to the various streams and associated fishery resources may occur with any of the potential dam and reservoir storage projects and should be considered during further environmental evaluation of these sites as discussed further below under mitigation in Section 6.5.

Wetland Resources. A formal wetland delineation in accordance with the USACE' guidelines has not been conducted across Thunder Basin. GIS digital mapping from the National Wetland Inventory (NWI) does exist and was acquired to preliminarily identify wetland habitats in the study area. The wetland habitats inferred to be present within the study area based on NWI mapping are shown on Map 11, National Wetland Inventory Map.

Some areas identified as wetlands may in fact not qualify as jurisdictional wetlands upon field investigation. This is due to limitations in the methodology used to prepare the NWI maps and the nature of wetlands to change over time based on natural events. As discussed previously, a formal delineation should be conducted once potential sites are selected to determine the level of impacts to wetlands located in the future project area.

6.4 Cultural and Paleontological Resources

Cultural resources include prehistoric and historic cultural resources, including prehistoric and historic archeological sites and standing structures. There is at least one known cultural resource within the study area, the DSD Bridge across the Cheyenne River in Niobrara County, which is listed on the National Register of Historic Places. Although a Class 1 cultural resources survey was not included in the scope of this study, it is likely that there are other cultural resources within the watershed, potentially at future project sites, as this area was known to be used by various Native American tribes as well as for historic ranching, transportation, and oil and gas exploration activities. Cultural resources may be protected by the National Historic Preservation Act (NHPA), if a federal action such as federal funding or permitting is part of a project. In addition, the Native American Graves Protection and Repatriation Act (NAGPRA) protects some archeological sites such as Native American burial sites.

Paleontological resources including fossil specimens are found throughout the watershed where bedrock is exposed at the surface. Collection of fossils on public lands is not permitted unless special permits are obtained. Collection of fossils on private land is not prohibited however; some spectacular, museum quality fossils have been found in Thunder Basin L&LC. Any such fossils should only be collected and preserved by a trained paleontologist.

6.5 Mitigation

Mitigation may be required for impacts to resources, including wetland and riparian vegetation, stream channel habitat, cultural resources, fish and game resources, and possibly threatened or endangered species. A variety of mitigation measures are presented in Appendix 3 – Wyoming BLM Guidelines for Surface-Disturbing and Disruptive Activities (BLM, 1998). As noted previously, it is preferred to avoid the need for mitigation of a potentially significant impact by relocation and/or "self-mitigating" design if technically and economically feasible.

If mitigation is required for wetland impacts, a detailed mitigation plan would need to be prepared and approved by USACE prior to construction of a dam. Wetland mitigation most likely be suggested near the reservoir, as hydrophytic communities will develop along the reservoir created by the dams.
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. If any threatened and endangered species have the potential to occur at a given site, special studies would be required to determine if appropriate mitigation could be implemented. In general, any such impacts should be avoided to the greatest extent possible.

Additional cultural resource fieldwork would need to be completed to identify and document any such resources that would be inundated or otherwise affected as a result of constructing any dams and reservoirs. This would include, in turn, 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 MOA between the Wyoming State Historic Preservation Office and the lead federal agency, with concurrence by the project sponsor(s), and possibly affected Native American tribes.

7.0 Economic Analysis and Project Financing

This section presents the potential funding sources and funding scenarios for the improvement projects identified in Section 4 of this report. The Wyoming Water Development Commission has requested that there be a semblance of consistency between the different watershed studies. This section, therefore, will be structured similar to the report prepared by (Olsson, 2009) and will address the following elements:

- Benefits associated with the alternative projects;
- The ability-to-pay of local irrigators;
- The minimum cost of water to irrigators under current WWDC guidelines; and
- The sponsor's ability-to-pay under different grant/loan scenarios.

The benefit to the grazing association participants from several of the proposed improvements (livestock wells and small reservoirs) are difficult to quantify because these benefits, primarily calf weight gain, are also greatly influenced by other factors, most notably weather. It is, therefore, difficult to perform a true economic analysis on the proposed modifications. The benefit analysis presented here is based on some general gross assumptions.

Potential funding sources are identified in Section 7.4. This is a general listing of funding sources identified and they may not all be applicable to the improvement projects identified. These funding sources may be applicable for future projects, yet to be identified, and are therefore provided here as a resource tool.

7.1 Direct Benefits Analysis

7.1.1 Irrigation System Improvements

The proposed improvements to the existing irrigation system (installation of pumps and spreader dike construction/improvement) target improving the delivery efficiency and minimizing the operational and maintenance expenses. In addition, the potential of developing several new storage facilities has been investigated. Over the past 30 years Wyoming meadows produce on average 1.3 tons of native hay per acre and 2.48 tons of alfalfa hay per acre (Wyoming Agricultural Statistics, 2010). In the Northeast Wyoming River Basin Plan prepared for the WWDC (HKM, 2002a), the average volume of surface water depleted (consumed) by crops in the drainages in the project area is approximately 1.1 ac-ft per irrigated acre. The predominant crop that is irrigated in the project drainages is native grass hay with some alfalfa production in the Lance Creek drainage (11% of crop production). Due to the lack of diversion volume records in the area, the efficiency of the delivery system is uncertain. Using an efficiency estimate of 40% (SEH, 2007), the volume of irrigation water that is diverted to meet this depletion requirement is 2.75 ac-feet per acre. Therefore, in the study area it is assumed that approximately 0.47 tons of native hay (1.3 tons/acre divided by 2.75 ac-ft/acre) or 0.90 tons of alfalfa hay (2.48 tons/acre divided by 2.75 ac-ft/acre) are produced per acre-foot of irrigation water diverted. By implementing the proposed modifications to the delivery systems and improving the efficiency of the irrigated water delivery system, theoretically, the production from the irrigated meadows could be increased by approximately 0.0047 tons (native hay) and 0.009 tons (alfalfa) for each percentage point of efficiency increase. This linear correlation of acre-feet of water to tonnage production is probably only applicable for a very small percentage increase, i.e. less than 10%.

The market value for this increased yield due to a more efficient delivery system will depend upon the current crop prices. The average cost (market year average) of native hay for the last 10 years[1] of record (2001 – 2010) was $92.35 per ton with a high of $109/ton and a low of $69.50/ton. The average cost (market year average) of alfalfa hay for the last 10 years[1] of record (2001 – 2010) was $96.45 per ton with a high of $111/ton and a low of $74.50/ton. At these prices, the increased benefit realized from the proposed irrigation improvements would range from approximately $0.32 to $0.51 per acre per each percent of increased efficiency for native hay production and from approximately $0.67 to $1.00 per acre per each percent of increased efficiency for alfalfa hay production.

Because there would be no increase to the amount of irrigated acres due to these improvements, there would be only a marginal increase in the production cost. This cost would be associated with the increase in the loading and stacking activities since the area actually being baled would not be increasing, therefore, the increased cost for baling per acre would be negligible.

The proposed construction of the off-channel storage reservoirs could potentially result in an increase in the irrigated acreage in the study area. Previous reports for the WWDC (SEH, 2007) have addressed the cost benefits of providing additional hay production resulting from additional storage water. Applying the assumed production of 1.18 tons of hay per acre-foot of consumptively used irrigation water (yield 1.3 tons/acre ÷ consumption 1.1 ac-ft per irrigated

[1] Costs were updated using the index of production costs paid by Wyoming farmers and ranchers available from the Wyoming Office of the National Agricultural Statistics Service at the following website: http://www.nass.usda.gov/Statistics_by_State/Wyoming/index.asp

acre) with a 40 percent delivery efficiency, every acre-feet of additional irrigation storage diverted will result in an increase in hay production of 0.47 tons (0.4 x 1.18 tons/acre-ft) of native hay and 0.9 tons of alfalfa hay.

The average cost to cut, rake, condition and bale hay is approximately $50.09 per ton (University of Illinois, 2010). Based on these numbers, the economic benefit from developing additional irrigation water supply from the off-channel storage facilities can be estimated. The value from the increased production of native hay, using the average cost of native hay over the last 10 years ($92.35), is $43.40 (0.47 tons x $92.35/ton) for the increased production. The value from the increased production of alfalfa hay, using the average cost of alfalfa hay over the last 10 years ($96.45), is $86.80 (0.90 tons x $96.45/ton) for the increased production. The net benefit after subtracting the production costs of $23.54 for native hay ($50.09/ton x 0.47 tons) and $45.08 for alfalfa ($50.09 x 0.9 tones) results in a net benefit estimate of $19.86 for native hay and $41.72 for alfalfa hay for each available acre-foot of supplemental irrigation water stored in the proposed off-channel storage reservoirs.

7.1.2 Livestock Watering Improvements

The following discussion on the benefits from providing additional pasture water sources and more specifically, tank water sources was borrowed from reports prepared by the Alberta Agriculture, Food and Rural Development entitled “Pasture Water Systems for Livestock” and from a report prepared for the Montana State Extension Service entitled “Dryland Pastures in Montana and Wyoming, Species and Cultivars, Seeding Techniques and Grazing Management by Larry Holzworth, Jeff Mosley, Dennis Cash, David Koch and Kelly Crane. Most ranchers want to maximize the return of their livestock enterprise while sustaining the resources used. Maximizing returns while ignoring the sustainability of the resources will result in eventual economic and environmental problems. Water distribution is critical for improving livestock grazing distribution in order to sustain or improve grazing conditions. Ranchers can improve the distribution of water by providing additional water sources where it has not been available before. This has allowed ranchers to utilize forage resources that were unused or had limited use in the past because of their distance from water.

Recently, there has been much more emphasis placed on developing rotational grazing systems that will benefit the pasture land, riparian areas and the livestock. Poor access to water and poor water quality can affect livestock behavior and production on pasture. The benefits to developing a pasture watering system include:

- water source protection, thus longer water source life
- improved herd health
- increased livestock production, in some situations
- better pasture utilization
- riparian protection

For livestock to perform up to their genetic potential, they must have adequate feed and water. Quality of the feed and water affects performance. Livestock will select the better quality feed and water when given a choice. Providing highest quality water possible to livestock may have added benefits similar to that of high quality forages. Many parameters can be used in defining water quality. For example, water temperatures between 40 and 65 degrees Fahrenheit are ideal. Steers having access to cool drinking water in the summer gained 0.3 to 0.4 pounds more per day than those drinking warm water (Boyles et al., 1988).

A large number of cattle in the northern Great Plains depend on earthen water basins, such as, reservoirs, ponds or dugouts for their drinking water. Cattle dependent on these sources for drinking water may influence water quality simply by their method of access. Cows, which drink from dam/pits, re-suspend sediments as they enter and move through the water to get a drink. The second cow to drink, many times, will wade farther, if possible, to get a cleaner drink of water. Fecal organisms, such as fecal coliform and streptococcus, are bound to sediments at the bottom of water sources until disturbed (Sherer et al., 1988). Livestock or wildlife walking into or through the water source is a typical disturbance. However, livestock drinking from a tank do not re-suspend bottom sediments, and rarely deposit urine and manure in the tank, as do those drinking from a dam/pit.

Cattle performance may be enhanced by providing a higher quality of drinking water. Research in Alberta, Canada (Willms et al., 1995) showed a 23% increase in weight gains over 71 days for yearling steers drinking well water versus those drinking from a dam/pit. Studies in 1993 showed a 20% difference in animal weights, when exposed to different water sources for a 30-day period. Some of the sources of water were pumped out of dugouts to tanks compared to cattle drinking directly out of a dugout. A 1994 study confirmed the impact on cows, with a lesser impact on calves (Kenzie, 1995).

Although it is difficult to quantify the improvement in calf production by simply improving the water supply because of the other factors that influence calf production. However, if a significant weight gain or cow/calf efficiency can be shown, it would be profitable for producers to improve their pasture water supply systems as proposed in Section 4. If these improvements are implemented and they result in, for example, a 5% increase in calf weights, 100 calves would yield an additional income of $2,607.50 in one year even at $1.043/pound calf prices (average price of Wyoming steers and heifers over the last 5 years, Wyoming Agricultural Statistics). This breakdown is shown below.

500 lb. calf x 0.05 = 25 lbs.

25 lbs. x $1.043/lb. = $26.075

$26.08 x 100 calves = $2,607.50

At the current market rate of $1.22/pound. (April 2011 – National Average), the increased production from 100 calves with a 5% increase in weight gain would yield an additional $3,050.00.

7.2 Indirect Benefits Analysis

Indirect benefits stem from the increase in income from one sector of business in a region upon other business sectors. An example of this would be the anticipated additional income from the additional weight gain in the cattle from the proposed Thunder Basin L&LC improvements being spent locally which increases the income in other business sectors in the area. The USDA Economic Research Service reported that each dollar of farm exports (cattle) stimulated $3.73 in U.S. business activity in calendar year 2009. This 3.73 multiplier is derived from the 2002 Benchmark Input-Output tables published by the Bureau of Economic Analysis of the U.S. Department of Commerce (USDOC). Therefore for each $1.00 of farm/ranch income generated an additional $2.73 of indirect income would be generated as an indirect benefit of new irrigation and/or grazing improvement projects.

7.3 Ability to Pay Analysis

The ability of the rancher's ability to pay for the proposed improvements will be predicated by the benefits realized and the income generated from the increased benefits (tonnage of hay and/or livestock weight gain) which will be dependent upon the current market values for the respective crop. Table 7.3.1 – Summary of Maximum Potential Benefits of Project Alternatives presents the maximum potential benefits of the proposed project improvements. As described earlier in Section 7.1.1, the estimated direct benefit from the additional storage volume is assumed to be $19.86 for each additional acre foot of storage (based on price for native hay). The benefits from the small reservoir improvements and/or construction was again based on the direct benefit from the additional storage volume for hay production as described previously for the large dam construction projects. Finally, the benefit from the pasture improvements (well construction) was based on an assumed increase of 5% weight gain applied to a calf weighing an average of 600 pounds. Table 7.3.1-1 shows the benefits of this weight gain when applied to the greater of 100 head of cattle or 25 head per new stock tank.

Table 7.3.1-1 Summary of Maximum Potential Benefits of Project Alternatives

Alternative	Irrigation Reservoir Capacity (acre-feet)	Assumed Annual Reservoir Yield (acre-feet)	Head of Cattle (Based on Lesser of 100 Head or 25 Head/Stock Tank)	Average Weight of Market Calves (lbs)	Benefit Per Single Animal Based upon a 5% Increase in Weight Gain at Market Price of $122/cwt	Maximum Potential Annual Benefits From Improvement Projects ($ per year)	Maximum Potential Present Value of All Direct Benefits ($)	Maximum Potential Present Value of All Direct and Indirect Benefits ($)
Large Off-Channel Reservoirs								
Lightning Creek 1	3,588	3,590.0				$ 71,300.00	$ 1,531,700.00	$ 5,713,200.00
Lightning Creek 2	5,176	5,180.0				$ 102,900.00	$ 2,210,500.00	$ 8,245,200.00
Lightning Creek and Tribs	3,482	3,480.0				$ 69,100.00	$ 1,484,400.00	$ 5,536,800.00
Old Woman Creek	1,622	1,620.0				$ 32,200.00	$ 691,700.00	$ 2,580,000.00
Small Reservoir Improvements								
Bruegger Improvements								
Rehabilitate existing storage area with sediment removal	23	23				$ 457.00	$ 9,800.00	$ 36,600.00
Hammell Improvements								
Rehabilitate existing dam by replacement	20	20				$ 397.00	$ 8,500.00	$ 31,700.00
Hereford / Hales Draw Ranch Improvements								
New storage area/dam	73	73				$ 1,450.00	$ 31,100.00	$ 116,000.00
Krein / Gunn Ranch Improvements								
New storage area/dam	3	3				$ 60.00	$ 1,300.00	$ 4,800.00
Kruse Improvements								
New storage area/dam where previous one was breached	17	17				$ 338.00	$ 7,300.00	$ 27,200.00
Rehabilitate existing storage area with sediment removal	1	1				$ 20.00	$ 400.00	$ 1,500.00
New storage area/dam	47	47				$ 933.00	$ 20,000.00	$ 74,600.00
Lund Improvements								
Realign existing dam	17	17				$ 338.00	$ 7,300.00	$ 27,200.00
McCormack / Lone Crow Ranch Improvements								
New storage area/dam	3	3				$ 60.00	$ 1,300.00	$ 4,800.00
New storage area/dam	22	22				$ 437.00	$ 9,400.00	$ 35,100.00
New storage area/dam	5	5				$ 99.00	$ 2,100.00	$ 7,800.00
Nelson Improvements								
New storage area/dam	1	1				$ 20.00	$ 400.00	$ 1,500.00
Snyder Improvements								
New storage area/dam	9	9				$ 179.00	$ 3,800.00	$ 14,200.00
Swanson Improvements								
Rehabilitate existing storage area with sediment removal	40	40				$ 794.00	$ 17,100.00	$ 63,800.00
Stock Watering Improvements								
Stock Well/Pasture Rotation Improvement			100	600	$ 36.60	$ 3,660.00	$ 78,600.00	$ 293,200.00
			150	600	$ 36.60	$ 5,490.00	$ 117,900.00	$ 439,800.00
			375	600	$ 36.60	$ 13,725.00	$ 294,800.00	$ 1,099,600.00

The column entitled "Maximum Potential Present Value of All Direct Benefits" is the "Present Value" of the projects based on an interest rate of 4% over a 50-year loan period. This interest rate and loan period were chosen to remain consistent with earlier basin study data. This "Present Value" reflects the break even project cost if no grant money is used and only a loan at a 4% interest rate over a 50-year period is used to finance the project. The final column represents the total benefit of the project (direct and indirect) to the economy in the region. This column reflects the "Present Value" multiplied by the 3.73 economy based ratio of total benefit to direct farm/ranch benefit increase.

Earlier reports (SEH, 2007) effectively addressed the lack of incentive to make system improvements if 100% of the additional income is required to retire the debt incurred in making the improvements. Therefore, for this ability to pay study, it is assumed that the ability to pay will be 50% of the additional income that could be generated from the proposed system improvements.

7.4 WWDC Financing Guidelines

The WWDC typically offers a 67% grant, 33% loan split for eligible projects. This can be increased to as much as a 75% grant, 25% loan for sponsors that can demonstrate severe financial hardship. It should be noted that an eligible project sponsor such as the local Conservation District office is required for such grant/loan project to be accepted without conditions. The current and minimum interest rate is 4% for program loans. The loan period shall not exceed the greater of 50 years or the economic life of the project. Additionally, the sponsor's method of loan repayment shall be considered in establishing the term of the loan. See Section 7.4 for additional information regarding the WWDC's available project options. Additional information regarding the terms and conditions of WWDC financing may be found in the Operating Criteria of the Wyoming Water Development Program contained in the following online document:

http://wwdc.state.wy.us/opcrit/final_opcrit.pdf

Table 7.4-1 is a summary of the project sponsor's ability to pay for the recommended off-channel reservoir system improvements utilizing the WWDC project financing format with a 67% Grant and 33% Loan combination. The loan was assumed to be financed by the State Loan Board at a rate of 4% annually for a 50 year period. Both the low estimated construction costs and high estimated construction cost values are summarized in this table.

Table 7.4-1 Summary of Ability to Pay for Project Alternatives – 67% Grant

Alternative	Level III Project Costs (Low Cost Estimate)	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Lightning 1	$24,000,000	$ 7,920,000.00	$ 369,072.00	$ 35,650.00	9.7%
Lightning 2	$53,000,000	$ 17,490,000.00	$ 815,034.00	$ 51,450.00	6.3%
Lightning and Tribs	$32,000,000	$ 10,560,000.00	$ 492,096.00	$ 34,550.00	7.0%
Lance South Trib	$28,000,000	$ 9,240,000.00	$ 430,584.00	$ 16,100.00	3.7%
Alternative	**Level III Project Costs (High Cost Estimate)**	**Sponsor's Share of Project Costs**	**Sponsor's Annual Payment**	**Sponsor's Maximum Ability to Pay**	**Sponsor's Percentage Ability to Pay**
Lightning 1	$44,000,000	$ 14,520,000.00	$ 676,632.00	$ 35,650.00	5.3%
Lightning 2	$96,000,000	$ 31,680,000.00	$1,476,288.00	$ 51,450.00	3.5%
Lightning and Tribs	$58,000,000	$ 19,140,000.00	$ 891,924.00	$ 34,550.00	3.9%
Lance South Trib	$51,000,000	$ 16,830,000.00	$ 784,278.00	$ 16,100.00	2.1%

As shown in Table 7.4-1, even with a 67% Grant, the project sponsor is only capable of paying approximately 2 to 10 percent of the anticipated annual loan payments for the proposed off-channel reservoirs. For comparison sakes, two additional grant/loan scenarios were reviewed – 75% and 90% Grant monies. These are shown in Tables 7.4-2 and 7.4-3, respectively.

Table 7.4-2 Summary of Ability to Pay for Project Alternatives – 75% Grant

Alternative	Level III Project Costs (Low Cost Estimate)	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Lightning 1	$24,000,000	$ 6,000,000.00	$ 279,600.00	$ 35,650.00	12.8%
Lightning 2	$53,000,000	$ 13,250,000.00	$ 617,450.00	$ 51,450.00	8.3%
Lightning and Tribs	$32,000,000	$ 8,000,000.00	$ 372,800.00	$ 34,550.00	9.3%
Lance South Trib	$28,000,000	$ 7,000,000.00	$ 326,200.00	$ 16,100.00	4.9%

Alternative	Level III Project Costs (High Cost Estimate)	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Lightning 1	$44,000,000	$ 11,000,000.00	$ 512,600.00	$ 35,650.00	7.0%
Lightning 2	$96,000,000	$ 24,000,000.00	$1,118,400.00	$ 51,450.00	4.6%
Lightning and Tribs	$58,000,000	$ 14,500,000.00	$ 675,700.00	$ 34,550.00	5.1%
Lance South Trib	$51,000,000	$ 12,750,000.00	$ 594,150.00	$ 16,100.00	2.7%

Even at the increased grant rate of 90%, the project sponsor would still need to seek additional funding sources.

Table 7.4-3 Summary of Ability to Pay for Project Alternatives – 90% Grant

Alternative	Level III Project Costs (Low Cost Estimate)	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Lightning 1	$ 9,300,000.00	$ 930,000.00	$ 43,338.00	$ 35,650.00	82.3%
Lightning 2	$ 11,000,000.00	$ 1,100,000.00	$ 51,260.00	$ 51,450.00	100.4%
Lightning and Tribs	$ 19,500,000.00	$ 1,950,000.00	$ 90,870.00	$ 34,550.00	38.0%
Old Woman Creek	$ 15,000,000.00	$ 1,500,000.00	$ 69,900.00	$ 16,100.00	23.0%

Alternative	Level III Project Costs (High Cost Estimate)	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Lightning 1	$44,000,000	$ 4,400,000.00	$205,040.00	$ 35,650.00	17.4%
Lightning 2	$96,000,000	$ 9,600,000.00	$447,360.00	$ 51,450.00	11.5%
Lightning and Tribs	$58,000,000	$ 5,800,000.00	$270,280.00	$ 34,550.00	12.8%
Old Woman Creek	$51,000,000	$ 5,100,000.00	$237,660.00	$ 16,100.00	6.8%

The ability of the project sponsor to pay for improvements to the present irrigation system or for new small dam construction was based on funding through the conventional WWDC funding package of 67% grant, 33% loan split or through the Wyoming Water Development Commission Small Water Project Program (SWPP) for those eligible projects (cost less than $100,000). The maximum contribution from the WWDC for the SWPP is $25,000. For consistency within the report, it was assumed that the loan rate would be 4% over a 50-year period when calculating the “Sponsor’s Annual Payment”. Because most of these projects consist of either developing new storage or reclaiming lost volume to sediment fill, the ability to pay was based on the income generated from the development of additional acreage and not just an increase in production from existing fields. As shown in Tables 7.4-4 and 7.4-5, the project sponsor would need to seek additional funding sources for even those projects eligible for Small Water Project Program funding. The project sponsor is only capable of paying approximately 0.1 to 19 percent of the anticipated annual loan payments for the proposed larger dam projects (construction cost over $100,000). The ability to meet the payment requirement on the smaller projects is slightly better where the sponsor is capable of paying between 2 and 34% of the anticipated annual loan payment. Even the most economically viable option (new storage dam for the Hammell

Ranch) would require more than 100% of the additional income to retire the debt incurred in making the improvements.

Table 7.4-4 Summary of Ability to Pay for Small Dam Project Alternatives – 67% Grant

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Bruegger Improvements					
Rehabilitate existing storage area with sediment removal	$ 6,430,282.00	$ 2,121,993.06	$ 98,884.88	$ 228.50	0.2%
Kruse Improvements					
New storage area/dam where previous one was breached	$ 93,163.00	$ 30,743.79	$ 1,432.66	$ 169.00	11.8%
Rehabilitate existing storage area with sediment removal	$ 459,584.00	$ 151,662.72	$ 7,067.48	$ 10.00	0.1%
New storage area/dam	$ 162,665.00	$ 53,679.45	$ 2,501.46	$ 466.50	18.6%
Lund Improvements					
Realign existing dam	$ 398,840.00	$ 131,617.20	$ 6,133.36	$ 169.00	2.8%
Swanson Improvements					
Rehabilitate existing storage area with sediment removal	$ 932,993.00	$ 307,887.69	$ 14,347.57	$ 397.00	2.8%

Table 7.4-5 Summary of Ability to Pay for Small Dam Project Alternatives – 50% Grant or $25,000

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Hammell Improvements					
New storage area/dam to replace existing dam	$ 24,872.00	$ 12,436.00	$ 579.52	$ 198.50	34.3%
Hereford / Hales Draw Ranch Improvements					
New storage area/dam	$ 80,556.00	$ 55,556.00	$ 2,588.91	$ 725.00	28.0%
Krein / Gunn Ranch Improvements					
New storage area/dam	$ 21,136.00	$ 10,568.00	$ 492.47	$ 30.00	6.1%
Kruse Improvements					
New storage area/dam where previous one was breached	$ 93,163.00	$ 68,163.00	$ 3,176.40	$ 169.00	5.3%
McCormack / Lone Crow Ranch Improvements					
New storage area/dam	$ 14,438.00	$ 7,219.00	$ 336.41	$ 30.00	8.9%
New storage area/dam	$ 44,048.00	$ 22,024.00	$ 1,026.32	$ 218.50	21.3%
New storage area/dam	$ 25,566.00	$ 12,783.00	$ 595.69	$ 49.50	8.3%
Nelson Improvements					
New storage area/dam	$ 23,310.00	$ 11,655.00	$ 543.12	$ 10.00	1.8%
Snyder Improvements					
New storage area/dam	$ 43,379.00	$ 21,689.50	$ 1,010.73	$ 89.50	8.9%

A similar funding scenario is presented for the proposed pasture improvement projects. The ability to pay summary for these projects is shown in Tables 7.4-6 and 7.4-7. This analysis was based upon an assumed average cost for a pasture improvement project and it was assumed that this pasture would benefit 100 head of cattle. For those larger options where additional piping and stock tanks were being implemented it was assumed that each stock tank would support an additional 25 head of cattle. Therefore, the ability to pay summary was based on either 25 head per stock tank or 100 head – the larger of these two values.

The funding sources for these improvement projects were again split between the conventional WWDC funding and the Small Water Project Program (SWPP). As indicated in Table 7.4.5, if a 5% livestock weight gain could be realized by improving the water source or grazing conditions, these improvement projects appear to be the most economically beneficial to the association based purely upon a rate of return on their investment dollar.

Table 7.4-6 Summary of Ability to Pay for Upland Well Development Project Alternatives – 50% Grant

Alternative	Number of New Stock Tanks	Assume 25 Head Per New Stock Tank	Head of Cattle to Benefit From Well	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Livestock Watering - Pasture Rotation Improvement								
Greer	0	0	100	$ 6,500.00	$ 3,250.00	$ 151.45	$ 1,830.00	1208.3%
Gunn	1	25	100	$ 22,500.00	$ 11,250.00	$ 524.25	$ 1,830.00	349.1%
Hales Draw	1	25	100	$ 12,660.00	$ 6,330.00	$ 294.98	$ 1,830.00	620.4%
Johnson North	3	75	100	$ 44,214.00	$ 22,107.00	$ 1,030.19	$ 1,830.00	177.6%
Johnson North	3	75	100	$ 41,996.00	$ 20,998.00	$ 978.51	$ 1,830.00	187.0%
Kremers A	1	25	100	$ 20,236.00	$ 10,118.00	$ 471.50	$ 1,830.00	388.1%
Kremers B	6	125	125	$ 42,760.00	$ 21,380.00	$ 996.31	$ 1,830.00	183.7%
Kremers C	1	25	100	$ 17,850.00	$ 8,925.00	$ 415.91	$ 1,830.00	440.0%
Kremers D	4	100	100	$ 45,386.00	$ 22,693.00	$ 1,057.49	$ 1,830.00	173.1%
Kremers E	3	75	100	$ 31,408.00	$ 15,704.00	$ 731.81	$ 1,830.00	250.1%
Porter	1	25	100	$ 20,120.00	$ 10,060.00	$ 468.80	$ 1,830.00	390.4%
Robinson East	1	25	100	$ 44,900.00	$ 22,450.00	$ 1,046.17	$ 1,830.00	174.9%
Robinson South	1	25	100	$ 44,900.00	$ 22,450.00	$ 1,046.17	$ 1,830.00	174.9%
Robinson West	1	25	100	$ 44,900.00	$ 22,450.00	$ 1,046.17	$ 1,830.00	174.9%
Stoddard A	1	75	100	$ 44,900.00	$ 22,450.00	$ 1,046.17	$ 1,830.00	174.9%
Stoddard B	1	75	100	$ 44,900.00	$ 22,450.00	$ 1,046.17	$ 1,830.00	174.9%
Stoddard C	1	75	100	$ 44,900.00	$ 22,450.00	$ 1,046.17	$ 1,830.00	174.9%
Swanson	0	0	100	$ 12,460.00	$ 6,230.00	$ 290.32	$ 1,830.00	630.3%

Table 7.4-7 Summary of Ability to Pay for Upland Well Development Project Alternatives – 67% Grant

Alternative	Number of New Stock Tanks	Assume 25 Head Per New Stock Tank	Head of Cattle to Benefit From Well	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Livestock Watering - Pasture Rotation Improvement								
	No Projects Proposed for this funding option in this report.							

7.5 Project Funding Sources

There are a variety of funding sources that may be able to offer funding for various portions of the project. The general criteria and applicability of each of the funding sources are discussed in this section and categorized by project type. A summary of the funding sources can be found in Appendix A, Data Summary 7.5-1.

Funding sources presented here are not necessarily inclusive of all funding options available. Information presented here is also subject to change as funding sources may change their terms and criteria. The contacts listed for the various funding sources are also considered volatile and may change in time.

The primary local resources for the project are the local conservation districts, the National Resources Conservation Service (NRCS), and the Bureau of Land Management (BLM). These entities offer local expertise relative to the area as well as intimate knowledge of potential funding programs that may apply to the projects outlined in this report. These key local resources include, but are not limited to:

- Weston County Natural Resource District (307-746-3264)
- Campbell County Conservation District (307-682-1824)
- Niobrara County Conservation District (307-334-2953)
- Converse County Conservation District (307-358-5719)
- Bureau of Land Management

- Buffalo Field Office - Buffalo, WY (307-684-1100)
- Newcastle Field Office – Newcastle, WY (307-746-6600)
- Natural Resource Conversation Service Offices:
- Weston County - Newcastle, WY (307-746-3264)
- Campbell County - Gillette, WY (307-682-8843)
- Niobrara County - Lusk, WY (307-334-2953)
- Converse County – Douglas, WY (307-358-3050)

Additionally, there are two online resources that outline a variety of funding sources for grant, loan, and in-kind support for watershed related projects. These two resources were used extensively for researching available funding sources for this project. The first is the Water Management & Conservation Assistance Programs Directory available from the WWDC which was last updated in May, 2009. The directory is available online:
http://wwdc.state.wy.us/wconsprog/consdir/ConservationDirectoryFinal.pdf

The second site is an online Catalog of Federal Funding Sources for Watershed Protection developed and maintained by the Environmental Protection Agency. The catalog can be accessed online: http://cfpub.epa.gov/fedfund/

The Wyoming Game and Fish Department has published "Habitat Extension Bulletin No. 50 – Fisheries and Wildlife Habitat Cost-Share Programs and Grants." The Bulletin provides a listing of potential funding sources for fisheries and wildlife habitat projects and may be viewed online:
http://gf.state.wy.us/habitat/ExtBulletinsCont/index.asp

7.5.1 Local Agencies

7.5.1.1 Niobrara Conservation District

The Niobrara Conservation District (NCD) operates primarily on mill levy funds and additional grants for specific projects. The District does not reserve any funds for rangeland improvements. The Thunder Basin project is NCD's first experience in obtaining funds from the WWDC.

7.5.1.2 Converse County Conservation District

The Converse County Conservation District (CoCCD) is funded primarily though a local mill levy tax and grant funds. Additional funding is acquired by the district's equipment rental and seedling tree program. The CoCCD typically aids and administers funding from outside sources such as the NRCS, but expressed the possibility of funding projects that prove beneficial to the District's mission for up to $10,000 tentatively.

7.5.2 State Agencies

7.5.2.1 Wyoming Department of Environmental Quality

The Wyoming Department of Environmental Quality (WDEQ) provides financial assistance for best management practices to address non-point sources of pollution under Section 319 of the Clean Water Act. Grant funding requires a 40% match from the applicant. The match may come from the local landowner, a conservation or irrigation district, or a non-profit organization. Applications are typically due in late summer of each year.

7.5.2.2 Wyoming Game and Fish Department

The Wyoming Game and Fish offers a variety of funding options and is best summarized from the Water Management & Conservation Assistance Program Directory (see previous link):

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.

Riparian Habitat Improvement Grant. The purpose of this program is to improve or maintain riparian and wetland resources. Fencing, herding, stock water development, stream bank 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 required from 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 righting are responsibilities of the grantee. There is a maximum of $7,500/project and 50% cash or in-kind contribution required from the grantee.

Industrial Water Habitat Project Fund. The purpose of this program is to develop water sources beneficial to fish and wildlife that are located by industrial drilling, mining or excavation operations. Examples of projects are tapped artesian wells, springs or ground water that could be used for wildlife watering or creation of wetlands or ponds. Industry must meet set criteria, obtain permitting and access, clean-up and restore the site and provide NEPA compliance. There is neither a funding limit nor matching contribution needed for these projects.

Upland Development Grant. The purpose of this program is to develop upland wildlife habitat. Examples of projects in this program are shrub management, grazing systems, prescribed burning, 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.

7.5.2.3 Wyoming Office of State Lands and Investments

The Wyoming Office of State Lands and Investments offers a variety of funding options and is best summarized from the Water Management & Conservation Assistance Program Directory (see previous link):

The Office of State Lands & Investments is the administrative arm of the Board of Land Commissioners and the State Loan and Investment Board. It is the statutory responsibility of the Office of State Lands & Investments to carry out the policy directives and decisions of these two Boards.

The organizational structure of Office of State Lands & Investments consists of the Office of the Director and five divisions: Financial Programs and Management Services, Real Estate Management and Farm Loans, Mineral Leasing and Royalty Compliance, Wyoming State Forestry and Information Technology. Collectively these divisions serve the trust beneficiaries - Wyoming's school children and state institutions; numerous clients in agriculture, mineral, timber, transportation, communication, public utility, recreation, tourism and other Wyoming industries; local government entities; state and federal agencies; and the resident and non-resident general public.

Farm Loan Program established in 1921, provides long term real estate loans to Wyoming's agricultural operators. The use of this program has been expanded over the years to also include loans for the purchase of livestock and to assist beginning agricultural producers.

The Irrigation Loans Program established in 1955, is designed to support small and large agricultural water development projects. The Legislature has allocated a total of $275 million for loans under the Farm Loan Program and $20 million for the Irrigation Loan Program. Both programs are funded from the Wyoming Permanent Mineral Trust Fund.

Joint Powers Act Loan Program was established in 1974 the Legislature authorized the Joint Powers Act Loan Program to benefit local communities for infrastructure needs. These loans are approved from funds within the State's Permanent Mineral Trust Fund. These programs are an aid to cities, counties and special districts in providing needed government services and public facilities. For the period January 1, 2010 through December 31, 2010, the interest rate is 5.17% for Joint Powers Act Loans. In January 2011, the State Treasurer will calculate a new interest rate for calendar year 2011.

7.5.2.4 Wyoming Water Development Commission

The Wyoming Water Development Commission offers a variety of funding options for reconnaissance and feasibility studies as well as construction projects. Reconnaissance and feasibility studies are typically 100% grant funded. Eligible construction projects are typically funded on a 67% grant, 33% loan split when an eligible entity is identified as the project sponsor. Projects typically funded include, but are not limited to agriculture, environmental, erosion control, new storage (dams and reservoirs), new water supply sources, watershed improvements, and recreation.

New Development Program. The New Development Program provides an opportunity for sponsors to develop water supplies for anticipated future needs to ensure that lack of water supply will not inhibit economic growth. The program encourages water development through state/local partnerships. The sponsor can complete a water supply project with state funding assistance.

Rehabilitation Program. The purpose of the Rehabilitation Program is to provide funding assistance for the improvement of water projects completed and in use for at least fifteen (15) years. Rehabilitation projects are typically initiated by an application from a project sponsor. If the application is approved, the project is usually assigned a Level II status and can proceed through construction if it is determined the project is technically and economically feasible. The project sponsor must be willing and capable of financially supporting a portion of the project development costs plus all operation and maintenance costs. The Rehabilitation Program serves to assist project sponsors in keeping existing water supplies effective and viable, thereby preserving their use for the future. Rehabilitation projects can improve an existing municipal or rural domestic water supply system or an agricultural storage facility or conveyance system. The projects serve to ensure dam safety, decrease operation, maintenance, and replacement costs and/or provide a more efficient means of using existing water supplies.

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. 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.

Small Water Project Program. The Small Water Project Program (SWPP) is intended to be compatible with the Wyoming Water Development Commission conventional program and criteria and to parallel and partner with other local, state and federal programs that perform water resource planning and water development in Wyoming. Small water projects are defined as those projects that provide multiple benefits and where estimated construction costs, permit procurement, construction engineering and project land procurement are one hundred thousand dollars ($100,000) or less, or where the maximum financial contribution from the commission is fifty percent (50%) of project costs or twenty-five thousand dollars ($25,000), whichever is less.

Projects eligible for SWPP grant funding assistance include the construction or rehabilitation of small reservoirs, wells, pipelines and conveyance facilities, springs, solar platforms, irrigation works, windmills and wetland developments. 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.

It is the intention of WWDC to work closely with the land management agencies and the sponsoring entities in the administration of this program. This additional source of grant funding will help develop a partnership where local, state, and Federal agencies can work together for the benefit of the people of Wyoming.

More Information. The options are best summarized from the Water Management & Conservation Assistance Program Directory (see previous link) and the Operating Criteria of the Wyoming Water Development Program (see previous link).

7.5.2.5 Wyoming Wildlife and Natural Resource Trust

The wildlife and Natural Resource Trust was created in 2005 and is funded by interest earned on a permanent account, donations, and legislative appropriations. The purpose of the program is to enhance and conserve wildlife habitat and natural resource values throughout the state. Any project designed to improve wildlife habitat or natural resource values is eligible for funding.

Wildlife and Natural Resource Trust funding is available for a wide variety of projects throughout the state, including natural resource programs of other agencies. Examples of projects eligible for funding include, but are not limited to:

- 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.

- Improvements and maintenance of aquatic habitats, including wetland creation or enhancement, stream restoration, water management or other methods.
- Mitigation of impacts detrimental to wildlife habitat, the environmental and the multiple use of renewable natural resources, or mitigation of conflicts and reduction of potential disease transmission between domestic wildlife and domestic livestock.

7.5.3 Federal Agencies

7.5.3.1 Bureau of Land Management

The Bureau of Land Management offers three distinct programs for funding which are best summarized in the Water Management & Conservation Assistance Programs Directory (see previous link):

Riparian Habitat Management Program. The program offers the opportunity to coordinate with outside interests in 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. 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.

Range Improvement Planning and Development. The 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. All rangeland improvement projects on lands administered by the BLM require the execution of a Permit. Although there are a couple of methods for authorizing range improvements on 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 BLM's share comes from the range improvement fund which is generated from grazing fees collected. There is also a limited amount of funding from general rangeland management appropriations. Contributions come either in the form of labor or may provide some material costs as well and is typically in the form of a grant.

Watershed and Water Quality Improvement. 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. This program is a cooperative effort between the BLM and the WDEQ. Goals of the program for watershed projects will typically be the restoration and maintenance of healthy watershed function and are typically accomplished through best management practices, prescribed burns, vegetation treatment, in-stream structures, to enhance vegetation cover, control accelerated soil erosion, increase water infiltration, and enhance stream flows and water quality.

7.5.3.2 Bureau of Reclamation

The Bureau of Reclamation's (BoR) mission emphasizes water conservation, recycling, reuse, development of partnerships with customers, states and tribes, bringing competing interests together to address needs, transferring title and operation of some facilities to local beneficiaries to enhance efficiency and achieving a higher level of fiscal responsibility to the tax payer.

Challenge Grant Program. Through Water for America, BoR administers the Challenge Grant Program, which generally provides up to $300,000 in Federal funding per project, for projects that will improve water efficiency, demonstrate advanced water treatment technologies, and help to avoid the decline of candidate species. Challenge Grant Funding is allocated through a west-wide competitive process that prioritizes projects that will address the most critical issues from a west-wide perspective.

Water Conservation Field Services Program. Provides smaller amounts of funding up to $100,000 per project through local competitions within the region or area. The projects funded are generally smaller in scope than the Challenge Grant Projects, and are focused on fundamental conservation improvements as identified in water conservation plans developed by water users. Financial assistance provided through the Challenge Grant Program and the WCFSP must be cost shared on at least a 50-50% split between the recipient and BoR. More information can be found online: www.grants.gov

7.5.3.3 Environmental Protection Agency

The Environmental Protection Agency (EPA) administers The Targeted Watershed Grants Program. The grant program is summarized as:

Established in 2003, the Targeted Watersheds Grant Program is designed to encourage successful community-based approaches and management techniques to protect and restore the nation's watersheds. The Targeted Watersheds Grant program is a competitive grant program based on the fundamental principles of environmental improvement: collaboration, new technologies, market incentives, and results-oriented strategies. The Targeted Watersheds Grant Program focuses on multi-faceted plans for protecting and restoring water resources that are developed using partnership efforts of diverse stakeholders. Targeted Watersheds Implementation Grants are focused on individual watershed organizations. Successful watershed organizations are chosen because they best demonstrated the ability to achieve on-the-ground, measurable environmental results relatively quickly, having already completed the necessary watershed assessments and developed a technically sound watershed plan. Each of the watershed organizations exhibits strong partnerships with a wide variety of support; creative, socio-economic approaches to water restoration and protection; and explicit monitoring and environmentally-based performance measures. Proposals must be nominated by either a Governor or a Tribal Leader from the state in which the project resides. More information can be found at: http://www.epa.gov/watershed/initiative/

7.5.3.4 Farm Service Agency

The Farm Service agency (FSA) is a member agency of the United States Department of Agriculture. Programs administered through the FSA are offered through local county committees. Technical assistance needed for implementation of FSA programs is provided through the NRCS. The FSA programs available are:

Conservation Resource Program. This program offers agricultural producers annual rental payments to remove highly erodible cropland from production. Farmers and ranchers establish long-term conservation practices on erodible and environmentally sensitive land. In exchange, they receive 10-15 years of annual rental payments and cost share assistance. This is a voluntary program specifically for highly erodible lands currently in active production planted 2 of the 5 most recent crop years. Land offered for the program is ranked according to environmental benefit for wildlife habitat, erosion control, water quality, and air quality.

