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Black Hills National Forest

Revised Forest Assessment:

Soils and Watersheds

Trees in a forest management area, Black Hills National Forest. Photo courtesy of Black Hills National Forest Historical Collection, Leland D. Case Library for Western Historical Studies, Black Hills State University.

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Chapter 1. Introduction

The Black Hills National Forest is managed by the U.S. Forest Service, an agency of the U.S. Department of Agriculture (USDA). The mission of the Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. The National Forest Management Act requires all National Forests to develop a land and resource management plan (forest plan) to guide management actions and decisions. The National Forest Management Act requires that forest plans be periodically updated. The current forest plan for the Black Hills National Forest was approved in 1997. Substantial plan amendments were last approved in March 2006 and minor amendments have occurred through 2018. The latest version can be found on the Black Hills National Forest website (USDA Forest Service 2006). In order to revise the current forest plan, the Black Hills National Forest has identified and evaluated existing information about relevant ecological, economic, and social conditions, trends and sustainability and how those conditions relate to management direction in the forest plan. This assessment documents that work for soils and watershed.

Soils and Watersheds in the Black Hills National Forest

This document is an assessment of the current known soil and watershed resources and uses in the Black Hills National Forest, or the "plan area." Consideration of soil resources and other biotic and abiotic resources and their functions within a watershed lend to sustainable ecosystem management. This assessment identifies biological, hydrological, and anthropogenic effects on watersheds in the plan area from a watershed-level perspective. Landscape-level information about other resources can be found in other assessments, such as those covering forested and non-forested ecosystems, aquatic, riparian, and groundwater dependent ecosystems, insects, disease, and invasive species, climate change vulnerability, and recreation.

Chapter 2. Conditions and Trends

Chapter 2 presents a discussion of the conditions and trends pertaining to soils and watersheds on the Black Hills National Forest based on available data.

Best Available Scientific Information

This assessment was prepared based on scientific data, reports, and prior analyses provided by the Black Hills National Forest. Additional resources were identified using internet searches of publicly available information. To the extent possible, reasonable efforts were made to verify that the information used in this assessment represents the best publicly available, science-based evidence. When science-based data were not available to address the key questions, data gaps were identified.

The resources used to address this assessment include U.S. Geologic Survey Watershed Boundary Dataset and the National Hydrography Dataset; U.S. Environmental Protection Agency's (USEPA) Assessment, Total Maximum Daily Load Tracking and Implementation System (ATTAINS) dataset for impaired waters; Natural Resources Conservation Service (NRCS) soils data, and Forest Service-provided Black Hills National Forest datasets for fire history, geology, soils, watershed condition classes and ratings, streams and springs, and invasive plant inventory.

Additional data that can be incorporated into this assessment includes climate change vulnerability information from modeling outputs from the Variable Infiltration Capacity model.

Data Gaps Identified

Data gaps were identified during the process of drafting this assessment – data and information that would add to the understanding or reduce uncertainty about conditions and trends related to soils and watersheds.

Data gaps are identified in each section of this document, with a summary list as follows:

- Watershed Condition Framework (WCF) ratings were developed in 2010 and the indicators are based on that data that has not yet been updated for all of these drivers: Riparian/wetland vegetation; fire regime/wildfire; forest health related to insects, disease, air pollution, and invasive species; invasive species; aquatic life
- Data on the effects of private land development on groundwater recharge
- Continuation of water rights and uses inventory and database updates for the Black Hills
- Recent cave and karst research

Watersheds Overview

River basins are delineated into a nested hierarchy represented by Hydrologic Unit Codes (HUCs) numbered with two to twelve digits. From largest to smallest these are categorized into named regions (HUC 2), sub-regions (HUC 4), basins (HUC 6), sub-basins (HUC 8), watersheds (HUC 10), and sub-watersheds (HUC 12) (USGS et al. 2013). The Black Hills National Forest is located within the Cheyenne (HUC 6: 101201) and Belle Fourche (HUC 6: 101202) basins of the Cheyenne subregion (HUC 4: 1012). The eight sub-basins (HUC 8) the Black Hills National Forest lies within (table 1) are further divided into watersheds (HUC 10: 40,000 to 250,000 acres) and sub-watersheds (HUC 12: 10,000 to 40,000 acres). The Black Hills National Forest lands lie within twenty-nine watersheds (HUC 10) and 112 sub-watersheds (HUC 12).

There are eight HUC 8 watersheds that contain the Black Hills National Forest (table 1) and 13 that surround the Black Hills National Forest (table 2). Resources within a watershed are not limited to set boundaries as wildlife, water, and people move from one area to another, including within and among the various watershed boundaries. Therefore, actions on watersheds near the Black Hills National Forest may have impacts on biotic and abiotic resources. Likewise, forest management activities may impact resources in watersheds outside the forest boundary.

Table 1. HUC 8 Sub-basins containing lands within the Black Hills National Forest

HUC 8 ID	HUC 8 Name	Black Hills National Forest Geographic Area
10120107	Beaver	Elk Mountain
10120106	Angostura Reservoir	Pleasant Valley, Red Canyon
10120109	Middle Cheyenne-Spring	Seven Sisters Range
10120110	Rapid	Rapid Creek
10120111	Middle Cheyenne-Elk	North-northeast of the Black Hills National Forest
10120202	Lower Belle Fourche	Bear Lodge Mountains, Strawberry Ridge
10120203	Redwater	Bear Lodge Mountains
10120201	Upper Belle Fourche	Bear Lodge Mountains

The Black Hills National Forest is drained by numerous small streams that feed into the Belle Fourche River and Cheyenne River, which converge and join the Missouri River approximately 140 miles to the east. The Missouri River then feeds into the Mississippi River in St. Louis, Missouri, which then enters the Gulf of Mexico at New Orleans, Louisiana.