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 the Conservation Reserve Program and be determined by NRCS to eligible and suitable for 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 is a cost share program that offers rental rates based on the average value of Dryland 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.

Emergency Conservation Program. The program provides emergency funding and technical assistance for farmers and ranchers to rehabilitate farmland damaged by natural disasters and for carrying out emergency water conservation measures for livestock during periods of severe drought. Participants receive cost-share assistance of up to 75% of the cost to implement approved emergency conservation practices as determined by county FSA committees. Some conservation practices are removing debris, restoring fences and conservation structures, and providing water for livestock in drought situations.

More information for each of the programs can be found at:

http://www.fsa.usda.gov/FSA/webapp?area=home&subject=landing&topic=landing

7.5.3.5 Fish and Wildlife Service

The Fish and Wildlife Service (FWS) offers technical and financial assistance to a variety of entities. They offer four programs addressing the management, conservation, restoration, or enhancement of wildlife and aquatic habitat.

Partners for Wildlife Habitat Restoration. 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 WEA's, 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.

Wildlife Conservation and Appreciation Program. This program provides grants to state fish and wildlife agencies to fund projects that bring together FWS, state agencies, 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 of 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 to 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.

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.

7.5.3.6 Natural Resource Conservation Service

The Natural Resource Conservation Service (NRCS) provides leadership in a partnership effort to help people voluntarily conserve, improve, and sustain natural resources on private lands. The purpose and mission of the agency is to help landowners treat every acre of their private property according to its needs and within its capability. The treatment includes a balance between the land use for economic return and protecting its ability to be productive from generation to generation. Technical and cost share assistance is available through NRCS. The NRCS administers the following 2009 Farm Bill programs:

Environmental Quality Incentives Program (EQIP). Through EQIP, technical assistance, cost share and inventive payments are available to agricultural producers to implement conservation practices that improve water quality, enhance grazing lands, and/or increase water conservation.

Conservation Security Program (CSP). The CSP is available in selected watersheds across the nation. The program is designed to reward farmers and ranchers who are implementing conservation on working lands and encourage them to do more.

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 conservation.

Farm and Ranch Lands Protection Program (FRPP). The program 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 environmental standard of living for residents of those communities.

7.5.3.7 US Forest Service

Conservation Practices funding. Contact the local US Forest Service or Thunder Basin Grazing Association staff for information about funding opportunities for projects involving National Forests or National Grasslands.

7.5.4 Non-Profit and Other Organizations

7.5.4.1 Ducks Unlimited

Ducks Unlimited, Inc. is a funding source for wetlands and waterfowl restoration. Ducks Unlimited (DU) conducts program development through a "Partner" agency in providing short term project funding assistance. Money availability is limited to what is within the organizational system. Generally there is $20,000 to $30,000 available annually statewide with additional funding support from project specific donations.

Ducks Unlimited offers a waterfowl habitat development and protection program called MARSH which stands for Matching Aid to Restore States Habitat. This is a reimbursement program that provides matching funds for restoration, protection or enhancement of wetlands. The financial extent of this program is dependent on DU's income within the state. Projects receiving funding support must demonstrate at least 30 years of beneficial life at a minimum.

7.5.4.2 National Fish and Wildlife Foundation

The National Fish and Wildlife Foundation provides a number of charter grant programs for regions across the nation. The most applicable programs for this project are:

Five-Star Restoration Matching Grants 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.

Bring Back the Natives. The National Fish and Wildlife Foundation (NFWF), in cooperation with the U.S. Fish and Wildlife Service (FWS), Bureau of Land Management (BLM), U.S.D.A. Forest Service (FS), and Trout Unlimited (TU), is pleased to request pre-proposals from nonprofit organizations, universities, Native American tribes, and local, state, and federal agencies interested in restoring, protecting, and enhancing native populations of sensitive or listed aquatic species, especially on lands on or adjacent to federal agency lands. Funding for the BBN program is administered through NFWF from federal agencies cooperating to support this program. This funding requires a $2 non-federal match for each federal dollar requested by applicants. Since 1991, BBN has supported 279 projects and benefited over 120 species, 29 of which are federally listed as threatened or endangered.

Native Plant Conservation Initiative. The National Fish and Wildlife Foundation (NFWF) is soliciting proposals for the 2011 Native Plant Conservation Initiative (NPCI) grants cycle. The NPCI grant program is conducted in cooperation with the Plant Conservation Alliance (PCA), a partnership between the Foundation, ten federal agencies, and more than 270 non-governmental organizations. PCA provides a framework and strategy for linking resources and expertise in developing a coordinated national approach to the conservation of native plants. Since 1995, the NPCI grant program has funded multi-stakeholder projects that focus on the conservation of native plants and pollinators under any of the following 6 focal areas: conservation, education, restoration, research, sustainability, and data linkages.

Pulling Together Initiative. The Pulling Together Initiative seeks proposals that will help control invasive plant species, mostly through the work of public/private partnerships such as Cooperative Weed Management Areas. PTI applications are accepted from private non-profit (501)(c) organizations, federally recognized Tribal governments, local, county, and state government agencies, and from field staff of federal government agencies. Individuals and for-profit businesses are not eligible to receive PTI grants, but are encouraged to work with eligible applicants to develop and submit applications to PTI. PTI applications must provide a 1:1 non-federal match for their grant request.

More information for each of these funding options and others can be found at NFWF's website: http://www.nfwf.org

7.5.4.3 Trout Unlimited

The mission of the Wyoming Council of Trout Unlimited is to conserve, protect, and restore Wyoming's coldwater (trout) fisheries and their watersheds. 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.

7.5.5 Funding for Sage Grouse Conservation Efforts

Sage Grouse conservation in the Thunder Basin area will provide a number of benefits as well as pitfalls relative to the construction and funding of projects proposed. There are a great number of funding sources whose mission is to benefit the habitat and success of the sage grouse. There are also a number of organizations who will have special requirements for any construction or modification to the local habitat. The Wyoming Game and Fish Department has compiled a list of funding opportunities for Wyoming Sage Grouse Conservation Efforts. More information may be found at the Wyoming Game and Fish Department's web site:
http://gf.state.wy.us/wildlife/wildlife_management/sagegrouse/index.asp

7.5.5.1 State of Wyoming Sources

Wyoming Wildlife and Natural Resource Trust Account. Created by legislative action in 2005 for the purposes of preserving and enhancing Wyoming's wildlife and natural resources. Income from the trust account is used to fund a wide variety of conservation programs. http://wwnrt.state.wy.us/

Wyoming Game and Fish Department (WGFD) Trust Fund. Matching grants program for riparian or upland habitat improvement, water development, and industrial water projects http://gf.state.wy.us

WGFD/Wyoming State General Fund. Wyoming Sage-Grouse Conservation Fund - Funding approved by the legislature via the Governor's budget request designed to implement projects identified in local Sage-Grouse Conservation Plans. http://gf.state.wy.us

Wyoming Animal Damage Management Board (ADMB). Provides funding for the purposes of mitigating damage caused to livestock, wildlife and crops by predatory animals, predacious birds and depredating animals or for the protection of human health and safety. http://www.wyadmb.com

7.5.5.2 Federal Sources

U.S. Dept. of Interior, Fish and Wildlife Service http://www.fws.gov

- **Partners for Fish and Wildlife Program**. Provides assistance to private landowners who want to restore or improve habitat on their property. The landowner is reimbursed based on the cost sharing formula in the agreement, after project completion.
- **Private Stewardship Program**. Provides grants or other assistance to individuals and groups engaged in private conservation efforts that benefits species listed or proposed as endangered or threatened under the Endangered Species Act, candidate species, or other at-risk species on private lands. Maximum Federal share is 90%.
- **Cooperative Conservation Initiative**. Supports efforts to restore natural resources and establish or expand wildlife habitat. Maximum Federal share is 50%.
- **Multistate Conservation Grant Program**. Supports sport fish and wildlife restoration projects identified by the International Association of Fish and Wildlife Agencies. Maximum Federal share is 100%.
- **Tribal Landowner Incentive Program**. For actions and activities that protect and restore habitats that benefit Federally listed, proposed, or candidate species, or other at-risk species on tribal lands. Maximum Federal share is 75%.
- **Tribal Wildlife Grants**. Provides for development and implementation of programs for the benefit of tribal wildlife and their habitat. Maximum Federal share is 100%.
- **Conservation Grants**. Provides financial assistance to States to implement wildlife conservation projects such as habitat restoration, species status surveys, public education and outreach, captive propagation and reintroduction, nesting surveys, genetic studies and development of management plans. Maximum Federal share is 75 % for a single state or 90% for two or more states implementing a joint project.

U.S.D.A. Farm Service Agency (FSA) http://www.fsa.usda.gov/pas/

- **Conservation Reserve Program (CRP).** A voluntary program for agricultural landowners. Through CRP, you can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers and enhance wildlife habitat on eligible agricultural land.

U.S.D.A. Natural Resource Conservation Service (NRCS) http://www.wy.nrcs.usda.gov

- **Conservation Innovation Grants (CIG).** CIG is a voluntary program that enables the NRCS to work with public and private entities to accelerate the development and adoption of innovative conservation approaches and technologies in conjunction with agricultural production.
- **Conservation Technical Assistance (CTA)**. Provides voluntary conservation technical assistance to land-users, communities, units of state and local government, and other Federal agencies in planning and implementing conservation systems. This assistance

is for planning and implementing conservation practices that address natural resource issues.

- **Environmental Quality Incentives Program (EQIP)**. Provides a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land.
- **Wildlife Habitat Incentives Program (WHIP).** Provides a voluntary program to develop and improve wildlife habitat primarily on private land by providing both technical assistance and up to 75% cost-share assistance to establish and/or improve fish and wildlife habitat.
- **Sage-Grouse Restoration Project (SGRP).** Cooperative effort involving private landowners, agencies, organizations and universities in a process to evaluate and document, through research and demonstration areas, the effects of NRCS conservation practices in restoring sage-grouse habitat and populations.
- **Grazing Land Conservation Initiative (GLCI) Grants**. A nationwide collaborative process of individuals and organizations working to maintain and improve the management, productivity, and health of the Nation's privately owned grazing land. This process has formed coalitions that actively seek sources to increase technical assistance and public awareness activities that maintain or enhance grazing land resources.
- **Cooperative Conservation Partnership Initiative (CCPI).** A voluntary program established to foster conservation partnerships that focus technical and financial resources on conservation priorities in watersheds and airsheds of special significance. Under CCPI, funds are awarded to State and local governments and agencies; Indian tribes; and non-governmental organizations that have a history of working with agricultural producers.
- **Conservation Security Program (CSP).** A unique program that goes beyond the past approach of installing conservation practices. Instead, CSP offers rewards to those who have been good stewards of the soil and water resources on their working agricultural land. It also offers incentives for those who wish to exceed the minimum levels of resource protection and enhance the natural resources on the land they manage. The program is available in designated watersheds.

U.S. Dept. of Interior, Bureau of Land Management http://www.blm.gov

- **Challenge Cost Share**. This program is designed to leverage funds with partners to monitor and inventory resources; implement habitat improvement projects; develop recovery plans; protect or document cultural resources; provide enhanced recreational experiences; and to better manage wild horse and burro populations. Matching funds, goods or services are required.
- **Cooperative Conservation Initiative (CCI)**. CCI was designed to remove barriers to citizen participation in the stewardship of our natural resources and to help people take conservation into their own hands by undertaking projects at the local level. Projects must seek to achieve the actual restoration of natural resources and/or the establishment or expansion of habitat for wildlife. Matching funds, goods or services are required.

U.S.D.A. Forest Service http://www.fs.fed.us

- **Cooperative project funding.** Contact local U.S. Forest Service staff for information about opportunities to develop partnerships in projects involving National Forests or National Grasslands.
- **Partnership Resource Center**. The Partnership Resource Center of the National Forest Foundation (NFF) and the USDA - Forest Service (FS) provides partnering organizations and FS staff with the information to enhance working relationships. Partnerships expand opportunities for obtaining grants. Many funding sources prefer or require them because projects involving partnerships have an increased potential for success. http://www.partnershipresourcecenter.org

7.5.5.3 Other Potential Sources

Wildlife Heritage Foundation of Wyoming. The Wyoming Wildlife Heritage Foundation is an independent, charitable organization whose purpose is to provide financial support, through philanthropy, to critical wildlife conservation efforts in Wyoming. http://whfw.org

Wyoming Governor's Big Game License Coalition. Funding generated from the sale of Governor's licenses placed in five accounts: bighorn sheep, moose, elk, mule deer and general wildlife. Funds administered by the Wildlife Heritage Foundation of Wyoming. http://whfw.org

National Fish and Wildlife Foundation (NFWF). General Matching Grant Program - Provides matching grants to priority projects that address fish and wildlife conservation and the habitats on which they depend, work proactively to involve other conservation and community interests, leverage NFWF funding, and evaluate project outcomes. Government agencies, educational institutions, and nonprofit organizations may apply. Grants typically range from $10,000-$150,000. http://www.nfwf.org

National Fish and Wildlife Foundation. Native Plant Conservation Initiative (NPCI) - NPCI grants of federal dollars are provided to non-profit organizations and agencies for conservation of native plants. NPCI grants range from $5,000 to $40,000, averaging $15,000. Non-Federal matching funds, goods or services are required. There is a strong preference for "on-the-ground" projects that involve local communities and citizen volunteers in the restoration of native plant communities. http://www.nfwf.org/programs/npci.cfm

National Fish and Wildlife Foundation. Pulling Together Initiative (PTI) - Provides support for the formation of local Weed Management Area (WMA) partnerships. These partnerships engage federal resource agencies, state and local governments, private landowners, and others in developing weed management projects within an integrated pest management strategy. Non-Federal matching funds, goods or services are required. http://www.nfwf.org/programs/pti.cfm

Intermountain West Joint Venture (IWJV). Joint Venture Cost-Share - Habitats within the IWJV area support nearly 100% of the range of all high priority sagebrush steppe land bird species, such as: Sage Sparrow, Sage Thrasher, Sage-Grouse and Brewer's Sparrow. The purpose of Cost-Share is long-term conservation of bird habitat through partnerships. http://iwjv.org/costshare.htm

The Nature Conservancy (TNC). TNC works with conservation supporters and partner organizations to create funding for conservation worldwide using a variety of creative methods. http://nature.org

Tom Thorne Sage-Grouse Conservation Fund. Provides grants for the conservation of sage-grouse in the Upper Green River Basin. The fund was created by Shell Exploration & Production Co. and managed by a board overseen by the Wyoming Community Foundation. www.wycf.com

Rocky Mountain Elk Foundation (RMEF). RMEF is a wildlife conservation organization with an emphasis on elk. It advocates sustainable, ethical use of resources and seeks common ground among stakeholders. RMEF funds habitat restoration and improvement projects, acquires land or conservation easements. http://www.rmef.org

Mule Deer Foundation (MDF). MDF's goals center on restoring, improving and protecting mule deer habitat. MDF achieves its goals through partnering with state and federal wildlife agencies, conservation groups, businesses and individuals to fund and implement habitat enhancement projects on both public and private lands. http://www.muledeer.org

One Shot Antelope Foundation -Water for Wildlife. Water for Wildlife is a conservation program designed to benefit wildlife and the environment in arid regions of the West. Emphasis focuses on the development of supplemental water resources in areas where both the habitat and wildlife are being impaired by lack of this vital resource. http://www.waterforwildlife.com

North American Grouse Partnership (NAGP). Promotes the conservation of prairie grouse and the habitats necessary for their survival and reproduction. http://www.grousepartners.org

Pheasants Forever (PF). Some sage-grouse populations in Wyoming occur within areas that have a local PF chapter. Local chapters determine how their funds are spent. Game birds other than pheasants may be eligible for funding. http://www.pheasantsforever.org/chapters/

8.0 Conclusions and Recommendations

This section provides a summary of the conclusions and recommendations presented throughout this report. The conclusions pertain to the watershed inventory and current conditions of the watershed. The recommendations include the proposed watershed improvements projects, environmental permitting and financing.

8.1 Conclusions

Natural Environment

Thunder Basin L&LC watershed lies within the geologic structural basin called the Powder River Basin, which is part of the Missouri Plateau of the Great Plains. Thunder Basin L&LC watershed consists of a dissected, rolling upland plain with low to moderate relief. The north to northeast oriented dissecting valleys originate along the southern edge of the study area in the uplands of the Hartville Uplift area. Buttes, mesas, hills, and ridges are present throughout the region, especially along the southern boundary of the Lightning watershed and throughout much of the southern and eastern portions of the Lance Creek watershed. The present-day landforms have been shaped mostly by water action, even though modern-day precipitation is low and is greatly exceeded by evaporation. The incised drainages crossing the study area are mostly ephemeral or intermittent, and do not provide permanent sources of water along the entire drainage reaches. Runoff from surface precipitation can in places be augmented by groundwater-fed springs and seeps from shallow aquifers, particularly in the upper reaches of tributary drainages in the Lance Creek watershed.

Climate - The climate of the Thunder Basin L&LC watershed can be classified as semiarid with average annual rainfall of 14 to 16 inches with more precipitation recorded on the eastern side of the watershed. Drought conditions persisted in the area from 2000 to 2010, however, in 2011, the Thunder Basin L&LC watershed was not listed on the Drought Monitor maps produced by U.S. Climate Prediction Center. Of the seven weather stations that used to monitor the Thunder Basin L&LC watershed, only one (Redbird 1 NW) is still operational. At Redbird, the average annual precipitation is 15.92 inches per year.

Vegetation and Land Cover - The bulk of upland vegetation is comprised of plant communities in which grasses are predominant, both biologically, and visually. These grasslands appear mostly in the form of mid-grass prairie in the eastern portion of the study area. In the uplands of the west and southwest portions, the grass component is joined by a substantial presence of big sagebrush. Shrub abundance varies both in response to substrates and climate but also in response to range condition. Stress, can encourage the establishment of shrubs, as grass competition is lessened.

Vegetational components that have particular importance with respect to the water resources and watershed function of Thunder Basin L&LC watershed include the salt cedar, Russian olive, and noxious weeds such as Canada thistle.

- Salt cedar is capable of establishing, far from known occurrences, in areas with only the slightest moisture accumulation. Salt cedar has recently begun to appear on the Cheyenne River, as well as certain tributaries.
- Russian olive has been present in the basin for decades, having survived from early farmstead plantings as isolated trees. If allowed to proceed, new establishment of stands of Russian olive and salt cedar can produce dense thickets. This will, in turn, increase depletion of massive amounts of shallow groundwater (with direct connection to surface water). Besides the loss of water, the dense thickets can be expected to shade out and out-compete previously existing riparian species, including the native cottonwoods and willows.
- Other noxious weeds are present in the study area and the most abundant is Canada thistle. To the extent that any of these noxious weeds displace diverse native plant communities to form extensive monocultures, they may not only diminish livestock and wildlife forage values, but they may negatively influence watershed function.

Soils - A comprehensive soil survey was completed by the NRCS across the entire Thunder Basin L&LC watershed. Soils within the study area watersheds have developed in residual material and alluvium in a climatic regime characterized by cold winters, warm summers, and low-to moderate precipitation. Soils in the Thunder Basin watershed are generally low in organic matter and are alkaline. Textures range from clay loams to sandy loams with varying amounts of gravel or coarser materials. Slopes range from nearly level to very steep with deeper soils found in the less steeply sloping areas. These soils support little crop agriculture except in irrigated valleys of perennial streams. Across Thunder Basin L&LC the predominant land use is rangeland. Vegetation developed on the soils is predominantly grass-shrub, used for grazing and wildlife habitat.

Geology - Surficial and bedrock deposits across the watershed are divided into three distinct types: 1) Bedrock, residuum and mined areas; 2) River Valley Deposits; and, 3) Upland Deposits. The four shallow bedrock units that directly underlie the surficial deposits, or are exposed in isolated outcrops and along ridges/slopes of Thunder Basin have played an important role in soil formation and other geomorphologic processes. The four shallow bedrock units from youngest to oldest include:

- Tertiary Wasatch Formation
- Tertiary Fort Union Formation; Lebo member
- Tertiary Fort Union Formation; Tullock member
- Cretaceous Lance Formation

Most of the surficial geologic material across Thunder Basin L&LC watershed is described as residuum with eolian and alluvium. The residuum deposits are composed of fine clay, silt, and sand ranging up to coarse sands and gravels. The river valley deposits are significant to the watershed study because they represent a significant source of surface and groundwater. The upland deposits include eolian deposits with scattered alluvium. Slopewash with colluvium is mapped along the steeper slopes in the western portion of the watershed.

Landslides – Although no significant landslides have been mapped within the Thunderbasin L&LC watershed,small, localized, slope failures can occur along the banks of active channels. Slope instability increases during times of material saturation accompanying storm events when undercutting of stream banks is most intense. For this reason, watershed improvement projects should include site-specific geologic hazard analyses, including an evaluation of the site's susceptibility to landslides.

Groundwater - Groundwater in Thunder Basin L&LC watershed occurs in both alluvial (shallow) and bedrock (deeper) aquifers. Alluvial aquifers occur in the stream-valley alluvium located along rivers and major drainages. The alluvial aquifers are generally less than 50 feet in thickness but can be as thick as 100 feet. Yield is 5-10 gpm on average with some isolated occurrences of higher production. The bedrock aquifers are part of the Northern Great Plains aquifer system. The aquifer system includes the Tertiary aquifers exposed at the surface, as well as the deeper regional aquifers within older sedimentary rocks deposited during the Upper and Lower Cretaceous and Paleozoic. Bedrock wells can produce up to 500 gpm. Springs occur where the groundwater table intersects the ground surface. Isolated springs occur across Thunder Basin L&LC but are locally abundant along exposures of clinker deposits.

Surface Water Hydrology - The majority of the streams within the Thunder Basin L&LC watershed are ephemeral or intermittent in nature. These streams are flashy and respond to temporary runoff events caused by snowmelt and precipitation events. Spring runoff events typically occur from March to April with early summer rains prolonging the stream flow into summer. Flows decrease and cease typically in mid to late summer only flowing in response to thunderstorm events. These flows vary with summer thunderstorms as well. Within the Thunder Basin L&LC Watershed, there are no active (and one historic) USGS streamflow gaging stations. The historic gage shows the majority of flow occurring between April and September with peaks generally occurring in June. With this sparse dataset and information developed for the Northeast Wyoming River Basins Plan Final Report, water availability and shortages as related to proposed water storage projects in the Thunder Basin L&LC study area were evaluated. Lance Creek within Thunder Basin L&LC was identified to have 3,184 acre-feet, 18,323 acre-feet, and 44,909 acre-feet of available flow during dry, normal, and wet years, respectively.

Stream Geomorphology - A Rosgen Level I classification was completed across the main tributaries of Thunder Basin L&LC watershed. The results are summarized as follows: The majority of the stream channels are classified as C channels (low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains). The Type G channels, or gullies, are typical in the upper reaches where the slope breaks and the head cut features formed along the slopes.

Land Uses and Management Activities

Land Ownership - The majority of land in Thunder Basin L&LC is privately owned with the second largest landowner being the Federal Government. Land ownership will play an important role in project implementation in that permitting and financing options depends heavily on land ownership and intended beneficial use.

Range Conditions – Shrub abundance varies in response to both substrates and range condition. Stress can encourage the establishment of shrubs as grass competition is lessened. Based on state and transition model information present in the NRCS Ecological Site Descriptions, most ecological sites of the Thunder Basin L&LC watershed can be expected to transition to greater shrub cover as the effects of stress compound. However, it should be noted that ESDs for most of the study area are currently being revised to incorporate on-going research into state descriptions and transition tipping points. This research suggests that grazing effects are likely not responsible for the presence of sagebrush in all cases. Extended drought is also an effective stressor. Recent research supports the view that sagebrush (and even abundant sagebrush) is a natural plant community component and not a vestige of stress, with abundance proportional to precipitation and snow cover.

Oil and Gas Production – The petroleum industry has been exploring and producing oil and gas in Wyoming for over 125 years and since that time, oil and gas production has become an important economic commodity in the Thunder Basin L&LC watershed. The largest fields are located in the Lightning watershed where approximately 160,000 acres have been designated as “High” potential areas for oil and gas production.

Mining and Mineral Resources – The Powder River Basin is one of the most prolific coal-producing regions in the world. Much of the active mining in the Powder River Basin occurs just north of the study area along the drainages of the Cheyenne River. Coal production is expected to continue into the foreseeable future with the potential for expansion as the energy demands increase across the nation. Although no active coal mines exist in the study area, data from the Wyoming Geographic Information Science Center indicates that nearly 40,000 acres of land, primarily in the Lightning watershed and the northwest corner of the Lance Creek watershed have "High" potential for coal production. Other mineral deposits within the Thunder Basin L&LC watershed include uranium, which has a similar outlook for production in response to energy demand.

Watershed Inventory

Irrigation Inventory – Irrigation systems to irrigate grass/hay fields are documented on less than 1 percent of the Thunder Basin L&LC watershed. The systems are privately owned small spreader dike systems that irrigate areas ranging in size from less than 20 acres to several hundred acres. Most of the systems visited are in need of repair. Significant improvement in the systems could be achieved through sediment removal and/or replacement or repair of diversion structures.

Groundwater – Groundwater is used for livestock/wildlife watering but not for irrigation purposes. The reason for this has to do with the depth and yield of the aquifers in Thunder

Basin. Groundwater is a viable resource for livestock/wildlife watering and should be expanded in areas where watering opportunities are scarce.

Water Storage Inventory – There are no natural lakes of significant size in the Thunder Basin L&LC watershed, however, there are 62 dams included in the National Inventory of Dams database within the study area. The combined storage behind the identified dams is 13,483 acre-feet. Available water for water storage projects was described above. Based on available stream gage and modeling information, during years of average precipitation, there is adequate available water for storage opportunities. The study area contains approximately 2,050 small impoundments and stock watering ponds. There are 290 small impoundments that appear to have been breached. These 290 structures had a median pond size of 0.7 acres and a median estimated volume of 3.6 acre-feet. The total estimated volume that could be achieved by rehabilitation of the dams was 1,946 acre-feet. Rehabilitation of the breached dams within the Thunder Basin L&LC watershed could provide livestock/wildlife watering opportunities.

Water Quality – The Niobrara Conservation District has been conducting stream sampling in three locations within the Thunder Basin L&LC watershed. Sites were located on Lance Creek, Lightning Creek, and Old Woman Creek. Limited data was also available from USGS sampling sites. The water quality criteria most often exceeded in samples collected throughout Thunder Basin L&LC watershed were sulfate, specific conductance, turbidity, total dissolved solids, and manganese. Exceeding the criteria does not necessarily indicate that water is unsuitable for livestock watering or agriculture. It does suggest that livestock and less tolerant plants might not be as productive as they would be with lower levels of the constituent.

Economic Analysis and Project Financing

- An economic analysis on the watershed rehabilitation plans proposed in this report was completed that included an indirect benefits analysis, ability to pay analysis and an evaluation of WWDC financing guidelines. Based on this analysis the livestock watering (upland well development) improvement projects appear to be the most economically beneficial based purely upon a rate of return on the investment.
- Project financing sources include federal, state, local and non-profit agencies. The primary sources of funding for the improvements presented in this report include the WWDC, NRCS and BLM. Numerous other opportunities are presented and should be pursued should the projects move to the next phase of implementation.

8.2 Recommendations

Irrigation Systems

- Rehabilitation plans are proposed as requested by ranchers/landowners in the Thunder Basin L&LC watershed. Rehabilitation plans focus on rehabilitation/replacement of existing structures, enhanced delivery of water, reduction in annual operation and maintenance costs, improvement in ditch management and efficiency, and economic practicality and physical feasibility. Additional improvements could be made across the watershed using the plans and cost estimates provided in this report as a guide for conceptual design, cost, and financing opportunities.

- The recommendations include regarding ditches, head gate replacements, and construction of spreader dikes. The cost estimates for the projects range from $6,000 to construct improved berms along Lightning Creek to $10,000 to install a centrifugal pump along Lance Creek.
- Recommended improvements include projects at three ranches. The individual projects can be implemented individually or as a complete package based on the preferences and financial ability of the owner. The most likely sources of funding for these projects are the WWDC Small Water Project Program and NRCS programs through the local Conservation District.

Surface Water Storage

- An evaluation of water available for storage projects was completed based on the existing datasets accessible for such an analysis. It is recommended that if any of the proposed Account III storage projects is undertaken that StateMod or similar water rights accounting model be developed so that the water rights can be appropriately exercised and potential water availability can be more accurately estimated.
- Due to the lack of streamflow and watershed yield data, temporary stream gages or some means by which drainage yield information be collected should be installed at sites for which storage projects are desired.
- Four WWDC Account III multipurpose storage sites were identified in the Thunder Basin L&LC watershed. The Lightning Creek 2 site is estimated to be the most expensive.
- Storage evaluation requests were completed and fourteen projects are recommended for further study and/or implementation. Most of the projects consist of constructing small dams to capture and store water. Two of the projects entail rehabilitating existing storage structures by excavating accumulated sediment.
- Livestock/wildlife watering opportunities were evaluated based on the assumption that cattle will graze up to a mile from a water source. Using this criterion, an analysis of the watershed was conducted to identify locations where additional water storage for livestock watering could be beneficial.
- Supplemental storage at existing breached dam locations is a potential option to address the areas underserved with the existing network of stock wells and functional stock ponds. The breached dams located outside of a mile radius totaled 120. The estimated volumes that could be gained from rehabilitating the structures ranged from 0.3 to 100 acre-feet. Site visits need to be made to ascertain the actual improvements needed. The most likely source of funding for breached dam rehabilitation is the WWDC Small Water Project Program, the Wyoming Wildlife and Natural Resource Trust, or the Bureau of Land Management Range Improvement Planning and Development Program.
- For expansion of existing reservoirs, each of the 62 dams identified in the National Inventory of Dams was evaluated to determine whether each dam has enough watershed area to yield a minimum of 1,000 acre-feet of available water based on the averages described in the preceding paragraph. None of the dams had sufficient watershed area to generate an additional 1,000 acre-feet of available water during a normal year.

Groundwater Development

- One of the best options to enhance rangeland and riparian habitat is to ensure that there are adequate watering opportunities in the upland areas of the watershed. Currently drainage ways are often the location of the water that is available and therefore livestock pressure in these portions of the landscape is disproportionately great. With dispersal of livestock watering sources to uplands, not only are riparian areas relieved of grazing and trampling pressure, but little used forage on remote uplands may be accessed by foraging animals. For these reasons upland water development projects in underserved areas are recommended. These projects include the combinations of the following elements: installation of shallow to moderately deep groundwater wells, solar powered pumps, stock tanks, piping and fencing to maximize water distribution for livestock and wildlife. The projects range in cost from $6,500 to nearly $100,000.
- Additional upland water development improvements could be made across the Thunder Basin L&LC watershed using the plans and cost estimates provided in this report as a guide for conceptual design, cost, and financing opportunities.
- Development of deep aquifer irrigation wells is not deemed feasible for this area unless significant advances in technology for installation and long-term pumping are realized.

Other Management Practices

- Control of noxious weeds including Russian olive, salt cedar and Canada thistle, to name a few, should continue to be implemented to promote overall health of the rangeland. Efforts should be concentrated in areas of large infestations in both rangeland and riparian areas.
- Continued implementation of the grazing management plans developed for the Thunder Basin L&LC watershed is recommended. These plans provide methods for pasture rotation and riparian habitat protection that will continue to add to the value and health of the watershed.
- Based on the geomorphologic evaluation completed, it is recommended that channel restoration and stabilization efforts should be coordinated as the proposed projects are implemented. For example, in areas where the stream is entrenched and a diversion structure is planned, a series of cross vane type structures could be constructed to provide an increase in head elevation for the diversion point and as part of the headgate repair/replacement an in-channel diversion structure will be needed. Additionally, the large storage structures will require additional evaluations to ensure stream stability after project implementation. These more detailed geomorphologic evaluations (i.e., Level II Rosgen Classifications) can be implemented as part of the Level II feasibility studies that could be completed during the next phase of project implementation should the projects go forward.
- Two wetland development projects were proposed in conjunction with a proposed well and small reservoir project. In both cases, the amount of water available will limit the extent of wetland which can be constructed. One wetland

would be created by overflow from a proposed well and stock tank. The extent of wetland that could be maintained by this hydrology may range up to 0.25 acres. The second proposed wetland area is a fringe wetland that would be maintained by an impoundment of an ephemeral creek. The wetland would be constructed in coordination with the construction of a new pond. However, due to the small size of the pond, at most 0.1 acre of wetland is likely to develop.

9.0 References

Bartos, T.T. and K.M. Ogle. 2002. Water Quality and Environmental Isotopic Analyses of Ground-Water Samples Collected from the Wasatch and Fort Union Formations in Areas of Coalbed Methane Development—Implications to Recharge and Ground-Water Flow, Eastern Powder River Basin, Wyoming. U.S. Geological Survey Water Resources Investigation Report 02-4045. Prepared in cooperation with the Wyoming State Engineer's Office and the U.S. Bureau of Land Management.

Benkobi, L., and D. W. Uresk. 1996. "Seral stage classification and monitoring model for big sagebrush/western wheatgrass/blue grama habitat." in Proceedings: Shrubland ecosystem dynamics in a changing environment, 1996 May 23-25; Las Cruces, NM.

Bohne, J., T. Rinkes, and S. Kilpatrick. 2007. Sage-Grouse Habitat Management Guidelines for Wyoming. Wyoming Game and Fish Department. Cheyenne, Wyoming.

Boyles, S., K. Wohlgemuth, G. Fisher, D. Lundstrom, and L. Johnson, 1988. Livestock and Water, AS-954. North Dakota State University, Fargo, ND.

Brown, J. L. 1993. Sedimentology and Depositional History of the Lower Paleocene Tullock Member of the Fort Union Formation, Powder River Basin, Wyoming and Montana. U.S. Geological Survey Bulletin 1917–L. 42 pages.

Case, J.C. and J.A. Green. 2000. Earthquakes in Wyoming. Information Pamphlet 6. Wyoming State Geological Survey, Laramie, WY.

Curry, W.H. III. 1971. Laramide Structural History of the Powder River Basin, Wyoming. In, Renfro, A.R., Madison, J.V., Jarre, G.A., and Bradley, W.A., eds. Symposium on Wyoming Tectonics and Their Economic Significance. Wyoming Geological Association Guidebook, 23rd Annual Field Conference, p. 49-60.

Crawford, J. A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, Michael A. Gregg and Chad S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Rangeland Ecology & Management. 57 (1), 2-19.

DeBruin, Rodney H., Lyman, Robert M., Jones, Richard W., and Cook, Lance W. 2000. Information Pamphlet 7. Wyoming State Geological Survey.

Dolton, G.L., J.E. Fox, and J.L. Clayton. 1988. Petroleum Geology of the Powder River Basin, Wyoming and Montana. U.S. Geological Survey Open-File Report 88-450 P. U.S. Government Printing Office, Washington, DC.

Emmett, W.W., 1975. The Channels and Waters of the Upper Salmon River Area, Idaho. U.S. Geological Survey Professional Paper 870-A, 116 p.

Emmett, W.W., L.B. Leopold, and R.M. Myrick, 1983. Some Characteristics of Fluvial Processes in Rivers. In: Proceedings, Second International Symposium on River Sedimentation, Nanjing, China, October 11-16, 1983, Water Resources and Electric Power Press, pp. 730-754.

Feathers, K.R., R. Libra, T.R. Stepheson, and C. Eisoen, 1981. Occurrence and Characteristics of Ground Water in the Powder River Basin, Wyoming. Laramie, WY: University of Wyoming, Water Resources Research Institute.

Federal Emergency Management Administration, 1998. Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams (FEMA 333), http://www.fema.gov/plan/prevent/damfailure/fema333.shtm

Gill, J.R. and W.A. Cobban. 1966. The Red Bird Section of the Upper Cretaceous Pierre Shale in Wyoming. U.S. Geological Survey Professional Paper 393-A. U.S. Government Printing Office, Washington, DC.

Glass, G.B., and D.L. Blackstone, Jr. 1996. Geology of Wyoming. Wyoming State Geological Survey Information Pamphlet No. 2. 12 pages.

Hart, C. 2004. Chapter 16 – Brush management for Water Conservation. In: Aquifers of the Edwards Plateau, Conference Proceedings, Report 360, Texas Water Development Board.

Heffern, E.L., and D.A. Coates. 1999. Hydrogeology and ecology of clinker in the Powder River Basin, Wyoming and Montana. Pages 231–252 *in* W. R. Miller, editor. Coalbed Methane and the Tertiary Geology of the Powder River Basin Wyoming and Montana. Wyoming Geological Association 50th Field Conference Guidebook.

HKM Engineering, Inc. February 2002a. Northeast Wyoming River Basins Plan Final Report. Prepared in association with Lord Consulting and Wates and Associates.

HKM Engineering, Inc. February 2002b. Northeast Wyoming River Basins Plan Spreadsheet Model Development and Calibration, Task 3B. Technical Memorandum.

HKM Engineering, Inc. February 2002c. Northeast Wyoming River Basins Plan Available Surface Water Determination, Task 3D. Technical Memorandum.

HKM Engineering, Inc. February 2002d. Northeast Wyoming River Basins Plan Surface Water Hydrology Tasks 3A and 3B. Technical Memorandum.

Hodson, W.G., R.H. Pearl, and S.A. Druse. 1973. Water Resources of the Powder River Basin and Adjacent Areas, Northeastern Wyoming. U.S. Geological Survey Hydrologic Investigations Atlas HA–465. 4 sheets.

Horton, J.S. and C.J Campbell. 1974. Management of Phreatophyte and Riparian Vegetation for Maximum Multiple Uses. USDA For. Serv. Research Paper RM-117. 23 pages.

Jacobs, J., J. Sciegienka, and F. Menalled. 2006. Ecology and Management of Canada thistle (*Cirsium arvense* (L.) Scop.).USDA NRCS, Invasive Species Technical Note No. MT-5.

Johnson, J.F. and D.C. Micale. 2008. Geologic Map of the Lance Creek 30' x 60' Quadrangle, Niobrara and Converse Counties, Wyoming, Fall River and Custer Counties, South Dakota, and Sioux County Nebraska. Wyoming State Geological Survey Map Series 79, Lance Creek 1:100,000 Scale Geologic Map.

Keefer, W. R. 1974. Regional Topography, Physiography, and Geology of the Northern Great Plains. U.S. Geological Survey Open-File Report 74–50. 18 pages and 4 sheets.

Kenzie, O., 1995. Alberta's Stockman's Range Management Course, Maycroft, AB, Canada.

Knight, K.B., T.P. Toombs and J.D. Derner. 2011. Cross-Fencing on Private US Rangelands: Financial Costs and Producer Risks. Rangelands. 33 (2), 41-44.

Love, J.D., Christiansen, A.C., and L.W. McGrew. 1987. Geologic map of the Newcastle 1° x 2° Quadrangle, northeastern Wyoming and western South Dakota: Wyoming State Geological Survey Map Series (MS) 25-I, scale 1:250,000.

Lowry, M.E. and J.F. Wilson, Jr., 1986. Hydrology of Area 50, Northern Great Plains and Rocky Mountain Coal Provinces, Wyoming and Montana. U.S. Geological Survey Water-Resources Investigations Open-File Report 83–545. 137 pages.

Miller, R. F., and L. L. Eddleman. 2001. Spatial and temporal changes of sage grouse habitat in the sagebrush biome. Agricultural Experiment Station Technical Bulletin 151. Oregon State University, Corvallis, USA.

Miller, K.A. 2003. Peak-Flow Characteristics of Wyoming Streams: U.S. Geological Survey, Water-Resources Investigation Report 03-4107. Prepared in cooperation with the Wyoming Department of Transportation.

National Inventory of Dams. http://crunch.tec.army.mil/nidpublic/webpages/nid.cfm

Olsson Associates, 2009, Thunder Basin Watershed Management Plan Watershed Study, Prepared for the Wyoming Water Development Commission, Volume I and II, August.

Pochop L., T. Teegarden, G. Kerr, R. Delaney, and C. Hasfurther. October 1992. Consumptive Use and Consumptive Irrigation Requirements – Wyoming. WWRC Publication #92-06. Laramie, Wyoming.

Rice, C.A., Ellis, M.S., and J.H. Bullock, 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.

Rice, P.M. 2011. INVADERS Database System, Division of Biological Sciences, University of Montana, Missoula, MT 59812-4824. Accessed April 5, 2011. http://invader.dbs.umt.edu.

Rosgen, D. L., 1994. A Classification of Natural Rivers. Catena, Vol 22, 169-199. Elsevier Science, B.V. Amsterdam.

Rosgen, D. L., 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Colorado.

Schnitkey, Gary, Farm Business Management, Machinery Cost Estimates: Forage Field Operations, University of Illinois Extension, April, 2010.

Sherer, Brett M., J. R. Miner, J. A. Moore, and J. C. Buckhouse, 1988. Resuspending Organisms from a Rangeland Stream Bottom. Transactions of the American Society of Agricultural Engineers, 31(4):1217-1222.

Short, Elliot Hendrickson, Inc. (SEH). October 2007. Final Report: Cottonwood/Grass Creek Watershed Management Plan Level I Study. Prepared in association with Anderson Consulting Engineers, Inc. and Donald A. Tranas, Range Consultant.

Simley, J.D., and W.J. Carswell Jr. 2009. *The National Map*—Hydrography: U.S. Geological Survey Fact Sheet 2009-3054, 4 p.

Sims, P.K. and W.C. Day. 1999. Geologic Map of the Precambrian Rocks of the Hartville Uplift, Southeastern Wyoming. U.S. Geological Survey Geologic Investigation Series I-2661.

State of Colorado Department of Natural Resources Division of Water Resources Office of the State Engineer. *Rules and Regulations for Dam Safety and Dam Construction*. Effective Date: January 1, 2007.

Thilenius, J.F., G.R. Brown and A.L. Medina, 1995. Vegetation on semi-arid rangelands, Cheyenne River Basin, Wyoming. US Department of Agriculture General Technical Report RM GTR 263.

Trimble, D. E. 1980. The Geologic Story of the Great Plains. U.S. Geological Survey Bulletin 1493. 55 pages.

U.S. Army Corps of Engineers. 2000. Regulatory Program of the US Army Corps of Engineers; Part 330 - Nationwide Permit Program: Part E: Definitions.