Table 2. HUC 8 Sub-basins surrounding the Black Hills National Forest

HUC 8 Watershed	Watershed Name
10090202	Upper Powder
10090208	Little Powder
10110201	Upper Little Missouri
10120101	Antelope
10120103	Upper Cheyenne
10120104	Lance
10120108	Hat
10120112	Lower Cheyenne
10120113	Cherry
10130304	South Fork Moreau
10140102	Bad
10140201	Upper White
10140202	Middle White

In 2010, sub-watersheds (HUC 12) were rated using the national Watershed Condition Framework (WCF; USDA Forest Service 2011a). Using an interdisciplinary team process, a watershed condition rating was assigned following an assessment of existing data, knowledge of the land, and professional judgment (USDA Forest Service 2011a). Four sub-watersheds were reassessed in 2015 and 2016, additional updates are needed.

Watershed condition is the state of the physical and biological characteristics and processes within a watershed that affect the soil and hydrologic functions supporting aquatic ecosystems. Watershed condition reflects a range of variability from natural pristine (functioning properly) to degraded (impaired). The Forest Service Manual classification defines watershed condition in terms of "geomorphic, hydrologic and biotic integrity" relative to "potential natural condition." In this context, integrity relates directly to functionality. Integrity is evaluated in the context of the natural disturbance regime, geo-climatic setting, and other key factors within the context of a watershed (USDA Forest Service 2011a).

WCF is a 12-indicator model that considers both aquatic and terrestrial physical and biological indicators (table 3). The indicators are grouped into four process categories: 1) Aquatic Physical; 2) Aquatic Biotic; 3) Terrestrial Physical; and 4) Terrestrial Biota. The first three categories constitute 30 percent of the total framework rating each. The fourth category constitutes the remaining 10 percent. For each sub-watershed, attributes within each condition indicator are given a rating between 1 and 3, with one being good and three being poor, according to a standardized rule set. The Watershed Condition Classification Technical Guide (USDA Forest Service 2011b) suggest the upper and lower bounds for each indicator be identified to differentiate high integrity or high functionality (1 or "good") compared with the unacceptable or impaired functionality (3 or "poor"), with the middle designation (2 or "fair") identified by default. Using this method could result in the middle designation containing a wide range of conditions. The attribute scores are then averaged to give a score for each indicator. The indicator scores are then averaged to give a rating of Class 1 (functioning properly), Class 2 (functioning at risk) or Class 3 (impaired function) for each process category. The Process Category scores are then combined based on weighting factors to determine an overall score for each watershed.

A watershed is considered to be functioning properly (Class 1) if the physical attributes are appropriate to maintain or improve biological integrity, i.e., the watershed is functioning in a manner similar to natural conditions (USDA Forest Service 2011a). Class 2 and Class 3 watersheds have an at risk or impaired function, respectively, because physical, hydrological, or biological thresholds have been exceeded. Class 2 watersheds exhibit moderately impaired functions and Class 3 watersheds exhibit severe impairments. This can occur due to natural processes, such as wildland fire or large slope failures, but are more typically caused by human related disturbance, such as roads close to streams, improper livestock grazing practices, invasive species, recreational activities, or presence of aquatic non-native species.

Table 3 Watershed condition framework process categories, condition indicators, and descriptions

Process Category	Condition Indicator	Description
Aquatic Physical	Water Quality	This indicator addresses the expressed alteration of physical, chemical, and biological components of water quality.
Aquatic Physical	Water Quantity	This indicator addresses changes to the natural flow regime with respect to the magnitude, duration, or timing of the natural streamflow hydrograph.
Aquatic Physical	Aquatic Habitat	This indicator addresses aquatic habitat condition with respect to habitat fragmentation, large woody debris, and channel shape and function.
Aquatic Biological	Aquatic Biota	This indicator addresses the distribution, structure, and density of native and introduced aquatic fauna.
Aquatic Biological	Riparian/Wetland Condition	This indicator addresses the function and condition of riparian vegetation along streams, water bodies, and wetlands.
Terrestrial Physical	Roads and Trails	This indicator addresses changes to the hydrologic and sediment regimes because of the density, location, distribution, and maintenance of the road and trail network.
Terrestrial Physical	Soil Condition	This indicator addresses alteration to natural soil condition, including productivity, erosion, and chemical contamination.
Terrestrial Biological	Fire Regime or Wildfire	This indicator addresses the potential for altered hydrologic and sediment regimes because of departures from historical ranges of variability in vegetation, fuel composition, fire frequency, fire severity, and fire pattern.
Terrestrial Biological	Forest Cover	This indicator addresses the potential for altered hydrologic and sediment regimes because of the loss of forest cover on forest lands.
Terrestrial Biological	Rangeland Vegetation	This indicator addresses effects on soil and water because of the vegetative health of rangelands.
Terrestrial Biological	Terrestrial Invasive Species	This indicator addresses potential effects on soil, vegetation, and water resources because of terrestrial invasive species (including vertebrates, invertebrates, and plants).
Terrestrial Biological	Forest Health	This indicator addresses forest mortality effects on hydrologic and soil function because of major invasive and native forest insect and disease outbreaks and air pollution.

The Black Hills National Forest has 112 sub-watersheds. In 2010, 43 were rated Class 1; fifty-two rated as Class 2, no sub-watersheds were Class 3, and 17 were not rated due to the small percentage of National Forest System lands in the sub-watershed (USDA Forest Service 2011a). Watershed condition ratings for each sub-basin are summarized in table 4(USDA Forest Service 2021b). Over 90 percent of the sub-watersheds in the Beaver and Angostura Reservoir sub-basins were rated as Class 1, whereas none of the sub-watersheds within the Rapid sub-basin were rated as Class 1.