U.S. Bureau of Land Management. 2005. BLM Buffalo Field Office. Weed Distributions located within the Buffalo Field Office jurisdiction. ftp://ftp.wygisc.uwyo.edu/pub/clearinghouse/BLM/BFO/weed_distribution_blm_bfo.zip

U.S. Bureau of Land Management. 2007. Platte River Resource Management Plan. U.S. Department of the Interior, Bureau of Land Management, Casper Field Office. Casper, Wyoming.

U.S. Bureau of Land Management. 2000, rv 2008. Newcastle Resource Management Plan. U.S. Department of the Interior, Bureau of Land Management, Newcastle Field Office. Newcastle, Wyoming.

U.S. Bureau of Land Management. 2009. Grazing Allotments. GIS Layers. Accessed July 2010. http://www.blm.gov/wy/st/en/resources/public_room/gis/datagis/office/allot.html

U.S. Bureau of Land Management, 1998. Wyoming Guidelines for Surface-Disturbing and Disruptive Activities, http://www.blm.gov/pgdata/etc/medialib/blm/wy/wildlife/baldeagle.Par.4022.File.dat/be-appa.pdf

U.S. Bureau of Land Management. 2001. Reasonably Foreseeable Development Scenario for Oil and Gas Development in the Buffalo Field Office Area. Buffalo Field Office, Buffalo, Wyoming. 28 pages.

U.S. Bureau of Land Management. 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project. BLM Wyoming State Office, Buffalo Field Office, Volumes 1-4.

U.S. Bureau of Mines, Department of Interior. 1990a. Potential Exploitable Oil and gas Fields for Wyoming at 1:500,000. DOI U.S. Bureau of Mines, Denver, Colorado. Available on the world wide web at: http://piney.wygisc.uwyo.edu/data/energy/oil_gas_fld.zip.

U.S. Bureau of Mines, Department of Interior. 1990b. Potential Exploitable Uranium in Wyoming at 1:500,000. DOI U.S. Bureau of Mines, Denver, Colorado. Available on the world wide web at: http://piney.wygisc.uwyo.edu/data/energy/uranium.zip.

U.S. Department of Agriculture, 1997 NATIONAL GRASSLANDS MANAGEMENT - A PRIMER, November 1997, Eric Olson, Natural Resources Division, Office of the General Counsel, United States Department of Agriculture. http://www.fs.fed.us/grasslands/resources/documents/primer/NG_Primer.pdf

U.S. Department of Agriculture, 2007. Final Environmental Impact Statement, Thunder Basin Analysis Area, Vegetation Management Medicine Bow-Routt National Forests and Thunder Basin National Grassland Douglas Ranger District, Medicine Bow-Routt National Forest and Thunder Basin National Grassland Campbell, Converse and Weston Counties, Wyoming.

US Department of Agriculture NRCS Montana. 2011. Cost List Fiscal Year 2011. Available at: http://efotg.sc.egov.usda.gov/references/public/MT/2011_Cost_List.pdf. Accessed 29 July 2011.

U.S. Department of Agriculture, NRCS, 2011. Conservation Stewardship Program Conservation Activity List. Accessed April 5, 2011. http://www.nrcs.usda.gov/programs/new_csp/2011/other-pdfs/csp-conservation-activity-list012411.pdf

U.S. Department of Commerce, 1992. Regional Multipliers: A User Handbook for the Regional input-Output Modeling System (RIMS II). Bureau of Economic Analysis, May.

U.S. Energy Information Administration (USEIA), 2008 Annual Coal Report. Accessed on 14 September 2010 at http://www.eia.doe.gov/cneaf/coal/page/acr/table2.pdf.

U.S. Energy Information Administration (USEIA) website. Petroleum and natural gas production information accessed on 10 September 2010 at www.eia.gov.

U.S. Fish and Wildlife Service, 2008, Threatened and Endangered Species in the Mountain-Prairie Region, http://ecos.fws.gov/tess_public/SpeciesReport.do?lead=6&listingType=L

U.S. Geological Survey (USGS), 2005. *Regional Aquifer Systems.* GROUND WATER ATLAS of the UNITED STATES Montana, North Dakota, South Dakota, Wyoming. http://capp.water.usgs.gov/gwa/ch_i/I-text2.html Accessed April 13, 2007.

Wells, D. K. 1982. Ground-water Data from Selected Wells in Alluvial Aquifers, Powder River Basin and Adjacent Areas, Northeastern Wyoming. U.S. Geological Survey Open-File Report 82–856. 35 pages.

Western Regional Climate Center (retrieved in 2010) Coop Sites. Retrieved from http://www.wrcc.dri.edu/summary/Climsmwy.html

Whitcomb, H.A. 1965. Groundwater resources and geology of Niobrara County, Wyoming. U.S. Geological Survey Water Supply Paper 1788.

Whitehead, R. L. 1996. Ground Water Atlas of the United States, Segment 8: Montana, North Dakota, South Dakota, Wyoming. U.S. Geological Survey Hydrologic Investigations Atlas 730–I. 24 pages.

Williams, G. P., 1978. Bankfull Discharge of Rivers. Water Resources Research, v. 14, pp. 1141-1154.

Willms, W.D., O. Kenzie, Z. Mir, and D. Quinton, 1995. Effects of water supplied from old dugouts on the performance of cattle. Fifth International Rangeland Congress, Salt Lake City, UT, July 1995.

Wolman, M.G. and L.B. Leopold, 1957. River Flood Plains: Some Observations on Their Formation. U. S. Geological Survey Professional Paper 282-C, pp. 86-109.

Wolman, M.G. and J.P. Miller, 1960. Magnitude and Frequency of Forces in Geomorphic Processes. Jour. Geology, v. 69, pp. 54-74.

Wyoming Department of Environmental Quality. 2010. Wyoming's 2010 305(b) Integrated State Water Quality Assessment Report. Water Quality Division, Cheyenne, Wyoming.

Wyoming Department of Environmental Quality. 2008. Wyoming's 2008 305(b) Integrated State Water Quality Assessment Report. Water Quality Division, Cheyenne, Wyoming.

Wyoming Department of Environmental Quality. 2007. Water Quality Rules and Regulations, Chapter 1 – Wyoming Surface Water Quality Standards. Water Quality Division, Cheyenne, Wyoming.

Wyoming Department of Environmental Quality. 2005. Water Quality Rules and Regulations, Chapter 8 – Quality Standards for Wyoming Groundwaters, Table I.

Wyoming Department of Environmental Quality. 2001. Wyoming Surface Water Classification List. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, Wyoming

Wyoming Game and Fish Department (WGFD). 2009. Grazing Influence, Management, and Objective Development in Wyoming's Greater Sage-Grouse Habitat. Web publication (http://gf.state.wy.us/downloads/pdf/GrazingInGrouseHabitat_081609%5B1%5D.pdf) dated Aug. 16, 2009.

Wyoming Mining Association, 2010. Uranium production information accessed 14 September 2010 online at www.wma-life.com/uranium/uranium.html

Wyoming Oil and Gas Conservation Commission, accessed at www.wogcc.state.wy.us
Wyoming Water Rights Database, 2011, http://seo.state.wy.us/wrdb/index.aspx

10.0 Acronyms

AMP	Allotment Management Plan
AUE	Animal Unit Equivalent
BLM	U.S. Bureau of Land Management
CBM	Coal Bed Methane
CIR	Color Infrared Imagery
CFS	Cubic feet per second
CoCCD	Converse County Conservation District
CCPI	Cooperative Conservation Partnership Initiative
CSP	Conservation Stewardship Program
CWA	Clean Water Act
DOQQ	Digital Orthophoto Quarter Quadrangle
EA	Environmental Assessment
EQIP	Environmental Quality Incentives Program
eFOTGs	Electronic Field Office Technical Guides
EPA	U.S. Environmental Protection Agency
ESD	Ecological Site Description
EIS	Environmental Impact Statement
ESA	Environmental Site Assessment
FEMA	Federal Emergency Management
FSA	Farm Service Agency
GIS	Geographic Information System
GLCI	Grazing Land Conservation Initiative
gpm	Gallons per minute
IDF	Inflow Design Flood
IWJV	Intermountain West Joint Venture
LRMP	Land and Resource Management Plan
NDC	No Distinct Channel
NEPA	National Environmental Policy Act
NFF	National Forest Foundation
NHD	National Hydrography Dataset
NHPA	National Historic Preservation Act
NIDS	National Inventory of Dams
NRCS	Natural Resources Conservation Service
PMF	Probable Maximum Flood
PRB	Powder River Basin
ROW	Rights-of-way
SGRP	Sage-Grouse Restoration Project (SGRP)
STATSGO	STATe Soil GeOgraphic
SSURGO	Soil SURvey GeOgraphic
TBGA	Thunder Basin Grazing Association
TBGPEA	Thunder Basin Grasslands Prairie Ecosystem Association
TDS	Total Dissolved Solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEIA	U.S. Energy Information Administration
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service

USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator System
WDEQ	Wyoming Department of Environmental Quality
WGFD	Wyoming Game and Fish Department
WHIP	Wildlife Habitat Incentives Program
WMA	Weed Management Area
WQD	Water Quality Division
WSGS	Wyoming State Geologic Survey
WSEO	Wyoming State Engineer's Office
WWDC	Wyoming Water Development Commission
WyGISC	Wyoming Geographic Information Science Center
WYNDD	Wyoming Natural Diversity Database
WYPDES	Wyoming Pollutant Discharge Elimination System

Appendix A

Data Summaries

Data Summary 1.2-1 GIS Layer Information		
Data Name in Map	**Directory in Geodatabase**	**Filename in Geodatabase**
Bureau of Land Management (BLM)		
Grazing Allotment - BLM	Administrative	Allotments_BLM
Land Ownership	Administrative	Landown24k
Sage Grouse Habitat	Animals	Sage_Grouse_Habitat
Sage Grouse Leks - BLM	Animals	SageGrouseLeks2007
Wildfires	Environment	wywildfires01to08
ESRI		
Generalized Lakes	Hydrology	HydroPoly_ESRI
Generalized Streams	Hydrology	HydroLine_ESRI
National Agriculture Imagery Program (NAIP)		
2006 NAIP Aerials		
Natural Resources Conservation Service (NRCS)		
Watershed Boundary	Hydrology	HUC12
Thunder Basin Grazing Association (TBGA)		
Sage Grouse Leks - TBGA	Animals	TBGA_SageGrouseLeks
Grazing Allotment - TBGA	Administrative	Allotments_TBGA
U.S. Army Corps of Engineers (USACE)		
National Inventory of Dams	Hydrology	Dams
U.S. Bureau of Mines (USBM)		
Oil Field	Geology	Oil_Fields
U.S. Census Bureau (USCB)		
Cities	Administrative	Cities
Major Roads	Infrastructure	major_roads_1
City	Statewide	City
Major Roads	Statewide	major_roads
U.S. Department of Agriculture (USDA)		
STATSGO Soils	Geology	STATSGOSoils
	Geology	SSURGOsoils
U.S. Fish & Wildlife Service (USFWS)		
NWI Arcs	Hydrology	NWI_Arcs
NWI Polygons	Hydrology	NWI_Polygons
Raptor Nesting Areas	Animals	RaptorNestingAreas
U.S. Geological Survey (USGS)		
Electrical Power Service	Administrative	Utilities
Springs/Seeps	Hydrology	NHD_Point
Regions for Peak-Flow Characteristics	Hydrology	PeakFlowRegions
Gauging Station	Hydrology	USGS_SiteInformation
1:250,000 Topographic Maps	Not applicable	Not applicable
University of Wyoming (UWYO)		
Counties	Administrative	State_Counties
Horizontal Acceleration	Geology	horiz_accel
County	Statewide	county
Wyoming Department of Environmental Quality (WDEQ)		
WYPDES Permitted Discharge	Environment	NPDESOutfalls
WDEQ Stream Classification	Hydrology	WDEQClassification
Wyoming Game and Fish Department (WGFD)		
Antelope Range	Animals	Antelope_Range
Big Game Crucial Ranges	Animals	BigGameCrucialRanges
Mule Deer Range	Animals	Mule_Deer_Range
White-Tailed Deer Range	Animals	WhiteTailed_Deer_Range
Wyoming Geographic Information Science Center (WyGISC)		
Sections	Administrative	PLSS
Townships	Administrative	Townships
Land Cover	Environment	LandCover
Landslides	Geology	Landslides
Watersheds	Hydrology	Watersheds
Coal Mines	Minerals	coal_mine_locations
Coal Potential	Minerals	coal
Mineral Potential	Minerals	uranium_clip

Uranium Mines	Minerals	uranium_mine
Watersheds	Statewide	Watershed_topo
Wyoming Natural Diversity Database (WYNDD)		
Prebles	Predictive Species	Prebles
Ute Ladies Tresses	Predictive Species	UteLadiesTresses
Wyoming State Engineers Office (WSEO)		
SEO Wells	Hydrology	SEO_Wells
Stock Pond	Hydrology	Surface_Water
Wyoming State Geological Survey (WSGS)		
Major Pipeline	Infrastructure	Pipelines
Railroads	Infrastructure	Railroads
Wyoming Water Development Commission (WWDC)		
Bedrock Geology	Geology	BedrockGeology
Surficial Geology	Geology	SurfaceGeology
Irrigated Lands	Northeast Wyoming Water Plan Data	IrrigatedLands
Irrigation Points of Diversion	Northeast Wyoming Water Plan Data	Points of Diversion
Developed for Project		
Property Boundary	Administrative	RanchPropertyBoundary
StudyAreaExtents	Administrative	StudyAreaExtent
Potential Additional Watering Opportunities	Animals	PotentialWateringOpportunities
Watering Opportunities	Animals	WateringOpportunities
Ground Elevation Contours	Contours	Contours_10FT_fromDEM
Annual Flow	Dam Information	annual_flow
Breached Dam	Dam Information	BreachedDams
Breached Dam Outline	Dam Information	Breached_Dam_Lines
Dam Centerline	Dam Information	DamCenterline
Dam Pools	Dam Information	DamPools
Point of Interest	Dam Information	PointofInterest
Potential Dam Site	Dam Information	PotentialDamSite
Canal Headgate/Siphon	Irrigation	Headgate_Siphon
Ditch/Dam/Terrace	Irrigation	Dam_Ditch
Field/Storage	Irrigation	Fields_Storage
Hillshade	Not applicable	Not applicable
RanchPageLayouts		RanchPageLayouts.shp
Western Regional Climate Center (WRCC)		
Weather Station	Weather	PrecipitationStations
Thunder Basin Grazing Association (TBGA) and Weston & Converse County Convervation Districts		
Small Water Project Wells	Hydrology	SmWtrPrj
ESCO		
Ecological Sites Legend	ESCO	ECOCLASSES
Weston Ecological Site	ESCO	WESTON_EcoSite_SDV
Niobrara Ecological Site	ESCO	NIOBRARA_EcoSite_SDV
Natrona Ecological Site	ESCO	NATRONA_EcoSite_SDV
Converse Ecological Site	ESCO	CONVERSE_EcoSite_SDV
Campbell Ecological Site	ESCO	CAMPBELL_EcoSite_SDV
Weston Irrigation Capability	ESCO	WESTON_IrrCap_SDV
Niobrara Irrigation Capability	ESCO	NIOBRARA_IrrCap_SDV
Natrona Irrigation Capability	ESCO	NATRONA_IrrCap_SDV
Converse Irrigation Capability	ESCO	CONVERSE_IrrCap_SDV
Campbell Irrigation Capability	ESCO	CAMPBELL_IrrCap_SDV
STREAM STEADY		
Rosgen Classification	StreamSteady	RosgenClassification

Data Summary 2.1.4-1 List of Soil Property Data Available and Report Name

Soil Property	Report Name
Map unit acres	Acreage and Proportionate Extent
Map unit name	Acreage and Proportionate Extent
Map unit percent	Acreage and Proportionate Extent
Calcium carbonate content Chemical Soil Properties	Chemical Soil Properties
Cation exchange capacity (CEC) Chemical Soil Properties	Chemical Soil Properties
Effective cation exchange capacity (ECEC) Chemical Soil Properties	Chemical Soil Properties
Gypsum content Chemical Soil Properties	Chemical Soil Properties
Horizon depths	Chemical Soil Properties
Salinity (EC)	Chemical Soil Properties
Sodium absorption ration (SAR)	Chemical Soil Properties
Soil reaction (pH)	Chemical Soil Properties
Component composition by map unit	Component Legend
Component kind	Component Legend
Component name by map unit	Component Legend
Slope range by component	Component Legend
AASHTO classification	Engineering Properties
Fragment content, by weight	Engineering Properties
Horizon depths	Engineering Properties
Liquid Limit	Engineering Properties
Percent passing sieves	Engineering Properties
Plasticity Index	Engineering Properties
Texture by horizon	Engineering Properties
Unified soil classification	Engineering Properties
Available Water Capacity	Physical Soil Properties
Clay content	Physical Soil Properties
Horizon depths	Physical Soil Properties
Kf erosion factor	Physical Soil Properties
Kw erosion factor	Physical Soil Properties
Linear Extensibility (shrink-swell)	Physical Soil Properties
Organic Matter content	Physical Soil Properties
Sand content	Physical Soil Properties
Sand content RUSLE2	Physical Soil Properties
Saturated Hydraulic Conductivity (Ksat)	Physical Soil Properties
Silt content	Physical Soil Properties
T factor	Physical Soil Properties
Wind erodibility group (WEG)	Physical Soil Properties
Wind erodibility index (WEI)	Physical Soil Properties
Clay content RUSLE2	Related Attributes
Hydrologic Soil Group RUSLE2	Related Attributes
Kf erosion factor RUSLE2	Related Attributes
Silt content RUSLE2	Related Attributes
T factor RUSLE2	Related Attributes
Potential frost action	Soil Features
Restrictive Layer depth	Soil Features
Restrictive Layer hardness	Soil Features

Soil Property	Report Name
Restrictive Layer kind	Soil Features
Restrictive Layer thickness	Soil Features
Risk of corrosion - concrete	Soil Features
Risk of corrosion - steel	Soil Features
Subsidence	Soil Features
Flooding duration, frequency Water Features	Water Features
Hydrologic Soil Group	Water Features
Ponding depth, duration, frequency	Water Features
Runoff	Water Features
Water table depth	Water Features

Note: Data available from NRCS Soil Data Mart - http://SoilDataMart.nrcs.usda.gov/

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

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+	Clay rich sandy silt, silt, sand and gravel; unconsolidated and interbedded; present along most streams. Thickness generally less than 50 feet but may be thicker. Coarser deposits in valleys of the Belle Fourche and the Cheyenne Rivers. Alluvium overlying formations of Tertiary age is generally fine to medium grained in central part of basin. (Hodson, Pearl and Druse, 1971)	Yield of 1000 gpm possible, often through induced recharge. Terraces topographically high and often drained. Specific capacity, 0.3-18 gpm/ft; porosity, 28-45%; permeability, 0.1-1100 gpd/ft^2; transmissivity, 15-64000 gpd/ft, specific yield, 2-39%. Coarser deposits have better aquifer properties.	TDS content generally range from about 100 to >4000 mg/l, and 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 underlying bedrock aquifers as well as surface water. Moderate to high mineralization tolerable for stock and domestic use. Suitability for irrigation generally limited to salt tolerant crops. Water in the alluvium in Black Hills generally is better quality than central part of basin (Hodson, Pearl and Druse, 1971).	Historical source for domestic and stock use. Production has ranged from 1 to 900 gpm. Ground water development potential generally better in coarse-grained deposits and poorer in fine-grained materials. Yields in the high end of the above range might be possible to optimally located and properly designed wells if induced infiltration from surface water can be tolerated (Belle Fourche, Cheyenne and Niobrara River Basins). Potential source for irrigation, municipal / public and industrial sources where more than 40 feet of saturated well sorted sand and gravel are present.	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.
Middle Tertiary Aquifer	Arikaree Formation	0-500 (southeast only)	Tuffaceous sandstone, fine-grained with silty zones, coarse sand lenses and concretionary zones	Yields up to 1000 gpm; specific capacity up to 232 gpm/ft; porosity, 5-24%; permeability <1-300 gpd/ft^2; transmissivity up to 77,000 gpd/ft.	TDS content of water ranges from 261 to 535 mg/l. Composition mainly Calcium Bicarbonate (Whitcomb, 1965). Median TDS content in samples from 12 wells in Niobrara County 321 mg/l (Larson, 1984).	Historical source for municipal / public, industrial, domestic, stock and irrigation supply with tested production ranging as high as 195 to 730 gpm (Whitcomb, 1965). Yields of 1000 gpm might be possible to optimally located and properly designed wells.	Water level data available from two observation wells located east and south east of Lusk in Niobrara County (32-62-05-baa01), (32-62-32-bbb01). Water levels have shown approximately 6 to 13 feet decline in water levels in the aquifer since the 1970s with possibly some stabilization and slight recovery since early to mid 1990s (USGS, 2001).
Fort Union / Wasatch Aquifer System	Wasatch Formation	up to 1600	Fine- to coarse-grained lenticular sandstones interbedded with shale and coal, coarser in south.	Yields generally <15 gpm, locally flowing wells exist. Yields historically could be expected to range from 10 to 50 gpm in the north part of the basin with the possibility of higher yields up to 500 gpm in the south part of the basin (Hodson, Pearl and Druse, 1973). Specific capacity, 0.10-14 gpm/ft (Hodson, Pearl and Druse, 1973); porosity, 28-30%; permeability, 0.01-65 gpd/ft^2; transmissivity, average 500 gpd/ft range 1-4000 gpd/ft.	TDS content of waters is variable and ranges from <200 to > 8000 mg/l (Hodson, Pearl and Druse, 1973). Sodium Sulfate and Sodium Bicarbonate are general dominate water types. Major ion composition varies with depth and shows more Sodium and Bicarbonate content with depth. Radium 226 + 228 may be of concern near uranium deposits.	Historical source for municipal / public, domestic and stock supply. Yields ranging from 10 to 50 gpm in the north part of the basin can be expected with the possibility of higher yields up to 500 gpm in the south part of the basin (Hodson, Pearl and Druse, 1973).	Water level data available from two observation wells located in Campbell County (50-72-21-aba01), (42-71-35-aaa01) and one observation well in Converse County (37-70-10-cbb01). Water levels in the aquifer have shown about a 40 feet rise between 1983 and 2000 in Gillette and about a 40 to 50 feet decline south east of Wright in Campbell County. Water levels in the aquifer in northwest Converse County have shown a rise of about 7 feet between 1988 and 1999 after a decline of about 6 feet between 1986 and 1988. (USGS, 2001)

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

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	1100-2270	Sandstone, fine- to medium-grained, lenticular, interbedded with siltstone, coal and shale. Middle part may be shaller in north, upper part siltier in south. "Clinker" associated with coal outcrops.	Flowing yields of 1-60 gpm where confined. Pumped yields up to 250 gpm with several hundred feet of drawdown. Specific capacity, 0.1-2 gpm/ft; permeability, 0.01-100 gpd/ft^2; transmissivity, 1-5000 gpd/ft. Coal and clinker generally have better aquifer properties than sandstones. Locally clinker transmissivity up to 3,000,000 gpd/ft. Anisotropy and leaky confining layers are common.	TDS content and major ion composition of Fort Union Formation Waters as above. Water co-produced with coal bed methane is predominantly Sodium Bicarbonate type with TDS content and SAR (32 samples), 270 - 1170 mg/l (mean of 653 mg/l) and 5.7 - 12 (mean of 7.85) respectively (Rice, Ellis & Bullock, 2000). BLM Wyodak EIS assumed average TDS concentration of 764 mg/l (USDI,BLM, 1999). High radionuclide content of concern in areas near uranium ore zones.	Historical source for municipal / public, domestic and stock supply. Maximum expected yields of about 130 to 150 gpm (Hodson, Pearl and Druse, 1973), (Wester - Wetstein and Associates, Inc., 1994). Exploration and development of new Fort Union well field including conjunctive use / recharge of Coal Bed Methane production water under consideration for the City of Gillette.	Source for approximately 14 municipal and public water supply systems including the City of Gillette and adjacent Districts, Joint Powers Boards and Privately Owned Water Systems and Water Users Associations in Campbell County. City of Gillette mixes Fort Union Formation water with that from the Madison and Fox Hills/Lance system for municipal / public water supply. Total of 5285 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 138 -5507 (mean 772) feet below ground surface (bgs), and 1 - 120 (mean 27) gpm respectively. Range of depths to main water bearing zone listed on WSEO Permits were 124 - 1558 (mean 124) feet bgs. 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 (USDI,BLM, 2000).
Fox Hills/Lance Aquifer System	Lance Formation	500-1000 (North) 1600-3000 (South)	Sandstone, fine- to medium-grained, lenticular, interbedded with sandy siltstone and claystone.	Yields up to 350 gpm but with large drawdowns and long well completion intervals. Locally flowing wells exist. Specific capacity, 0.05-2 gpm/ft; permeability, 6-35 gpd/ft^2; transmissivity, 170-2100 gpd/ft	TDS content in waters at Foxhills/Lance System outcrops north of Niobrara County range from 600 - 1,500 mg/l, and in Niobrara County range from 1,000 - 3,300 mg/l. Composition mainly Sodium - Bicarbonate - Sulfate. Fluoride enrichment is characteristic of Fox Hills/Lance Formation waters. Possible high Sodium, and radionuclide content could be of concern in some areas.	Lance Formation historical source for municipal / public, domestic and stock supply. Generally yields less than 20 gpm, but yields of several hundred gallons per minute may be possible from complete section of the formation. (Hodson, Pearl and Druse, 1973)	High Fluoride content is of concern for development as source for municipal / public water systems.
	Fox Hills Sandstone	150-200 (North) 400-700 (South)	Sandstone, fine-to medium-grained, interbedded with shale and siltstone.	Yields up to 705 gpm but with large drawdowns and long well completion intervals. Locally flowing wells exist. Specific capacity, 0.05-2 gpm/ft; permeability, 34 gpd/ft^2; transmissivity, 76-1600 gpd/ft for wells also completed in Lance.	Similar to Lance Formation	Historical source for municipal / public, industrial, domestic and stock supply. Tested yields of Gillette municipal / public supply wells have ranged from 85 to 705 gpm (Wester-Wetstein and Associates, Inc., 1994).	High Fluoride content is of concern for development as source for municipal / public water systems. Has been used for oil well water flooding operations. Water level data available from one observation well completed in the aquifer south east of Gillette in Campbell County (49-70-31bbb01) has shown approximately 50 feet decline since 1983 (USGS, 2001).

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems. Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability/Development Potential [C]	Remarks
Dakota Aquifer System	Newcastle Sandstone	0-60 (Northeastern Basin) 0-100 (Southeastern Basin)	Sandstone, fine-to medium-grained, locally conglomeratic, lenticular, with interbedded siltstone, shale and claystone.	Minor unit of Dakota Aquifer System exploited near outcrop only; often excessive pumping lift. Oil field data. porosity, 5-27%· permeability, <11 gpd/ft^2; transmissivity, 0-140 gpd/ft.	Waters at Dakota System outcrop generally contain over 1,000 mg/l TDS. TDS content 180 - 3200 mg/l in 17 samples in Weston County (Larson, 1984). Composition changes basinward from Calcium - Magnesium - Sulfate at outcrop to Sodium - Sulfate, to Sodium - Bicarbonate. Deep Basin waters > 10,00 mg/l TDS & are enriched to Sodium - Chloride. Possible high Fluoride, Selenium and radionuclide content could be of concern in some areas.	Dakota Aquifer System historical source for domestic and stock use.	Few reported wells in northern Black Hills (1958) due to excessive drilling depths except in outcrop areas. Yields typically adequate for stock and domestic purposes. Historically, wells typically have been completed in both the Lakota and Fall River Formations to obtain maximum production. (Whitcomb, Morris, Gordon & Robinove, 1958) Water level data available from one observation well completed in the aquifer (Lakota Formation) northeast of Lusk in Niobrara County (36-62-28ab02) has shown approximately 23 feet decline between 1974 and 2000 (USGS, 2001).
	Fall River Formation	95-150 (Northeastern Basin) 35-85 (Southeastern Basin)	Sandstone, fine-to coarse-grained with interbedded shale and siltstone.	Flowing yield 1-10 gpm, wells often also completed in Lakota Formation. Specific capacity, <0.5 gpm/ft. Oil field data: porosity, 11-23%; permeability, 0-36 gpd/ft^2 ; transmissivity, 1-900 gpd/ft.			
	Lakota Formation	45-300 (Northeastern Basin) 115-200 (Southeastern Basin)	Sandstone, fine-to coarse-grained, in places conglomeratic, very lenticular, irregularly interbedded with shale which becomes dominant at top (Fuson Shale).	Flowing yield 1-10 gpm, up to 150 gpm. Water well data specific capacity, 0.01-1.4 gpm/ft; permeability, 2-14 gpd/ft^2 transmissivity, 220-810 gpd/ft for 2 wells also in Fall River.			
Madison Aquifer System	Minnelusa Formation (Hartville Formation)[D]	600-800 (Northeastern Basin) 1000± (Southeastern Basin)	Sandstone, fine-to coarse-grained, interbedded with limestone, dolomite, and shale, locally gypsiferous, especially at top.	Upper part has historically been considered part of Madison Aquifer System, middle is aquitard. lower is minor aquifer in hydraulic connection with Madison. Flowing yields of over 200 gpm possible; specific capacity, 1-5 gpm/ft. Oil field data: porosity, 6-25%; permeability, <0.1-18 gpd/ft^2; transmissivity, 2-900 gpd/ft.	Similar to Madison Formation Waters at Outcrop (TDS < 800mg/l, predominantly Calcium - Magnesium - Bicarbonate type water). TDS content 230 - 2450 mg/l from 26 samples in Crook County with median and mean of 520 and 773 mg/l respectively (Larson, 1984). Some east basin waters near outcrops show TDS up to 3,000 mg/l (Calcium & Sulfate enrichment). Deep basin waters TDS > 10,000 mg/l (mainly Sodium - Chloride type water). Fluoride enrichment characteristic of Madison System waters throughout the basin. Concentrations of radionuclides could be of concern in some areas.	Historical source for municipal / public water supply, domestic and stock use.	Large quantities of water produced from flowing wells at Hulett (1958). Generally deeply buried (> 600 - 700 feet minimum) in area (northern Black Hills - 1958), (Whitcomb, Morris, Gordon & Robinove, 1958). Subject of USGS investigation with Pahasapa / Madison Limestone (Ogle, 2001). Water level data available from one observation well located in Crook (44-62-36-cbb02) and one in Niobrara (36-62-28-bbd01) Counties. Water levels have risen about 2 feet (since 1998) and 15 feet (since 1995) respectively in the two observation wells (USGS, 2001).

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

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)	Pahasapa Limestone (Madison Limestone)[D]	550-990 (Northeastern Basin) 250± (Southeastern Basin)	Massive fine-grained limestone and dolomitic limestone, locally cherty or cavernous.	Principal unit of Madison Aquifer System. Flowing or pumped yields up to 1000 gpm; specific capacity, 0.5-50+ gpm/ft, flow-dependent; transmissivity, 1000-60,000 gpd/ft locally to 300,000 gpd/ft+.	Waters at Outcrop (TDS < 600mg/l, predominantly Calcium - Magnesium - Bicarbonate type water). TDS increase basinward to > 3,000 mg/l, Sodium - Sulfate - Chloride predominating. Fluoride enrichment characteristic of Madison System waters throughout the 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. Several fish hatcheries use Pahasapa / Madison aquifer as water source. Base flow and spring discharge from the Pahasapa / Madison aquifer form part of the surface run-off in the Black Hills area. (Ogle, 2001) Tested pumping rate of seven City of Gillette Pahasapa / Madison aquifer wells ranged from 535 to 900 gpm (Wester-Wetstein and Associates, Inc., 1994).	Subject of USGS investigation with the Minnelusa Formation (Ogle, 2001). Water level data available from nine observation wells located in Crook (56-67-28-aab01), (56-67-28-aab02), (53-65-18bbd02), (52-63-25-dcd01), (49-62-36-cbb01), Weston (48-65-35ccb01), (46-66-25dbb01), (44-63-26cac01), and Niobrara (36-62-28-ab01) Counties. Water levels have generally risen from 13 to 40 feet in some of the observation wells since 1995 (USGS, 2001). Total estimated recharge to the Madison Limestone in the Powder River Basin in 1973 was about 75,000 acre feet/year (WSEO, 1976).
	Englewood Limestone (Gumsey Formation, part)[D]	30-60 (Northeastern Basin) 0-50± (Southeastern Basin)	Thin-bedded limestone, locally shaley.	Minor unit of Madison Aquifer System; USGS test: porosity, 15-18%; permeability, <0.1 gpd/ft^2.			Generally no ground water development in area (Northern Black Hills - 1958). Formations may contain some water in permeable zones, but are generally considered to be too deeply bured to be considered important aquifers. (Whitcomb, Morris, Gordon & Robinove, 1958)
	Whitewood Dolomite	50-60 (Northeastern Basin) absent (Southeastern Basin)	Massive bedded dolomite, locally cherty.	Minor unit of Madison Aquifer System; the few existing wells also produce from the Madison aquifer. USGS test: porosity, 10-25%; specific capacity, 15 gpm/ft; permeability, <0.1-11 gpd/ft^2; transmissivity, 6400 gpd/ft.			

[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 aquifers or screened in only part of a single aquifer. Reported ranges include varying amounts of data. (Feathers, Libra, Stephenson and Eisen 1981)

[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 permeability. Test data are usually for limited horizons of high anticipated yields and are not therefore representative of the formation as a whole. (Feathers, Libra, Stephenson and Eisen, 1981)

[C]Actual development potential will require site specific office and field investigations to define aquifer capability and constraints unique to each project and site.

[D]Nomenclature for equivalent strata exposed in the Hartville uplift on the southeastern basin flank (Feathers, Libra, Stephenson and Eisen, 1981).

Data Summary 2.1.7-1 Watershed Hydrologic Features Index	
HUC 12 ID Number	Watershed Name
101201020105	Willow Creek-Dry Fork Cheyenne River
101201020201	Dry Fork Cheyenne River-Cottonwoo d Draw
101201020202	Dry Fork Cheyenne River-Dugout Creek
101201020204	Barker Draw
101201020205	Lake Creek
101201030101	Cheyenne River-Meadow Creek
101201030102	Cheyenne River-Keyton Creek
101201030402	Upper Snyder Creek
101201030403	Lower Snyder Creek
101201030404	Cheyenne River-Sevenmile Creek
101201030405	Boggy Creek
101201040101	Lance Creek-Bills Creek
101201040102	Lance Creek-Rusty Creek
101201040103	Lance Creek-Sand Creek
101201040104	Little Lightning Creek
101201040105	Lance Creek-Lance Creek Road
101201040201	Upper Cow Creek
101201040202	Lower Cow Creek
101201040203	Lance Creek-Hancock Draw
101201040204	Dogie Creek
101201040205	Buck Creek-Lance Creek
101201040206	Lance Creek-Spring Creek
101201040207	Greasewood Creek
101201040301	Upper Old Woman Creek
101201040302	Young Woman Creek
101201040303	Middle Old Woman Creek
101201040304	Upper Sage Creek-Old Woman Creek
101201040305	Spring Creek-Old Woman Creek
101201040306	Lower Sage Creek-Old Woman Creek
101201040307	Lower Old Woman Creek
101201040308	Antelope Creek-Old Woman Creek
101201050101	Lightning Creek-Alexander Draw
101201050102	Little Lighning Creek
101201050103	Lightning Creek-Goochy Reservoir
101201050104	North Fork Box Creek
101201050105	South Fork Box Creek
101201050106	Middle Box Creek
101201050107	Lower Box Creek
101201050108	Lightning Creek-Willow Draw
101201050109	Lightning Creek-Deep Creek
101201050201	Dry Creek-Poison Draw
101201050202	Dry Creek-Sheldon Draw
101201050203	Dry Creek-Rat Creek
101201050204	Dry Creek-Bobcat Creek
101201050301	Upper Walker Creek
101201050302	Middle Walker Creek
101201050303	Willow Creek
101201050304	Lower Walker Creek
101201050401	Upper Twentymile Creek
101201050402	Harney Creek
101201050403	Middle Twentymile Creek
101201050404	Lower Twentymile Creek
101201060101	Cheyenne River-Bobcat Creek
101201060102	Mule Creek-Cheyenne River
101201060104	Lower Alkali Creek-Angostura Reservoir
101201060106	Cheyenne River-Sage Creek
101201060202	Moss Agate Creek
101201060301	Upper Cottonwood Creek-Angostura Reservoir
101201060302	Middle Cottonwood Creek-Angostura Reservoir
101201060303	Lower Cottonwood Creek-Angostura Reservoir
101201080107	Antelope Creek-Hat Creek
101201080201	Indian Creek-Middle Creek
101201080202	Indian Creek-S-Bar Creek
101201080203	Indian Creek-Brush Creek
101201080204	Indian Creek-Alkali Creek
101201080205	Oat Creek
101500020101	Niobrara River-Manville
101500020201	Upper Bergreen Creek
101500020202	North Duck Creek
101500020302	Upper Van Tassel Creek
101500020303	Lower Van Tassel Creek
101800070910	North Platte River-Fetterman Creek
101800071201	Upper Sage Creek
101800071202	Middle Sage Creek
101800071203	Lower Sage Creek-North Platte River

Data Summary 2.1.7-2. USGS Streamflow Stations and Water Quality Sites in the Thunder Basin Watershed

Station Number	Station Name	Flow Measurement Period of Record, Water Years	Daily/ Monthly Data	Peak Flows	Water Quality Data Period of Record	Water Quality Data Samples
06378640	Lance Creek Tributary near Lance Creek, WY	6/10/1965 - 9/8/1973	No	9	---	---
06379600	Box Creek near Bill, WY	6/9/1957 - 7/25/1981	No	23	---	---
06382200	Pritchard Draw near Lance Creek, WY	1964 - 8/5/1981	No	18	---	---
06384000	Obs Res 33 on Unnamed Triburaty South Fork Cheyenne River	No data	No	---	---	---
06384500	Obs Res 43 on Unnamed Tributary of Crazy Woman Creek	No data	No	---	---	---
06385000	Obs Res 43A on Unnamed Tributary to Crazy Woman Creek	No data	No	---	---	---
06385400	Cottonwood Creek at Hat Creek, WY	8/9/1979	No	1	---	---
06385500	Obs Res 44 on Unnamed Tributary of Old Woman Creek	No data	No	---	---	---
06386000	Lance Creek near Riverview, WY	5/1/1948 - 9/1983	Yes	34	5/13/1971 - 9/21/1983	127
06386200	Obs Res 39 on Unnamed Tributary of Mule Creek	No data	No	---	---	---
430328105281501	North Box Creek #2 below Exxon Pond near Bill, WY	---	---	---	8/26/1983	1
430331105282701	North Box Creek #3 below Exxon Pond near Bill, WY	---	---	---	8/26/1983	1
430355105291101	Exxon Seepage Pump #1	---	---	---	7/1/1980	1
430433105234301	Box Creek at County Road 32 near Bill, WY	---	---	---	4/11/1980 - 3/12/1981	14
430435105233700	Box Creek below Confluence near Bill, WY	---	---	---	8/2/1976 - 5/15/1978	3
430452104372801	Lance Creek below Little Lightning Creek	---	---	---	10/11/1978	1
430609105163901	Box Creek at Johnson Ranch near Bill, WY	---	---	---	8/19/1980 - 9/23/1980	3
430718105002301	Lightning Creek below Box Creek near Janet, WY	---	---	---	10/12/1978	1
431230104360401	Lance Creek above Lightning Creek near Cow Creek, WY	---	---	---	10/11/1978	1
431346104372201	Lightning Creek near Mouth near Cow Creek, WY	---	---	---	10/11/1978	1
431400104372500	Lightning Creek near Cow Creek	---	---	---	6/7/1978	1
431512104232001	Lance Creek below Crazy Woman Creek at Bright, WY	---	---	---	8/30/1978 - 10/17/1978	3

Data Summary 2.1.8-1 **Reach ID's**

Reach ID	Reach ID - Formulas	Watershed	Reach Name	Sub-Branch	Reach Number
A-Bri-1-B	A-Bri-1-B	Angostura Reservoir	Bridge Creek		1
A-Bri-2-E	A-Bri-2-E	Angostura Reservoir	Bridge Creek		2
A-Cot-1-E	A-Cot-1-E	Angostura Reservoir	Cottonwood Creek		1
A-Hen-1-C	A-Hen-1-C	Angostura Reservoir	Hen Creek		1
A-Hen-2-E	A-Hen-2-E	Angostura Reservoir	Hen Creek		2
A-Lit-N1-B	A-Lit-N1-B	Angostura Reservoir	Little Cottonwood Creek	North	1
A-Lit-N2-C	A-Lit-N2-C	Angostura Reservoir	Little Cottonwood Creek	North	2
A-Lit-S1-B	A-Lit-S1-B	Angostura Reservoir	Little Cottonwood Creek	South	1
A-Lit-S2-C	A-Lit-S2-C	Angostura Reservoir	Little Cottonwood Creek	South	2
A-Mul-E1-D	A-Mul-E1-D	Angostura Reservoir	Mule Creek	East	1
A-Mul-E2-C	A-Mul-E2-C	Angostura Reservoir	Mule Creek	East	2
A-Mul-W1-C	A-Mul-W1-C	Angostura Reservoir	Mule Creek	West	1
A-Mul-1-E	A-Mul-1-E	Angostura Reservoir	Mule Creek		1
A-Nor-N1-C	A-Nor-N1-C	Angostura Reservoir	North Fork Cottonwood Creek	North	1
A-Nor-S1-C	A-Nor-S1-C	Angostura Reservoir	North Fork Cottonwood Creek	South	1
A-Nor-1-E	A-Nor-1-E	Angostura Reservoir	North Fork Cottonwood Creek		1
A-Nor-N1-G	A-Nor-N1-G	Angostura Reservoir	North Fork Moss Agate Creek	North	1
A-Nor-S1-G	A-Nor-S1-G	Angostura Reservoir	North Fork Moss Agate Creek	South	1
A-Nor-1-E	A-Nor-1-E	Angostura Reservoir	North Fork Moss Agate Creek		1
A-Sag-1-G	A-Sag-1-G	Angostura Reservoir	Sage Creek		1
A-Sag-2-E	A-Sag-2-E	Angostura Reservoir	Sage Creek		2
A-Sag-3-G	A-Sag-3-G	Angostura Reservoir	Sage Creek		3
A-Sou-1-C	A-Sou-1-C	Angostura Reservoir	South Fork Cottonwood Creek		1
A-Sou-2-E	A-Sou-2-E	Angostura Reservoir	South Fork Cottonwood Creek		2
A-Sou-1-G	A-Sou-1-G	Angostura Reservoir	South Fork Moss Agate Creek		1
A-Sou-2-C	A-Sou-2-C	Angostura Reservoir	South Fork Moss Agate Creek		2
A-Sou-3-E	A-Sou-3-E	Angostura Reservoir	South Fork Moss Agate Creek		3
H-Ant-1-B	H-Ant-1-B	Hat	Antelope Creek		1
H-Bru-1-G	H-Bru-1-G	Hat	Brush Creek		1
H-Bru-2-C	H-Bru-2-C	Hat	Brush Creek		2
H-Bru-3-C	H-Bru-3-C	Hat	Brush Creek		3
H-Bru-4-E	H-Bru-4-E	Hat	Brush Creek		4
H-Cot-1-C	H-Cot-1-C	Hat	Cottonwood Prong		1
H-Cot-2-E	H-Cot-2-E	Hat	Cottonwood Prong		2
H-Due-1-B	H-Due-1-B	Hat	Duell Creek		1
H-Due-2-C	H-Due-2-C	Hat	Duell Creek		2
H-Due-3-B	H-Due-3-B	Hat	Duell Creek		3
H-Due-4-C	H-Due-4-C	Hat	Duell Creek		4
H-Fit-1-B	H-Fit-1-B	Hat	Fitzsimmons Creek		1
H-Fit-2-G	H-Fit-2-G	Hat	Fitzsimmons Creek		2
H-Ind-1-B	H-Ind-1-B	Hat	Indian Creek		1
H-Ind-2-C	H-Ind-2-C	Hat	Indian Creek		2
H-Ind-3-C	H-Ind-3-C	Hat	Indian Creek		3
H-Ind-4-C	H-Ind-4-C	Hat	Indian Creek		4
H-Mid-1-B	H-Mid-1-B	Hat	Middle Creek		1
H-Mil-1-B	H-Mil-1-B	Hat	Mill Creek		1
H-Mil-2-C	H-Mil-2-C	Hat	Mill Creek		2
H-Nor-1-C	H-Nor-1-C	Hat	North Brush Creek		1
H-Nor-1-C	H-Nor-1-C	Hat	North Oat Creek		1
H-Oat-1-E	H-Oat-1-E	Hat	Oat Creek		1
H-Plu-1-B	H-Plu-1-B	Hat	Plum Creek		1
H-Plu-2-G	H-Plu-2-G	Hat	Plum Creek		2
H-Plu-3-C	H-Plu-3-C	Hat	Plum Creek		3
H-S B-1-B	H-S B-1-B	Hat	S Bar Creek		1
H-S B-2-G	H-S B-2-G	Hat	S Bar Creek		2
H-S B-3-C	H-S B-3-C	Hat	S Bar Creek		3
H-Sag-1-C	H-Sag-1-C	Hat	Sage Creek		1
H-Sag-2-C	H-Sag-2-C	Hat	Sage Creek		2
H-Sou-1-F	H-Sou-1-F	Hat	South Antelope Creek		1
H-Sou-2-B	H-Sou-2-B	Hat	South Antelope Creek		2
H-Sou-1-B	H-Sou-1-B	Hat	South Brush Creek		1
H-Sou-2-C	H-Sou-2-C	Hat	South Brush Creek		2
H-Sou-1-C	H-Sou-1-C	Hat	South Oat Creek		1
H-Sou-2-C	H-Sou-2-C	Hat	South Oat Creek		2
H-Swa-1-B	H-Swa-1-B	Hat	Swanski Creek		1
H-Swa-2-F	H-Swa-2-F	Hat	Swanski Creek		2
L-Alu-W1-B	L-Alu-W1-B	Lance	Alum Creek	West	1

Data Summary 2.1.8-1 Reach ID's

Reach ID	Reach ID - Formulas	Watershed	Reach Name	Sub-Branch	Reach Number
L-Alu-W2-D	L-Alu-W2-D	Lance	Alum Creek	West	2
L-Alu-W3-E	L-Alu-W3-E	Lance	Alum Creek	West	3
L-Alu-E1-E	L-Alu-E1-E	Lance	Alum Creek	East	1
L-Alu-E2-C	L-Alu-E2-C	Lance	Alum Creek	East	2
L-Alu-1-E	L-Alu-1-E	Lance	Alum Creek		1
L-Ant-1-B	L-Ant-1-B	Lance	Antelope Creek		1
L-Ant-2-E	L-Ant-2-E	Lance	Antelope Creek		2
L-Ant-3-C	L-Ant-3-C	Lance	Antelope Creek		3
L-Ant-4-C	L-Ant-4-C	Lance	Antelope Creek		4
L-Bil-N1-B	L-Bil-N1-B	Lance	Bills Creek	North	1
L-Bil-S1-B	L-Bil-S1-B	Lance	Bills Creek	South	1
L-Bil-1-E	L-Bil-1-E	Lance	Bills Creek		1
L-Bil-2-E	L-Bil-2-E	Lance	Bills Creek		2
L-Bog-1-A	L-Bog-1-A	Lance	Boggy Creek		1
L-Bog-2-C	L-Bog-2-C	Lance	Boggy Creek		2
L-Bog-3-C	L-Bog-3-C	Lance	Boggy Creek		3
L-77 -1-NDC	L-77 -1-NDC	Lance	77 Creek		1
L-77 -2-F	L-77 -2-F	Lance	77 Creek		2
L-77 -3-C	L-77 -3-C	Lance	77 Creek		3
L-Buc-1-C	L-Buc-1-C	Lance	Buck Creek		1
L-Buc-2-C	L-Buc-2-C	Lance	Buck Creek		2
L-Buc-3-E	L-Buc-3-E	Lance	Buck Creek		3
L-Buc-4-C	L-Buc-4-C	Lance	Buck Creek		4
L-Buc-5-C	L-Buc-5-C	Lance	Buck Creek		5
L-Buc-6-C	L-Buc-6-C	Lance	Buck Creek		6
L-Buc-1-B	L-Buc-1-B	Lance	Buck Tail Creek		1
L-Buc-2-E	L-Buc-2-E	Lance	Buck Tail Creek		2
L-Bul-1-B	L-Bul-w1-B	Lance	Bull Creek	west	1
L-Bul-2-C	L-Bul-w2-C	Lance	Bull Creek	west	2
L-Bul-1-C	L-Bul-1-C	Lance	Bull Creek		1
L-Bul-2-C	L-Bul-2-C	Lance	Bull Creek		2
L-Che-1-A	L-Che-1-A	Lance	Cherry Creek		1
L-Che-2-E	L-Che-2-E	Lance	Cherry Creek		2
L-Chi-1-C	L-Chi-1-C	Lance	Chip Creek		1
L-Chi-2-B	L-Chi-2-B	Lance	Chip Creek		2
L-Chi-3-C	L-Chi-3-C	Lance	Chip Creek		3
L-Cot-1-B	L-Cot-1-B	Lance	Cottonwood Creek		1
L-Cot-2-C	L-Cot-2-C	Lance	Cottonwood Creek		2
L-Cot-3-E	L-Cot-3-E	Lance	Cottonwood Creek		3
L-Cow-1-B	L-Cow-1-B	Lance	Cow Creek		1
L-Cow-2-C	L-Cow-2-C	Lance	Cow Creek		2
L-Cow-3-C	L-Cow-3-C	Lance	Cow Creek		3
L-Cow-4-C	L-Cow-4-C	Lance	Cow Creek		4
L-Cow-5-E	L-Cow-5-E	Lance	Cow Creek		5
L-Cow-6-E	L-Cow-6-E	Lance	Cow Creek		6
L-Cow-7-C	L-Cow-7-C	Lance	Cow Creek		7
L-Coy-1-C	L-Coy-1-C	Lance	Coyote Creek		1
L-Coy-2-C	L-Coy-2-C	Lance	Coyote Creek		2
L-Dog-1-B	L-Dog-1-B	Lance	Dogie Creek		1
L-Dog-2-C	L-Dog-2-C	Lance	Dogie Creek		2
L-Dog-3-C	L-Dog-3-C	Lance	Dogie Creek		3
L-Dog-4-C	L-Dog-4-C	Lance	Dogie Creek		4
L-Dog-5-C	L-Dog-5-C	Lance	Dogie Creek		5
L-Gre-S1-B	L-Gre-S1-B	Lance	Greasewood Creek	South	1
L-Gre-S2-B	L-Gre-S2-B	Lance	Greasewood Creek	South	2
L-Gre-N1-B	L-Gre-N1-B	Lance	Greasewood Creek	North	1
L-Gre-1-C	L-Gre-1-C	Lance	Greasewood Creek		1
L-Lan-1-E	L-Lan-1-E	Lance	Lance Creek		1
L-Lan-2-E	L-Lan-2-E	Lance	Lance Creek		2
L-Lan-3-C	L-Lan-3-C	Lance	Lance Creek		3
L-Lan-4-C	L-Lan-4-C	Lance	Lance Creek		4
L-Lan-5-C	L-Lan-5-C	Lance	Lance Creek		5
L-Lan-6-G	L-Lan-6-G	Lance	Lance Creek		6
L-Lan-7-C	L-Lan-7-C	Lance	Lance Creek		7
L-Lan-7-C	L-Lan-7-C	Lance	Lance Creek		7
L-Lan-8-C	L-Lan-8-C	Lance	Lance Creek		8
L-Lan-9-E	L-Lan-9-E	Lance	Lance Creek		9

Data Summary 2.1.8-1 **Reach ID's**

Reach ID	Reach ID - Formulas	Watershed	Reach Name	Sub-Branch	Reach Number
L-Lan-10-E	L-Lan-10-E	Lance	Lance Creek		10
L-Lan-11-E	L-Lan-11-E	Lance	Lance Creek		11
L-Lan-12-E	L-Lan-12-E	Lance	Lance Creek		12
L-Lan-13-E	L-Lan-13-E	Lance	Lance Creek		13
L-Lan-14-E	L-Lan-14-E	Lance	Lance Creek		14
L-Lan-15-E	L-Lan-15-E	Lance	Lance Creek		15
L-Lit-1-B	L-Lit-1-B	Lance	Little Cow Creek		1
L-Lit-2-C	L-Lit-2-C	Lance	Little Cow Creek		2
L-Lit-3-C	L-Lit-3-C	Lance	Little Cow Creek		3
L-Lit-4-C	L-Lit-4-C	Lance	Little Cow Creek		4
L-Lit-5-C	L-Lit-5-C	Lance	Little Cow Creek		5
L-Lit-6-E	L-Lit-6-E	Lance	Little Cow Creek		6
L-Lit-1-B	L-Lit-1-B	Lance	Little Lightning		1
L-Lit-2-C	L-Lit-2-C	Lance	Little Lightning		2
L-Lit-3-C	L-Lit-3-C	Lance	Little Lightning		3
L-Lit-4-C	L-Lit-4-C	Lance	Little Lightning		4
L-Lit-5-C	L-Lit-5-C	Lance	Little Lightning		5
L-Lit-6-C	L-Lit-6-C	Lance	Little Lightning		6
L-Lit-7-E	L-Lit-7-E	Lance	Little Lightning		7
L-Mid-1-B	L-Mid-1-B	Lance	Middle Creek		1
L-Mid-2-G	L-Mid-2-G	Lance	Middle Creek		2
L-Mid-3-G	L-Mid-3-G	Lance	Middle Creek		3
L-Mid-M1-B	L-Mid-M1-B	Lance	Middle Creek	Middle	1
L-Mid-M2-G	L-Mid-M2-G	Lance	Middle Creek	Middle	2
L-Mid-M3-E	L-Mid-M3-E	Lance	Middle Creek	Middle	3
L-Mid-M4-G	L-Mid-M4-G	Lance	Middle Creek	Middle	4
L-Old-1-B	L-Old-1-B	Lance	Old Women Creek		1
L-Old-2-B	L-Old-2-B	Lance	Old Women Creek		2
L-Old-3-C	L-Old-3-C	Lance	Old Women Creek		3
L-Old-4-C	L-Old-4-C	Lance	Old Women Creek		4
L-Old-5-F	L-Old-5-F	Lance	Old Women Creek		5
L-Old-6-C	L-Old-6-C	Lance	Old Women Creek		6
L-Old-7-C	L-Old-7-C	Lance	Old Women Creek		7
L-Old-8-C	L-Old-8-C	Lance	Old Women Creek		8
L-Rus-1-B	L-Rus-1-B	Lance	Rusty Creek		1
L-Rus-2-G	L-Rus-2-G	Lance	Rusty Creek		2
L-Rus-3-C	L-Rus-3-C	Lance	Rusty Creek		3
L-Sag-1-A	L-Sag-1-A	Lance	Sage Creek		1
L-Sag-2-C	L-Sag-2-C	Lance	Sage Creek		2
L-Sag-3-C	L-Sag-3-C	Lance	Sage Creek		3
L-Sag-4-E	L-Sag-4-C	Lance	Sage Creek		4
L-Sag-5-C	L-Sag-5-C	Lance	Sage Creek		5
L-Sot-1-B	L-Sot-1-B	Lance	Sothman Draw		1
L-Sot-N1-D	L-Sot-N1-D	Lance	Sothman Draw	North	1
L-Sot-2-C	L-Sot-2-C	Lance	Sothman Draw		2
L-Spr-1-B	L-Spr-1-B	Lance	Spring Creek		1
L-Spr-2-B	L-Spr-2-B	Lance	Spring Creek		2
L-Spr-3-C	L-Spr-3-C	Lance	Spring Creek		3
La-Spr-1-B	La-Spr-1-B	Lance	Spring Creek		1
La-Spr-2-C	La-Spr-2-C	Lance	Spring Creek		2
La-Spr-3-C	La-Spr-3-C	Lance	Spring Creek		3
La-Spr-4-C	La-Spr-4-C	Lance	Spring Creek		4
L-Ten-1-B	L-Ten-1-B	Lance	Tena		1
L-Ten-2-B	L-Ten-2-B	Lance	Tena		2
L-Ten-3-G	L-Ten-3-G	Lance	Tena		3
L-Wya-N1-B	L-Wya-N1-B	Lance	Wyatte Creek	North	1
L-Wya-N2-C	L-Wya-N2-C	Lance	Wyatte Creek	North	2
L-Wya-N3-C	L-Wya-N3-C	Lance	Wyatte Creek	North	3
L-Wya-1-B	L-Wya-1-B	Lance	Wyatte Creek		1
L-Wya-2-C	L-Wya-2-C	Lance	Wyatte Creek		2
L-Wya-3-G	L-Wya-3-G	Lance	Wyatte Creek		3
L-Wya-4-F	L-Wya-4-F	Lance	Wyatte Creek		4
L-You-1-B	L-You-1-B	Lance	Young Women Creek		1
L-You-2-C	L-You-2-C	Lance	Young Women Creek		2
L-You-3-C	L-You-3-C	Lance	Young Women Creek		3
L-You-4-F	L-You-4-F	Lance	Young Women Creek		4
L-You-N1-B	L-You-N1-B	Lance	Young Women Creek	North	1

Data Summary 2.1.8-1 **Reach ID's**

Reach ID	Reach ID - Formulas	Watershed	Reach Name	Sub-Branch	Reach Number
L-You-N2-C	L-You-N2-C	Lance	Young Women Creek	North	2
L-You-N3-C	L-You-N3-C	Lance	Young Women Creek	North	3
L-You-5-C	L-You-5-C	Lance	Young Women Creek		5
L-Bob-1-G	L-Bob-1-G	Lightning	Bobcat Creek		1
L-Bob-2-E	L-Bob-2-E	Lightning	Bobcat Creek		2
L-Box-S1-Unidentified	L-Box-S1-Unidentified	Lightning	Box Creek	South	1
L-Box-S2-C	L-Box-S2-C	Lightning	Box Creek	South	2
L-Box-N1-E	L-Box-N1-E	Lightning	Box Creek	North	1
L-Box-N2-Unidentified	L-Box-N2-Unidentified	Lightning	Box Creek	North	2
L-Box-N3-C	L-Box-N3-C	Lightning	Box Creek	North	3
L-Box-1-C	L-Box-1-C	Lightning	Box Creek		1
L-Box-2-C	L-Box-2-C	Lightning	Box Creek		2
L-Box-3-C	L-Box-3-C	Lightning	Box Creek		3
Li-Cot-1-C	Li-Cot-1-C	Lightning	Cottonwood Creek		1
Li-Cot-2-E	Li-Cot-2-E	Lightning	Cottonwood Creek		2
L-Dee-1-A	L-Dee-1-A	Lightning	Deer Creek		1
L-Dee-2-C	L-Dee-2-C	Lightning	Deer Creek		2
L-Dry-1-G	L-Dry-1-G	Lightning	Dry Creek		1
L-Dry-2-B	L-Dry-2-B	Lightning	Dry Creek		2
L-Dry-3-C	L-Dry-3-C	Lightning	Dry Creek		3
L-Dry-4-C	L-Dry-4-C	Lightning	Dry Creek		4
L-Dry-5-C	L-Dry-5-C	Lightning	Dry Creek		5
L-Dry-6-E	L-Dry-6-E	Lightning	Dry Creek		6
L-Eas-1-C	L-Eas-1-C	Lightning	East Fork Twentymile Creek		1
L-Eas-2-E	L-Eas-2-E	Lightning	East Fork Twentymile Creek		2
L-Eas-1-F	L-Eas-1-F	Lightning	East Harney Creek		1
L-Eas-2-C	L-Eas-2-C	Lightning	East Harney Creek		2
L-Har-1-B	L-Har-1-B	Lightning	Harney Creek		1
L-Har-2-C	L-Har-2-C	Lightning	Harney Creek		2
L-Har-3-C	L-Har-3-C	Lightning	Harney Creek		3
L-Hor-1-E	L-Hor-1-E	Lightning	Horse Creek		1
L-Hor-2-B	L-Hor-2-B	Lightning	Horse Creek		2
L-Lig-1-B	L-Lig-1-B	Lightning	Lightning Creek		1
L-Lig-2-C	L-Lig-2-C	Lightning	Lightning Creek		2
L-Lig-3-C	L-Lig-3-C	Lightning	Lightning Creek		3
L-Lig-4-E	L-Lig-4-E	Lightning	Lightning Creek		4
L-Lig-5-C	L-Lig-5-C	Lightning	Lightning Creek		5
L-Lig-6-C	L-Lig-6-C	Lightning	Lightning Creek		6
L-Lig-7-C	L-Lig-7-C	Lightning	Lightning Creek		7
L-Lig-8-E	L-Lig-8-E	Lightning	Lightning Creek		8
L-Lig-9-C	L-Lig-9-C	Lightning	Lightning Creek		9
L-Lig-10-E	L-Lig-10-E	Lightning	Lightning Creek		10
L-Lig-11-E	L-Lig-11-E	Lightning	Lightning Creek		11
Li-Lit-1-E	Li-Lit-1-E	Lightning	Little Lightning Creek		1
Li-Lit-2-E	Li-Lit-2-E	Lightning	Little Lightning Creek		2
Li-Lit-3-C	Li-Lit-3-C	Lightning	Little Lightning Creek		3
Li-Lit-4-D	Li-Lit-4-D	Lightning	Little Lightning Creek		4
L-Lit-1-G	L-Lit-1-G	Lightning	Little Rat Creek		1
L-Lit-2-C	L-Lit-2-C	Lightning	Little Rat Creek		2
L-Pin-1-B	L-Pin-1-B	Lightning	Piney Creek		1
L-Pin-2-C	L-Pin-2-C	Lightning	Piney Creek		2
L-Pin-3-E	L-Pin-3-E	Lightning	Piney Creek		3
Li-Pin-1-E	Li-Pin-1-E	Lightning	Piney Creek		1
Li-Pin-2-C	Li-Pin-2-C	Lightning	Piney Creek		2
L-Rat-1-E	L-Rat-1-E	Lightning	Rat Creek		1
L-Rat-2-E	L-Rat-2-E	Lightning	Rat Creek		2
L-Spr-1-F	L-Spr-1-F	Lightning	Spring Branch Harney Creek		1
L-Sti-1-A	L-Sti-1-A	Lightning	Stivers Creek		1
L-Sti-2-C	L-Sti-2-C	Lightning	Stivers Creek		2
L-Twe-1-B	L-Twe-1-B	Lightning	Twentymile Creek		1
L-Twe-2-C	L-Twe-2-C	Lightning	Twentymile Creek		2
L-Twe-3-E	L-Twe-3-E	Lightning	Twentymile Creek		3
L-Wal-S1-C	L-Wal-1-C	Lightning	Walker Creek		1
L-Wal-S2-F	L-Wal-2-F	Lightning	Walker Creek		2
L-Wal-3-C	L-Wal-3-C	Lightning	Walker Creek		3
L-Wal-4-F	L-Wal-4-F	Lightning	Walker Creek		4
L-Wal-5-F	L-Wal-5-F	Lightning	Walker Creek		5

Data Summary 2.1.8-1 Reach ID's

Reach ID	Reach ID - Formulas	Watershed	Reach Name	Sub-Branch	Reach Number
L-Wal-S1-B	L-Wal-S1-B	Lightning	Walker Creek	South	1
L-Wal-S2-C	L-Wal-S2-C	Lightning	Walker Creek	South	2
L-Wal-S3-F	L-Wal-S3-F	Lightning	Walker Creek	South	3
L-Wal-6-F	L-Wal-6-E	Lightning	Walker Creek		6
L-Wes-1-C	L-Wes-1-C	Lightning	West Fork Twentymile Creek		1
L-Wes-2-E	L-Wes-2-E	Lightning	West Fork Twentymile Creek		2
L-Wes-1-G	L-Wes-1-G	Lightning	West Harney Creek		1
L-Wes-2-C	L-Wes-2-C	Lightning	West Harney Creek		2
L-Wes-3-Unidentified	L-Wes-3-Unidentified	Lightning	West Harney Creek		3
L-Wes-4-C	L-Wes-4-C	Lightning	West Harney Creek		4
L-Wil-1-E	L-Wil-1-E	Lightning	Willow Creek		1
L-Wil-2-C	L-Wil-2-C	Lightning	Willow Creek		2
L-Wil-3-C	L-Wil-3-C	Lightning	Willow Creek		3

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
A-Bri-1-B	glacial/fluvial terrace	III	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
A-Bri-2-E	alluvial fan	III	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	yes	E	appears the mouth of Bridge Crk does not reach Lance Crk channel, flood plain only
A-Cot-1-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Hen-1-C	glacial/fluvial terrace	III	none	flat	step/pool	12-40 w:d	active apparent	single	slight	no	C	
A-Hen-2-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Lit-N1-B	glacial/fluvial terrace	III	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
A-Lit-N2-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
A-Lit-S1-B	glacial/fluvial terrace	III	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
A-Lit-S2-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
A-Mul-E1-D	glacial/fluvial terrace	III	none	flat	step/pool	>40 w:d	active apparent	multiple	slight	no	D	
A-Mul-E2-C	alluvial fan	III	none	flat	step/pool	12-40 w:d	active apparent	single	slight	no	C	
A-Mul-W1-C	glacial/fluvial terrace	III	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
A-Mul-1-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Nor-N1-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	no	C	
A-Nor-S1-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	no	C	
A-Nor-1-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Nor-N1-G	glacial/fluvial terrace	III	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
A-Nor-S1-G	glacial/fluvial terrace	III	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
A-Nor-1-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Sag-1-G	glacial/fluvial terrace	III	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
A-Sag-2-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Sag-3-G	alluvial fan	V	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
A-Sou-1-C	glacial/fluvial terrace	III	none	steep	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
A-Sou-2-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
A-Sou-1-G	glacial/fluvial terrace	III	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
A-Sou-2-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
A-Sou-3-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
H-Ant-1-B	glacial/fluvial terrace	II	none	steep	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	B	
H-Bru-1-G	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	G	
H-Bru-2-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	none apparent	single	moderate	no	C	
H-Bru-3-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	multiple	moderate	no	C	
H-Bru-4-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
H-Cot-1-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	yes	C	
H-Cot-2-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
H-Due-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Due-2-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	none apparent	single	entrenched	yes	C	
H-Due-3-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Due-4-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	C	
H-Fit-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Fit-2-G	alluvial fan	V	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	G	
H-Ind-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Ind-2-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
H-Ind-3-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	moderate	no	C	
H-Ind-4-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
H-Mid-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Mil-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Mil-2-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	C	
H-Nor-1-C	glacial/fluvial terrace	III	none	flat	step/pool	12-40 w:d	none apparent	single	slight	no	C	
H-Nor-1-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	none apparent	multiple	slight	no	C	
H-Oat-1-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
H-Plu-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
H-Plu-2-G	alluvial fan	V	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	G	
H-Plu-3-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
H-S B-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-S B-2-G	alluvial fan	V	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	G	

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
H-S B-3-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
H-Sag-1-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	no	C	
H-Sag-2-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
H-Sou-1-F	alluvial fan	V	none	flat	step/pool	12-40 w:d	none apparent	single	slight	no	F	
H-Sou-2-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
H-Sou-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
H-Sou-2-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
H-Sou-1-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	C	
H-Sou-2-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
H-Swa-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
H-Swa-2-F	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	no	F	
L-Alu-W1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Alu-W2-D	glacial/fluvial terrace	II	none	flat	riffle/pool	>40 w:d	active apparent	multiple	slight	no	D	
L-Alu-W3-E	alluvial fan	V	none	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Alu-E1-E	alluvial fan	V	none	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Alu-E2-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Alu-1-E	alluvial fan	V	multiple	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Ant-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Ant-2-E	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	E	
L-Ant-3-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Ant-4-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Bil-N1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Bil-S1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Bil-1-E	glacial/fluvial terrace	VII	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	North Bills and South Bills Crk. conflluence
L-Bil-2-E	glacial/fluvial terrace	VIII	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	Lance Crk. and Bills Crk. confluence
L-Bog-1-A	glacial/fluvial terrace	VII	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
L-Bog-2-C	glacial/fluvial terrace	II	none	steep	step/pool	<12 w:d	none apparent	single	moderate	yes	C	
L-Bog-3-C	glacial/fluvial terrace	II	none	steep	step/pool	<12 w:d	none apparent	single	moderate	yes	C	Boggy Crk. and Little Bogey Crk. confluence
L-77 -1-NDC	glacial/fluvial terrace	II	none	flat	step/pool		none apparent				NDC	no defined channel
L-77 -2-F	alluvial fan	VIII	none	flat	step/pool	12-40 w:d	none apparent	single	moderate	no	F	
L-77 -3-C	floodplain	VIII	none	flat	step/pool	<12 w:d	active apparent	single	moderate	no	C	
L-Buc-1-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	moderate	no	C	
L-Buc-2-C	glacial/fluvial terrace	VII	none	flat	riffle/pool	12-40 w:d	none apparent	multiple	moderate	no	C	
L-Buc-3-E	glacial/fluvial terrace	VII	none	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Buc-4-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	yes	C	
L-Buc-5-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	slight	yes	C	
L-Buc-6-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Buc-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Buc-2-E	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	E	
L-Bul-1-B	glacial/fluvial terrace	III	none	flat	riffle/pool	<12 w:d	none apparent	single	moderate	yes	B	
L-Bul-2-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Bul-1-C	glacial/fluvial terrace	V	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Bul-2-C	glacial/fluvial terrace	V	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
L-Che-1-A	glacial/fluvial terrace	VII	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
L-Che-2-E	glacial/fluvial terrace		multiple	flat	riffle/pool	<12 w:d	active apparent	multiple	moderate	no	E	
L-Chi-1-C	glacial/fluvial terrace	VII	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	no	C	
L-Chi-2-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Chi-3-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Cot-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Cot-2-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	none apparent	single	slight	no	C	
L-Cot-3-E	alluvial fan	V	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Cow-1-B	glacial/fluvial terrace	III	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	B	
L-Cow-2-C	glacial/fluvial terrace	III	multiple	steep	step/pool	12-40 w:d	active apparent	multiple	slight	yes	C	
L-Cow-3-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	moderate	no	C	Tena and Cow Crk. confluence
L-Cow-4-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	moderate	no	C	Middle and Cow Crk. confluence

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
L-Cow-5-E	alluvial fan	VII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Cow-6-E	alluvial fan	VII	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	Little Cow and Cow Crk. confluence
L-Cow-7-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Coy-1-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Coy-2-C	glacial/fluvial terrace	II	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Dog-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Dog-2-C	glacial/fluvial terrace	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Dog-3-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Dog-4-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Dog-5-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Gre-S1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Gre-S2-B	glacial/fluvial terrace	II	multiple	steep	step/pool	12-40 w:d	active apparent	single	entrenched	yes	B	
L-Gre-N1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Gre-1-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lan-1-E	glacial/fluvial terrace	VIII	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Lan-2-E	glacial/fluvial terrace	VIII	none	flat	riffle/pool	<12 w:d	active apparent	single	moderate	yes	E	Sothman Crk. and Lance Crk. confluence
L-Lan-3-C	glacial/fluvial terrace	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	Middle Crk. and Lance Crk. confluence
L-Lan-4-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	yes	C	
L-Lan-5-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lan-6-G	alluvial fan	VII	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	G	Cherry and and Lance crk. confluence
L-Lan-7-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	C	
L-Lan-7-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	C	Rusty and Lance crk. confluence
L-Lan-8-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Lan-9-E	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	Little Lightning and Lance Crk. confluence
L-Lan-10-E	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Lan-11-E	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Lan-12-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	multiple	slight	no	E	
L-Lan-13-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	multiple	slight	no	E	
L-Lan-14-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Lan-15-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Lit-1-B	glacial/fluvial terrace	II	none	steep	step/pool	<12 w:d	none apparent	single	moderate	yes	B	
L-Lit-2-C	glacial/fluvial terrace	III	multiple	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Lit-3-C	glacial/fluvial terrace	III	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Lit-4-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lit-5-C	alluvial fan	VII	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lit-6-E	alluvial fan	VII	none	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	E	
L-Lit-1-B	glacial/fluvial terrace	III	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	B	
L-Lit-2-C	glacial/fluvial terrace	III	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lit-3-C	glacial/fluvial terrace	III	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lit-4-C	glacial/fluvial terrace	VII	multiple	steep	riffle/pool	12-40 w:d	active apparent	multiple	moderate	no	C	
L-Lit-5-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Lit-6-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Lit-7-E	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	E	
L-Mid-1-B	glacial/fluvial terrace	II	none	flat	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	B	
L-Mid-2-G	glacial/fluvial terrace	II	multiple	flat	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
L-Mid-3-G	glacial/fluvial terrace	II	multiple	flat	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
L-Mid-M1-B	glacial/fluvial terrace	III	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	B	
L-Mid-M2-G	glacial/fluvial terrace	III	multiple	steep	riffle/pool	<12 w:d	active apparent	multiple	slight	no	G	
L-Mid-M3-E	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	E	
L-Mid-M4-G	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	G	
L-Old-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Old-2-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Old-3-C	glacial/fluvial terrace	VII	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Old-4-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Old-5-F	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	F	

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
L-Old-6-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Old-7-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Old-8-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Rus-1-B	glacial/fluvial terrace	III	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	B	
L-Rus-2-G	alluvial fan	VII	none	flat	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
L-Rus-3-C	alluvial fan	IV	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	C	
L-Sag-1-A	glacial/fluvial terrace	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
L-Sag-2-C	glacial/fluvial terrace	II	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	yes	C	
L-Sag-3-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Sag-4-E	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Sag-5-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Sot-1-B	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	active apparent	single	entrenched	yes	B	
L-Sot-N1-D	glacial/fluvial terrace	IX	none	flat	riffle/pool	>40 w:d	active apparent	multiple	slight	no	D	
L-Sot-2-C	glacial/fluvial terrace	VII	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	North and South branches of Sothman confluence
L-Spr-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Spr-2-B	glacial/fluvial terrace	II	none	steep	riffle/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Spr-3-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
La-Spr-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
La-Spr-2-C	glacial/fluvial terrace	II	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
La-Spr-3-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
La-Spr-4-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Ten-1-B	glacial/fluvial terrace	III	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	B	
L-Ten-2-B	glacial/fluvial terrace	III	multiple	steep	step/pool	12-40 w:d	active apparent	single	entrenched	yes	B	
L-Ten-3-G	glacial/fluvial terrace	III	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	G	
L-Wya-N1-B	glacial/fluvial terrace	VIII	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Wya-N2-C	alluvial fan	VIII	multiple	flat	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
L-Wya-N3-C	glacial/fluvial terrace	VII	multiple	flat	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
L-Wya-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Wya-2-C	glacial/fluvial terrace	II	multiple	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	N. Frk. Wyatte Crk. and Wyatte Crk. confluence
L-Wya-3-G	glacial/fluvial terrace	IV	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	G	
L-Wya-4-F	glacial/fluvial terrace	II	none	steep	riffle/pool	12-40 w:d	none apparent	single	moderate	no	F	
L-You-1-B	glacial/fluvial terrace	II	multiple	steep	step/pool	12-40 w:d	active apparent	single	moderate	yes	B	
L-You-2-C	glacial/fluvial terrace	VII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-You-3-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	C	
L-You-4-F	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	F	
L-You-N1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-You-N2-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-You-N3-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	multiple	slight	no	C	
L-You-5-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Bob-1-G	glacial/fluvial terrace	II	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
L-Bob-2-E	glacial/fluvial terrace	II	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	yes	E	
L-Box-S1-Unid	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	active apparent	single	slight	yes	Unide	majority of channel in reach filled with sand, unidentifiable
L-Box-S2-C	glacial/fluvial terrace	II	multiple	flat	step/pool	12-40 w:d	active apparent	single	slight	yes	C	a portion of reach still filled with sand
L-Box-N1-E	glacial/fluvial terrace	II	none	flat	step/pool	<12 w:d	none apparent	single	moderate	yes	E	
L-Box-N2-Unidentified											Unide	reach lies within a mine, unidentifiable
L-Box-N3-C	glacial/fluvial terrace	II	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Box-1-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Box-2-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Box-3-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
Li-Cot-1-C	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	none apparent	single	slight	no	C	
Li-Cot-2-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
L-Dee-1-A	glacial/fluvial terrace	I	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
L-Dee-2-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	none apparent	single	slight	no	C	
L-Dry-1-G	glacial/fluvial terrace	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
L-Dry-2-B	glacial/fluvial terrace	II	multiple	steep	step/pool	12-40 w:d	active apparent	single	moderate	yes	B	

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
L-Dry-3-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Dry-4-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	multiple	moderate	no	C	
L-Dry-5-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	multiple	moderate	no	C	
L-Dry-6-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	slight	yes	E	
L-Eas-1-C	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	none apparent	single	moderate	yes	C	
L-Eas-2-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	yes	E	
L-Eas-1-F	alluvial fan	II	none	flat	step/pool	12-40 w:d	none apparent	single	slight	no	F	
L-Eas-2-C	alluvial fan	II	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Har-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Har-2-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Har-3-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	slight	yes	C	
L-Hor-1-E	glacial/fluvial terrace	II	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	yes	E	
L-Hor-2-B	glacial/fluvial terrace	II	multiple	steep	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	B	
L-Lig-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	entrenched	yes	B	
L-Lig-2-C	glacial/fluvial terrace	VII	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lig-3-C	alluvial fan	VII	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lig-4-E	alluvial fan	VII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Lig-5-C	alluvial fan	VII	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lig-6-C	alluvial fan	VII	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Lig-7-C	alluvial fan	VIII	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Lig-8-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Lig-9-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	slight	no	C	
L-Lig-10-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Lig-11-E	floodplain	VIII	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
Li-Lit-1-E	glacial/fluvial terrace	II	none	flat	riffle/pool	<12 w:d	none apparent	single	moderate	yes	E	
Li-Lit-2-E	glacial/fluvial terrace	II	none	flat	riffle/pool	<12 w:d	active apparent	single	moderate	no	E	
Li-Lit-3-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
Li-Lit-4-D	alluvial fan	VIII	multiple	flat	riffle/pool	>40 w:d	active apparent	multiple	slight	no	D	
L-Lit-1-G	glacial/fluvial terrace	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
L-Lit-2-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Pin-1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	active apparent	single	moderate	yes	B	
L-Pin-2-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Pin-3-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	slight	yes	E	
Li-Pin-1-E	glacial/fluvial terrace	II	none	flat	step/pool	<12 w:d	active apparent	single	slight	no	E	
Li-Pin-2-C	glacial/fluvial terrace	II	multiple	steep	step/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Rat-1-E	glacial/fluvial terrace	II	multiple	flat	riffle/pool	<12 w:d	active apparent	single	moderate	yes	E	
L-Rat-2-E	alluvial fan	V	multiple	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Spr-1-F	alluvial fan	II	none	flat	step/pool	12-40 w:d	active apparent	single	slight	no	F	
L-Sti-1-A	glacial/fluvial terrace	I	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
L-Sti-2-C	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Twe-1-B	glacial/fluvial terrace	I	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Twe-2-C	alluvial fan	V	multiple	flat	riffle/pool	12-40 w:d	active apparent	single	moderate	no	C	
L-Twe-3-E	alluvial fan	V	multiple	flat	step/pool	<12 w:d	active apparent	single	slight	no	E	
L-Wal-S1-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Wal-S2-F	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	active apparent	single	entrenched	no	F	
L-Wal-3-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Wal-4-F	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	active apparent	single	entrenched	no	F	
L-Wal-5-F	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	entrenched	no	F	
L-Wal-S1-B	glacial/fluvial terrace	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
L-Wal-S2-C	glacial/fluvial terrace	II	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	no	C	
L-Wal-S3-F	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	entrenched	yes	F	
L-Wal-6-F	floodplain	VIII	multiple	flat	step/pool	<12 w:d	active apparent	single	moderate	no	E	
L-Wes-1-C	glacial/fluvial terrace	II	none	flat	step/pool	12-40 w:d	active apparent	single	slight	yes	C	
L-Wes-2-E	glacial/fluvial terrace	II	none	flat	step/pool	<12 w:d	active apparent	single	slight	yes	E	
L-Wes-1-G	glacial/fluvial terrace	II	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
L-Wes-2-C	glacial/fluvial terrace	II	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Wes-3-Unidentified											Unide	reach filled with sediment, unable to view a chanel.
L-Wes-4-C	alluvial fan	V	none	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	
L-Wil-1-E	glacial/fluvial terrace	II	none	flat	riffle/pool	<12 w:d	active apparent	single	slight	no	E	
L-Wil-2-C	alluvial fan	V	none	flat	riffle/pool	12-40 w:d	active apparent	single	entrenched	yes	C	
L-Wil-3-C	alluvial fan	V	multiple	flat	step/pool	12-40 w:d	active apparent	single	moderate	yes	C	

Data Summary 2.1.8-3	**Channel Type Statistics by Watershed**

Watershed	Angostura Reservoir	
Channel Type	**Data**	**Total**
A	Sum of Percents	0.0%
	Sum of Count	0
B	Sum of Percents	11.1%
	Sum of Count	3
C	Sum of Percents	33.3%
	Sum of Count	9
D	Sum of Percents	3.7%
	Sum of Count	1
E	Sum of Percents	33.3%
	Sum of Count	9
F	Sum of Percents	0.0%
	Sum of Count	0
G	Sum of Percents	18.5%
	Sum of Count	5
NDC	Sum of Percents	0.0%
	Sum of Count	0
Total Sum of Percents		100.0%
Total Sum of Count		27

Watershed	Hat	
Channel Type	**Data**	**Total**
A	Sum of Percents	0.0%
	Sum of Count	0
B	Sum of Percents	30.8%
	Sum of Count	12
C	Sum of Percents	46.2%
	Sum of Count	18
D	Sum of Percents	0.0%
	Sum of Count	0
E	Sum of Percents	7.7%
	Sum of Count	3
F	Sum of Percents	5.1%
	Sum of Count	2
G	Sum of Percents	10.3%
	Sum of Count	4
NDC	Sum of Percents	0.0%
	Sum of Count	0
Total Sum of Percents		100.0%
Total Sum of Count		39

Watershed	Lance	
Channel Type	**Data**	**Total**
A	Sum of Percents	2.2%
	Sum of Count	3
B	Sum of Percents	21.7%
	Sum of Count	30
C	Sum of Percents	47.8%
	Sum of Count	66
D	Sum of Percents	1.4%
	Sum of Count	2
E	Sum of Percents	17.4%
	Sum of Count	24
F	Sum of Percents	2.9%
	Sum of Count	4
G	Sum of Percents	5.8%
	Sum of Count	8
NDC	Sum of Percents	0.7%
	Sum of Count	1
Total Sum of Percents		100.0%
Total Sum of Count		138

Watershed	Lightning	
Channel Type	**Data**	**Total**
A	Sum of Percents	2.6%
	Sum of Count	2
B	Sum of Percents	9.1%
	Sum of Count	7
C	Sum of Percents	44.2%
	Sum of Count	34
D	Sum of Percents	1.3%
	Sum of Count	1
E	Sum of Percents	26.0%
	Sum of Count	20
F	Sum of Percents	7.8%
	Sum of Count	6
G	Sum of Percents	5.2%
	Sum of Count	4
NDC	Sum of Percents	3.9%
	Sum of Count	3
Total Sum of Percents		100.0%
Total Sum of Count		77

Data Summary 2.2.3-1 Oil Fields

ID Number	Name
1	FIDDLER CREEK, FIDDLER CREEK EAST
2	HILIGHT,ROCKY HILL
3	QUEST
4	HAY CREEK
5	LONETREE CREEK
6	GEORGE RANCH
7	LONETREE CREEK
8	LONETREE CREEK
9	TODD
10	LODGEPOLE CREEK
11	LODGEPOLE CREEK
12	LODGEPOLE CREEK
13	HOUSE CREEK
14	MUSH CREEK WEST
15	CLARETON,CHEYENNE RIV.,HAMPSHIRE,BL. THU
16	HA CREEK
17	RW CREEK
18	RW CREEK
19	ROCKY HILL
20	THUNDER CREEK
21	UNNAMED
22	PORCUPINE
23	UNNAMED
24	LITTLE THUNDER
25	K-BAR
26	PAYNE
27	TUIT DRAW
28	PAYNE
29	PAYNE
30	TUIT DRAW
31	PORCUPINE
32	THUNDER CREEK
33	ROCHELLE
34	TUIT DRAW
35	PINE TREE
36	ARCHIBALD
37	WILDCAT CREEK
38	ARCHIBALD
39	TURNERCREST
40	TURNERCREST
41	SCHOOL CREEK
42	BUCK DRAW NORTH
43	KEYTON ROAD
44	TURNERCREST
45	SHERWIN, FROG CREEK
46	PORCUPINE
47	TURNERCREST
48	MONGOOSE
49	JIGGS THOMPSON
50	UNNAMED
51	JIGGS THOMPSON
52	BUCK DRAW
53	JIGGS THOMPSON
54	FENTON
55	POWELL
56	NINEMILE
57	FROG CREEK
58	SCHOOL CREEK
59	UNNAMED
60	GLASSER DRAW
61	FROG CREEK
62	PINE TREE
63	LOGAN DRAW
64	TAYLOR
65	CLARETON
66	MARY DRAW
67	GLASSER DRAW
68	CLARETON
69	DENNEL DRAW
70	BUCK DRAW
71	POWELL
72	PINE TREE
73	MARY DRAW
74	BUCK DRAW
75	JIGGS THOMPSON

ID Number	Name
76	SEEDY DRAW
77	GIBSON DRAW
78	MOORE
79	UNNAMED
80	UNNAMED
81	BOGGY CREEK
82	SNYDER CREEK
83	FINLEY DRAW
84	SHERWOOD
85	GIBSON DRAW
86	ROSS
87	MOORE
88	POISON DRAW
89	BOGGY CREEK
90	SUPPLY CREEK
91	SUPPLY CREEK
92	RAWLES
93	SPEARHEAD RANCH
94	SUPPLY CREEK
95	FINLEY DRAW
96	SPEARHEAD RANCH
97	SPEARHEAD RANCH
98	AVERY DRAW
99	MANNING
100	UNNAMED
101	OGALALLA HILLS
102	UNNAMED
103	SPEARHEAD RANCH
104	STEINLE RANCH
105	SPEARHEAD RANCH
106	UNNAMED
107	DILTS
108	SAND CREEK NORTH
109	DRY FORK
110	NUTCRACKER
111	POWELL
112	POWELL
113	POWELL
114	SNAKE CHARMER DRAW
115	BRUSH CREEK
116	ALLEMAND
117	BRUSH CREEK
118	HORNBUCKLE
119	POWELL
120	BEAR CREEK
121	HORNBUCKLE
122	PHILLIPS CREEK
123	SPEARHEAD RANCH
124	SPEARHEAD RANCH
125	ORMSBY ROAD
126	PHILLIPS CREEK
127	SPEARHEAD RANCH
128	COLE NORTHEAST
129	HORNBUCKLE
130	HARVEY DRAW, SCOTT DRAW, SCOTT
131	SAND DUNES
132	COLE NORTHEAST
133	MARTIN SPRING
134	BLUE HILL
135	BLUE HILL
136	BLIZZARD
137	DERRICK DRAW

Data Summary 3.3.1-1 Monthly Flow at Lance Creek near Riverview, Wyoming, in Acre-feet

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1970	6	17	24	87	76	158	334	179	1,660	344	473	3	3,361
1971	0	1	0	0	0	2	4,660	34,320	13,160	1,350	17	1	53,510
1972	10	29	28	2	1,280	509	120	322	2,900	87	340	75	5,702
1973	6	11	1	0	1	48	1,950	5,990	239	7,680	601	7,040	23,567
1974	477	462	130	3,760	545	381	1,160	365	40	193	17	0	7,530
1975	0	14	5	0	0	191	484	168	1,710	8	324	0	2,904
1976	0	0	4	0	380	103	12	619	2,680	343	1,190	0	5,331
1977	11	17	29	2	15	39	12	20	5	47	945	677	1,819
1978	384	10	14	0	7	9,080	577	35,320	2,550	10,970	4,030	272	63,214
1979	130	233	79	7	5	3,120	1,000	548	1,110	4,960	11,210	601	23,004
1980	134	245	274	177	8,050	1,920	714	178	165	563	5,070	117	17,607
1981	206	110	173	180	320	73	65	612	2,020	11,330	2,160	54	17,303
1982	310	148	135	5	498	557	190	894	9,520	5,420	2,510	1,270	21,457
1983	259	327	314	634	1,500	1,370	1,860	1,960	1,830	307	1,380	7	11,748
1984	176	148	110	443	1,156	1,601	1,198	7,434	3,611	3,977	2,761	923	23,540
1985	35	30	22	89	232	322	241	1,495	726	800	555	186	4,733
1986	173	146	108	435	1,136	1,573	1,178	7,306	3,549	3,909	2,713	907	23,134
1987	153	128	96	384	1,003	1,388	1,039	6,446	3,132	3,449	2,394	800	20,413
1988	26	22	16	65	171	237	177	1,099	534	588	408	136	3,481
1989	45	38	28	113	296	410	307	1,904	925	1,019	707	236	6,028
1990	58	49	37	147	383	531	397	2,464	1,197	1,318	915	306	7,801
1991	310	260	194	778	2,032	2,814	2,106	13,065	6,347	6,990	4,852	1,622	41,370
1992	28	23	17	69	181	251	188	1,165	566	623	433	145	3,689
1993	162	136	101	406	1,061	1,469	1,100	6,821	3,314	3,650	2,533	847	21,600
1994	110	93	69	277	724	1,002	750	4,653	2,260	2,489	1,728	578	14,734
1995	105	88	66	264	690	956	715	4,437	2,155	2,374	1,648	551	14,050
1996	125	105	78	314	821	1,137	851	5,279	2,564	2,824	1,960	655	16,715
1997	164	138	103	412	1,076	1,490	1,116	6,920	3,362	3,702	2,570	859	21,913
1998	130	109	81	326	853	1,180	884	5,481	2,662	2,932	2,035	680	17,355
1999	246	206	154	617	1,611	2,230	1,669	10,355	5,031	5,540	3,846	1,286	32,791
2000	78	65	49	196	511	708	530	3,287	1,597	1,759	1,221	408	10,409
2001	98	83	61	247	646	895	670	4,155	2,019	2,223	1,543	516	13,158
2002	27	23	17	68	178	246	184	1,142	555	611	424	142	3,616
2003	77	65	48	193	505	700	524	3,249	1,578	1,738	1,207	403	10,288
2004	21	18	13	53	139	193	144	895	435	479	333	111	2,835
2005	34	28	21	84	221	305	229	1,418	689	759	527	176	4,491
2006	19	16	12	49	128	177	133	822	399	440	305	102	2,603
2007	21	18	13	53	138	191	143	887	431	474	329	110	2,808
2008	111	94	70	279	731	1,012	757	4,698	2,282	2,513	1,745	583	14,876
2009	55	46	34	138	362	501	375	2,325	1,129	1,244	863	289	7,362
2010	112	94	70	281	736	1,019	763	4,730	2,298	2,531	1,757	587	14,979
Monthly distribution	0.75%	0.63%	0.47%	1.88%	4.91%	6.80%	5.09%	31.58%	15.34%	16.90%	11.73%	3.92%	

Notes: USGS published monthly values are indicated by regular type. Synthetic data from annual regression is indicated by italicized type.
Monthly distribution was ased on average monthly distribution from the raw data.