Table 4. Watershed condition class ratings for sub-watersheds in each sub-basin

Sub-basin (HUC 8) ID	Sub-basin Name	Sub-watersheds Rated Class 1 (no.)	Sub-watersheds Rated Class 2 (no.)	Sub-watersheds Rated Class 3 (no.)	Sub-watersheds without Condition Assessments (no.)
10120107	Beaver	10	1	0	2
10120106	Angostura Reservoir	10	1	0	4
10120109	Middle Cheyenne-Spring	8	13	0	3
10120110	Rapid	0	12	0	0
10120111	Middle Cheyenne-Elk	3	7	0	0
10120202	Lower Belle Fourche	2	4	0	3
10120203	Redwater	7	10	0	0
10120201	Upper Belle Fourche	3	4	0	5

While there were no sub-watersheds in the plan area rated as Class 3 (impaired function), several sub-watersheds had condition indicators with a condition rating of poor (table 5). Specifically, the Roads and Trails indicator was rated as poor across most of the Black Hills National Forest sub-watersheds, as was the Fire Regime indicator. Other indicators with a high percentage rated as poor in some of the Black Hills National Forest sub-watersheds included Aquatic Habitat, Aquatic Biota, and Forest Cover.

Table 1 displays the ratings for each watershed condition process category indicator as a percentage of sub-watersheds that received each rating. For example, 86 percent of the sub-watersheds on the Black Hills National Forest were given a rating of good for water quality. Note the total percentages of all ratings does not equal 100 percent because only those sub-watersheds that contain rangeland were scored on the rangeland condition indicator (USDA Forest Service 2011b).

Table 5. Percentage of sub-watersheds given a good, fair, or poor condition rating for each WCF indicator and sub-indicator

Process Category	Indicator	Condition Rating Good (%)	Condition Rating Fair (%)	Condition Rating Poor (%)	Total (%)
Aquatic Physical		77	21	2	100
	Water Quality	86	9	4	100
	Water Quantity	80	17	3	100
	Aquatic Habitat	60	20	20	100
Aquatic Biological		47	42	11	100
	Aquatic Biota	58	17	25	100

Process Category	Indicator	Condition Rating Good (%)	Condition Rating Fair (%)	Condition Rating Poor (%)	Total (%)
	Riparian/Wetland Vegetation	4	93	3	100
Terrestrial Physical		4	88	7	100
	Roads and Trails	4	24	72	100
	Soil Condition	0	100	0	100
Terrestrial Biological		17	71	13	100
	Fire Regime	0	16	84	100
	Forest Cover	86	1	13	100
	Rangeland Vegetation	6	0	0	6
	Invasive Species	57	41	2	100
	Forest Health	6	94	0	100

Drivers of watershed processes, conditions, and change are typically created by disturbance regimes. Some disturbance regimes are natural, and others are caused by humans. Climate change, weather, wildfire, insects, disease, animals, and humans are the most common factors in disturbances. Often, they cause watershed conditions to change much faster than they would otherwise. While disturbance regimes can push a watershed or ecosystem to a point where it is not functioning properly (at risk), disturbance regimes can also create biodiversity and improve watershed condition.

The primary watershed drivers in the Black Hills National Forest are listed below with associated ratings. Note that the WCF ratings are based on 2010 data and have not been updated. Further data collection efforts are needed to provide updated information.

- Riparian/Wetland Vegetation – the function and condition of riparian vegetation along streams, water bodies and wetlands contribute to the rating of riparian/wetland vegetation. Riparian/wetland vegetation was fair for almost all sub-watersheds throughout the Black Hills National Forest (three were poor and four were good).
- Roads and Trails –roads and trails were rated fair or poor due to high numbers of roads, , proximity to water, and outstanding maintenance issues . This is an indicator of hydrology and sediment changes from the natural baseline.
- Soils – the soils indicator was rated overall as fair. The indicator has three attributes, productivity, erosion, and contamination. Productivity was rated mostly good throughout the sub-watersheds, erosion and chemical contamination were rated fair in every sub-watershed (a few were poor, none were good)
- Fire Regime – the fire regime was rated poor almost everywhere because of high fuel load, vegetation changes, and fire frequency, intensity, and severity. This is an indicator of hydrology and sediment changes from the natural baseline.
- Forest Health – invasive species, insects, disease, and air pollution contributed to the fair and poor ratings for forest health. This indicator was rated as fair and poor because the insects/disease attribute was rated as poor in nearly every sub-watershed. Air quality was rated as good and invasive species was a mix of good and fair.
- Terrestrial Invasive Species – this indicator assesses the effect of terrestrial invasive species on soil, vegetation, and water resources. Invasive species ratings were good or fair for almost all sub-watersheds throughout the Black Hills National Forest (two were rated poor).

However, the *Insects, Disease and Invasives Assessment* notes there has been a substantial increase in invasive plants on the forest, so the rating for this indicator will likely change with updated data.

- Aquatic Biota – the distribution, structure, and density of native and introduced aquatic fauna contribute to the overall rating for Aquatic Biota. The attribute Lifeform Presence was rated as good throughout most of the Black Hills sub-watersheds, although it was rated as fair in sub-watersheds in the middle region of the Forest. This center region is also where the attributes Native Species and Exotic/Aquatic Invasive Species were rated as mostly poor with some rated as fair. In areas outside the center region of the forest, there were more good ratings for Native Species and Exotic/Aquatic Invasive Species. Again, the *Insects, Disease and Invasives Assessment* notes new invaders are known to be present on the forest so this rating will likely change with updated data.

Below is a summary of the indicators that were rated as poor or fair in a high percent of sub-watersheds. These are watershed indicators that could be drivers and should be considered when identifying priorities for management.

- Roads and Trails was rated as poor in 72 percent of sub-watersheds.
- Fire Regime was rated as poor in 84 percent of sub-watersheds.
- Soils was rated as fair in all sub-watersheds.
- Forest Health was rated as fair in 94 percent of sub-watersheds.
- Riparian/Wetland Vegetation was rate fair in 93 percent of sub-watersheds.

Factors that affect the Roads and Trails, Fire Regime, Soils, Forest Health, and Riparian/Wetland Vegetation indicators can and should be improved upon to the extent possible as they are potentially drivers of watershed processes, conditions, and change. As noted previously, invasive species are known to have increased since 2010 (See *Insects, Disease and Invasive Species Assessment*), and indicators that include the presence of invasive species will likely change when the WCF ratings are updated.