Gaged data from Table in Appendix D of Northeast Wyoming River Basins Surface Water Hydrology Memo
Synthetic data from Table in Appendix D of Northeast Wyoming River Basins Surface Water Hydrology Memo
Synthetic data calculated for this study

Data Summary 3.3.2-1. Dams within the Study Area Included in the National Inventory of Dams

NID ID	StateID	Dam Name	River	Height (feet)	Storage (acre-ft)	Year Completed	Owner	Longitude	Latitude	Section	County
WY00531	6927R	AMELIA #1	ALUM CREEK	29	125	1961	MARK L. THOMPSON	-104.3097	43.1625	SWSE 21,T37N,R62W	NIOBRARA
WY00812	6592R	BAD LAND NO. 1	BAD LAND DRAW	18	194	1962	JOHN E. DEGERING	-104.3444	43.0841	SENE 19,T36N,R62W	NIOBRARA
WY00744	6804R	BAD LAND NO. 2	BAD LAND DRAW	24	552	1965	JOHN E. DEGERING	-104.3392	43.0791	NWSW 20,T36N,R62W	NIOBRARA
WY00862	6431R	BAST NO. 1 STOCK	CANYON CREEK DRAW	29	49	1968	REESE LTD. PARTNERSHIP (CHARLES REESE)	-104.5778	42.9494	NWSW 5,T34N,R64W	NIOBRARA
WY01078	7053R	BEARDSLEY NO. 1	NATURAL BRIDGE DRAW	27	47	1962	STANLEY & CLAUDIA SWANSON	-104.5367	43.3108	NWSW 34,T39N,R64W	NIOBRARA
WY00419	7201R	BLISS NO. 1	BILLS CREEK	33	428	1970	ARTHUR JOSS	-104.7286	42.8458	SESW 12,T33N,R66W	NIOBRARA
WY01566	1825R	BRADLEY	BRADLEY GULCH	31	644	1914	ROBERT SIDES ET UX	-104.7303	43.0419	NWNW 1,T35N,R66W	NIOBRARA
WY00722	5541R	BUCK PASTURE	MIDDLE FK WALKER CR	20	193	1943	GEORGENNE LEBAR	-105.1897	42.9225	SENW 18,T34N,R69W	CONVERSE
WY00741	6456R	CARRICO NO. 1	CARRICO DRAW	27	45	1959	KAREN KAY SIDES	-104.5564	42.9583	NWNW 4,T34N,R64W	NIOBRARA
WY02087	6377R	CHERRY NO. 1	CHERRY DRAW	27	82	1958	J. P. WERNER & SONS	-105.1583	43.0700	SENE 29,T36N,R69W	CONVERSE
WY00517	6342R	CLARK NO. 1	CLARK DRAW	27	77	1956	JACK PFISTER RANCH, INC.	-104.2644	43.2208	SESE 35,T38N,R62W	NIOBRARA
WY00743	6476R	CLARK NO. 1	ALUM CREEK	25	496	1959	CLARK LAND COMPANY, LLC	-104.2833	43.1383	NESE 34,T37N,R62W	NIOBRARA
WY00731	5875R	DOGIE NO. 3	DOGIE CREEK	30	342	1952	CLYDE PETERSON	-104.5889	43.2750	NENW 18,T38N,R64W	NIOBRARA
WY00767	5990R	DOLORES NO. 1	DOLORES DRAW	27	107	1953	RICHARD E. TOLLMAN, ET UX	-104.0725	42.9355	SWSE 9,T34N,R60W	NIOBRARA
WY00826	6860R	DRY CREEK NO. 1	DRY CREEK	31	348	1967	BONER BROS. PARTNERSHIP	-105.4317	43.1358	NESW 31,T37N,R71W	CONVERSE
WY00742	6473R	EAST NO. 1 BEARDSLEY	GREASEWOOD DRAW	35	58	1959	STANLEY SWANSON	-104.5114	43.3194	NENW 35,T39N,R64W	NIOBRARA
WY00467	6038R	FIELDS	COTTONWOOD DRAW	25	161	1953	JOHNSON RANCHES	-104.3678	42.9350	NWSE 12,T34N,R63W	NIOBRARA
WY00584	5774R	GEIGER	CHAPMAN DRAW	32	544	1952	SAM/VIVIAN RENNARD LIVING TRUST	-104.1619	43.3339	NWNW 26,T39N,R61W	NIOBRARA
WY00755	6164R	GRISWOLD #1	GRISWOLD DRAW	25	133	1954	DOUBLE 8 LAND CORPORATION	-104.1569	43.2127	NESW 2,T37N,R61W	NIOBRARA
WY01687	7213R	HELEN	LITTLE LTNG. CREEK,TRIB LANCE	22	83	1966	ROBINSON RANCH CO.	-105.2642	42.9622	NWSE 33,T35N,R70W	CONVERSE
WY00724	5575R	HERRICK	TWENTY MILE CREEK	30	146	1946	DICKAU BROTHERS	-105.0739	42.9355	NWSW 7,T34N,R68W	CONVERSE
WY00435	7254R	JAMES THOMPSON NO. 1 STOCK	THOMPSON EAST DRAW	30	109	1960	SHANNON BRUEGGER, RANCHLAND INC.	-104.7017	43.2800	SESE 7,T38N,R65W	NIOBRARA
WY00528	5539R	JOHNSON #3	SWEDE DRAW	22	161	1944	ROY JOHNSON & STATE BOARD OF LAND COMM.	-104.4842	43.1413	SENE 36,T37N,R64W	NIOBRARA
WY00933	2478R	JOHNSON NO. 1	HANCOCK DRAW	30	333	1916	CROSS A RANCH	-104.4783	43.2350	NESE 25,T38N,R64W	NIOBRARA
WY02238	5928R	JOLLY NO. 1	JOLLY DRAW	25	60	1952	KEN & TOM DIXON	-104.6933	43.3161	SWNW 32,T39N,R65W	NIOBRARA
WY00729	5966R	JORDAN	JORDAN DRAW	26	307	1952	NINE-0 CATTLE COMPANY	-104.0858	42.9841	SENW 28,T35N,R60W	NIOBRARA
WY00968	2092R	JOSS	LANCE CREEK	24	538	1918	ARTHUR JOSS	-104.7331	42.8933	NESW 25,T34N,R66W	NIOBRARA
WY00770	6449R	KEEL STOCK	E DEUEL CREEK	30	31	1958	RON & ALICE A. CARTER	-104.0794	42.9044	SESW 21,T34N,R60W	NIOBRARA
WY00747	6803R	LANCE CREEK NO. 1	LANCE CREEK	26	195	1965	ARTHUR JOSS	-104.7625	42.8363	SWNE 15,T33N,R66W	NIOBRARA
WY00418	7182R	LANCE CREEK NO. 2	LANCE CREEK	20	171	1966	ARTHUR JOSS	-104.7475	42.8552	NENW 11,T33N,R66W	NIOBRARA
WY02239	6527R	LEACH NO. 1 STOCK	LEACH CREEK	30	73	1961	MONTE FINLEY	-104.5806	43.0761	NENE 30,T36N,R64W	NIOBRARA
WY01738	7876R	LEONARD DEGERING	DEGERING DRAW, OLD WOMAN CREEK	21	303	1979	KENNY L. DEGERING	-104.3114	43.0850	SENW 21,T36N,R62W	NIOBRARA
WY01743	7431R	LONGELEY	LONGELY DRAW	22	88	1972	DOUBLE 8 LAND CORPORATION	-104.1719	43.2722	SWNE 15,T38N,R61W	NIOBRARA
WY00615	6229R	MAGOON NO. 1	YOUNG WOMAN CREEK	25	593	1959	KAREN KAY SIDES	-104.5517	42.9333	NESW 9,T34N,R64W	NIOBRARA
WY00600	6632R	MIDDLE NO. 1	MIDDLE COW CREEK	17	246	1962	TILLARD "55" LTD. PARTNERSHIP	-104.9272	43.2805	NWSE 8,T38N,R67W	CONVERSE
WY01769	7615R	MOSIER NO. 1	LITTLE BOGGY CREEK	26	60	1974	HAROLD MILLER	-104.6628	42.9761	SWSE 28,T35N,R65W	NIOBRARA
WY00822	6854R	MULE CREEK NO. 1	EAST MULE CREEK	30	415	1962	DOUBLE 8 LAND CORP.	-104.1425	43.2683	NWSW 13,T38N,R61W	NIOBRARA
WY00819	6649R	PADDY NO. 1	PADDY DRAW	29	87	1963	JAMES E. WERNER - ATT: BARBARA WERNER	-104.5058	43.1750	NWNE 23,T37N,R64W	NIOBRARA
WY00831	6650R	PADDY NO. 2	S PADDY DRAW	30	84	1963	JAMES E. WERNER - ATT: BARBARA WERNER	-104.5067	43.1638	SWSE 23,T37N,R64W	NIOBRARA
WY00736	5854R	PFISTER NO. 2	OAT CREEK	22	209	1952	RONDA PFISTER	-104.1372	43.0730	SENW 25,T36N,R61W	NIOBRARA
WY00437	7202R	PHIL NO. 1	PHIL DRAW	36	83	1966	JOSS RANCHES, INC.	-104.8642	43.0855	SWNE 23,T36N,R67W	NIOBRARA
WY00813	6570R	PROVOST NO. 2	TEXACO DRAW	23	199	1962	JAMES KREMERS	-104.5692	43.0480	SESW 32,T36N,R64W	NIOBRARA
WY00519	6319R	RAT NO. 1	WEST FORK RAT CREEK	21	191	1956	REED LIVESTOCK CO. (EARL REED)	-105.1067	43.2658	SESW 14,T38N,R69W	CONVERSE
WY00824	-	RENOT NO. 1	RENOT DRAW	34	63	1964	ARTHUR JOSS	-104.9056	43.0677	NESW 28,T36N,R67W	CONVERSE
WY00581	5844R	RUMNEY NO. 2	SCOBY DRAW	29	320	1950	USDI BLM	-104.2939	43.3294	SENW 27,T39N,R62W	NIOBRARA
WY00737	5944R	RUMNEY NO. 3	SCOBY DRAW	31	180	1951	USDI BLM	-104.2719	43.3178	NWNE 35,T39N,R62W	NIOBRARA
WY00529	5949R	SIDES NO. 1	SIDES DRAW	30	234	1952	WERNER RANCH (J. P. WERNER)	-104.6331	43.2086	NWSW 2,T37N,R65W	NIOBRARA
WY00612	6286R	SLATES #1	SLATES DRAW	27	77	1956	J. P. WERNER & SONS	-105.1317	43.0691	SENW 27,T36N,R69W	CONVERSE
WY00621	5040R	STOCKWATER	CHRISTIAN DRAW	24	163	1939	J. RUSSEL THOMPSON ET UX	-104.1642	43.0016	NWNW 23,T35N,R61W	NIOBRARA
WY00715	6443R	STORY NO. 1	DEGEARING DRAW	22	373	1961	JOHN E. DEGERING	-104.3428	43.0897	SESE 18,T36N,R62W	NIOBRARA
WY00745	5991R	SWOPE NO. 2	SHIRRAL DRAW	26	114	1953	RICHARD TOLLMAN & (STATE OF WYO.)	-104.0783	42.9319	NENW 16,T34N,R60W	NIOBRARA
WY00798	5731R	THOMPSON	CODY DRAW	37	173	1950	JRT & MJT THOMPSON TRUSTS	-104.1764	42.9955	SENW 22,T35N,R61W	NIOBRARA
WY00420	7177R	TURNER NO. 1	TURNER DRAW	19	339	1969	MELVIN THAYER	-104.1100	42.9675	NWSE 31,T35N,R60W	NIOBRARA
WY00430	7437R	WALKER	ZIMMERMAN DRAW	21	103	1972	LOREN R. WALKER	-104.4186	43.3041	NWNW 3,T38N,R63W	NIOBRARA
WY00948	6358R	WALLACE NO. 2	N BRUSH CRK, TRIB. BRUSH CREEK	20	280	1958	EDGAR BONNER	-104.1917	43.0744	NWNE 28,T36N,R61W	NIOBRARA
WY00827	5061R	WATER STORAGE	LANCE CREEK	30	51	1939	BUCK CREEK OIL COMPANY	-104.6442	43.0547	SWNE 34,T36N,R65W	NIOBRARA
WY00794	5749R	WERNER	LIGHTNING CREEK	22	570	1950	J. P. WERNER & SONS, INC.	-105.1394	43.0716	NENE 28,T36N,R69W	CONVERSE
WY01957	8618R	WERNER RANCH SITE	WERNER DRAW	18	113	1982	J. P. WERNER & SONS, INC.	-105.2617	43.0727	NWNE 28,T36N,R70W	CONVERSE
WY00730	5972R	WILDCAT NO. 1	WILDCAT DRAW	40	327	1953	JOHN KINCHEN TRUST	-104.6283	43.1336	SESW 35,T37N,R65W	NIOBRARA
WY00605	6177R	WILDCAT NO. 2	SOUTH FORK WILDCAT	35	317	1955	JOHN KINCHEN	-104.6447	43.1128	SWNE 10,T36N,R65W	NIOBRARA
WY00740	7144R	WILDCAT NO. 3	SOUTH FORK WILDCAT DRAW	35	176	1959	JOHN KINCHEN TRUST	-104.6278	43.1261	SENW 2,T36N,R65W	NIOBRARA
WY00814	6566R	WILLIAMS	KREJCI DRAW	27	120	1960	WILLIAM E. GREER ET UX TRUSTEES	-104.6014	43.1661	SESE 24,T37N,R65W	NIOBRARA

Data Summary 3.4.3-1. Water Quality Standards for Irrigation and Animal Watering

Constituent	Units	Agriculture			Livesock and Wildlife Watering		
		WDEQ (2007)	Ayres and Westcot (1994)	Bauder, et al. (2006)	WDEQ (2007)	Ayres and Westcot (1994)	Raisbeck, et al. (2007)
Aluminum	µg/L	5000	5000	--	5000	5000	--
Arsenic	µg/L	100	100	--	200	200	1000
Beryllium	µg/L	100	100	--	--	100	--
Boron	µg/L	750	--	4100-6000[2]	5000	5000	--
Cadmium	µg/L	10	10	--	50	50	--
Chloride	mg/L	100	--	141-350[3]	2000	--	--
Chromium	µg/L	100	100	--	50	1000	--
Cobalt	µg/L	50	50	--	--	1000	--
Copper	µg/L	200	200	--	500	500	--
Flouride	µg/L	--	1000	--	--	2000	2000
Iron	µg/L	5000	5000	--	--	--	--
Lead	µg/L	5000	5000	--	100	100	--
Lithium	µg/L	2500	2500	--	--	--	--
Magnesium	mg/L	--	--	--	--	250-500	--
Manganese	µg/L	200	200	--	--	50	--
Mercury	µg/L	--	--	--	0.05	10	--
Molybdenum	µg/L	--	10	--	--	10	300
Nickel	µg/L	200	200	--	--	200	--
Nitrate (NO3-N)	mg/L	--	--	--	10	--	500
Nitrite (NO2-N)	mg/L	--	--	--	100	--	100
(NO3+NO2)-N	mg/L	--	5-30[1]	--	10	100	--
Selenium	µg/L	20	20	--	50	50	100
Sulfate	mg/L	200	--	--	3000	--	1800 - acute 1000 - chronic
Vanadium	µg/L	100	100	--	100	100	--
Zinc	µg/L	2000	2000	--	25000	24000	--
Oil and Grease	mg/L	10	--	--	10	--	--
Radium 226 and 228	pCi/L	5	--		5	--	
Total Strontium 90	pCi/L	8	--	--	8	--	--
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium)	pCi/L	15	--	--	15	--	--
TDS	mg/L	2000	450-2000[1]	--	5000	--	--
pH	Standard units	4.5-9.0	--	--	6.5-8.5	--	--
Residual Sodium Carbonate (RSC)	meq/L	1.25	--	--	--	--	--
SAR	n/a	8	--	9	--	--	--
Specific Conductance	µS/cm	--	2000	760-2000[4]	--	5000-8000	--

[1] Range of slight to moderate use restriction; i.e., no use restrictions on lower values, severe use restrictions higher values
[2] Alfalfa tolerance range
[3] Range that causes injury for moderately tolerant plants; concentrations in the range of 351-700 mg/L causes foliar damage to alfalfa
[4] Leaching is required to mitigate potential accumulation in soil

Data Summary 3.4.3-2 Surface Water Suitability for Irrigation and Animal Watering Based on Comparison of USGS Water Quality Samples to Standards

			USGS Gage Identification												
Constituent	USGS Code[1]	Units	6386000	4303281-05281501	4303311-05282701	4303551-05291101	4304331-05234301	4304351-05233700	4304521-04372801	4306091-05163901	4307181-05002301	4312301-04360401	4313461-04372201	4314001-04372500	4315121-04232001
Aluminum	1106	µg/L	0-40				70								
Aluminum	1105 UF	µg/L	0-150000				200								
Arsenic	1000	µg/L	0-2				2								
Arsenic	1002 UF	µg/L	<1-45				2								
Beryllium	1010	µg/L	0-10												
Beryllium	1012 UF	µg/L	0-10												
Boron	1020	µg/L	40-310				60	80						80	190-230
Cadmium	1025	µg/L	0				M								
Cadmium	1027 UF	µg/L	0				0								
Chloride	940	mg/L	5-190			230	8.5-9.9	11						14	65-140
Chromium	1030	µg/L	0-10				0								
Chromium	1034 UF	µg/L	0-180				0								
Cobalt	1035	µg/L					<3								
Cobalt	1037 UF	µg/L					M								
Copper	1040	µg/L	<2-20				M								
Copper	1042 UF	µg/L	0-330				M								
Flouride	950	µg/L	0.2-0.9			0.2	0.1-0.3	0.3						0.5	0.7-0.8
Iron	1046	µg/L	10-1700			320	10-20	30						20	20-70
Iron	1045 UF	µg/L	90-190000				550								
Lead	1049	µg/L	0-M				0								
Lead	1051 UF	µg/L	0-200				M								
Lithium	1130	µg/L	50-130												
Lithium	1132 UF	µg/L	50-310												
Magnesium	925	mg/L	11-150			210	34-35	33						74	66-85
Manganese	1056	µg/L	100-620			400	60-150								
Manganese	1055 UF	µg/L	100-4100				80								
Mercury	71890	µg/L	0-<0.5				0								
Mercury	71900 UF	µg/L	0-0.5				0								
Molybdenum	1060	µg/L	0-4												
Molybdenum	1062 UF	µg/L	1-76												
Nickel	1065	µg/L	M				M								
Nickel	1067 UF	µg/L	0-200				M								
Nitrate (NO3-N)	618	mg/L	0.02												
Nitrate (NO3-N)	71851	mg/L	0.1												
Nitrite (NO2-N)	613	mg/L													
Nitrite (NO2-N)	71856	mg/L													
(NO3+NO2)-N	602	mg/L	0.36				0.39	0.24						0.59	
(NO3+NO2)-N	600 UF	mg/L	0.36-21				0.29	0.51						0.79	0.6-1
Selenium	1145	µg/L	0-1			17	0								
Selenium	1147 UF	µg/L	0-10				0								
Sulfate	945	mg/L	150-3000			2100	360-370	340						830	1200-1400
Vanadium	1085	µg/L	0-3												
Zinc	1090	µg/L	<20-80				10								
Zinc	1092 UF	µg/L	10-1100				20								
Oil and Grease		mg/L													
Radium 226 and 228	9511	pCi/L	0.1-0.62	11	2.1	0.5	0.19								
Total Strontium 90		pCi/L													
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium)		pCi/L													
TDS	70301	mg/L	297-4680			3800	742-817	793						1430	2100-2540
pH	400	Standard units	6.7-8.3				7.5-8.4	8.2		9.1				7.8	7.3-8.3
Residual Sodium Carbonate (RSC)		meq/L													
SAR	931	n/a[2]	4.9-8.4			1.8	2.6-2.9	3.3						3.5	6.4-7.9
Specific Conductance	95	µS/cm	540-7500			4800	850-1600	1190	4200	3300-5800	1400	4100	3200	1900	2800-3600

Notes:

[1]UF = unfiltered sample
[2]n/a = not available
M = Detected but not measured
Gages listed in Data Summary 2.1.7-2

Blank cells indicate no results were available
Values in red indicate exceedance of one or more criteria in Data Summary 3.4.3-1
Values in blue indicate potential exceedance of one or more criteria in Data Summary 3.4.3-1

Data Summary 3.4.3-3 Surface Water Suitability for Irrigation and Animal Watering Based on Comparison of Niobrara Conservation District Water Quality Samples to Standards

Constituent	Units	Lance Creek	Lightning Creek	Old Woman Creek
Temperature	°C	0.7-30	1.1-29	0.5-30.9
Specific Conductance	uS	391-4900	228-4910	479-2173
Dissolved Oxygen[1]	mg/L	3.2-15.6	3.9-18.5	5.0-13.4
pH		6.6-8.8	6.7-8.7	6.9-8.3
Discharge	cfs	0.01-53	0-109	0.009-9.2
Turbidity	NTU	1-2609	3-2066	3-157
Total Suspended Solids	mg/L	2-10900	9-10400	2-124
Suspended Sediment Concentration	mg/L	6-66500	9-101000	240
Total Disolved Solids	mg/L	370-3930	350-2580	472-636
Hardness	mg/L	124-1120	141-857	58-250
Total Phosphorous[2]	mg/L	0.03-2.1	ND-2	ND-0.2
Nitrates	mg/L	0.05-1	ND-1	ND
Ammonia	mg/L	0.1-0.2	ND-0.2	<.1
Alkalinity	mg/L	74-427	57-327	268-662
Chlorides	mg/L	2.3-135	2-26	10-46
Sulfates	mg/L	114-2500	100-1690	15-210
Calcium	mg/L	33-264	33-156	19-75
Magnesium	mg/L	10-127	14-92	3-10
Sodium	mg/L	29-926	23-601	116-265
Sodium Absorption Ratio (SAR)		0.8-12.1	0.7-9.9	2.2-8.7
Bicarbonates	mg/L	90-515	1.4-396	337-586
Carbonate	mg/L	5-16	ND-18	6.3
Cation/Anion Balance[3]		-3.2-39	0-26	-4.9-3.6

Values in red indicate exceedance of one or more criteria in Data Summary 3.4.3-1

[1]Standard is for greater than 5.0

[2]State guideline is for <1 mg/L

[3]State guideline is for ±5%

Data Summary 4.2.2-1. Normal Year Hydrologic Conditions Available Flow for Potential Account III Dams

NE WY River Basins Model Reach	Potential Dam Site	Drainage Area, sq mi	Available Water, Normal Years Hydrologic Conditions in acre-feet (AF)													
			Annual	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Sum of Monthly Flows
Reach 23	Lance Creek, acre-feet	2,097	18,323	332	498	186	756	8,465	3,984	1,480	405	2,363	26	51	22	18,568
	Lance Creek, acre-ft per square mile		8.74	0.16	0.24	0.09	0.36	4.04	1.90	0.71	0.19	1.13	0.01	0.02	0.01	8.86
	Lightning 1 potential dam, acre-feet	719	6,284	114	171	64	259	2,903	1,366	508	139	810	9	17	8	6,368
	Lightning 1 potential dam, inches			0.0030	0.0045	0.0017	0.0068	0.0757	0.0356	0.0132	0.0036	0.0211	0.0002	0.0005	0.0002	
Reach 23	Lance Creek, acre-feet	2,097	18,323	332	498	186	756	8,465	3,984	1,480	405	2,363	26	51	22	18,568
	Lance Creek, acre-ft per square mile		8.74	0.16	0.24	0.09	0.36	4.04	1.90	0.71	0.19	1.13	0.01	0.02	0.01	8.86
	Lightning 2 potential dam, acre-feet	977	8,534	155	232	87	352	3,943	1,856	689	189	1,101	12	24	10	8,649
	Lightning 2 potential dam, inches			0.0030	0.0045	0.0017	0.0068	0.0757	0.0356	0.0132	0.0036	0.0211	0.0002	0.0005	0.0002	
Reach 23	Lance Creek, acre-feet	2,097	18,323	332	498	186	756	8,465	3,984	1,480	405	2,363	26	51	22	18,568
	Lance Creek, acre-ft per square mile		8.74	0.16	0.24	0.09	0.36	4.04	1.90	0.71	0.19	1.13	0.01	0.02	0.01	8.86
	Lightning and Tribs potential dam, acre-feet	721	6,300	114	171	64	260	2,911	1,370	509	139	813	9	18	8	6,385
	Lightning and Tribs potential dam, inches			0.0030	0.0045	0.0017	0.0068	0.0757	0.0356	0.0132	0.0036	0.0211	0.0002	0.0005	0.0002	
Reach 23	Lance Creek, acre-feet	2,097	18,323	332	498	186	756	8,465	3,984	1,480	405	2,363	26	51	22	18,568
	Lance Creek, acre-ft per square mile		8.74	0.16	0.24	0.09	0.36	4.04	1.90	0.71	0.19	1.13	0.01	0.02	0.01	8.86
	Old Woman Creek, acre-feet	376	3,285	60	89	33	136	1,518	714	265	73	424	5	9	4	3,329
	Old Woman Creek potential dam, inches			0.0030	0.0045	0.0017	0.0068	0.0757	0.0356	0.0132	0.0036	0.0211	0.0002	0.0005	0.0002	

Data Summary 4.2.2-2. Alternative Surface Water Storage Sites

Potential Dam Sites	Lightning Creek 1	Lightning Creek 2	Lightning Creek and Tributaries	Old Woman Creek
Local Information				
USGS 7.5-minute Topographic Quadrangle	Mercer Draw/Split Hill	Lance Creek NW	Funny Rock	Brown Flat
County	Converse/Niobrara	Niobrara	Niobrara	Niobrara
Township, Range, Section	37N, 67W, 26	37N, 66W, 12	38N, 65W, 24&25	38N, 62W, 6
Basin Characteristics and Hydrology				
Drainage Area (mi^2)	719	977	721	376
Onstream / Offstream	Onstream	Onstream	Onstream	Onstream
Main Source	Lightning Creek	Lightning Creek	Lightning Creek, Lance Creek	Old Woman Creek
Secondary Source	Walker Creek	Twentymile Creek	Cow Creek	---
Estimated PMF Flood Characteristics				
Estimated Peak Discharge (cfs)	153,292	176,905	153,467	121,833
Estimated Runoff Volume (ac-ft)	361,520	507,512	362,606	167,017
Annual Peak Flow Characteristics				
Region	Eastern Basins/Plains	Eastern Basins/Plains	Eastern Basins/Plains	Eastern Basins/Plains
Average Annual Precipitation (in)	14.0	14.0	14.0	14.0
Reservoir Characteristics and Operation				
Normal High Water				
Capacity (ac-ft)	17603	23536	17670	9557
Irrigation Storage (ac-ft)	1622	3588	5176	3482
Surface Area (ac)	1006	1262	1062	621
Water Surface Elevation	4296.00	4170.00	4027.00	3817.00
Average Water Depth (ft)	18	19	17	15
Reservoir Life (years)	57	57	57	57
Site Geology				
Geology				
Klinker				
Landslide Deposits				
Bedrock Geology Units	Qa, Tft	Qa, Kl	Kl, Qa	Qa, Kl
Surficial Geology Units	at, rsRa	ar, rRs	at	at, srae
Site Environmental Conditions				
Environmental Issues				
NWI Wetlands (ac)	14.4	83.2	41.6	0.0
Irrigated Lands (ac)	34	100	6	0
Sage Grouse Leks				
Big Game Habitat - Crucial				
Raptor Nesting Area	0	1	4	0
Mineral Resources				
Coal Potential				
Uranium				
Other Metals				
Infrastructure and Ownership				
Infrastructure/Utilities Conflicts				
Residences/Facilities	0	0	0	0
Highways (mi)	0.1	0	0	0
Railroads (mi)	0	0	0	0
Pipelines (mi)	0.003	0	0	0
Power Lines (mi)	1.1	0	0	0
Energy Resources				
Oil Field				
Gas Field				
Land Ownership				
Private	X	X	X	X
State		X	X	
Federal		X		
Dam Characteristics and Hydraulic Structures				
Dam				
Freeboard/Head Spillway (ft)	11.05	11.60	9.85	9.85
Crest Elevation (ft)	4307.05	4181.60	4036.85	3826.85
Total Crest Length (ft)	2,850	3,680	4,390	2,880
Crest Width (ft)	14	14	0	0
Maximum Dam Height (ft)	58	67	51	51
Foundation Excavation Volume (1000 cy)	269	635	370	336
Total Earthwork Fill Volume (1000 cy)	1,343	3,174	1,848	1,679
Storage Efficiency (ac-ft/1000 cy)	13.1	7.4	9.6	5.7
Height Efficiency (ft/1000 ac-ft)	3.3	2.8	2.9	5.4
Outlet Works				
Proposed Type	Conduit	Conduit	Conduit	Conduit
Outlet Elevation	4248.60	4115.04	3985.37	3775.52
Principle Spillway				
Proposed Type	Concrete Chute	Concrete Chute	Concrete Chute	Concrete Chute
Crest Elevation (ft)	4296.00	4170.00	4027.00	3817.00
Design Capacity (cfs)	48,080	62,704	41,290	30,033
Approximate Width (ft)	422	512	456	340
Approximate Length (ft)	150	174	132	131
Emergency Spillway				
Crest Elevation (ft)	4302.85	4176.85	4033.85	3823.85
Design Capacity (cfs)	28,566	25,748	35,444	30,883
Approximate Width (ft)	230	300	340	270
Approximate Length (ft)	1,808	2,060	1,616	1,611
Cut Volume (1000 cy)	32	54	31	24
Supply and Delivery Facilities				
Delivery Canals				
Length				
Terrain				
Other				
Access				
Costing				
Total Project Cost	$26,300,000	$60,000,000	$35,200,000	$31,000,000
Total Project Cost per cy of Fill	$19.58	$18.90	$19.05	$18.46
Annual Project Cost per ac-ft of Irrigation Storage	$284.47	$293.38	$119.31	$156.19

Excellent or more than adequate
Favorable or adequate
Marginal or unfavorable value
Probable fatal flaw or very unfavorable value

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Angostura	40	60	31	81,119	1.86	5	405,596	9.3
Angostura	40	60	30	11,181	0.26	5	55,906	1.3
Angostura	40	60	29	16,321	0.37	5	81,603	1.9
Angostura	39	62	24	31,155	0.72	5	155,775	3.6
Angostura	39	62	24	5,561	0.13	5	27,807	0.6
Angostura	39	61	34	39,237	0.90	5	196,186	4.5
Angostura	39	61	30	36,077	0.83	5	180,384	4.1
Angostura	39	61	29	19,595	0.45	5	97,973	2.2
Angostura	39	61	27	96,259	2.21	5	481,296	11.0
Angostura	39	61	27	23,716	0.54	5	118,581	2.7
Angostura	39	61	27	31,146	0.72	5	155,729	3.6
Angostura	39	61	27	44,077	1.01	5	220,383	5.1
Angostura	39	61	27	184,739	4.24	5	923,696	21.2
Angostura	39	61	20	99,115	2.28	5	495,573	11.4
Angostura	39	61	20	277,257	6.36	5	1,386,283	31.8
Angostura	39	61	20	16,495	0.38	5	82,473	1.9
Angostura	39	61	17	32,388	0.74	5	161,941	3.7
Angostura	39	61	10	17,554	0.40	5	87,770	2.0
Angostura	39	61	7	9,120	0.21	5	45,601	1.0
Angostura	39	61	7	6,369	0.15	5	31,847	0.7
Angostura	39	61	5	10,304	0.24	5	51,519	1.2
Angostura	39	61	3	30,732	0.71	5	153,658	3.5
Angostura	39	61	3	23,728	0.54	5	118,640	2.7
Angostura	39	60	30	4,708	0.11	5	23,540	0.5
Angostura	39	60	30	2,194	0.05	5	10,970	0.3
Angostura	39	60	30	6,978	0.16	5	34,889	0.8
Angostura	39	60	29	73,133	1.68	5	365,666	8.4
Angostura	39	60	29	19,339	0.44	5	96,697	2.2
Angostura	39	60	29	43,517	1.00	5	217,583	5.0
Angostura	39	60	28	24,023	0.55	5	120,115	2.8
Angostura	39	60	21	11,814	0.27	5	59,072	1.4
Angostura	39	60	20	2,265	0.05	5	11,326	0.3
Angostura	39	60	19	6,939	0.16	5	34,696	0.8
Angostura	39	60	15	15,439	0.35	5	77,196	1.8
Angostura	39	60	9	7,757	0.18	5	38,784	0.9
Angostura	38	61	15	5,039	0.12	5	25,193	0.6
Angostura	38	61	15	7,594	0.17	5	37,971	0.9
Angostura	38	61	14	6,526	0.15	5	32,629	0.7
Angostura	38	61	11	9,630	0.22	5	48,150	1.1
Angostura	38	61	11	16,482	0.38	5	82,410	1.9
Angostura	38	61	10	149,860	3.44	5	749,299	17.2
Angostura	38	61	10	74,691	1.71	5	373,453	8.6

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Angostura	38	61	3	10,187	0.23	5	50,933	1.2
Angostura	38	61	3	9,854	0.23	5	49,272	1.1
Angostura	38	60	9	91,121	2.09	5	455,604	10.5
Angostura	38	60	6	10,705	0.25	5	53,527	1.2
Angostura	38	60	3	43,572	1.00	5	217,859	5.0
Angostura	38	60	3	4,084	0.09	5	20,421	0.5
Angostura	37	61	36	223,816	5.14	5	1,119,080	25.7
Angostura	37	61	27	21,147	0.49	5	105,735	2.4
Angostura	37	61	26	27,783	0.64	5	138,913	3.2
Angostura	37	61	26	29,103	0.67	5	145,513	3.3
Angostura	37	61	25	88,752	2.04	5	443,762	10.2
Angostura	37	61	25	5,232	0.12	5	26,160	0.6
Angostura	37	61	23	41,353	0.95	5	206,764	4.7
Angostura	37	61	13	16,685	0.38	5	83,425	1.9
Angostura	37	61	13	27,969	0.64	5	139,843	3.2
Angostura	37	60	34	186,055	4.27	5	930,275	21.4
Angostura	37	60	32	121,599	2.79	5	607,997	14.0
Angostura	37	60	29	65,352	1.50	5	326,759	7.5
Angostura	37	60	29	61,009	1.40	5	305,045	7.0
Angostura	37	60	7	111,193	2.55	5	555,964	12.8
Angostura	37	60	5	40,247	0.92	5	201,235	4.6
Angostura	37	60	3	39,208	0.90	5	196,041	4.5
Angostura	37	60	3	32,970	0.76	5	164,850	3.8
Angostura	36	61	26	6,124	0.14	5	30,620	0.7
Angostura	36	61	26	3,451	0.08	5	17,256	0.4
Angostura	36	61	25	12,399	0.28	5	61,994	1.4
Angostura	36	61	25	23,441	0.54	5	117,206	2.7
Angostura	36	61	25	8,936	0.21	5	44,679	1.0
Angostura	36	61	24	70,938	1.63	5	354,688	8.1
Angostura	36	60	30	24,192	0.56	5	120,960	2.8
Angostura	36	60	28	42,009	0.96	5	210,043	4.8
Angostura	36	60	19	30,024	0.69	5	150,120	3.4
Angostura	36	60	16	23,373	0.54	5	116,865	2.7
Angostura	36	60	9	10,462	0.24	5	52,312	1.2
Angostura	36	60	8	7,977	0.18	5	39,885	0.9
Angostura	36	60	7	7,108	0.16	5	35,542	0.8
Angostura	35	62	11	27,336	0.63	5	136,680	3.1
Angostura	35	60	34	12,834	0.29	5	64,171	1.5
Angostura	35	60	31	875,772	20.10	5	4,378,861	100.5
Angostura	35	60	29	40,391	0.93	5	201,956	4.6
Angostura	35	60	28	8,557	0.20	5	42,785	1.0
Angostura	35	60	16	369,156	8.47	5	1,845,778	42.4

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Angostura	35	60	9	47,166	1.08	5	235,829	5.4
Angostura	35	60	4	25,269	0.58	5	126,346	2.9
Angostura	34	61	16	9,223	0.21	5	46,114	1.1
Angostura	34	61	13	31,628	0.73	5	158,140	3.6
Angostura	34	60	30	7,130	0.16	5	35,648	0.8
Angostura	34	60	30	8,401	0.19	5	42,003	1.0
Angostura	34	60	22	42,644	0.98	5	213,222	4.9
Angostura	34	60	9	8,005	0.18	5	40,025	0.9
Angostura	33	62	14	5,471	0.13	5	27,357	0.6
Lance	39	68	28	9,414	0.22	5	47,070	1.1
Lance	39	68	22	14,628	0.34	5	73,140	1.7
Lance	39	67	31	72,333	1.66	5	361,665	8.3
Lance	39	67	25	5,324	0.12	5	26,620	0.6
Lance	39	67	25	4,826	0.11	5	24,130	0.6
Lance	39	67	25	5,306	0.12	5	26,530	0.6
Lance	39	67	29	15,110	0.35	5	75,550	1.7
Lance	39	67	23	38,033	0.87	5	190,165	4.4
Lance	39	67	21	79,621	1.83	5	398,105	9.1
Lance	39	67	21	30,362	0.70	5	151,810	3.5
Lance	39	67	20	71,711	1.65	5	358,555	8.2
Lance	39	67	19	132,030	3.03	5	660,148	15.2
Lance	39	67	15	26,610	0.61	5	133,050	3.1
Lance	39	67	14	44,129	1.01	5	220,645	5.1
Lance	39	67	14	38,534	0.88	5	192,670	4.4
Lance	39	67	13	23,689	0.54	5	118,445	2.7
Lance	39	66	33	27,483	0.63	5	137,415	3.2
Lance	39	66	33	39,729	0.91	5	198,645	4.6
Lance	39	66	30	188,784	4.33	5	943,920	21.7
Lance	39	66	27	24,838	0.57	5	124,190	2.9
Lance	39	66	19	183,849	4.22	5	919,245	21.1
Lance	39	66	13	33,913	0.78	5	169,565	3.9
Lance	39	65	29	19,601	0.45	5	98,005	2.2
Lance	39	65	27	19,606	0.45	5	98,030	2.3
Lance	39	65	27	7,776	0.18	5	38,880	0.9
Lance	39	65	24	12,726	0.29	5	63,630	1.5
Lance	39	65	21	19,329	0.44	5	96,645	2.2
Lance	39	65	7	49,800	1.14	5	248,999	5.7
Lance	39	64	28	8,325	0.19	5	41,623	1.0
Lance	39	64	27	82,860	1.90	5	414,302	9.5
Lance	38	66	11	62,184	1.43	5	310,921	7.1
Lance	38	66	21	33,919	0.78	5	169,596	3.9
Lance	38	65	17	43,198	0.99	5	215,990	5.0

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Lance	38	65	24	76,249	1.75	5	381,244	8.8
Lance	38	65	22	27,783	0.64	5	138,916	3.2
Lance	38	65	29	24,761	0.57	5	123,803	2.8
Lance	38	64	21	26,347	0.60	5	131,735	3.0
Lance	38	64	20	17,911	0.41	5	89,555	2.1
Lance	38	64	27	97,803	2.25	5	489,014	11.2
Lance	38	64	31	18,701	0.43	5	93,503	2.1
Lance	38	63	18	105,382	2.42	5	526,908	12.1
Lance	38	62	2	6,617	0.15	5	33,086	0.8
Lance	38	62	16	37,962	0.87	5	189,810	4.4
Lance	38	62	15	89,439	2.05	5	447,194	10.3
Lance	38	62	14	73,852	1.70	5	369,258	8.5
Lance	37	64	28	33,074	0.76	5	165,372	3.8
Lance	37	64	20	86,867	1.99	5	434,337	10.0
Lance	37	63	20	235,570	5.41	5	1,177,848	27.0
Lance	37	63	24	64,449	1.48	5	322,244	7.4
Lance	37	62	30	21,614	0.50	5	108,070	2.5
Lance	37	62	19	61,753	1.42	5	308,763	7.1
Lance	37	62	32	4,277	0.10	5	21,387	0.5
Lance	37	62	23	2,787	0.06	5	13,935	0.3
Lance	37	62	11	119,845	2.75	5	599,225	13.8
Lance	37	61	19	18,812	0.43	5	94,058	2.2
Lance	37	61	29	182,902	4.20	5	914,511	21.0
Lance	37	61	15	53,738	1.23	5	268,690	6.2
Lance	36	66	36	17,016	0.39	5	85,081	2.0
Lance	36	66	35	35,490	0.81	5	177,451	4.1
Lance	36	64	27	25,545	0.59	5	127,724	2.9
Lance	36	64	27	9,636	0.22	5	48,180	1.1
Lance	36	64	29	12,710	0.29	5	63,552	1.5
Lance	36	63	31	20,369	0.47	5	101,846	2.3
Lance	36	63	27	23,203	0.53	5	116,013	2.7
Lance	36	63	20	7,022	0.16	5	35,112	0.8
Lance	36	63	20	5,959	0.14	5	29,795	0.7
Lance	36	63	24	46,948	1.08	5	234,741	5.4
Lance	36	63	15	385,500	8.85	5	1,927,502	44.2
Lance	36	63	8	14,657	0.34	5	73,283	1.7
Lance	36	63	11	79,569	1.83	5	397,846	9.1
Lance	36	62	30	8,123	0.19	5	40,617	0.9
Lance	36	62	19	13,576	0.31	5	67,881	1.6
Lance	36	62	15	6,950	0.16	5	34,749	0.8
Lance	36	62	9	7,725	0.18	5	38,626	0.9
Lance	36	61	3	86,444	1.98	5	432,222	9.9

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Lance	36	61	8	33,525	0.77	5	167,626	3.8
Lance	35	66	33	91,068	2.09	5	455,342	10.5
Lance	35	66	36	19,355	0.44	5	96,777	2.2
Lance	35	66	10	15,696	0.36	5	78,481	1.8
Lance	35	65	34	65,585	1.51	5	327,927	7.5
Lance	35	65	22	33,812	0.78	5	169,060	3.9
Lance	35	64	25	9,090	0.21	5	45,449	1.0
Lance	35	64	10	28,395	0.65	5	141,975	3.3
Lance	35	64	12	39,922	0.92	5	199,612	4.6
Lance	35	63	33	15,860	0.36	5	79,299	1.8
Lance	35	63	30	47,911	1.10	5	239,553	5.5
Lance	35	63	30	33,749	0.77	5	168,745	3.9
Lance	35	63	14	10,730	0.25	5	53,649	1.2
Lance	35	63	10	125,531	2.88	5	627,654	14.4
Lance	35	63	1	12,610	0.29	5	63,048	1.4
Lance	35	62	31	193,933	4.45	5	969,667	22.3
Lance	35	62	23	30,963	0.71	5	154,817	3.6
Lance	35	62	14	35,909	0.82	5	179,547	4.1
Lance	35	62	16	23,088	0.53	5	115,441	2.7
Lance	35	62	7	32,822	0.75	5	164,111	3.8
Lance	35	62	8	8,969	0.21	5	44,844	1.0
Lance	34	66	5	65,044	1.49	5	325,218	7.5
Lance	34	64	1	28,360	0.65	5	141,802	3.3
Lance	34	63	34	15,564	0.36	5	77,822	1.8
Lance	33	65	15	2,810	0.06	5	14,050	0.3
Lightning	38	71	35	95,287	2.19	5	476,433	10.9
Lightning	38	70	32	47,942	1.10	5	239,709	5.5
Lightning	38	70	24	7,928	0.18	5	39,642	0.9
Lightning	38	69	36	1,737	0.04	5	8,685	0.2
Lightning	38	69	27	20,788	0.48	5	103,942	2.4
Lightning	38	69	13	10,044	0.23	5	50,218	1.2
Lightning	38	68	33	73,823	1.69	5	369,115	8.5
Lightning	38	68	14	15,895	0.36	5	79,475	1.8
Lightning	38	68	15	16,269	0.37	5	81,343	1.9
Lightning	38	65	32	113,071	2.60	5	565,355	13.0
Lightning	37	71	9	15,455	0.35	5	77,274	1.8
Lightning	37	70	36	84,718	1.94	5	423,590	9.7
Lightning	37	70	26	336,291	7.72	5	1,681,454	38.6
Lightning	37	70	14	296,215	6.80	5	1,481,075	34.0
Lightning	37	69	11	110,173	2.53	5	550,866	12.6
Lightning	37	69	12	446,679	10.25	5	2,233,394	51.3
Lightning	37	68	35	289,845	6.65	5	1,449,224	33.3

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Lightning	37	68	36	187,743	4.31	5	938,713	21.5
Lightning	37	68	27	134,627	3.09	5	673,137	15.5
Lightning	37	68	30	50,504	1.16	5	252,520	5.8
Lightning	37	68	30	145,682	3.34	5	728,409	16.7
Lightning	37	68	20	57,252	1.31	5	286,258	6.6
Lightning	37	68	21	83,343	1.91	5	416,717	9.6
Lightning	37	68	22	64,221	1.47	5	321,105	7.4
Lightning	37	68	23	41,767	0.96	5	208,837	4.8
Lightning	37	68	15	24,332	0.56	5	121,658	2.8
Lightning	37	68	7	97,683	2.24	5	488,416	11.2
Lightning	37	68	7	58,957	1.35	5	294,786	6.8
Lightning	37	68	11	20,072	0.46	5	100,358	2.3
Lightning	37	67	35	12,060	0.28	5	60,300	1.4
Lightning	37	67	30	42,686	0.98	5	213,431	4.9
Lightning	37	67	22	40,539	0.93	5	202,697	4.7
Lightning	37	67	13	16,210	0.37	5	81,050	1.9
Lightning	37	67	12	27,839	0.64	5	139,197	3.2
Lightning	37	67	3	109,602	2.52	5	548,010	12.6
Lightning	37	67	4	17,619	0.40	5	88,096	2.0
Lightning	37	67	6	238,633	5.48	5	1,193,167	27.4
Lightning	37	66	23	16,242	0.37	5	81,210	1.9
Lightning	37	66	10	33,260	0.76	5	166,302	3.8
Lightning	37	66	3	67,002	1.54	5	335,011	7.7
Lightning	37	65	20	108,951	2.50	5	544,753	12.5
Lightning	37	65	15	31,811	0.73	5	159,055	3.7
Lightning	37	65	11	145,919	3.35	5	729,596	16.7
Lightning	37	65	4	26,627	0.61	5	133,135	3.1
Lightning	37	65	3	19,555	0.45	5	97,774	2.2
Lightning	36	73	26	30,418	0.70	5	152,088	3.5
Lightning	36	71	14	160,724	3.69	5	803,621	18.4
Lightning	36	71	7	18,241	0.42	5	91,207	2.1
Lightning	36	71	2	31,877	0.73	5	159,383	3.7
Lightning	36	71	6	12,174	0.28	5	60,870	1.4
Lightning	36	70	25	43,708	1.00	5	218,538	5.0
Lightning	36	70	21	55,930	1.28	5	279,652	6.4
Lightning	36	70	13	75,318	1.73	5	376,591	8.6
Lightning	36	70	18	37,809	0.87	5	189,045	4.3
Lightning	36	69	17	94,866	2.18	5	474,328	10.9
Lightning	36	69	10	18,312	0.42	5	91,560	2.1
Lightning	36	68	2	129,766	2.98	5	648,830	14.9
Lightning	36	68	2	50,355	1.16	5	251,775	5.8
Lightning	36	68	4	57,368	1.32	5	286,840	6.6

Data Summary 4.2.5-1. Breached Dam Locations and Estimated Sizes

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
Lightning	36	68	4	7,422	0.17	5	37,110	0.9
Lightning	36	68	4	10,075	0.23	5	50,375	1.2
Lightning	36	68	6	646,250	14.84	5	3,231,248	74.2
Lightning	36	67	36	46,774	1.07	5	233,870	5.4
Lightning	36	67	4	141,781	3.25	5	708,904	16.3
Lightning	36	66	32	119,903	2.75	5	599,514	13.8
Lightning	36	66	30	166,917	3.83	5	834,585	19.2
Lightning	36	66	21	58,189	1.34	5	290,944	6.7
Lightning	36	66	14	20,147	0.46	5	100,735	2.3
Lightning	36	66	11	67,567	1.55	5	337,836	7.8
Lightning	36	66	11	153,654	3.53	5	768,270	17.6
Lightning	36	66	11	92,165	2.12	5	460,823	10.6
Lightning	35	71	33	39,918	0.92	5	199,588	4.6
Lightning	35	71	36	42,448	0.97	5	212,242	4.9
Lightning	35	71	20	89,553	2.06	5	447,764	10.3
Lightning	35	71	8	10,680	0.25	5	53,399	1.2
Lightning	35	70	13	60,643	1.39	5	303,213	7.0
Lightning	35	68	17	8,273	0.19	5	41,364	0.9
Lightning	35	67	35	46,790	1.07	5	233,951	5.4
Lightning	35	67	23	57,862	1.33	5	289,312	6.6
Lightning	35	66	19	10,078	0.23	5	50,392	1.2
Lightning	34	70	13	8,472	0.19	5	42,362	1.0
Lightning	34	70	17	48,329	1.11	5	241,644	5.5
Lightning	34	69	2	15,098	0.35	5	75,488	1.7
Lightning	34	68	21	20,023	0.46	5	100,117	2.3
Lightning	34	68	32	27,905	0.64	5	139,525	3.2
Lightning	34	67	11	89,461	2.05	5	447,305	10.3
Lightning	34	67	26	67,288	1.54	5	336,439	7.7
Lightning	34	67	29	73,655	1.69	5	368,275	8.5
Lightning	33	68	1	31,539	0.72	5	157,693	3.6
Lightning	33	68	1	27,319	0.63	5	136,595	3.1
Lightning	33	68	3	137,660	3.16	5	688,299	15.8
Lightning	33	68	9	33,442	0.77	5	167,210	3.8
Lightning	33	68	12	78,691	1.81	5	393,456	9.0
Lightning	33	68	12	20,322	0.47	5	101,612	2.3
Lightning	33	68	13	52,385	1.20	5	261,923	6.0
Lightning	33	68	13	50,334	1.16	5	251,669	5.8
Lightning	33	67	20	43,581	1.00	5	217,904	5.0

Data Summary 4.2.5-2. Increased Animal Watering Benefit - Breached Dam Repair Conceptual Opinon of Probable Cost

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)[1]	Unit Cost ($/ac-ft)	Total Cost ($)[2]
Angostura	40	60	31	81,119	1.86	5	405,596	9.3	$17,000	$158,300
Angostura	39	62	24	31,155	0.72	5	155,775	3.6	$17,000	$60,800
Angostura	39	62	24	5,561	0.13	5	27,807	0.6	$17,000	$20,000
Angostura	39	61	34	39,237	0.90	5	196,186	4.5	$17,000	$76,600
Angostura	39	61	30	36,077	0.83	5	180,384	4.1	$17,000	$70,400
Angostura	39	61	29	19,595	0.45	5	97,973	2.2	$17,000	$38,200
Angostura	39	61	27	96,259	2.21	5	481,296	11.0	$17,000	$187,800
Angostura	39	61	27	23,716	0.54	5	118,581	2.7	$17,000	$46,300
Angostura	39	61	27	31,146	0.72	5	155,729	3.6	$17,000	$60,800
Angostura	39	61	27	44,077	1.01	5	220,383	5.1	$17,000	$86,000
Angostura	39	61	20	99,115	2.28	5	495,573	11.4	$17,000	$193,400
Angostura	39	61	20	277,257	6.36	5	1,386,283	31.8	$17,000	$541,000
Angostura	39	61	20	16,495	0.38	5	82,473	1.9	$17,000	$32,200
Angostura	39	61	17	32,388	0.74	5	161,941	3.7	$17,000	$63,200
Angostura	39	61	10	17,554	0.40	5	87,770	2.0	$17,000	$34,300
Angostura	39	61	3	30,732	0.71	5	153,658	3.5	$17,000	$60,000
Angostura	39	61	3	23,728	0.54	5	118,640	2.7	$17,000	$46,300
Angostura	39	60	29	43,517	1.00	5	217,583	5.0	$17,000	$84,900
Angostura	39	60	28	24,023	0.55	5	120,115	2.8	$17,000	$46,900
Angostura	39	60	21	11,814	0.27	5	59,072	1.4	$17,000	$23,100
Angostura	39	60	20	2,265	0.05	5	11,326	0.3	$17,000	$20,000
Angostura	39	60	15	15,439	0.35	5	77,196	1.8	$17,000	$30,100
Angostura	39	60	9	7,757	0.18	5	38,784	0.9	$17,000	$20,000
Angostura	38	61	15	5,039	0.12	5	25,193	0.6	$17,000	$20,000
Angostura	38	61	15	7,594	0.17	5	37,971	0.9	$17,000	$20,000
Angostura	38	61	14	6,526	0.15	5	32,629	0.7	$17,000	$20,000
Angostura	38	61	11	9,630	0.22	5	48,150	1.1	$17,000	$20,000
Angostura	38	61	11	16,482	0.38	5	82,410	1.9	$17,000	$32,200
Angostura	38	61	10	149,860	3.44	5	749,299	17.2	$17,000	$292,400
Angostura	38	61	10	74,691	1.71	5	373,453	8.6	$17,000	$145,700
Angostura	38	61	3	10,187	0.23	5	50,933	1.2	$17,000	$20,000
Angostura	38	61	3	9,854	0.23	5	49,272	1.1	$17,000	$20,000
Angostura	38	60	9	91,121	2.09	5	455,604	10.5	$17,000	$177,800
Angostura	38	60	6	10,705	0.25	5	53,527	1.2	$17,000	$20,900
Angostura	38	60	3	43,572	1.00	5	217,859	5.0	$17,000	$85,000
Angostura	38	60	3	4,084	0.09	5	20,421	0.5	$17,000	$20,000
Angostura	37	61	27	21,147	0.49	5	105,735	2.4	$17,000	$41,300
Angostura	37	61	26	27,783	0.64	5	138,913	3.2	$17,000	$54,200
Angostura	37	61	26	29,103	0.67	5	145,513	3.3	$17,000	$56,800
Angostura	37	61	25	88,752	2.04	5	443,762	10.2	$17,000	$173,200
Angostura	37	61	25	5,232	0.12	5	26,160	0.6	$17,000	$20,000
Angostura	37	61	23	41,353	0.95	5	206,764	4.7	$17,000	$80,700
Angostura	37	61	13	16,685	0.38	5	83,425	1.9	$17,000	$32,600
Angostura	37	61	13	27,969	0.64	5	139,843	3.2	$17,000	$54,600
Angostura	37	60	34	186,055	4.27	5	930,275	21.4	$17,000	$363,100
Angostura	37	60	32	121,599	2.79	5	607,997	14.0	$17,000	$237,300
Angostura	37	60	29	65,352	1.50	5	326,759	7.5	$17,000	$127,500
Angostura	37	60	29	61,009	1.40	5	305,045	7.0	$17,000	$119,000
Angostura	37	60	7	111,193	2.55	5	555,964	12.8	$17,000	$217,000
Angostura	37	60	5	40,247	0.92	5	201,235	4.6	$17,000	$78,500
Angostura	37	60	3	39,208	0.90	5	196,041	4.5	$17,000	$76,500
Angostura	37	60	3	32,970	0.76	5	164,850	3.8	$17,000	$64,300
Angostura	36	61	26	6,124	0.14	5	30,620	0.7	$17,000	$20,000
Angostura	36	61	24	70,938	1.63	5	354,688	8.1	$17,000	$138,400
Angostura	36	60	30	24,192	0.56	5	120,960	2.8	$17,000	$47,200
Angostura	36	60	28	42,009	0.96	5	210,043	4.8	$17,000	$82,000
Angostura	36	60	16	23,373	0.54	5	116,865	2.7	$17,000	$45,600
Angostura	36	60	9	10,462	0.24	5	52,312	1.2	$17,000	$20,400
Angostura	36	60	8	7,977	0.18	5	39,885	0.9	$17,000	$20,000
Angostura	36	60	7	7,108	0.16	5	35,542	0.8	$17,000	$20,000
Angostura	35	60	31	875,772	20.10	5	4,378,861	100.5	$17,000	$1,708,900
Angostura	35	60	29	40,391	0.93	5	201,956	4.6	$17,000	$78,800
Angostura	35	60	16	369,156	8.47	5	1,845,778	42.4	$17,000	$720,300
Angostura	35	60	9	47,166	1.08	5	235,829	5.4	$17,000	$92,000
Angostura	35	60	4	25,269	0.58	5	126,346	2.9	$17,000	$49,300

Data Summary 4.2.5-2. Increased Animal Watering Benefit - Breached Dam Repair Conceptual Opinon of Probable Cost

Basin	Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)[1]	Unit Cost ($/ac-ft)	Total Cost ($)[2]
Angostura	34	61	16	9,223	0.21	5	46,114	1.1	$17,000	$20,000
Angostura	34	60	22	42,644	0.98	5	213,222	4.9	$17,000	$83,200
Lance	39	68	22	14,628	0.34	5	73,140	1.7	$17,000	$28,500
Lance	39	67	31	72,333	1.66	5	361,665	8.3	$17,000	$141,100
Lance	39	67	25	5,324	0.12	5	26,620	0.6	$17,000	$20,000
Lance	39	67	25	4,826	0.11	5	24,130	0.6	$17,000	$20,000
Lance	39	67	25	5,306	0.12	5	26,530	0.6	$17,000	$20,000
Lance	39	67	15	26,610	0.61	5	133,050	3.1	$17,000	$51,900
Lance	39	67	14	44,129	1.01	5	220,645	5.1	$17,000	$86,100
Lance	39	67	14	38,534	0.88	5	192,670	4.4	$17,000	$75,200
Lance	38	66	21	33,919	0.78	5	169,596	3.9	$17,000	$66,200
Lance	38	65	17	43,198	0.99	5	215,990	5.0	$17,000	$84,300
Lance	38	65	22	27,783	0.64	5	138,916	3.2	$17,000	$54,200
Lance	38	65	29	24,761	0.57	5	123,803	2.8	$17,000	$48,300
Lance	38	63	18	105,382	2.42	5	526,908	12.1	$17,000	$205,600
Lance	38	62	2	6,617	0.15	5	33,086	0.8	$17,000	$20,000
Lance	38	62	16	37,962	0.87	5	189,810	4.4	$17,000	$74,100
Lance	38	62	15	89,439	2.05	5	447,194	10.3	$17,000	$174,500
Lance	38	62	14	73,852	1.70	5	369,258	8.5	$17,000	$144,100
Lance	37	63	24	64,449	1.48	5	322,244	7.4	$17,000	$125,800
Lance	37	62	19	61,753	1.42	5	308,763	7.1	$17,000	$120,500
Lance	37	62	11	119,845	2.75	5	599,225	13.8	$17,000	$233,900
Lance	37	61	29	182,902	4.20	5	914,511	21.0	$17,000	$356,900
Lance	36	64	29	12,710	0.29	5	63,552	1.5	$17,000	$24,800
Lance	36	63	27	23,203	0.53	5	116,013	2.7	$17,000	$45,300
Lance	36	63	20	7,022	0.16	5	35,112	0.8	$17,000	$20,000
Lance	36	63	20	5,959	0.14	5	29,795	0.7	$17,000	$20,000
Lance	36	63	15	385,500	8.85	5	1,927,502	44.2	$17,000	$752,200
Lance	36	63	11	79,569	1.83	5	397,846	9.1	$17,000	$155,300
Lance	36	62	30	8,123	0.19	5	40,617	0.9	$17,000	$20,000
Lance	36	61	3	86,444	1.98	5	432,222	9.9	$17,000	$168,700
Lance	36	61	8	33,525	0.77	5	167,626	3.8	$17,000	$65,400
Lance	35	66	33	91,068	2.09	5	455,342	10.5	$17,000	$177,700
Lance	35	66	10	15,696	0.36	5	78,481	1.8	$17,000	$30,600
Lance	35	63	14	10,730	0.25	5	53,649	1.2	$17,000	$20,900
Lance	35	62	23	30,963	0.71	5	154,817	3.6	$17,000	$60,400
Lance	35	62	14	35,909	0.82	5	179,547	4.1	$17,000	$70,100
Lance	34	66	5	65,044	1.49	5	325,218	7.5	$17,000	$126,900
Lance	34	64	1	28,360	0.65	5	141,802	3.3	$17,000	$55,300
Lightning	38	70	32	47,942	1.10	5	239,709	5.5	$17,000	$93,600
Lightning	38	69	13	10,044	0.23	5	50,218	1.2	$17,000	$20,000
Lightning	38	68	33	73,823	1.69	5	369,115	8.5	$17,000	$144,100
Lightning	37	70	36	84,718	1.94	5	423,590	9.7	$17,000	$165,300
Lightning	37	68	35	289,845	6.65	5	1,449,224	33.3	$17,000	$565,600
Lightning	37	68	36	187,743	4.31	5	938,713	21.5	$17,000	$366,300
Lightning	37	68	27	134,627	3.09	5	673,137	15.5	$17,000	$262,700
Lightning	37	68	30	50,504	1.16	5	252,520	5.8	$17,000	$98,600
Lightning	37	68	30	145,682	3.34	5	728,409	16.7	$17,000	$284,300
Lightning	37	67	30	42,686	0.98	5	213,431	4.9	$17,000	$83,300
Lightning	37	67	12	27,839	0.64	5	139,197	3.2	$17,000	$54,300
Lightning	37	67	4	17,619	0.40	5	88,096	2.0	$17,000	$34,400
Lightning	35	71	20	89,553	2.06	5	447,764	10.3	$17,000	$174,700
Lightning	35	71	8	10,680	0.25	5	53,399	1.2	$17,000	$20,800
Lightning	34	70	17	48,329	1.11	5	241,644	5.5	$17,000	$94,300
Lightning	33	68	9	33,442	0.77	5	167,210	3.8	$17,000	$65,300

[1]Some ponds still hold some water, depth reflects storage that could be added to the existing ponds if the dams were repaired.
[2]If estimated cost was less than $20,000, the total cost was rounded up to $20,000

Data Summary 7.5-1

Primary Potential Funding Sources

Agency/Entity	Program Name	Project Type(s)	Internet URL	Telephone	Email
Local					
Niobrara County Conservation District	N/A	Liaison, In-Kind administrative and technical assistance, program coordination/partnering	N/A	307-334-2953	lshaw@wyoming.com
Converse County Conservation District	N/A	Liaison, In-Kind administrative and technical assistance, program coordination/partnering	www.conserveconverse.com	307-358-3050	michelle.huntington@wy.nacdnet.net
State					
Wyoming Department of Environmental Quality	Nonpoint Source Implementation Grants (Section 319 Program)	Water Quality Best Management Practices	http://deq.state.wy.us/wqd/watershed/	307-777-6709	dwater@wyo.gov
Wyoming Game and Fish Department	Riparian Habitat Improvement Grant	Fencing, Herding, Stockwater Development, stream bank stabilization, small dams, etc.	http://gf.state.wy.us/habitat/StrategicPlan/index.asp	307-777-4565	gbutle@state.wy.us
	Water Development/Maintenance Habitat Project Grant	Spring Development, Windmills, Guzzlers, Water Protection, and Pumping Payments, etc.			
	Industrial Water Habitat Project Fund	Tapped Artesial Wells, Springs or Groundwater for Wildlife, Creation of Wetlands/ponds, etc.			
	Upland Development Program	Shrub Management, Grazing Systems, Prescribed Burning, Wildlife Food Plots, Range Seeding, etc.			
	Fish Wyoming	Boat Ramps, Fishing Acces, etc.			
Wyoming Office of State Lands and Investments	Farm Loan Program	Agricultural and Livestock Assistance	http://slf-web.state.wy.us/	307-777-7331	lboomg@state.wy.us
	The Irrigation Loans Program	Small and large Agricultural Water Development Projects			
	Joint Powers Act Loan Program	Government Services and Public Facilities			
Wyoming Water Development Commission	New Development Program	Water Supply Development	http://wwdc.state.wy.us/	307-777-7626	jwade@state.wy.us
	Rehabiliation Program	Improvements of Existing Water Projects			
	Dam and Reservoir Program	New Dams and Dam expansion			
	Small Water Projects Program	Construction/Rehabilitation of Small Reservoirs, Wells, Pipelines, Springs, Solar Platforms, Irrigation Works, Windmills, and Wetland Development			
Wyoming Wildlife and Natural Resource Trust	N/A	Wildlife Habitat Improvements and Natural Resource Improvements/Preservation	http://wwnrt.state.wy.us/	307-856-4665	bbudd@state.wy.us
Federal					
Bureau of Land Management	RiparianHabitat Management Program	Improve/Restore/Protect Riparian Areas	http://www.blm.gov/wy/st/en.html	307-775-6092	rick_schulder@blm.gov
	Range Improvement Planning and Development	Water Development for Livestock, Livestock BMP,			
	Watershed and Water Quality Improvement	Restoration and Maintenance of Watershed Function			
Bureau of Reclamation	Challenge Grant Program	Improve Water Efficiency, Water Treatment, Habitat Preservation	http://www.usbr.gov/gp/wyao/	307-261-5671	jlawson@gp.usbr.gov
	Water Conservation Field Services Program	Conservation Improvements			
Environmental Protection Agency	Targed Watersheds Grants Program	Riparian, Wetland, Aquatic and Upland Habit Protection and Improvement	http://www.epa.gov/watershed/initiative/	303-312-6692	eriksen.stacey@epa.gov
Farm Service Agency	Conservation Resource Program	Removal of Highly Erodible Cropland from Production	www.fsa.usda.gov/wy/	307-261-5081	cindy.hottel@wy.usda.gov
	Continuous Sign-Up for High Priority Conservation Practices	Riparian Buffers, Filter Strips, Grass Waterways, Shelter Belts, Field Windbreak, Living Snow Fences, Contour Grass Strips, Salt Tolerant Vegetation, and Shallow Water Areas			
	Emergency Conservation Program	Farmland Rehabilitation Damaged by Natural Disasters or Emergency Water Conservation for Livestock			
Fish and Wildlife Service	Partners for Wildlife Habitat Restoration	Habitat Restoration and Improvements	http://www.fws.gov/	307-332-8719	mark_j_hogan@fws.gov
	Wildlife Conservation and Appreciation Program	Identification and Preservation of Fish and Widlife and Their Habitats			
	Cooperative Endangered Species Conservation Fund	Conservation of Threatened and Endangered Species			
	North American Wetlands Conservation Act Grant Program	Conservation of Wetland Ecosystems, Waterfowl, Fish, and Wildlife			
Natural Resource Conservation Service	Environmental Quality Incentives Program	Improve Water Quality, Enhance Grazing Lands, and Increase Water Conservation	http://www.wy.nrcs.usda.gov/	307-233-6750	jill.binette@wy.usda.gov
	Conservation Security Program	Promotes BMP and Conservation			
	Wildlife Habitat Incentives Program	Improve Wildlife Habitats on Private Lands			
	Wetlands Reserve Program	Wetland, Wildlife Habitat, Soil, Water, and Related Natural Resource Concerns on Private Lands			
	Grassland Reserve Program	Grazing Operations, Pland and Animal Biodiversity, and Foliage			
	Farm and Ranch Lands Protection Program	Farm and Ranch Land Preservation			
	Resource Conservation and Development	Promote Conservation, Development, and use of Natural Resources			
Non-Profit and Other Organizations					
Ducks Unlimited	Matching Aid to Restore States Habitat	Wetlands and Waterfowl Restoration	http://www.ducks.org/	307-472-6980	carol.m.perry@wellsfargo.com
National Fish and Wildlife Foundation	Five-Star Restoration Matching Grants Program	Wetland, Riparian, and Coastal Habitat Restoration	http://www.nfwf.org/	202-857-0166	lacy.alison@nfwf.org
	Bring Back the Natives	Preserve/Enhance Native Aquatic Species			barrett.Bohnengel@nfwf.org
	Native Plant Conservation Initiative	Conservation of Native Plantlife			ellen.gabel@nfwf.org
	Pulling Together Initiative	Invasive Plant Species Control			ellen.gabel@nfwf.org
Trout Unlimited	Watershed Restoration	Protect and Restore Coldwater Fisheries and their Watersheds	http://www.tu.org	307-733-6991	syates@tu.org
Sage Grouse Initiatives (multiple)	Multiple	Habitat Improvements to Benefit Sage Grouse	Varies, See Section 7.4.5		

Appendix B

Precipitation Data

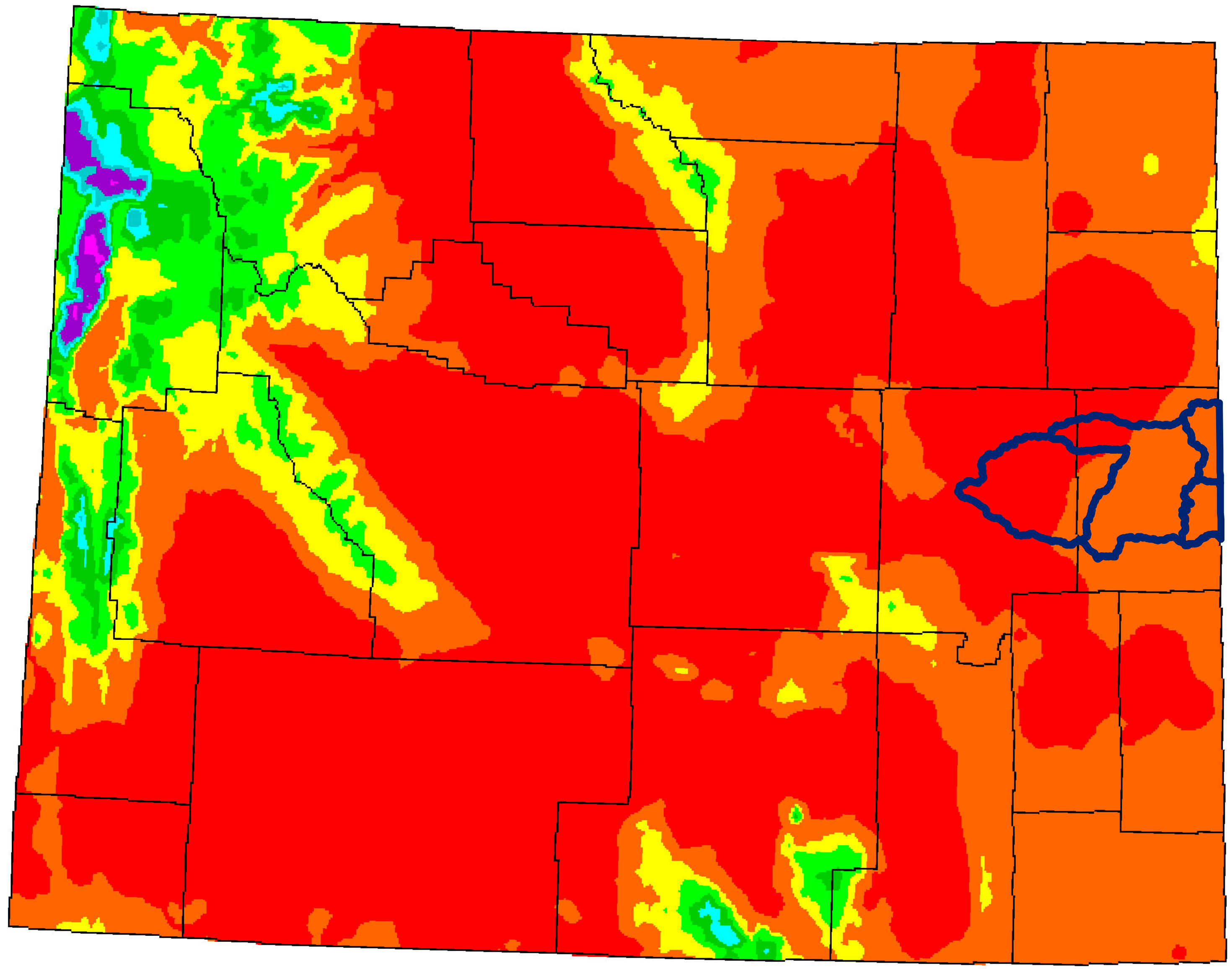
Average Annual Precipitation

Wyoming

Legend (in inches)

Under 14	46 to 54
14 to 22	54 to 62
22 to 30	62 to 70
30 to 38	Above 70
38 to 46	

Period: 1961-1990



This map is a plot of 1961-1990 annual average precipitation contours from NOAA Cooperative stations and (where appropriate) USDA-NRCS SNOTEL stations. Christopher Daly used the PRISM model to generate the gridded estimates from which this map was derived; the modeled grid was approximately 4x4 km latitude/longitude, and was resampled to 2x2 km using a Gaussian filter. Mapping was performed by Jenny Weisburg. Funding was provided by USDA-NRCS National Water and Climate Center.

12/7/97

BILL, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(480725) BILL														
From Year=1948 To Year=1978														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.38	2.03	1949	0.00	1958	1.60	05/1949	3	1	0	0	3.8	15.0	1953
February	0.33	1.75	1953	0.00	1974	0.40	13/1952	3	1	0	0	3.6	21.0	1953
March	0.59	1.84	1950	0.00	1949	1.44	22/1950	4	2	0	0	6.6	20.0	1958
April	1.41	3.48	1971	0.19	1961	1.33	18/1971	6	4	1	0	4.6	13.0	1968
May	2.66	7.72	1978	0.14	1966	2.92	17/1978	7	6	2	1	0.6	10.0	1965
June	1.83	4.11	1967	0.00	1973	2.00	29/1959	6	4	1	0	0.1	3.0	1969
July	1.57	5.31	1951	0.00	1959	2.50	27/1951	4	3	1	0	0.0	0.0	1949
August	0.86	3.52	1972	0.00	1973	1.54	18/1972	3	2	0	0	0.0	0.0	1949
September	0.88	2.81	1961	0.00	1958	1.40	02/1973	3	2	1	0	0.5	14.0	1965
October	0.67	2.08	1961	0.00	1960	1.54	06/1962	3	2	0	0	1.6	10.0	1971
November	0.43	1.75	1953	0.00	1949	0.82	01/1973	2	1	0	0	2.4	9.0	1953
December	0.53	3.16	1949	0.00	1959	1.50	20/1949	3	2	0	0	4.2	11.0	1970
Annual	12.14	16.41	1971	5.16	1960	2.92	19780517	48	31	7	2	28.0	63.5	1953
Winter	1.24	3.83	1950	0.09	1977	1.60	19490105	9	4	0	0	11.7	38.0	1953
Spring	4.67	11.62	1971	1.31	1960	2.92	19780517	17	11	3	1	11.7	30.0	1968
Summer	4.25	7.94	1951	1.19	1971	2.50	19510727	14	10	3	1	0.1	3.0	1969
Fall	1.98	4.89	1961	0.35	1958	1.54	19621006	9	5	1	0	4.5	15.0	1966

Table updated on Mar 24, 2011
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons

Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, wrcc@dri.edu

HAT CREEK 5 E, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(484303) HAT CREEK 5 E														
From Year=1967 To Year=1983														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.52	1.31	1976	0.13	1981	0.82	01/1976	5	2	0	0	12.4	26.6	1979
February	0.45	0.90	1978	0.00	1983	0.33	06/1974	4	2	0	0	9.1	17.5	1978
March	1.11	2.55	1977	0.09	1974	1.21	02/1978	5	3	1	0	13.6	31.0	1975
April	2.45	5.03	1971	1.08	1981	2.51	19/1971	8	6	1	0	10.6	29.3	1970
May	2.67	6.97	1971	0.66	1974	2.85	23/1971	7	6	2	0	1.7	9.0	1983
June	2.10	4.97	1969	0.36	1980	3.09	12/1970	6	5	1	0	0.0	0.0	1968
July	2.21	4.83	1969	0.64	1971	2.75	16/1969	6	5	1	0	0.0	0.0	1968
August	1.65	4.52	1968	0.00	1969	2.77	09/1968	4	3	1	0	0.0	0.0	1968
September	1.04	5.10	1973	0.00	1979	1.25	09/1973	4	3	1	0	0.2	3.0	1973
October	0.99	1.55	1981	0.22	1968	1.10	29/1979	4	3	1	0	4.7	13.6	1969
November	0.70	1.74	1983	0.03	1970	0.90	09/1983	4	2	0	0	11.3	31.0	1983
December	0.42	1.12	1978	0.00	1979	0.40	16/1981	5	2	0	0	9.6	26.9	1978
Annual	16.33	23.38	1973	12.03	1974	3.09	19700612	63	42	10	2	73.3	113.9	1978
Winter	1.39	2.53	1974	0.47	1977	0.82	19760101	14	6	0	0	31.2	63.5	1979
Spring	6.23	12.84	1971	3.09	1974	2.85	19710523	21	15	4	1	25.9	47.6	1975
Summer	5.97	10.07	1979	2.68	1971	3.09	19700612	17	13	4	1	0.0	0.0	1968
Fall	2.74	7.32	1973	1.35	1968	1.25	19730909	12	8	2	0	16.2	35.4	1979

Table updated on Mar 24, 2011
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, wrcc@dri.edu

KEELINE 3 W, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(485085) KEELINE 3 W														
From Year=1953 To Year=1987														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.51	1.62	1965	0.00	1954	0.63	28/1965	6	2	0	0	8.9	21.9	1965
February	0.54	1.59	1969	0.00	1977	0.55	07/1969	6	2	0	0	8.3	23.5	1964
March	0.90	2.94	1970	0.10	1976	1.47	18/1970	7	3	0	0	10.9	30.5	1970
April	1.86	4.12	1967	0.32	1954	1.40	02/1964	9	5	1	0	11.2	39.0	1984
May	2.22	5.79	1971	0.05	1966	2.78	23/1971	10	5	1	0	3.5	33.0	1967
June	2.11	6.54	1986	0.00	1980	3.62	09/1986	9	5	1	0	0.1	2.5	1976
July	1.63	4.90	1984	0.15	1953	2.80	13/1981	8	4	1	0	0.0	0.0	1953
August	1.09	3.11	1979	0.00	1969	1.80	15/1976	5	3	1	0	0.0	0.0	1953
September	1.09	4.55	1973	0.00	1977	1.78	02/1973	5	3	1	0	1.1	14.2	1965
October	0.80	2.28	1971	0.00	1970	1.25	09/1982	5	2	0	0	3.4	20.0	1971
November	0.64	2.10	1983	0.02	1963	0.71	08/1983	5	2	0	0	8.5	27.0	1983
December	0.49	1.22	1982	0.00	1976	0.47	24/1982	6	2	0	0	8.7	29.0	1967
Annual	13.87	23.44	1967	8.14	1977	3.62	19860609	80	37	7	1	64.5	128.2	1967
Winter	1.54	3.02	1969	0.01	1977	0.63	19650128	17	6	0	0	25.9	46.0	1964
Spring	4.98	11.25	1971	1.41	1966	2.78	19710523	26	13	3	1	25.6	62.5	1967
Summer	4.83	8.98	1982	1.57	1960	3.62	19860609	22	12	3	1	0.1	2.5	1976
Fall	2.52	6.05	1973	0.69	1958	1.78	19730902	15	7	1	0	13.0	35.6	1971

Table updated on Mar 24, 2011
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Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, wrcc@dri.edu

LANCE CREEK 3 WNW, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(485372) LANCE CREEK 3 WNW														
From Year=1962 To Year=1984														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.41	0.86	1972	0.00	1983	0.40	02/1972	6	1	0	0	4.8	12.0	1974
February	0.29	0.66	1969	0.00	1983	0.48	27/1963	4	1	0	0	3.0	11.0	1966
March	0.65	1.66	1970	0.08	1974	2.50	06/1983	5	2	0	0	6.0	21.5	1970
April	1.93	4.38	1973	0.25	1980	2.13	14/1967	7	5	1	0	5.1	18.0	1973
May	3.29	7.58	1971	0.14	1966	3.70	23/1971	10	7	2	1	0.9	10.0	1967
June	2.51	5.24	1969	0.20	1973	2.60	12/1970	9	5	1	0	0.0	0.0	1963
July	2.18	4.25	1973	0.30	1971	2.51	20/1973	8	5	1	0	0.0	0.0	1962
August	1.20	4.56	1979	0.17	1970	2.20	09/1979	5	3	1	0	0.0	0.0	1962
September	1.32	5.89	1973	0.00	1969	1.42	08/1973	5	3	1	0	0.0	0.0	1962
October	0.93	2.02	1966	0.06	1964	1.38	25/1973	4	3	0	0	0.8	7.0	1970
November	0.58	2.00	1983	0.06	1965	0.86	26/1983	4	2	0	0	2.1	12.8	1979
December	0.34	1.54	1982	0.00	1979	0.52	02/1982	4	1	0	0	3.7	8.0	1967
Annual	15.63	19.33	1967	8.59	1974	3.70	19710523	70	38	8	2	26.4	42.5	1966
Winter	1.04	1.62	1963	0.50	1977	0.52	19821202	13	3	0	0	11.4	20.5	1969
Spring	5.87	10.93	1971	1.60	1966	3.70	19710523	21	14	4	1	12.1	31.5	1970
Summer	5.88	9.06	1982	2.40	1971	2.60	19700612	23	13	3	1	0.0	0.0	1963
Fall	2.83	8.31	1973	1.05	1964	1.42	19730908	13	8	1	0	2.9	12.8	1979

Table updated on Mar 24, 2011
For monthly and annual means, thresholds, and sums:
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Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, wrcc@dri.edu

REDBIRD 1 NW, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(487555) REDBIRD 1 NW															
From Year=1948 To Year=2010															
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.27	0.82	1974	0.00	1952	0.70	21/1974	4	1	0	0	6.1	19.5	1978
February	0.38	1.91	1953	0.00	1949	1.12	09/1953	3	1	0	0	6.4	24.0	1993
March	0.77	2.04	1954	0.00	1974	1.12	03/1985	5	3	0	0	10.0	28.0	1998
April	1.71	3.96	2000	0.12	1962	2.83	19/2000	7	4	1	0	6.4	19.0	1997
May	2.46	6.27	1957	0.11	1974	2.80	23/1971	10	6	1	0	0.6	8.0	1983
June	2.52	5.88	1952	0.30	1961	3.55	27/1952	9	6	2	0	0.0	2.0	1951
July	1.91	5.68	1973	0.21	1989	1.76	21/1973	8	4	1	0	0.0	0.0	1949
August	1.34	4.79	1976	0.05	1961	4.02	01/1976	6	3	1	0	0.0	0.0	1948
September	1.23	4.67	1989	0.03	1983	1.66	09/1973	5	3	1	0	0.3	8.0	1995
October	0.91	4.24	1998	0.00	1958	1.25	29/1948	5	2	1	0	2.4	19.0	2009
November	0.49	2.24	1983	0.00	1951	0.97	01/2000	4	2	0	0	5.5	33.0	1985
December	0.29	1.26	1992	0.00	1959	0.52	13/1992	4	1	0	0	6.4	42.0	1992
Annual	14.27	23.61	1998	8.77	1961	4.02	19760801	68	36	8	2	44.2	90.0	1993
Winter	0.94	2.26	1953	0.25	1970	1.12	19530209	11	3	0	0	18.9	76.0	1993
Spring	4.94	9.54	1971	1.00	1966	2.83	20000419	22	12	3	0	17.0	34.0	1975
Summer	5.76	10.56	1998	2.20	2000	4.02	19760801	22	13	4	1	0.0	2.0	1951
Fall	2.63	6.71	1998	0.44	1958	1.66	19730909	13	7	1	0	8.3	33.0	1985

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Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, wrcc@dri.edu

SPENCER 10 NE, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(488475) SPENCER 10 NE														
From Year=1917 To Year=1974														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.39	2.53	1949	0.00	1919	1.50	09/1949	3	1	0	0	5.6	18.5	1944
February	0.44	2.37	1953	0.00	1947	1.00	25/1923	3	1	0	0	5.2	22.5	1953
March	0.80	1.63	1952	0.00	1974	1.02	12/1960	4	3	0	0	7.1	21.0	1943
April	1.80	4.36	1940	0.08	1954	1.50	02/1918	6	4	1	0	5.1	21.0	1918
May	2.46	6.79	1957	0.07	1936	2.38	31/1935	9	6	1	0	1.0	16.0	1942
June	2.50	6.02	1947	0.09	1974	1.72	21/1947	7	5	2	0	0.0	1.5	1937
July	1.79	5.75	1958	0.15	1964	1.75	28/1938	6	4	1	0	0.0	0.0	1919
August	1.25	3.01	1968	0.00	1961	2.55	15/1930	4	3	1	0	0.0	0.0	1917
September	1.13	3.18	1963	0.00	1956	1.54	18/1945	4	3	1	0	0.3	3.0	1961
October	0.81	2.51	1919	0.00	1952	1.55	16/1934	3	2	1	0	1.7	10.0	1932
November	0.43	1.79	1947	0.00	1917	0.74	08/1970	3	1	0	0	3.7	21.0	1947
December	0.34	1.04	1941	0.00	1935	0.76	13/1924	3	1	0	0	5.0	15.5	1941
Annual	14.13	19.66	1963	9.71	1960	2.55	19300815	57	35	8	2	34.7	66.3	1955
Winter	1.17	4.23	1953	0.16	1970	1.50	19490109	10	4	0	0	15.8	35.5	1953
Spring	5.06	9.34	1957	1.75	1966	2.38	19350531	19	13	3	1	13.1	28.0	1970
Summer	5.54	9.40	1951	1.44	1919	2.55	19300815	18	12	4	1	0.0	0.0	1919
Fall	2.37	4.38	1973	0.24	1917	1.55	19341016	10	7	1	0	5.8	12.0	1919

Table updated on Mar 24, 2011
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons

Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, wrcc@dri.edu

Appendix C

Ecological Site Description

(Loamy 10-14 NP)

UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

ECOLOGICAL SITE DESCRIPTION (Old Format Report)

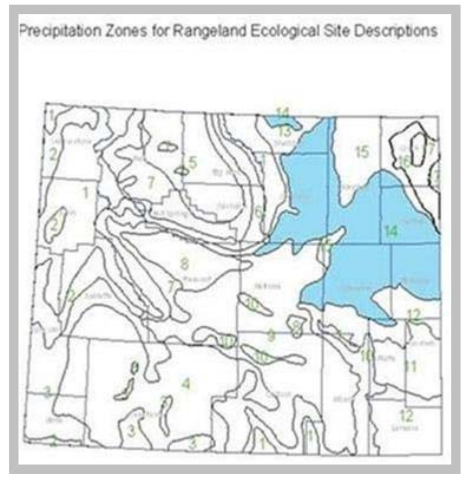
ECOLOGICAL SITE CHARACTERISTICS

Site Type: Rangeland

Site Name: Loamy (Ly) 10-14” Northern Plains Precipitation Zone

Site ID: R058BY122WY

Major Land Resource Area: 058B-Northern Rolling High Plains, Southern Part



Physiographic Features

This site occurs on gently undulating rolling land.