Watershed Soils and Geology

Soil Properties and Productivity

Soil characteristics, including particle size, texture, depth, porosity, bulk density, organic matter, and structure influence water movement, storage, and quality as well as which vegetation communities are within a forest ecosystem. Soil productivity refers to the ability to supply nutrients and water for plant growth. Factors that reduce soil productivity include compaction, erosion, displacement, and loss of ground cover from disturbances such as timber harvest, improper grazing practices, recreation, mineral extraction, vehicular and foot traffic, and the effects of large-scale wildfires (e.g., runoff). Implementing best management practices, such as livestock grazing management, ensures organic matter availability and decomposition which contribute to soil productivity. Soil organisms (e.g., bacteria, fungi) decompose organic matter such as duff and litter (e.g., leaves, needles, twigs) and large woody debris in a nutrient cycling process that benefits plant communities. Retention of forest litter, duff, and woody debris can improve conditions for conifers and other vegetation but can build up over time without proper management. Inherent productivity of the soil relates more to rooting depth and the chemical, biological, and physical properties of the soil, than transient factors such as litter layer thickness.

Soil productivity depends in part on the plant species and/or plant community present on the site. A highly productive soil for one plant community type may not necessarily be productive for a different type. However, overall generalizations can be made about soil and landscape factors that contribute to increased site productivity in general for most plant communities in the forest. For many plant species, ideal soil and site conditions include the following:

- The appropriate soil texture for the desired plant species/community type with some rock fragments in the soil,
- Appropriate soil pH for the desired species,
- Primarily deep to very deep soils (most species),
- Moderately well-drained (i.e., evidence of an ephemeral high-water table within seventy-two inches of the soil surface, or well-drained soil conditions),
- Run-in landscape positions (i.e., areas where water accumulates in the soil from upslope positions), and
- No limiting factors, such as soil contamination or saline/sodic soil conditions.

As mentioned previously, the Soil Condition indicator of the WCF evaluates alteration to natural soil conditions, including productivity, erosion, and chemical contamination (table 3). The indicator is informed by these attributes: Soil Productivity, Soil Erosion, and Soil Contamination. All sub-watersheds in the Black Hills National Forest were given a rating of fair, indicating they have a moderate amount of alteration to soil condition and that overall soil disturbance is moderate. The Soil Productivity attribute within the Soils Condition indicator was given a rating of good throughout most of the forest. It is important to note that soil productivity is not the main factor contributing to the fair soils condition indicator ratings. The Soil Contamination condition indicator was rated as fair for all but two sub-watersheds which were rated as poor (USDA Forest Service 2011b, USDA Forest Service 2021b). The two sub-watersheds that received a poor rating for are located in the southernmost area of the forest and results from abandoned mines and polluted waters associated with mine reclamation sites.

Erosion and Sedimentation

According to the 2010 WCF data, all sub-watersheds in the Black Hills National Forest had a Soil Erosion attribute condition rating of fair. Disturbances such as timber harvest, large ungulate use, vehicular and foot traffic, recreation, mineral extraction and wildfires can be drivers of erosion in the Black Hills National Forest.

Another important indicator of erosion is the Roads and Trails indicator, which was rated as poor for 72 percent of sub-watersheds, fair for 24 percent, with only 4 percent given a condition rating of good. A poor condition rating is a combination of poor ratings in all attributes (i.e., Open Road Density, Road and Trail Maintenance, Proximity to Water, Mass Wasting).

Most of the sub-watersheds in the northern half of the Black Hills National Forest were rated fair for Mass Wasting. Mass wasting is more likely to be a concern where the geological formations are more prone to slope failures, and wetter climatological conditions are present. A small portion of sub-watersheds in the northern portion of the forest were given a condition rating of poor for mass wasting. The southern half of the Black Hills National Forest watersheds were rated good for mass wasting, again mostly due to the geological formations present.

The following summarizes the reasons for the poor condition ratings for each attribute (USDA Forest Service 2011b):

- Open Road Density: more than 2.4 mi/mi^2,
- Road and Trail Maintenance: Best management practices for drainage applied to less than 50 percent of road, trails, and crossings,
- Proximity to Water: Greater than 25 percent of road and trail length is within three hundred feet of water bodies, and

- Mass Wasting: Most roads are located on landforms that are at risk for mass wasting and show evidence of road movement. There is potential for mass wasting to deliver copious quantities of debris to stream channels.

The soil erosion hazard ratings from the U.S. Forest Service (USDA Forest Service 2021b, Reyher 2018) GIS data collection efforts are shown in table 6. These were developed by the Black Hills National Forest soil scientists in conjunction with Natural Resources Conservation Service (NRCS) soil scientists utilizing NRCS soil data. The soil erosion hazard ratings help classify soil erosion. The majority of soils (54 percent) are considered a slight erosion hazard, 28 percent have a moderate rating, and 12.4 percent range from severe to very severe. Shallow soils are defined as soils less than 20 inches deep. They are sensitive because they are susceptible to erosion. They are weakly developed, with little organic matter, and have low nutrient levels. Any soil displacement or loss can affect their productivity. The current forest plan has a standard in place (standard 1102) requiring special management on shallow soils.

Table 6. Soil erosion hazard

Soil Erosion Potential Category	Number of Soil Units	Percent of Total
Slight	154	54
Slight/Moderate	1	0.4
Moderate/Slight	2	1
Moderate	80	28
Moderate to Severe	3	1
Severe	20	7
Very Severe	15	5
Very Severe/Severe	1	0.4

Soil Disturbance Monitoring

Soil disturbance monitoring that has occurred since the 2010 WCF evaluation includes project-specific monitoring. Such monitoring data helps to inform effects analyses conducted for project-level environmental documents, forest plan implementation monitoring and will be used inform an updated WCF evaluation. Standard 1103 in the current forest plan states *Manage land treatments to limit the sum of severely burned and detrimentally compacted, eroded, and displaced land to no more than 15% of any land unit.* 'Land unit' is defined in the Rocky Mountain Region Watershed Conservation Practices Handbook (USDA Forest Service 2006a) as an activity area, such as a timber sale unit. To monitor implementation of standard 1103 the Black Hills National Forest uses the national Forest Soil Disturbance Monitoring Protocol (Page-Dumroese et al. 2009, 2009a). Sites for soil disturbance monitoring are randomly selected timber sale units that had been harvested in previous recent years.