Landform: (1) Hill
(2) Alluvial fan
(3) Ridge

	Minimum	Maximum
Elevation (feet):	3800	5100
Slope (percent):	0	30
Water Table Depth (inches):		
Flooding:		
Frequency:	None	None
Duration:	None	None
Ponding:		
Depth (inches):	0	0
Frequency:	None	None
Duration:	None	None
Runoff Class:	Negligible	High

Aspect: No Influence on this site

Climatic Features

Annual precipitation ranges from 10-14 inches per year. Wide fluctuations may occur in yearly precipitation and result in more drought years than those with more than normal precipitation. Temperatures show a wide range between summer and winter and between daily maximums and minimums. This is predominantly due to the high elevation and dry air, which permits rapid incoming and outgoing radiation. Cold air outbreaks from Canada in winter move rapidly from northwest to southeast and account for extreme minimum temperatures. Chinook winds may occur in winter and bring rapid rises in temperature. Extreme storms may occur during the winter, but most severely affect ranch operations during late winter and spring.

Wind speed averages about 8 mph, ranging from 10 mph during the spring to 7 mph during late summer. Daytime winds are generally stronger than nighttime and occasional strong storms may bring brief periods of high winds with gusts to more than 75 mph.

Growth of native cool season plants begins about April 1 and continues to about July 1. Native warm season plants begin growth about May 15 and continue to about August 15. Green up of cool season plants may occur in September and October of most years.

The following information is from the “Clearmont 5 SW” climate station:
Frost-free period (32 F): 76 - 132 days; (5 yrs. out of 10, these days will occur between May 30 – September 11)
Freeze-free period 28 F): 110 - 145 days; (5 yrs. out of 10, these days will occur between May 16 – September 21)
Mean annual precipitation: 12.4 inches
Mean annual air temperature: 43.2 F (28.4 F Avg. Min. – 57.9 F Avg. Max.)
For detailed information visit the Natural Resources Conservation Service National Water and Climate Center at http://www.wcc.nrcs.usda.gov/ website. Other climate station(s) representative of this precipitation zone include: “Dull Center”

	Minimum	Maximum
Frost-free period (days):	76	132
Freeze-free period (days):	110	145
Mean annual precipitation (inches):	10.0	14.0

Monthly precipitation (inches) and temperature (°F):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precip. Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Precip. Max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temp. Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temp. Max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Climate Stations:

Influencing Water Features

Stream Type: None

Wetland Description:	System	Subsystem	Class

Representative Soil Features

The soils of this site are deep to moderately deep (greater than 20" to bedrock), well drained & moderately permeable. Layers of the soil most influential to the plant community varies from 3 to 6 inches thick. These layers consist of the A horizon with very fine sandy loam, loam, or silt loam texture and may also include the upper few inches of the B horizon with sandy clay loam, silty clay loam or clay loam texture.
Major Soil Series correlated to this site includes: Bidman, Cambria, Cushman, Forkwood, Kishona, Parmleed, Theedle and Zigweid.

Other Soil Series correlated to this site in MLRA 58B include: Absted, Arvada, Ascalon, Big Horn, Bowbac, Briggsdale, Cambria Variant, Cedak Dry, Clarkelen, Connerton, Docpar, El Rancho, Emigha, Emigrant, Forkwood Variant, Fort Collins, Garrett, Glendo, Harlan, Harlan Dry, Haverdad, Hiland, Jonpol, Kadoka, Keota, Keyner, Kim, Kirtley, Larim, Larimer, Lawver, Lohsman, Maysdorf, Neville, Noden, Nuncho, Platmak, Platmak Dry, Pugsley, Recluse, Recluse Dry, Redbow, Reddale, Renohill, Roughlock, Senlar, Spearman, Stoneham, Teckla, Thirtynine, Ulm, Ulm Dry, Wages, Wolf, Wolf Variant, Wolf Dry, and Wyotite.

Parent Materials:
Kind:
Origin:

Surface Texture: (1) Loam
(2) Gravelly Sandy loam
(3) Cobbly Very fine sandy loam

Subsurface Texture Group: Loamy

	Minimum	Maximum
Surface Fragments <=3" (% Cover):	0	0
Surface Fragments > 3" (% Cover):	0	10
Subsurface Fragments <=3" (% Volume):	0	15
Subsurface Fragments > 3" (% Volume):	0	10

Drainage Class: Moderately well drained To Well drained

Permeability Class: Moderately slow To Moderate

	Minimum	Maximum
Depth (inches):	20	60
Electrical Conductivity (mmhos/cm):	0	4
Sodium Absorption Ratio:	0	5
Calcium Carbonate Equivalent (percent):	0	10

Soil Reaction (1:1 Water):	6.6	8.4
Soil Reaction (0.01M $CaCl_2$):		
Available Water Capacity (inches):	3.0	6.3

Plant Communities

Ecological Dynamics of the Site

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.

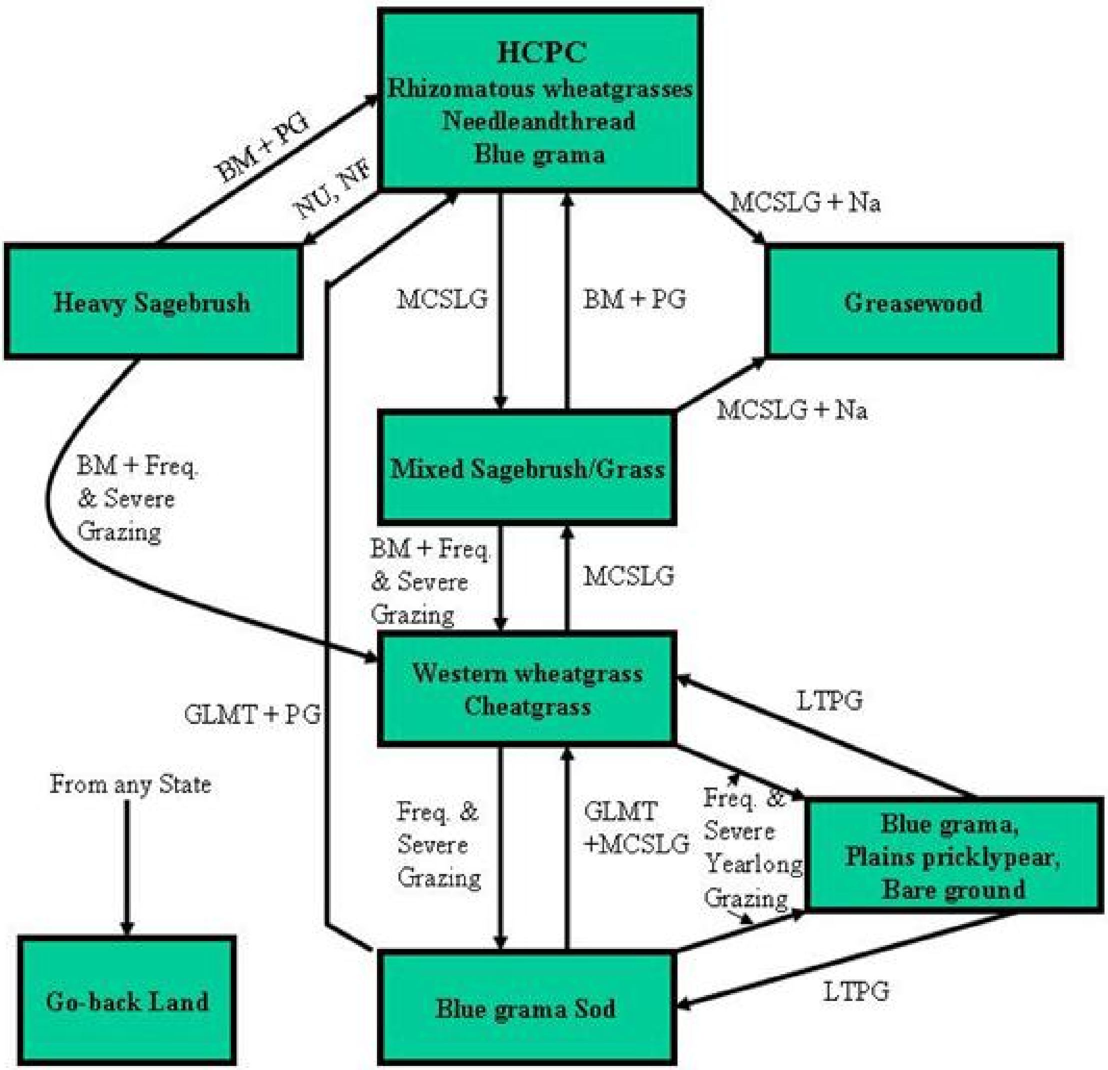
Due to the amount and pattern of the precipitation, the big sagebrush component typically is not resilient once it has been removed if a healthy and vigorous stand of grass exists and is maintained. The exception to this is where the herbaceous component is severely degraded at the time of treatment,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

The Historic Climax Plant Community (description follows the plant community diagram) has been determined by study of rangeland relic areas, or areas protected from excessive disturbance. Trends in plant communities going from heavily grazed areas to lightly grazed areas, seasonal use pastures, and historical accounts have also been used.

The following is a State and Transition Model Diagram that illustrates the common plant communities (states) that can occur on the site and the transitions between these communities. The ecological processes will be discussed in more detail in the plant community narratives following the diagram.

Site Type: Rangeland
MLRA: 58B – Northern Rolling High Plains

Loamy 10-14" P.Z.
R058BY122WY



BM - Brush Management (fire, chemical, mechanical)
Freq. & Severe Grazing - Frequent and Severe Utilization of the Cool-season Mid-grasses during the Growing Season
GLMT - Grazing Land Mechanical Treatment
LTPG - Long-tem Prescribed Grazing
MCSLG - Moderate, Continuous Season-long Grazing
NU, NF - No Use and No Fire
PG - Prescribed Grazing (proper stocking rates with adequate recovery periods during the growing season)
VLTPG - Very Long-term Prescribed Grazing (could possibly take generations)
Na - found adjacent to a saline site

<u>Rhizomatous wheatgrasses/Needleandthread/Blue Grama Plant Community</u>

This plant community is the interpretive plant community for this site and is considered to be the

Historic Climax Plant Community (HCPC). 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. 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.

Rhizomatous wheatgrasses/Needleandthread/Blue Grama Plant Community Plant Species Composition:

Grass/Grasslike

Group	Group Name	Common Name	Symbol	Scientific Name	Annual Production in Pounds Per Acre Low	High
1					175	375
		streambank wheatgrass, thickspike wheatgrass	ELLAL	*Elymus lanceolatus ssp. lanceolatus*	175	375
		western wheatgrass	PASM	*Pascopyrum smithii*	175	375
2					105	225
		green needlegrass	NAVI4	*Nassella viridula*	105	225
3					175	375
		needle and thread, needleandthread	HECO26	*Hesperostipa comata*	175	375

4					70	150
		Cusick's bluegrass, Cusick bluegrass	POCU3	*Poa cusickii*	70	150
5					105	225
		blue grama	BOGR2	*Bouteloua gracilis*	105	225
6					175	375
		Indian ricegrass	ACHY	*Achnatherum hymenoides*	35	75
		hairy grama	BOHI2	*Bouteloua hirsuta*	35	75
		needleleaf sedge	CADU6	*Carex duriuscula*	35	75
		threadleaf sedge	CAFI	*Carex filifolia*	35	75
		plains reedgrass	CAMO	*Calamagrostis montanensis*	35	75
		prairie Junegrass	KOMA	*Koeleria macrantha*	35	75
		Sandberg bluegrass, big bluegrass, Canby bluegrass, alkali bluegrass	POSE	*Poa secunda*	35	75
		bluebunch wheatgrass	PSSP6	*Pseudoroegneria spicata*	35	75

Forb

Group	Group Name	Common Name	Symbol	Scientific Name	Annual Production in Pounds Per Acre Low	High
7					105	225
		yarrow	ACHIL	*Achillea*	35	75
		textile onion	ALTE	*Allium textile*	35	75
		rosy pussytoes, rose pussytoes	ANRO2	*Antennaria rosea*	35	75
		aster	ASTER	*Aster*	35	75
		milkvetch	ASTRA	*Astragalus*	35	75
		tapertip hawksbeard	CRAC2	*Crepis acuminata*	35	75
		white prairie clover	DACA7	*Dalea candida*	35	75
		violet prairie clover, purple prairie clover	DAPU5	*Dalea purpurea*	35	75
		sulphur-flower buckwheat	ERUM	*Eriogonum umbellatum*	35	75
		scarlet beeblossom, scarlet gaura	GACO5	*Gaura coccinea*	35	75
		stemless mock goldenweed	HAAC	*Haplopappus acaulis(syn)*	35	75
		desertparsley, biscuitroot	LOMAT	*Lomatium*	35	75
		bluebells	MERTE	*Mertensia*	35	75
		large Indian breadroot, breadroot scurfpea	PEES	*Pediomelum esculentum*	35	75
		upright prairie coneflower, prairie coneflower	RACO3	*Ratibida columnifera*	35	75
		American vetch	VIAM	*Vicia americana*	35	75

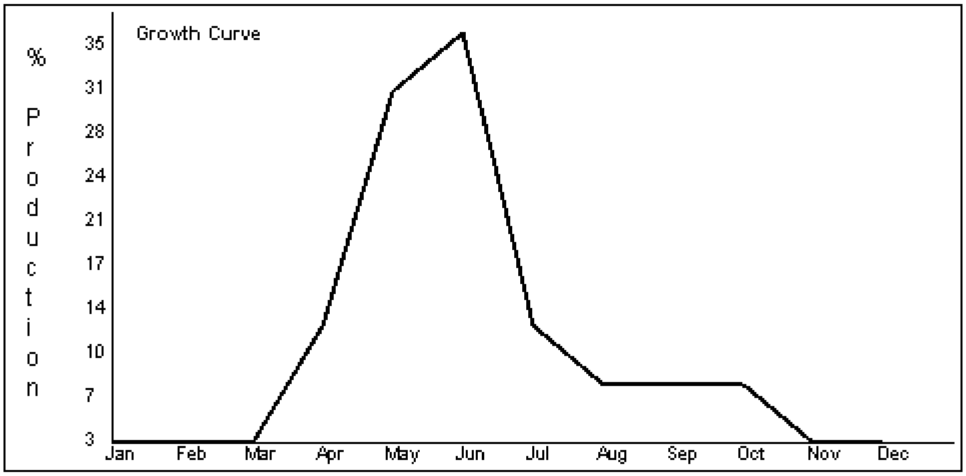
Shrub/Vine

Group	Group Name	Common Name	Symbol	Scientific Name	Annual Production in Pounds Per Acre Low	High
8					70	150
		big sagebrush	ARTR2	*Artemisia tridentata*	70	150
9					35	75
		winterfat	KRLA2	*Krascheninnikovia lanata*	35	75

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Mixed Sagebrush/Grass Plant Community

Historically, this plant community evolved under grazing by bison and a low fire frequency. Currently, it is found under moderate, season-long grazing by livestock in the absence of fire or brush management. Wyoming big sagebrush is a significant component of this plant community. Cool-season grasses make up the majority of the understory with the balance made up of short warm-season grasses, annual cool-season grasses, and miscellaneous forbs.

Dominant grasses include needleandthread, western wheatgrass, and green needlegrass. Grasses of secondary importance include blue grama, prairie junegrass, and Sandberg bluegrass. Forbs commonly found in this plant community include plains wallflower, hairy goldaster, slimflower scurfpea, and scarlet globemallow. Sagebrush canopy ranges from 20% to 30%. Fringed sagewort is commonly found. Plains pricklypear can also occur.

When compared to the Historic Climax Plant Community, sagebrush and blue grama have increased. Production of cool-season grasses, particularly green needlegrass, has been reduced. The sagebrush canopy protects the cool-season mid-grasses, but this protection makes them unavailable for grazing. Cheatgrass (downy brome) has invaded the site. The overstory of sagebrush and understory of grass and forbs provide a diverse plant community that will support domestic livestock and wildlife such as mule deer and antelope.

The total annual production (air-dry weight) of this state is about 900 pounds per acre, but it can range from about 700 lbs./acre in unfavorable years to about 1,200 lbs./acre in above average years.

This plant community is resistant to change. A significant reduction of big sagebrush can only be accomplished through fire or brush management. The herbaceous species present are well adapted to grazing; however, species composition can be altered through long-term overgrazing. If the herbaceous component is intact, it tends to be resilient if the disturbance is not long-term.

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

• Brush management (chemical, fire, or mechanical), followed by prescribed grazing, will convert this plant community to the Rhizomatous wheatgrasses, Needleandthread, Blue grama Plant Community. The probability of this occurring is high. When prescribed fire is used, sufficient fine fuels will need to be present. This may require deferment from grazing prior to treatment. Post management is critical to ensure success. This can range from two or more years of rest to partial growing season deferment, depending on the condition of the understory at the time of treatment and the growing conditions following treatment. In the case of an intense wildfire that occurs when desirable plants are not completely dormant, the length of time required to reach the Rhizomatous wheatgrasses, Needleandthread, Blue grama Plant Community may be increased.

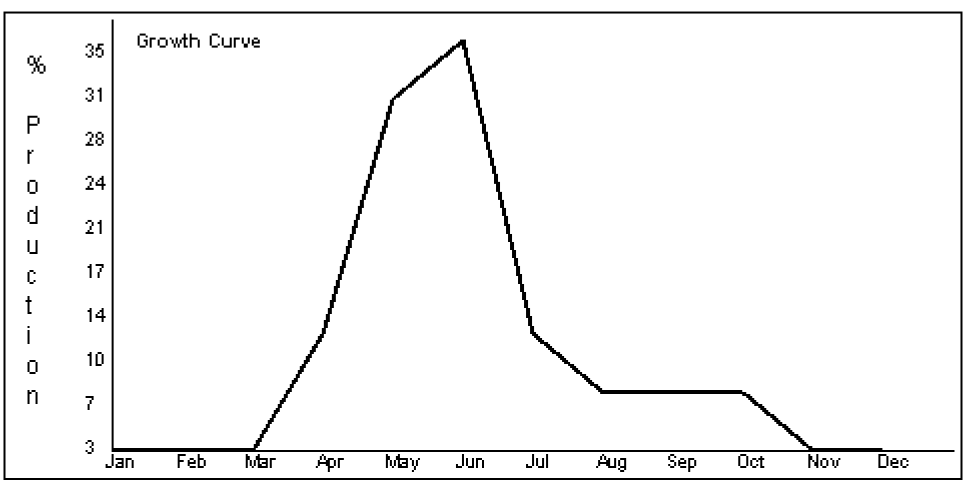
• Brush management, followed by frequent and severe grazing, will convert the plant community to the Western Wheatgrass/Cheatgrass Plant Community. The probability of this occurring is high. If bare areas exist after treatment, along with no recovery periods from grazing, cheatgrass will invade and plants not as resistant to grazing as western wheatgrass will be reduced.

• Moderate continuous season-long grazing, where greasewood occurs adjacent to this state, will convert the plant community to the Greasewood Plant Community.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Heavy Sagebrush Plant Community

This plant community is the result of long-term protection from grazing and fire. Sagebrush eventually dominates this plant community with canopy cover often exceeding 60%. At first, excessive litter builds up, shading out some of the grasses and forbs. Other plants become decadent with low vigor. Bunch grasses often develop dead centers. Eventually, the interspaces between plants increase in size leaving more soil surface exposed. Organic matter oxidizes in the air rather than being incorporated into the soil.

The dominant plants tend to be somewhat similar to those found in the Historic Climax Plant Community. Weedy species, cool-season grasses, and sedges have increased. Blue grama has decreased. Rodent activity has resulted in an increase in soil disturbance. Cactus and sageworts often increase. Noxious weeds such as Dalmatian toadflax, leafy spurge, or Canada thistle may invade the site if a seed source is present. Plant diversity is moderate to high.

The total annual production (air-dry weight) of this state is about 800 pounds per acre, but it can range from about 600 lbs./acre in unfavorable years to about 1,000 lbs./acre in above average years.

This plant community is not resistant to change and is more vulnerable to severe disturbance than the HCPC. The introduction of grazing or fire quickly changes the plant community.

Soil erosion is accelerated because of increased bare ground. Water flow patterns and pedestaling are obvious. Infiltration is reduced and runoff is increased.

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

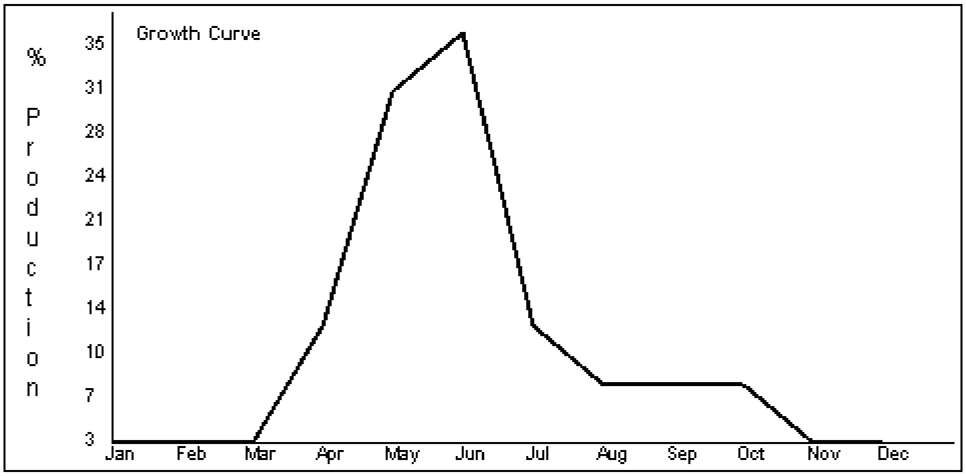
• Brush management, followed by prescribed grazing, will return this plant community to at or near the Rhizomatous Wheatgrasses, Needleandthread, Blue Grama Plant Community.

• Brush management, followed by frequent and severe grazing, will convert the plant community to the Western Wheatgrass/Cheatgrass Plant Community. The probability of this occurring is high because of the amount of bare ground exposed to cheatgrass invasion.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Western Wheatgrass/Cheatgrass Plant Community

This plant community is created when the Mixed Sagebrush/Grass Plant Community or the Heavy Sagebrush Plant Community is subjected to fire or brush management not followed by prescribed grazing. Rhizomatous wheatgrasses and annuals will eventually dominate the site.

Compared to the HCPC, cheatgrass has invaded with western wheatgrass and thickspike wheatgrass maintaining at a similar or slightly higher level. Virtually all other cool-season mid-grasses are severely decreased. Blue grama is the same or slightly less than found in the HCPC. Plant diversity is low.

The total annual production (air-dry weight) of this state is about 600 pounds per acre, but it can range from about 450 lbs./acre in unfavorable years to about 750 lbs./acre in above average years.

This plant community is relatively stable with the rhizomatous wheatgrasses being somewhat resistant to overgrazing and the cheatgrass effectively competing against the establishment of perennial cool-season grasses.

An increase in bare ground reduces water infiltration and increases soil erosion. The watershed is usually functioning. The biotic integrity is reduced by the lack of diversity in the plant community.

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

• Moderate continuous season-long grazing will eventually return this plant community to the Mixed Sagebrush/Grass Plant Community.

• Frequent and severe grazing will convert this plant community to Blue Grama Sod Plant Community.

• Frequent and severe yearlong grazing will convert this plant community to Blue grama, Plains Pricklypear, Bare Ground Plant Community.

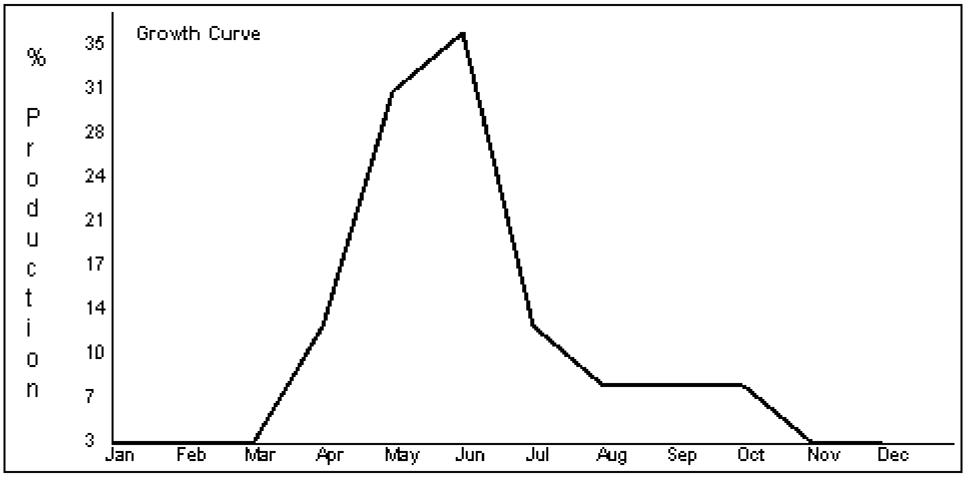
• Long-term, prescribed grazing will eventually return this plant community to at or near the Rhizomatous Wheatgrasses, Needleandthread, Blue Grama Plant Community.

Plant Growth Curve:

Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Blue Grama Sod Plant Community

This plant community is the result of frequent and severe grazing during the growing season of the cool-season mid-grasses. A dense sod of blue grama dominates it. Pricklypear cactus can become dense enough so that livestock cannot graze forage growing within the cactus clumps.

When compared to the Historic Climax Plant Community, blue grama and threadleaf sedge have increased. All cool-season mid-grasses and forbs have been greatly reduced. Plant diversity is extremely low.

The total annual production (air-dry weight) of this state is about 600 pounds per acre, but it can range from about 450 lbs./acre in unfavorable years to about 750 lbs./acre in above average years.

This sod bound plant community is very resistant to water infiltration. While this sod protects the site itself, off-site areas are affected by excessive runoff that can cause gully erosion. This sod is very resistant to change and may require a grazing land mechanical treatment, such as chiseling, to return the cool-season grass component.

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

• Grazing land mechanical treatment (chiseling, etc.) and pricklypear cactus control (if needed), followed by prescribed grazing, will return this plant community to near Historic Climax Plant Community condition.

• Grazing land mechanical treatment, followed by moderate continuous season-long grazing, will convert this plant community to the Western Wheatgrass/Cheatgrass Plant Community.

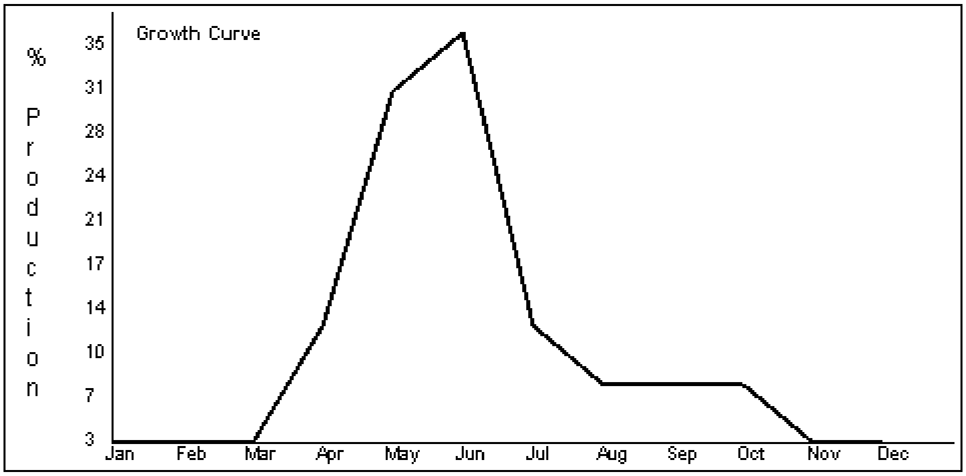
• Frequent and severe yearlong grazing will eventually convert this state to the Blue Grama, Plains

Pricklypear, Bare Ground Plant Community.

<u>Plant Growth Curve:</u>
<u>Growth Curve Number:</u> WY1401
<u>Growth Curve Name:</u> 10-14NP upland sites
<u>Growth Curve Description:</u>

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



<u>Greasewood Plant Community</u>

This plant community can occur where states are subjected to continuous season-long grazing at moderate stocking rates and where greasewood occurs adjacent to the site. It is dominated by an overstory of greasewood and possibly big sagebrush. Rhizomatous wheatgrasses, cheatgrass, and inland saltgrass make up the understory. Salts in the surface will increase due to the shedding of the salt-filled leaves of the greasewood. Plant diversity is high.

The total annual production (air-dry weight) of this state is about 700 pounds per acre, but it can range from about 525 lbs./acre in unfavorable years to about 875 lbs./acre in above average years.

This plant community is resistant to change. A significant reduction of greasewood can only be accomplished through repeated brush control treatments. The herbaceous species present are well adapted to grazing; however, species composition can be altered through long-term overgrazing. If the herbaceous component is intact, it tends to be resilient if the disturbance is not long-term.

The site is protected from erosion as long as ground cover is maintained. The biotic integrity of this state is somewhat intact because of the woody overstory and perennial grass understory. The watershed is functioning as long as a grass cover is maintained.

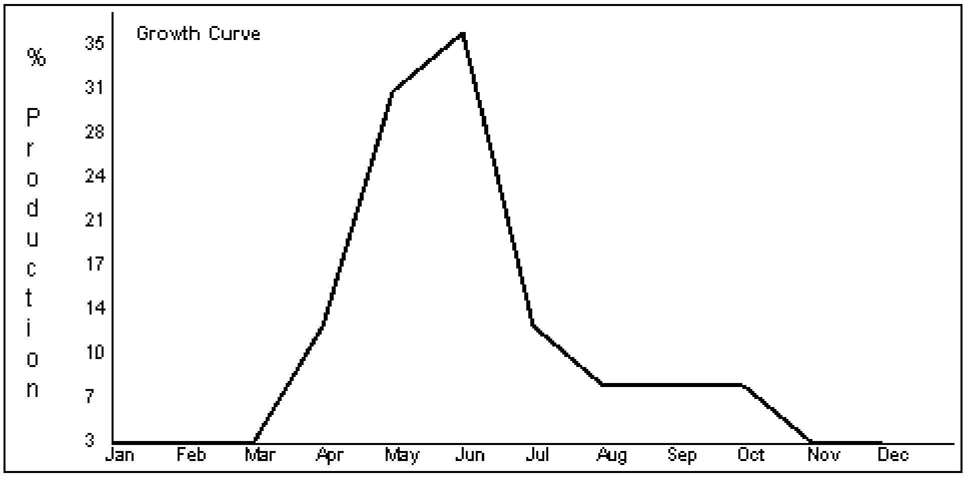
• Recovery to near Historic Climax Plant Community condition is difficult due to the resistance of greasewood to herbicides and accumulated effects of salts on the soil.

<u>Plant Growth Curve:</u>

Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Blue Grama Sod/Plains Pricklypear/Bare Ground Plant Community

This plant community is the result of frequent and severe yearlong grazing over the long-term. Perennial plants are decreased. Cheatgrass, annual weeds, and bare ground are increased. Plains pricklypear may have increased, rendering much of the forage unusable by livestock.

This plant community is highly variable depending on the severity, frequency, and duration of the grazing and also the condition of the plant community when this level of grazing began. Virtually all plants not resistant to overgrazing may have been eliminated. Dominant plants may include blue grama, threeawns, annuals, and, to a lesser degree, rhizomatous wheatgrasses. Perennial plant diversity is low.

The total annual production (air-dry weight) of this state is about 500 pounds per acre, but it can range from about 375 lbs./acre in unfavorable years to about 625 lbs./acre in above average years.

This state is unhealthy and subject to increased erosion. Runoff is high on this state due to the sod nature of blue grama and bare ground.

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

• Long-term prescribed grazing will convert this plant community initially to the Blue Grama Sod Plant Community, when this state is dominated by blue grama sod at the time of treatment.

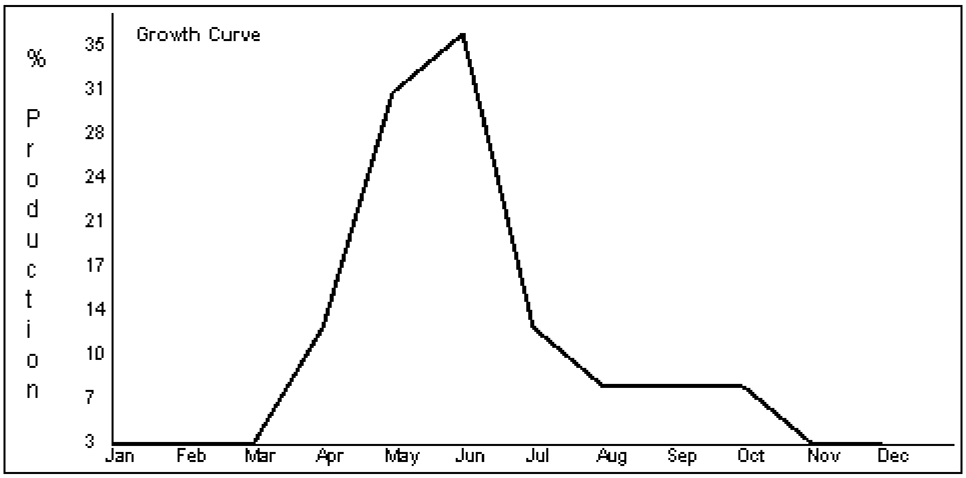
• Long-term prescribed grazing will convert this plant community to the Western Wheatgrass /Cheatgrass Plant Community, when this state has large amounts of cheatgrass, annual weeds, and bare ground at the time of treatment. Control of plains pricklypear cactus may be necessary.

Reseeding areas with native plant species and proper grazing management may be necessary to accelerate recovery where few desirable plants remain.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Go-back Land

This plant community occurs on land that has been cropped annually in the past and then abandoned without reseeding. Natural succession has resulted in a plant community dominated by varying combinations of red threeawn, cheatgrass, blue grama, Sandberg bluegrass, and some rhizomatous wheatgrasses. Forage production is low and grasses such as red threeawn and cheatgrass are not used efficiently by livestock.

The total annual production (air-dry weight) of this state is about 600 pounds per acre, but it can range from about 500 lbs./acre in unfavorable years to about 900 lbs./acre in above average years.

The potential for accelerated erosion can be highly variable depending on amount of bare ground present. Biological diversity is low.

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

• Prescribed grazing may be used to increase desirable native cool-season grass production. It is usually difficult to return to near Historic Climax Plant Community condition in a timely manner because of past soil loss.

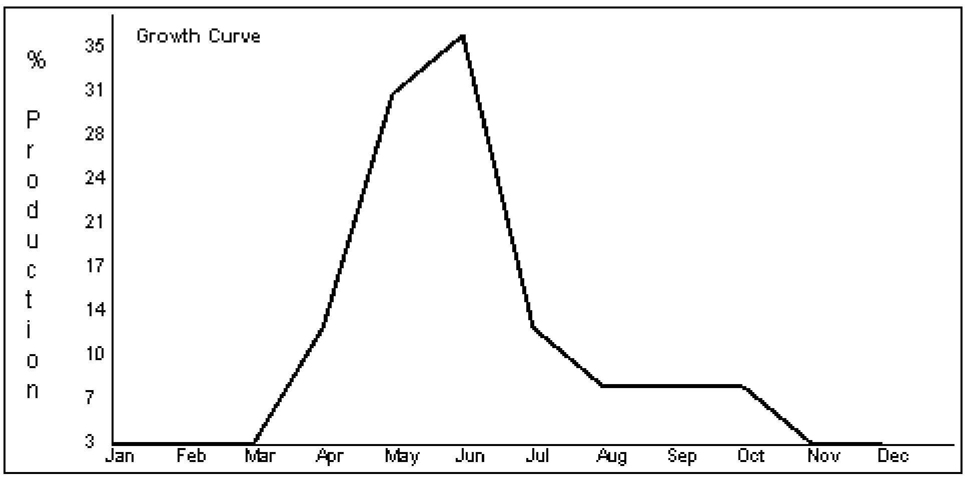
• Grazing land mechanical treatment (i.e., chiseling) may improve forage production where significant rhizomatous wheatgrass is present to respond.

Where there is a lack of perennial grasses, reseeding to tame or native species may be necessary to return these lands to production in the form of pastureland. These pastures are normally seeded to crested wheatgrass, pubescent wheatgrass, or Russian wildrye. They require considerable investment to establish and have a variable life expectancy. They do produce up to 50% more than native range, but their value as forage is somewhat limited due to the single species usually seeded. In some cases, the single species or certain groups of species (e.g., wheatgrasses) may be more vulnerable to infestation by associated insects and/or diseases (e.g., black grass bugs).

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0



Ecological Site Interpretations

Animal Community:
Animal Community – Wildlife Interpretations
Rhizomatous Wheatgrasses, Needleandthread, Blue Grama Plant Community (HCPC): The predominance of grasses in this plant community favors grazers and mixed-feeders, such as bison, elk, and antelope. Suitable thermal and escape cover for deer may be limited due to the low quantities of woody plants. However, topographical variations could provide some escape cover. When found adjacent to sagebrush dominated states, this plant community may provide brood rearing/foraging areas for sage grouse, as well as lek sites. Other birds that would frequent this plant community include western meadowlarks, horned larks, and golden eagles. Many grassland obligate small mammals would occur here.