The latest forest plan monitoring report (USDA Forest Service 2015a) notes the soil disturbance information collected by forest watershed personnel on post-harvest timber units during the 2013 and 2014 monitoring season indicated that disturbances of a level that may be considered detrimental were well less than that of 15 percent of the activity area on the sites assessed. More recently, soil disturbance data were collected in 2016 and 2017 specifically for the (Forestwide) Mountain Pine Beetle Restoration Project. The soil disturbance within the activity unit on 73 percent of the sites monitored was considered to be within the limits specified in the Forest Service Manual, the Watershed Conservation Practices Handbook and the direction in the forest plan. The soil disturbance on the remaining 27 percent was considered to be at the upper limit of those specified in the Forest Service Manual, the Watershed Conservation Practices Handbook and the direction in the forest plan. However, it is noted much of the soil disturbance identified during the monitoring were short-term effects (due to the timing of the monitoring), and that for those sites at the upper limits of allowable disturbance, further impacts to the soil resource should be limited until some recovery (such as site revegetation) occurred.

Geologic Features and Hazards

The geology of the Black Hills National Forest is characterized as a dome of Precambrian igneous and metamorphic rock (mostly granite and pegmatites) at its core, overlain by shales, limestones, and sandstones from the Proterozoic to the Cenozoic eras. The granite ranges in age from 1.8 to 2.8 billion years old. Subsequent erosion of the overlying sedimentary units exposed the underlying granite in areas of the Black Hills, including Mt. Rushmore. Pegmatites have been sources of common commodities, such as quartz, feldspar, mica, and schist, and sometimes precious crystals such as beryl. Where the sedimentary units exist, they serve as important sources of water (aquifers) and recharge.

Prominent hazards in the Black Hills National Forest include subsidence associated with karst collapse and mining, mass wasting events including landslides, and natural acid drainage from acid-producing rock. Cave and karst features are impacted by anthropogenic and natural disturbances that result in subsidence and collapse issues. Mass wasting events as a result of natural and anthropogenic disturbances as well. As discussed previously, mass wasting events are more common in the northern Black Hills due to the presence of geological formations are more prone to slope failures. Natural acid drainage contributes to deposits of “bog iron” in wetlands, streams, and peatland. This primarily occurs in the central and northern hills areas. Outside of the wetlands, soils also tend to be more acidic, especially in the alluvial valley deposits with periodic groundwater contact. For an example, in these areas, measures are included with infrastructure projects to include corrosion resistant coatings to mitigate the natural acidity in the soils.

The current forest plan has a guideline (guideline 1108) requiring on-site slope stability examinations on in areas and on soils that are susceptible to mass movement, as well as direction to limit resource damage and investment loss in such areas. Hence there are data identifying mass movement hazards, particularly on the northern portion of the forest, as well as known mining hazards. Newly acquired LiDAR (light detection and ranging) coverage of the entire Black Hills National Forest will help identify hazards Forestwide.

Watershed Hydrology, Water Resources and Conditions

The hydrology of the Black Hills reflects a complex interaction between precipitation, surface water, and groundwater. A detailed description of the hydrogeology of this region has been developed by Driscoll and others (2002). The Black Hills are an important source of water and regional aquifer recharge for the surrounding region, supporting aquatic, riparian, and groundwater dependent ecosystems, as well as municipal, industrial, agricultural, and recreational uses. The quantity, timing and distribution of surface water and the flow regimes observed in area streams are a direct result of precipitation patterns and exchange with aquifers in highly porous geologic units. Streams can lose or gain flow based on their position in the landscape. In certain locations, particularly where streams cross the Madison and Minnelusa formations, the entire surface flow can be absorbed, resulting in dry stream beds downstream. This surface-groundwater exchange recharges local aquifers, which are the source of springs in other areas, and provides groundwater resources that are pumped for human use. Another major factor that determines streamflow is human regulation via water withdrawals, diversions, and reservoirs.

Surface Water Resources

The Black Hills National Forest is the headwater source for many municipal and public water supplies in the Black Hills National Forest region. The water sourced from the Back Hills National Forest provides water to the Cheyenne River, directly in the south, and via the Belle Fourche River in the north. It is also a primary source of recharge for underlying aquifers in western South Dakota and eastern Wyoming. There is a complex relationship between groundwater and surface water because of numerous fractures, faults, solution cavities, sinkholes, and karst features. Without these features, groundwater recharge would be lower where the underlying rock has low permeability. These features are the result of physical and chemical processes which create fissures, holes, cracks, or cavities that allow surface water to recharge aquifers.

Surface water areas in the Black Hills National Forest are classified into five distinct geologic or hydrogeologic regions: (1) the limestone headwaters, (2) the crystalline core, (3) the loss zone basins, (4) the artesian spring basins, and (5) the exterior basins (Carter et al. 2002). Each is associated with a primary geologic formation that controls whether the hydrology of the region is predominantly surface water, groundwater, or both, and whether the region has extremely high loss rates because it is located on a geologic formation that is a major source for aquifer recharge.