Mixed Sagebrush/Grass Plant Community: The combination of an overstory of sagebrush and an understory of grasses and forbs provide a very diverse plant community for wildlife. The crowns of sagebrush tend to break up hard crusted snow on winter ranges, so mule deer and antelope may use this state for foraging and cover year-round, as would cottontail and jack rabbits. It provides important winter, nesting, brood-rearing, and foraging habitat for sage grouse. Brewer’s sparrows’ nest in big sagebrush plants, and hosts of other nesting birds utilize stands in the 20-30% cover range.

Heavy Sagebrush Plant Community: This plant community can provide important winter foraging for elk, mule deer and antelope, as sagebrush can approach 15% protein and 40-60% digestibility during that time. This community provides excellent escape and thermal cover for large ungulates, as well as nesting and brood rearing habitat for sage grouse.

Western Wheatgrass/Cheatgrass Plant Community: This plant community may be useful for the same large grazers that would use the Historic Climax Plant Community. However, the plant community composition is less diverse, and thus, less apt to meet the seasonal needs of these animals. It may provide some foraging opportunities for sage grouse when it occurs proximal to woody cover. Good grasshopper habitat equals good foraging for birds.

Blue Grama Sod and Go-back Land Plant Communities: These communities provide limited foraging for antelope and other grazers. They may be used as a foraging site by sage grouse if proximal to woody cover and if the Historic Climax Plant Community or the Western Wheatgrass/Cheatgrass Plant Community is limiting. Generally, these are not target plant communities for wildlife habitat management.

Greasewood Plant Community: This plant community exhibits a low level of plant species diversity due to the accumulation of salts in the soil. It may provide some thermal and escape cover for deer and antelope if no other woody community is nearby, but in most cases it is not a desirable plant community to select as a wildlife habitat management objective.

Blue Grama, Plains Pricklypear, Bare Ground Plant Community: Benefits to other wildlife are largely due to the subterranean structure created by the prairie dogs, not the sparse vegetation found on this plant community.

Introduced Pasture: These communities are highly variable depending on the species planted. Refer to Forage Suitability Groups for more information.

Animal Community – Grazing Interpretations

The following table lists suggested stocking rates for cattle under continuous season-long grazing under normal growing conditions. These are conservative estimates that should be used only as guidelines in the initial stages of the conservation planning process. Often, the current plant composition does not entirely match any particular plant community (as described in this ecological site description). Because of this, a field visit is recommended, in all cases, to document plant composition and production. More precise carrying capacity estimates should eventually be calculated using this information along with animal preference data, particularly when grazers other than cattle are involved. Under more intensive grazing management, improved harvest efficiencies can result in an increased carrying capacity. If distribution problems occur, stocking rates must be reduced to maintain plant health and vigor.

Plant Community Production Carrying Capacity*
(lb./ac) (AUM/ac)
Rhizomatous WG, Needleandthread, Blue Grama 700-1500 .4

Heavy Sagebrush 800-1400 .3
Blue Grama Sod 400-1000 .2
Mixed Sagebrush/Grass 700-1200 .33
Western Wheatgrass/Cheatgrass 600-1200 .2
Blue grama, Plains Pricklypear, Bare ground 300-800 .1
Greasewood 525-875 .3
Go-back Land 500-900 .2

* - Continuous, season-long grazing by cattle under average growing conditions.

Grazing by domestic livestock is one of the major income-producing industries in the area. Rangeland in this area may provide yearlong forage for cattle, sheep, or horses. During the dormant period, the forage for livestock use needs to be supplemented with protein because the quality does not meet minimum livestock requirements.

Plant Preference by Animal Kind:

Animal Kind: AllAntelope

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Indian ricegrass	*Achnatherum hymenoides*	Leaves	N	N	N	P	P	P	N	N	N	D	D	D
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand bluestem	*Andropogon hallii*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rosy pussytoes, rose pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
silver sagebrush	*Artemisia cana*	Leaves	P	P	P	P	P	P	P	P	P	P	P	P
tarragon, green sagewort	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort, fringed sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn, red threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
twogrooved milkvetch	*Astragalus bisulcatus*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	P	P	P	P	P	P	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sideoats grama	*Bouteloua curtipendula*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue grama	*Bouteloua gracilis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
buffalograss	*Buchloe dactyloides(syn)*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint, bluejoint reedgrass	*Calamagrostis canadensis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Leaves	P	P	P	P	P	P	P	P	P	P	P	P
inland sedge	*Carex interior*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sandreed	*Calamovilfa longifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
plains reedgrass	*Calamagrostis montanensis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

Nebraska sedge	Carex nebrascensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
yellow rabbitbrush, green rabbitbrush, low rabbitbrush, Douglas rabbitbrush	Chrysothamnus viscidiflorus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	Cicuta	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	Conium maculatum	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	Crepis acuminata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
white prairie clover	Dalea candida	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
violet prairie clover, purple prairie clover	Dalea purpurea	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
tufted hairgrass	Deschampsia caespitosa(syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland saltgrass	Distichlis spicata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	Elymus caninus	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
Canada wildrye	Elymus canadensis	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
silverberry	Elaeagnus commutata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail, bottlebrush squirreltail	Elymus elymoides ssp. elymoides	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
streambank wheatgrass, thickspike wheatgrass	Elymus lanceolatus ssp. lanceolatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	Elymus trachycaulus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
horsetail	Equisetum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	Ericameria nauseosa	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sulphur-flower buckwheat	Eriogonum umbellatum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom, scarlet gaura	Gaura coccinea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	Glycyrrhiza lepidota	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
stemless mock goldenweed	Haplopappus acaulis(syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread, needleandthread	Hesperostipa comata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	Iris	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Baltic rush	Juncus balticus(syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Rocky Mountain juniper	Juniperus scopulorum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	Koeleria macrantha	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	Kraschenninkovia lanata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	Leymus cinereus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
desertparsley, biscuitroot	Lomatium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	Mertensia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly, stoneyhills muhly	Muhlenbergia cuspidata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
mat muhly	Muhlenbergia richardsonis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	Nassella viridula	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	Pascopyrum smithii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot, breadroot scurfpea	Pediomelum esculentum	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	Pinus ponderosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Sandberg bluegrass	Poa canbyi(syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass, Cusick bluegrass	Poa cusickii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	Populus deltoides ssp. monilifera	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Sandberg bluegrass, big bluegrass, Canby bluegrass, alkali bluegrass	Poa secunda	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	Poa secunda ssp. juncifolia(syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
bluebunch wheatgrass	Pseudoroegneria spicata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nuttall's alkaligrass	Puccinellia nuttalliana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower, prairie coneflower	Ratibida columnifera	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
skunkbush sumac	Rhus trilobata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	Rosa woodsii var. woodsii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	Salix	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
greasewood	Sarcobatus vermiculatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	Schizachyrium scoparium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue-eyed grass	Sisyrinchium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
alkali sacaton	Sporobolus airoides	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand dropseed	Sporobolus cryptandrus	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
alkali cordgrass	Spartina gracilis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Pursh seepweed	Suaeda calceoliformis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	Symphoricarpos occidentalis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie thermopsis	Thermopsis rhombifolia var. annulocarpa(syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	Triglochin	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	Typha angustifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broadleaf cattail	Typha latifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American vetch	Vicia americana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca, small soapweed	Yucca glauca	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	Achillea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

Animal Kind: allCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Indian ricegrass	Achnatherum hymenoides	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

Animal Kind: AllCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
textile onion	Allium textile	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	Andropogon gerardii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand bluestem	Andropogon hallii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
rosy pussytoes, rose pussytoes	Antennaria rosea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
tarragon, green sagewort	Artemisia dracunculus	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort, fringed sagewort	Artemisia frigida	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	Artemisia pedatifida	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn, red threeawn	Aristida purpurea var. longiseta	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	Artemisia tridentata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
aster	Aster	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	Astragalus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	Atriplex canescens	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

Gardner's saltbush	Atriplex gardneri	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sideoats grama	Bouteloua curtipendula	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue grama	Bouteloua gracilis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	Bouteloua hirsuta	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
buffalograss	Buchloe dactyloides(syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint, bluejoint reedgrass	Calamagrostis canadensis	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
needleleaf sedge	Carex duriuscula	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	Carex filifolia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	Carex interior	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie sandreed	Calamovilfa longifolia	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains reedgrass	Calamagrostis montanensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	Carex nardina	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nebraska sedge	Carex nebrascensis	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
yellow rabbitbrush, green rabbitbrush, low rabbitbrush, Douglas rabbitbrush	Chrysothamnus viscidiflorus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	Cicuta	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	Conium maculatum	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	Crepis acuminata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
white prairie clover	Dalea candida	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
violet prairie clover, purple prairie clover	Dalea purpurea	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
tufted hairgrass	Deschampsia caespitosa(syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
inland saltgrass	Distichlis spicata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	Elymus caninus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Canada wildrye	Elymus canadensis	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
silverberry	Elaeagnus commutata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail, bottlebrush squirreltail	Elymus elymoides ssp. elymoides	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
streambank wheatgrass, thickspike wheatgrass	Elymus lanceolatus ssp. lanceolatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	Elymus trachycaulus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
horsetail	Equisetum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	Ericameria nauseosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
sulphur-flower buckwheat	Eriogonum umbellatum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom, scarlet gaura	Gaura coccinea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	Glycyrrhiza lepidota	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
stemless mock goldenweed	Haplopappus acaulis(syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread, needleandthread	Hesperostipa comata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	Iris	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Baltic rush	Juncus balticus(syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Rocky Mountain juniper	Juniperus scopulorum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	Koeleria macrantha	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	Krascheninnikovia lanata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	Leymus cinereus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

desertparsley,

biscuitroot	*Lomatium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	*Mertensia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly, stoneyhills muhly	*Muhlenbergia cuspidata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
mat muhly	*Muhlenbergia richardsonis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	*Nassella viridula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	*Pascopyrum smithii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot, breadroot scurfpea	*Pediomelum esculentum*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	*Pinus ponderosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Sandberg bluegrass	*Poa canbyi(syn)*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass, Cusick bluegrass	*Poa cusickii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	*Populus deltoides ssp. monilifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass, big bluegrass, Canby bluegrass, alkali bluegrass	*Poa secunda*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: allCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Sandberg bluegrass	*Poa secunda ssp. juncifolia(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
bluebunch wheatgrass	*Pseudoroegneria spicata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Nuttall's alkaligrass	*Puccinellia nuttalliana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower, prairie coneflower	*Ratibida columnifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
skunkbush sumac	*Rhus trilobata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	*Rosa woodsii var. woodsii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	*Salix*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
greasewood	*Sarcobatus vermiculatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	*Schizachyrium scoparium*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
alkali sacaton	*Sporobolus airoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand dropseed	*Sporobolus cryptandrus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: allCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
alkali cordgrass	*Spartina gracilis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllCattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Pursh seepweed	*Suaeda calceoliformis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	*Symphoricarpos occidentalis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie thermopsis	*Thermopsis rhombifolia var. annulocarpa(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	*Triglochin*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	*Typha angustifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
broadleaf cattail	*Typha latifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
American vetch	*Vicia americana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca, small soapweed	*Yucca glauca*	Fruits/Seeds	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllDeer

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D

yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand bluestem	*Andropogon hallii*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rosy pussytoes, rose pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
tarragon, green sagewort	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort, fringed sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn, red threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Wyoming big sagebrush	*Artemisia tridentata ssp. wyomingensis*	Entire plant	P	P	P	P	P	P	D	D	D	D	D	D
twogrooved milkvetch	*Astragalus bisulcatus*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sideoats grama	*Bouteloua curtipendula*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue grama	*Bouteloua gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
buffalograss	*Buchloe dactyloides(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint, bluejoint reedgrass	*Calamagrostis canadensis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	*Carex interior*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sandreed	*Calamovilfa longifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
plains reedgrass	*Calamagrostis montanensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Nebraska sedge	*Carex nebrascensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
yellow rabbitbrush, green rabbitbrush, low rabbitbrush, Douglas rabbitbrush	*Chrysothamnus viscidiflorus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	*Cicuta*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	*Conium maculatum*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	*Crepis acuminata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
white prairie clover	*Dalea candida*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
violet prairie clover, purple prairie clover	*Dalea purpurea*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
tufted hairgrass	*Deschampsia caespitosa(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland saltgrass	*Distichlis spicata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	*Elymus caninus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Canada wildrye	*Elymus canadensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
silverberry	*Elaeagnus commutata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
squirreltail, bottlebrush squirreltail	*Elymus elymoides ssp. elymoides*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
streambank wheatgrass, thickspike wheatgrass	*Elymus lanceolatus ssp. lanceolatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

slender wheatgrass	*Elymus trachycaulus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
horsetail	*Equisetum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	*Ericameria nauseosa*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sulphur-flower buckwheat	*Eriogonum umbellatum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom, scarlet gaura	*Gaura coccinea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	*Glycyrrhiza lepidota*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
stemless mock goldenweed	*Haplopappus acaulis(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread, needleandthread	*Hesperostipa comata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	*Iris*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Baltic rush	*Juncus balticus(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Rocky Mountain juniper	*Juniperus scopulorum*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie Junegrass	*Koeleria macrantha*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	*Krascheninnikovia lanata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	*Leymus cinereus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
desertparsley, biscuitroot	*Lomatium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	*Mertensia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly, stoneyhills muhly	*Muhlenbergia cuspidata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
mat muhly	*Muhlenbergia richardsonis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	*Nassella viridula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	*Pascopyrum smithii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot, breadroot scurfpea	*Pediomelum esculentum*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	*Pinus ponderosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Sandberg bluegrass	*Poa canbyi(syn)*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass, Cusick bluegrass	*Poa cusickii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	*Populus deltoides ssp. monilifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass, big bluegrass, Canby bluegrass, alkali bluegrass	*Poa secunda*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	*Poa secunda ssp. juncifolia(syn)*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
bluebunch wheatgrass	*Pseudoroegneria spicata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nuttall's alkaligrass	*Puccinellia nuttalliana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower, prairie coneflower	*Ratibida columnifera*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
prairie coneflower	*Ratibida*	Entire plant	D	D	D	P	P	P	D	D	D	D	D	D
skunkbush sumac	*Rhus trilobata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	*Rosa woodsii var. woodsii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	*Salix*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
greasewood	*Sarcobatus vermiculatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	*Schizachyrium scoparium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue-eyed grass	*Sisyrinchium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
alkali sacaton	*Sporobolus airoides*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand dropseed	*Sporobolus cryptandrus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
alkali cordgrass	*Spartina gracilis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

Pursh seepweed	*Suaeda calceoliformis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	*Symphoricarpos occidentalis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie thermopsis	*Thermopsis rhombifolia var. annulocarpa(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	*Triglochin*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	*Typha angustifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broadleaf cattail	*Typha latifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American vetch	*Vicia americana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca, small soapweed	*Yucca glauca*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand bluestem	*Andropogon hallii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
rosy pussytoes, rose pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
silver sagebrush	*Artemisia cana ssp. cana*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
tarragon, green sagewort	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort, fringed sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn, red threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	U	U	U	N	N	N	N	N	N	U	U	U
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	D	D	D	U	U	U	U	U	U	D	D	D
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue grama	*Bouteloua gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
buffalograss	*Buchloe dactyloides(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint, bluejoint reedgrass	*Calamagrostis canadensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	*Carex interior*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie sandreed	*Calamovilfa longifolia*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains reedgrass	*Calamagrostis montanensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nebraska sedge	*Carex nebrascensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
yellow rabbitbrush, green rabbitbrush, low rabbitbrush, Douglas rabbitbrush	*Chrysothamnus viscidiflorus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	*Cicuta*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	*Conium maculatum*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	*Crepis acuminata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
white prairie clover	*Dalea candida*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

violet prairie clover, purple prairie clover	*Dalea purpurea*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
tufted hairgrass	*Deschampsia caespitosa(syn)*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
inland saltgrass	*Distichlis spicata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	*Elymus caninus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Canada wildrye	*Elymus canadensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
silverberry	*Elaeagnus commutata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail, bottlebrush squirreltail	*Elymus elymoides ssp. elymoides*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
streambank wheatgrass, thickspike wheatgrass	*Elymus lanceolatus ssp. lanceolatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	*Elymus trachycaulus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
horsetail	*Equisetum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	*Ericameria nauseosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
sulphur-flower buckwheat	*Eriogonum umbellatum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom, scarlet gaura	*Gaura coccinea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	*Glycyrrhiza lepidota*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
stemless mock goldenweed	*Haplopappus acaulis(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread, needleandthread	*Hesperostipa comata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	*Iris*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Baltic rush	*Juncus balticus(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Rocky Mountain juniper	*Juniperus scopulorum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	*Koeleria macrantha*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	*Krascheninnikovia lanata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	*Leymus cinereus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
desertparsley, biscuitroot	*Lomatium*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bluebells	*Mertensia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly, stoneyhills muhly	*Muhlenbergia cuspidata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
mat muhly	*Muhlenbergia richardsonis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	*Nassella viridula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	*Pascopyrum smithii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot, breadroot scurfpea	*Pediomelum esculentum*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	*Pinus ponderosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Sandberg bluegrass	*Poa canbyi(syn)*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass, Cusick bluegrass	*Poa cusickii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	*Populus deltoides ssp. monilifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass, big bluegrass, Canby bluegrass, alkali bluegrass	*Poa secunda*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: allHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Sandberg bluegrass	*Poa secunda ssp. juncifolia(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
bluebunch wheatgrass	*Pseudoroegneria spicata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Nuttall's alkaligrass	*Puccinellia nuttalliana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower, prairie coneflower	*Ratibida columnifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
skunkbush sumac	*Rhus trilobata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	*Rosa woodsii var. woodsii*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
willow	*Salix*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: allHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
greasewood	*Sarcobatus vermiculatus*	Leaves	U	U	U	U	U	U	U	U	U	U	U	U

Animal Kind: AllHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
little bluestem	*Schizachyrium scoparium*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue-eyed grass	*Sisyrinchium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
alkali sacaton	*Sporobolus airoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand dropseed	*Sporobolus cryptandrus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: allHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
alkali cordgrass	*Spartina gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllHorses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Pursh seepweed	*Suaeda calceoliformis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	*Symphoricarpos occidentalis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie thermopsis	*Thermopsis rhombifolia var. annulocarpa(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	*Triglochin*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	*Typha angustifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
broadleaf cattail	*Typha latifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
American vetch	*Vicia americana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca, small soapweed	*Yucca glauca*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: AllSheep

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand bluestem	*Andropogon hallii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
rosy pussytoes, rose pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
silver sagebrush	*Artemisia cana*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
tarragon, green sagewort	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort, fringed sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn, red threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Wyoming big	*Artemisia tridentata ssp.*													

sagebrush	*wyomingensis*	Entire plant	P	P	P	D	D	D	D	D	D	P	P	P
twogrooved milkvetch	*Astragalus bisulcatus*	Entire plant	N	N	N	T	T	T	T	T	T	T	T	T
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue grama	*Bouteloua gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
buffalograss	*Buchloe dactyloides(syn)*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint, bluejoint reedgrass	*Calamagrostis canadensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	*Carex interior*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie sandreed	*Calamovilfa longifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains reedgrass	*Calamagrostis montanensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nebraska sedge	*Carex nebrascensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
yellow rabbitbrush, green rabbitbrush, low rabbitbrush, Douglas rabbitbrush	*Chrysothamnus viscidiflorus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	*Cicuta*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	*Conium maculatum*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	*Crepis acuminata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
white prairie clover	*Dalea candida*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
violet prairie clover, purple prairie clover	*Dalea purpurea*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
tufted hairgrass	*Deschampsia caespitosa(syn)*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
inland saltgrass	*Distichlis spicata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	*Elymus caninus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Canada wildrye	*Elymus canadensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
silverberry	*Elaeagnus commutata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail, bottlebrush squirreltail	*Elymus elymoides ssp. elymoides*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
streambank wheatgrass, thickspike wheatgrass	*Elymus lanceolatus ssp. lanceolatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	*Elymus trachycaulus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
horsetail	*Equisetum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	*Ericameria nauseosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
sulphur-flower buckwheat	*Eriogonum umbellatum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom, scarlet gaura	*Gaura coccinea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	*Glycyrrhiza lepidota*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broom snakeweed	*Gutierrezia sarothrae*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
stemless mock goldenweed	*Haplopappus acaulis(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread, needleandthread	*Hesperostipa comata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	*Iris*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Baltic rush	*Juncus balticus(syn)*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Rocky Mountain														

juniper	Juniperus scopulorum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	Koeleria macrantha	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	Krascheninnikovia lanata	Entire plant	P	P	P	D	D	D	D	D	D	P	P	P
basin wildrye	Leymus cinereus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
desertparsley, biscuitroot	Lomatium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	Mertensia	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains muhly, stoneyhills muhly	Muhlenbergia cuspidata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
mat muhly	Muhlenbergia richardsonis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	Nassella viridula	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	Pascopyrum smithii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot, breadroot scurfpea	Pediomelum esculentum	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	Pinus ponderosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Sandberg bluegrass	Poa canbyi(syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass, Cusick bluegrass	Poa cusickii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	Populus deltoides ssp. monilifera	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass, big bluegrass, Canby bluegrass, alkali bluegrass	Poa secunda	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	Poa secunda ssp. juncifolia(syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
bluebunch wheatgrass	Pseudoroegneria spicata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Nuttall's alkaligrass	Puccinellia nuttalliana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower, prairie coneflower	Ratibida columnifera	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
skunkbush sumac	Rhus trilobata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	Rosa woodsii var. woodsii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	Salix	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
greasewood	Sarcobatus vermiculatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	Schizachyrium scoparium	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue-eyed grass	Sisyrinchium	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand dropseed	Sporobolus cryptandrus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Pursh seepweed	Suaeda calceoliformis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	Symphoricarpos occidentalis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie thermopsis	Thermopsis rhombifolia var. annulocarpa(syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	Triglochin	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	Typha angustifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broadleaf cattail	Typha latifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American vetch	Vicia americana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca, small soapweed	Yucca glauca	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Legend: P = Preferred D = Desirable U = Undesirable N = Not consumed E = Emergency T = Toxic X = Used, but degree of utilization unknown

Hydrology Functions:

Water is the principal factor limiting forage production on this site. This site is dominated by soils in hydrologic group B and C, with localized areas in hydrologic group D. Infiltration ranges from moderately slow to moderate. Runoff potential for this site varies from low to moderate depending on soil hydrologic group and ground cover. In many cases, areas with greater than 75% ground cover have the greatest potential for high infiltration and lower runoff. An example of an exception would be where short-grasses form a strong sod and dominate the site. Areas where ground cover is less than 50% have the greatest potential to have reduced infiltration and higher runoff (refer to Part 630, NRCS National Engineering Handbook for detailed hydrology information).

Rills and gullies should not typically be present. Water flow patterns should be barely distinguishable if at all present. Pedestals are only slightly present in association with bunchgrasses. Litter typically falls in place, and signs of movement are not common. Chemical and physical crusts are rare to non-existent. Cryptogamic crusts are present, but only cover 1-2% of the soil surface.

Recreational Uses:
This site provides hunting opportunities for upland game species. The wide variety of plants which bloom from spring until fall have an esthetic value that appeals to visitors.

Wood Products:
No appreciable wood products are present on the site.

Other Products:
None noted.

Other Information:

Supporting Information

Associated Sites:

Site Name	Site ID	Site Narrative
Clayey (Cy) 10-14" Northern Plains Precipitation Zone	R058BY104WY	Clayey
Lowland (LL) 10-14" Northern Plains Precipitation Zone	R058BY128WY	Lowland
Overflow (Ov) 10-14" Northern Plains Precipitation Zone	R058BY130WY	Overflow
Sandy (Sy) 10-14" Northern Plains Precipitation Zone	R058BY150WY	Sandy
Shallow Loamy (SwLy) 10-14" Northern Plains Precipitation Zone	R058BY162WY	Shallow Loamy

Similar Sites:

Site Name	Site ID	Site Narrative
Loamy (Ly) 15-17" Northern Plains Precipitation Zone	R058BY222WY	Loamy 15-17" Northern Plains P.Z. has higher production.

State Correlation:
This site has been correlated with the following states:
MT

Inventory Data References:
Information presented here has been derived from NRCS clipping data and other inventory data. Field observations from range trained personnel was also used. Those involved in developing this site include: Glen Mitchell, Range Management Specialist, NRCS; Chuck Ring, Range Management Specialist, NRCS; and Everet Bainter, Range Management Specialist. Other sources used as

references include USDA NRCS Water and Climate Center, USDA NRCS National Range and Pasture Handbook, and USDA NRCS Soil Surveys from various counties.

Inventory Data References
Data Source Number of Records Sample Period State County
SCS-RANGE-417 12 1971-1994 WY Campbell & others
Ocular estimates 5 1990-1999 WY Campbell & others

Type Locality:

Relationship to Other Established Classifications:

Other References:
Field Offices
Buffalo, Douglas, Gillette, Lusk, Newcastle, Sheridan

Site Description Approval:

Author	Date	Approval	Date
G. Mitchell	4/25/2000	E. Bainter	3/7/2008

Reference Sheet

Author(s)/participant(s):

Contact for lead author:

Date:4/1/2005 **MLRA:**058B **Ecological Site:**Loamy (Ly) 10-14" Northern Plains Precipitation ZoneR058BY122WY This *must* be verified based on soils and climate (see Ecological Site Description). Current plant community cannot be used to identify the ecological site.

Composition (indicators 10 and 12) based on: XAnnual Production, Foliar Cover, Biomass

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Indicators. For each indicator, describe the potential for the site. Where possible, (1) use numbers, (2) include expected range of values for above- and below-average years for **each** community and natural disturbance regimes within the reference state, when appropriate and (3) cite data. Continue descriptions on separate sheet.

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1. **Number and extent of rills:** Rills should not be present.

2. **Presence of water flow patterns:** Barely observable.

3. **Number and height of erosional pedestals or terracettes:** Essentially non-existent.

4. **Bare ground from Ecological Site Description or other studies (rock, litter, standing dead, lichen, moss, plant canopy are not bare ground):** Bare ground is 20-30% occurring in small areas throughout site.

5. **Number of gullies and erosion associated with gullies:** Active gullies should not be present.

6. **Extent of wind scoured, blowouts and/or depositional areas:** None

7. **Amount of litter movement (describe size and distance expected to travel):** Little to no plant litter movement. Plant litter remains in place and is not moved by erosional forces.

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** Plant cover and litter is at 70% or greater of soil surface and maintains soil surface integrity. Soil Stability class is anticipated to be 5 or greater.

9. **Soil surface structure and SOM content (include type and strength of structure, and A-horizon color and thickness):** Use Soil Series description for depth and color of A-horizon.

10. **Effect on plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Grass canopy and basal cover should reduce raindrop impact and slow overland flow providing increased time for infiltration to occur. Healthy deep rooted native grasses enhance infiltration and reduce runoff. Infiltration is Moderate.

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):** No compaction layer or soil surface crusting should be present.

12. **Functional/Structural Groups (list in order of descending dominance by above-ground weight using symbols: >>, >, = to indicate much greater than, greater than, and equal to) with dominants and sub-dominants and "others" on separate lines:**
    Dominant: Cool Season Bunch grasses > Cool Season Rhizomatous grasses > Short stature grasses/grasslikes > Forbs = Shrubs
    Sub-dominant:
    Other:
    Additional:

13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** Very Low.

14. **Average percent litter cover (%) and depth (inches):** Average litter cover is 25-35% with depths of 0.25 to 1.0 inches.

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15. **Expected annual production (this is TOTAL above-ground production, not just forage production):** 1200 lbs/ac

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16. **Potential invasive (including noxious) species (native and non-native). List Species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicator, we are describing what in NOT expected in the reference state for the ecological site:** Blue grama, Threadleaf sedge, Fringed sagewort, Prickly Pear, Big sagebrush, Broom Snakeweed,
and Species found on Noxious Weed List

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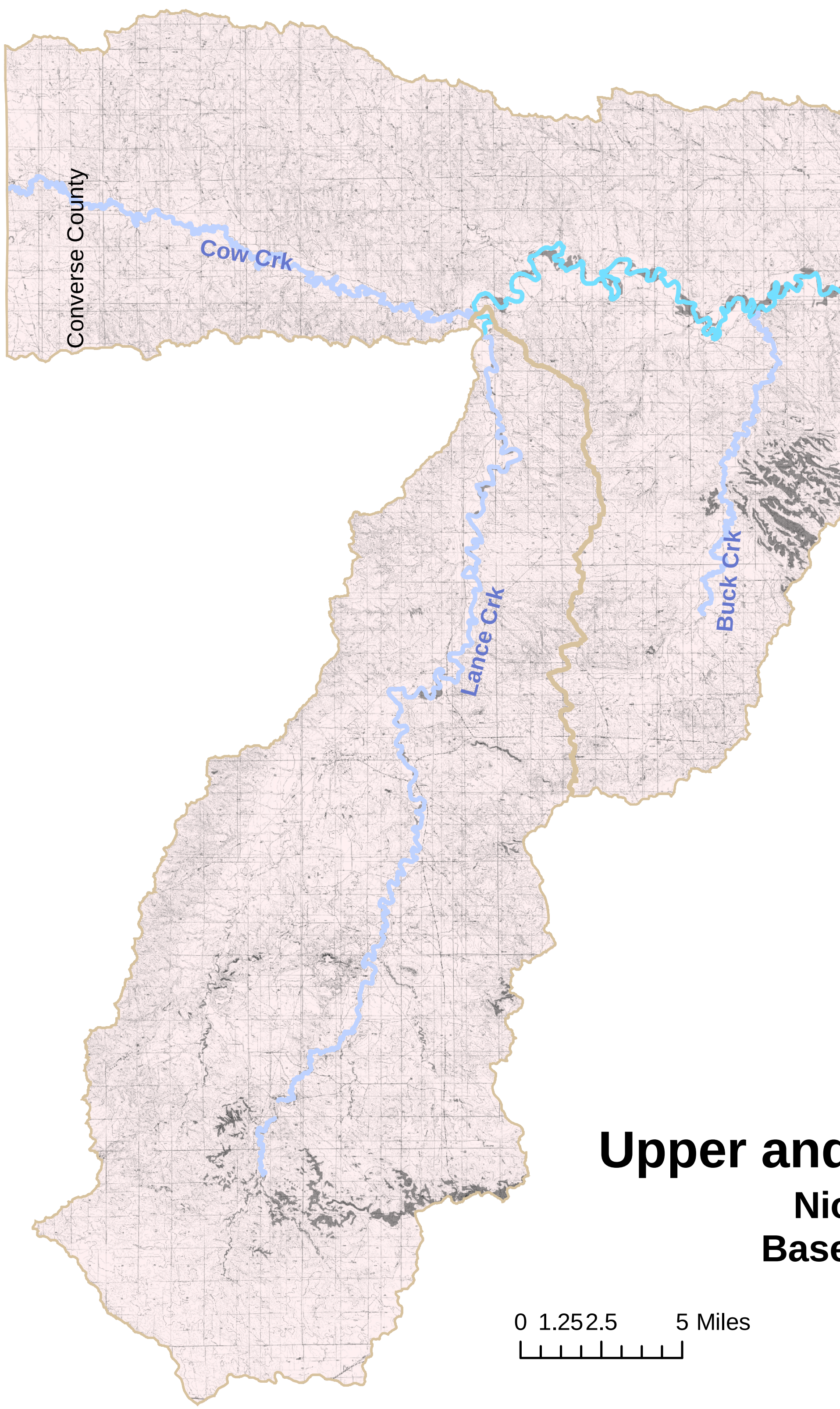
17. **Perennial plant reproductive capability:** All species are capable of reproducing.

Reference Sheet Approval:

Approval	Date
E. Bainter	3/7/2008

Appendix D
Niobrara Conservation District Baseline Stream Sampling Sites



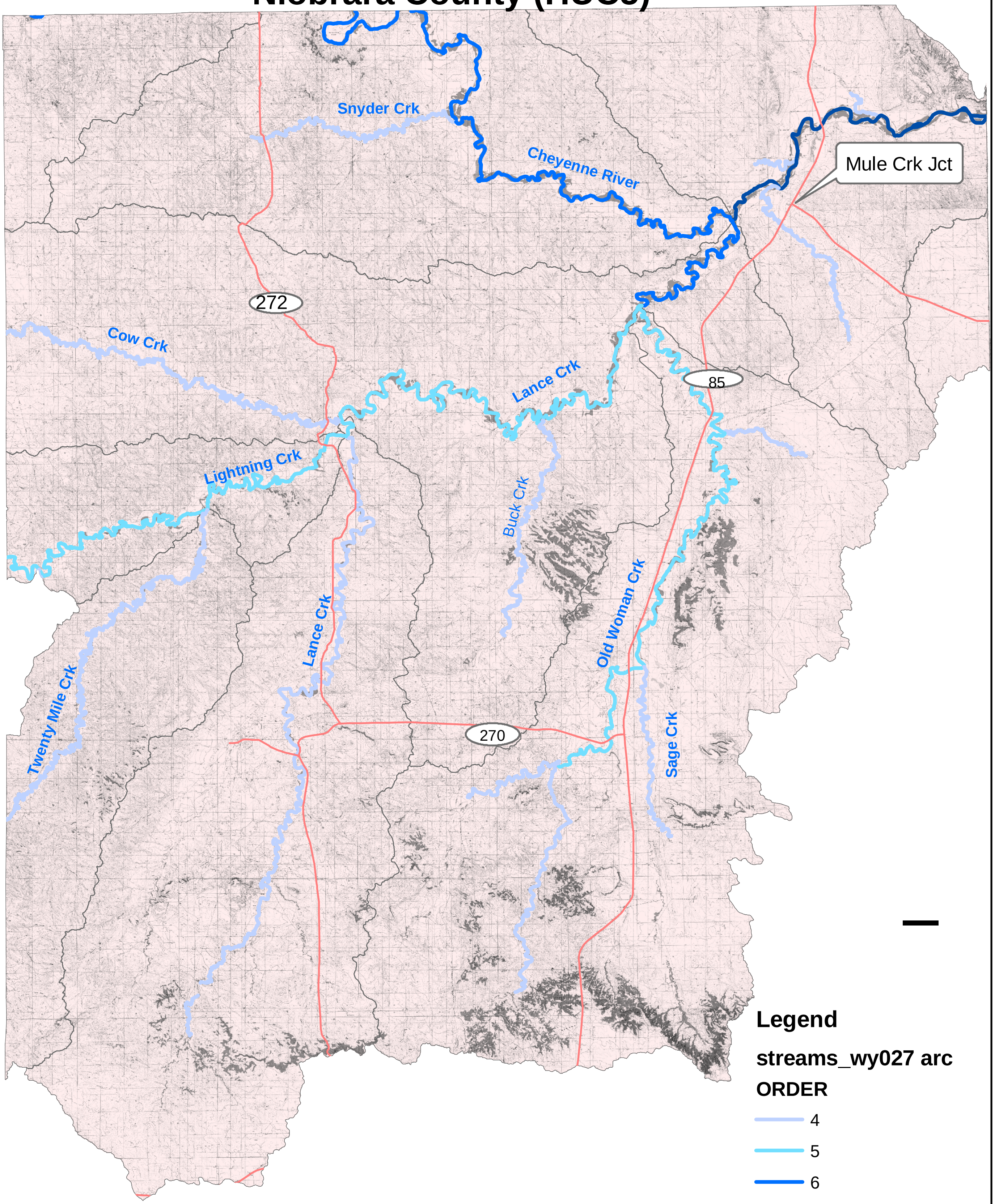
Lance Creek
Upper and Lower Watersheds (HUC 5)

Niobrara Conservation District
Baseline Stream Sampling Project
Sampling Site

668.901 sq. miles
428,096.349 Acres

Created by Heidi L. Sturman
Niobrara Conservation District
1/6/05

Cheyenne River Sub Watersheds
Niobrara County (HUC5)



Legend

streams_wy027 arc

ORDER

- 4
- 5
- 6
- 7

0 3 6 12 Miles

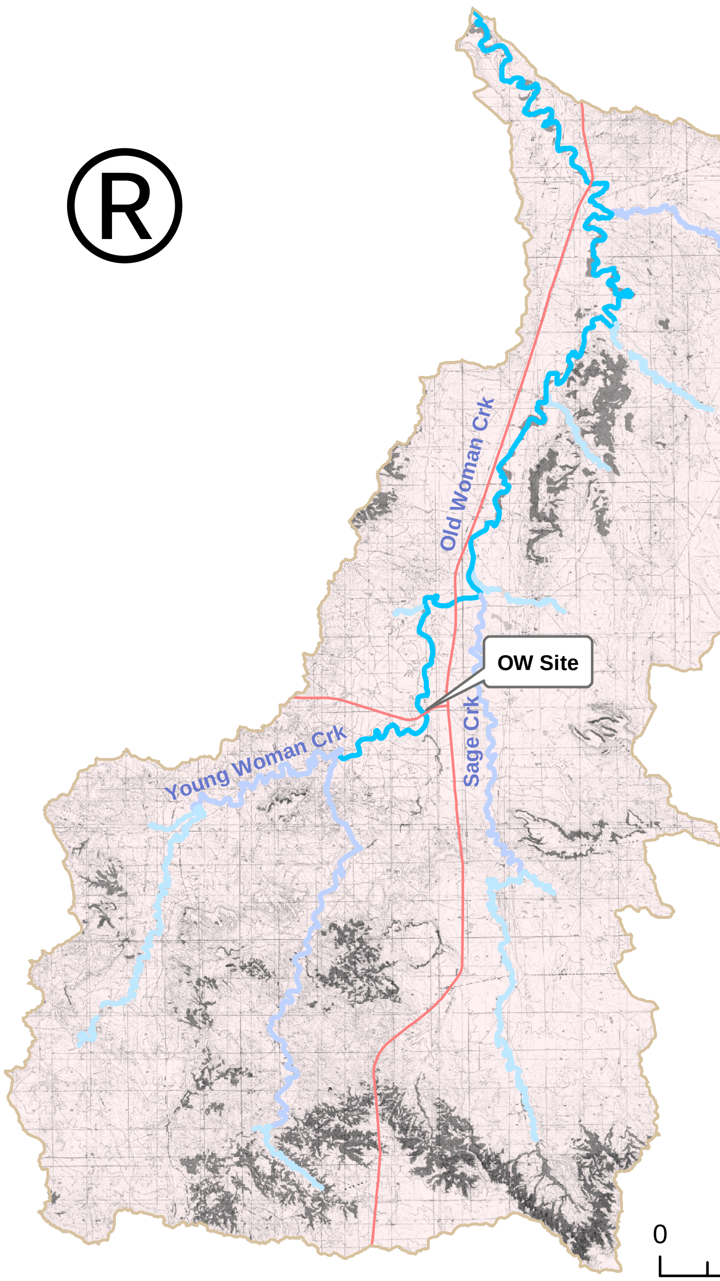
1:380,393

Created by Heidi L. Sturman
Niobrara Conservation District
1/10/05

1,727.434 Sq. Miles
1,105,557.476 Acres

Old Woman Creek
Sub Watershed (HUC 5)

Niobrara Conservation Disrtict
Baseline Stream Sampling Project
Sampling Site



0 2.5 5 10 Miles

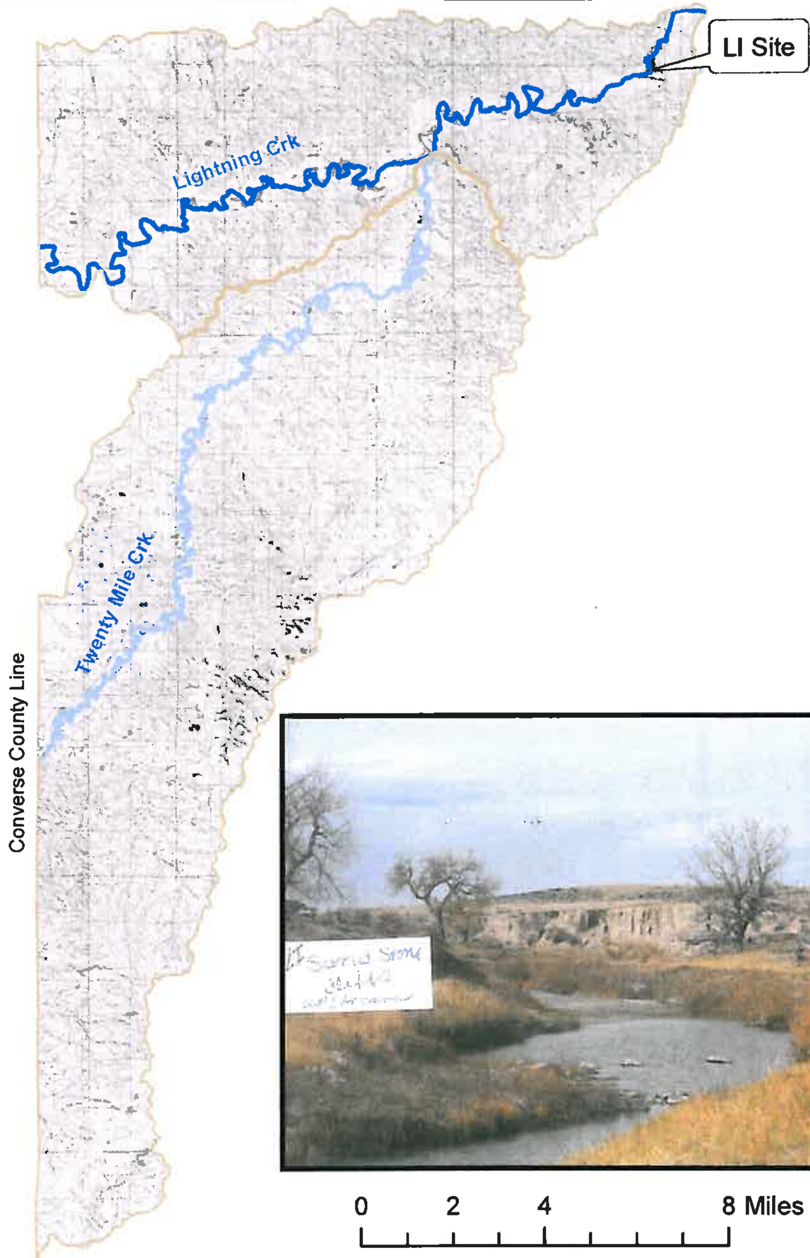
375.127 Sq. Miles
240081.108 Acres

Created by Heidi L. Sturman
Niobrara Conservation District
1/11/05

Lightning Crk

Lightning and Twenty Mile Crk Sub Watersheds (HUC 5)

Niobrara Conservation District Baseline Stream Sampling Project Sampling Site



N
W
E
S

186.186 Sq. Miles
119,158.724 Acres

Created by Heidi L. Sturman
Niobrara Conservation District
1/11/05