- The limestone headwaters are dominated by groundwater recharge and the streamflow variability is low. Surface water discharge is predominantly spring flow. There are several large springs (Rapid Springs) and spring complexes (Sand Creek Springs at Ranch A/Babcock House) that account for much of the discharge in the limestone headwaters.
- The crystalline core area is in the central region of the Black Hills where igneous and metamorphic rocks are exposed. Direct runoff is the main type of discharge in the crystalline core area, which can diminish quickly in dry conditions because groundwater influence is low. Rapid Creek drains a substantial portion of this area.
- The loss zone is characterized by areas that cross the Madison Limestone and/or Minnelusa formation, which both have high recharge rates. Where streams cross one of these two formations, losses are high and streams usually dry during times when base flow dominates. These areas are important for recharging the Madison and Minnelusa aquifers. Some stream segments over these formations can lose up to fifty cubic feet per second. In places the subsurface flow resurfaces in another drainage basin.
- The artesian spring area is defined by areas where the Madison Limestone and the Minnelusa outcrop, around the periphery of the Black Hills (and mainly outside the proclaimed boundary of the Black Hills National Forest) and where the Inyan Kara Group outcrops. Artesian springs receive recharge from groundwater and are an important and substantial source of water for rivers and streams through upwell through overlaying formations. Given the high loss rates in the area that springs occur, they are the reason streams have perennial flow in the area around the periphery of Black Hills National Forest exterior setting. Springs also are the sole source of the majority of streams in the Black Hills National Forest including Fall River, and Stockade Beaver Creek where spring flow is high and consistent. They also contribute to base flow in several larger rivers, such as Redwater River in the northern Black Hills National Forest.
- The exterior setting represents flows at the outer extent of the Black Hills (beyond the Inyan Kara Group outcrop). In these areas, streamflow variability is high because they are dominated by direct runoff (including discharge form springs) and groundwater influence is low.

Typical stream hydrographs depend on the underlying geologic characteristics and source of flow. For example, in limestone headwater basins (figure 1) and artesian spring basins (figure 2), streamflows are relatively constant throughout the year, whereas other basin types (crystalline core basins, figure 3; exterior basins, figure 4) have peak flows that mirror seasonal precipitation patterns (i.e., highest in May and June; Driscoll et al 2002).

The condition of the different flow regimes in the Black Hills National Forest are stable because they are driven by large-scale climatic and long-term geologic processes. However, population growth and the associated increasing demand for water resources do have the potential to change this trend over time. The artesian springs are groundwater fed, so they have more stability of flow when compared to surface waters, but they are also vulnerable to depletion due to aquifer demands and extended droughts. The exterior basins and loss zones sometimes have more variation in streamflow because they represent areas that rely more on surface water flow and have areas with high infiltration rates.

Observations over the last 100 years show that water resources in the Black Hills National Forest are affected by large scale climate oscillations which produce warmer and dryer cycles, followed by cooler and wetter cycles (Matt Bunkers at Rapid City National Weather Service). During the dry cycles, many springs reduce in flow output or dry completely due to the lack of groundwater aquifer recharge (both the deeper aquifers and the alluvial). Spring-fed streams and wetlands also decrease in flow volume, duration, and length; and may also dry up completely. There are U.S. Geological Survey groundwater aquifer studies that document the cyclic patterns of flow volume, duration, and length. Additionally, in more recent years, Black Hills watershed personnel have noted flow patterns as they map and inventory water features across the forest.

Although the Driscoll and others (2002) study is nearly 20 years old, many of the large-scale precipitation and hydrogeologic patterns are still similar. The precipitation pattern is driven by elevation, and much of the hydrology is driven by the geology, neither of which have changed appreciably. However, the U.S. Geological Survey monthly stream hydrographs that were presented in Driscoll and others (2002) were recreated for the purpose of updating this report since climate and water use changes could also change the hydrology (USGS 2022). The years of record used for this assessment were 1995 to 2019. This period of record adds nearly 20 years to the record discussed in Driscoll and others (2002). Since several of the gages did not have monthly statistics complete through 2020, the records through 2019 were used instead so that each month would have the same period of record. The same U.S. Geological Survey gages were used as in Driscoll and others (2002), to the extent possible, but several gages were no longer available or active. Neither of the gages used in Driscoll and others 2002 for the loss zone were available, for instance. The other four regions had enough of the same gages available to confirm that the predominant hydrologic patterns are unchanged since they the early 2000s. In some cases, the magnitude of discharge, cubic feet per second (cfs), was lower.

Increased demand in groundwater pumping associated with the exponential population growth, particularly along the I-90 corridor and in smaller, established communities, poses a significant risk of further impacts to groundwater dependent features (springs, streams, wetlands).

Broad scale changes to plant communities in the terrestrial and riparian ecosystems can influence the natural processes within a watershed. These changes can result from timber harvest, invasive species, fire suppression, recreational impacts or other unintended management consequences. Each of these changes are discussed in greater detail in the respective assessment documents (please see *Aquatic Riparian and Groundwater Dependent Ecosystems* assessment and the *Insects, Disease and Invasive Species* Assessment).

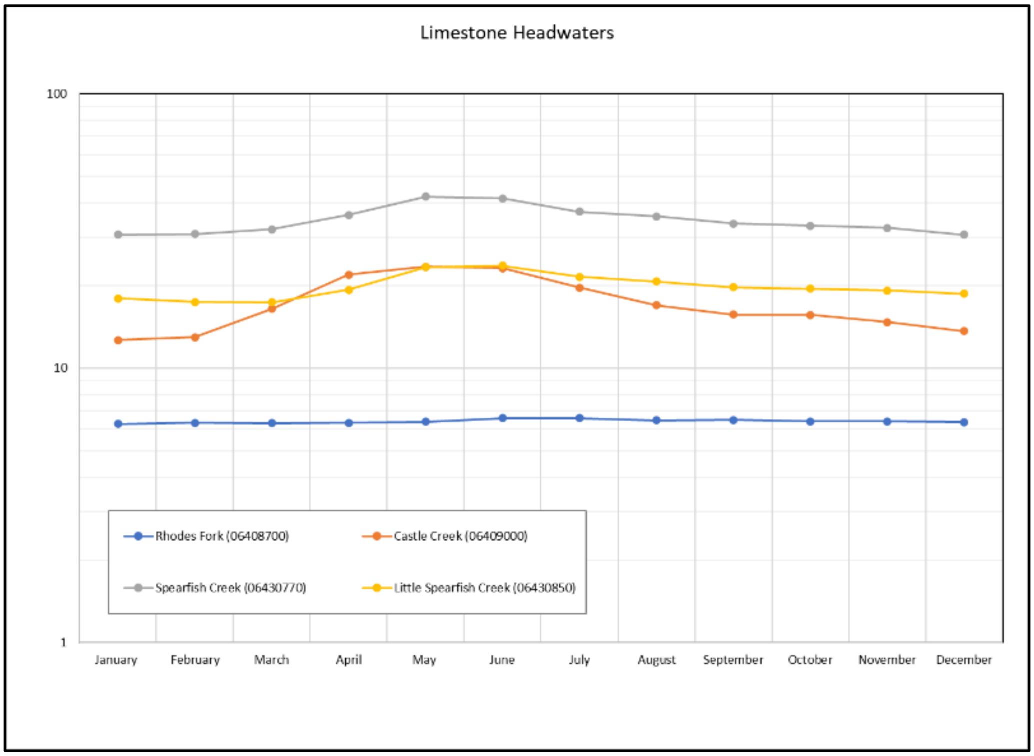

Figure 1. Hydrographs for the limestone headwaters basins based on monthly streamflow (cfs) data from 1995 to 2019

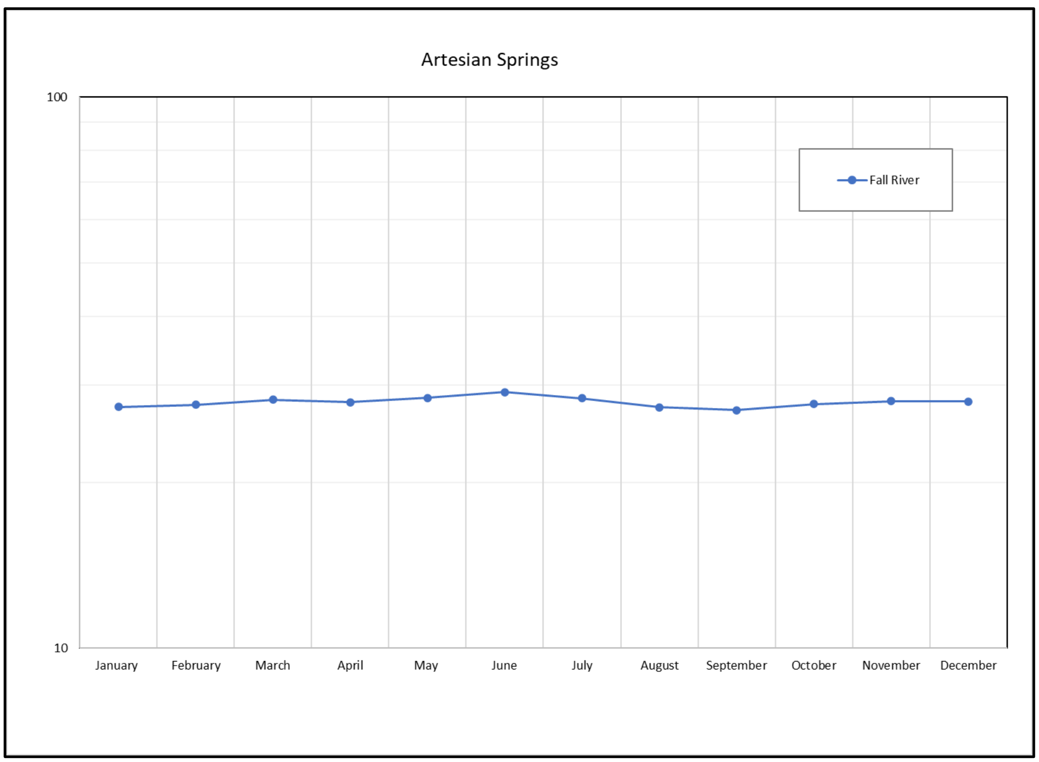

Figure 2. Hydrographs for the artesian springs basins based on monthly streamflow (cfs) data from 1995 to 2019

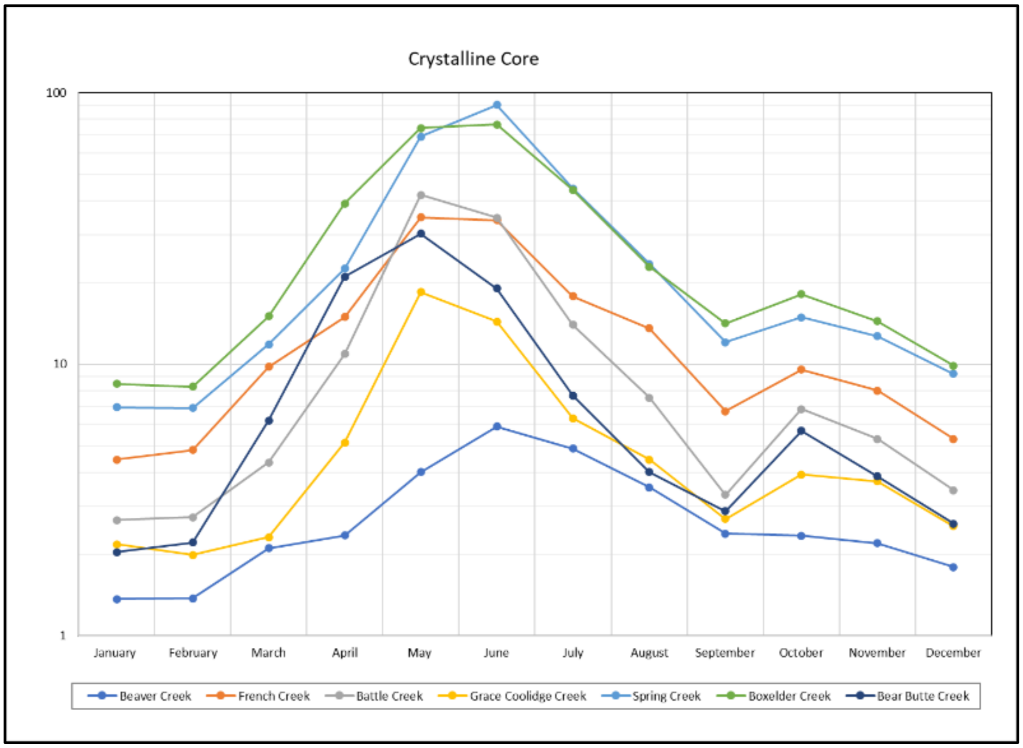

Figure 3. Hydrographs for the crystalline core basins based on monthly streamflow (cfs) data from 1995 to 2019

Figure 4. Hydrographs for the exterior basins based on monthly streamflow (cfs) data from 1995 to 2019

Precipitation patterns across the Black Hills reflect orographic effects as well as regional climatic differences between the north and south zones of the Forest. Seasonally, the most precipitation comes in May and June, and the least precipitation comes in the winter (November-February). Figure 5 shows a precipitation map of the area of Black Hills that is within South Dakota.

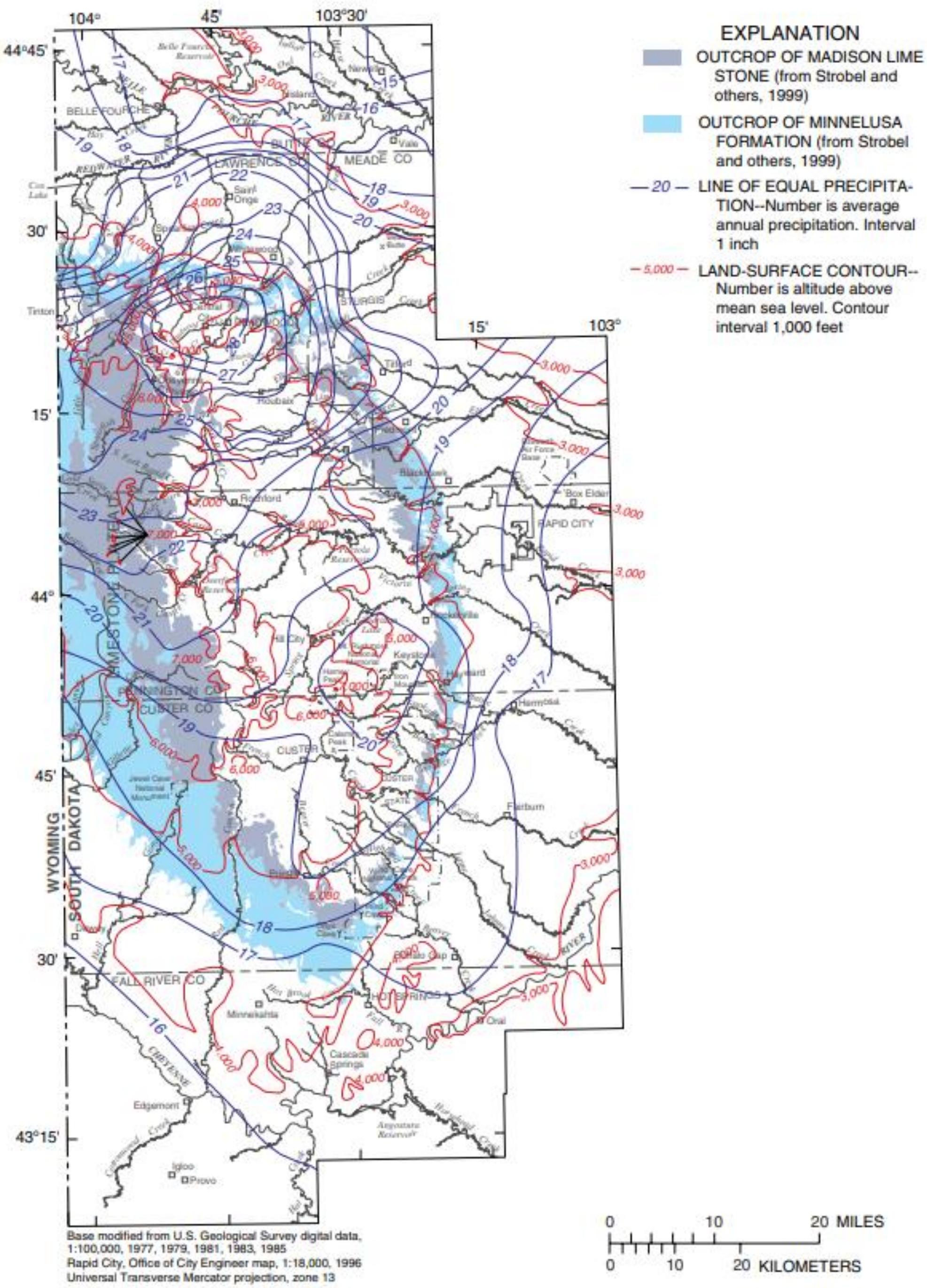

Figure 5. Monthly precipitation distribution for October 1995 (Driscoll et al. 2002)

Groundwater Resources

The major aquifers in the Black Hills area are the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers (Carter et al. 2002). The Madison and Minnelusa aquifers are used extensively and heavily influence the surface water resources of the area (Carter et al. 2002). Carter and others (2002) evaluated water resources including surface and ground water budgets and quality. The study used data from seventy-one observation wells to evaluate groundwater storage from 1950 to 1998. The Hermosa South Inyan Kara well was the only well with a steady decline; it declined four feet from 1983 to 1998. The other wells that were reviewed showed seasonal declines, typically as a response to irrigation withdrawals, followed by a rebound in aquifer water levels. (Driscoll and Carter 2001). In general, aquifers recharge quickly after irrigation.

Carter and others (2002) estimated 256 million acre-feet of recoverable water are stored in the major aquifers. Recharge rates for the Madison and Minnelusa aquifers are high; flowing streams on the Limestone Plateau area in the western Black Hills are uncommon because of these high recharge rates. The large recharge potential of the Madison and Minnelusa aquifers may provide options for management of surface and groundwater resources and demonstrates the highly connected nature of surface and ground water in the Black Hills National Forest.

Water Quality

Groundwater quality on the Black Hills National Forest is generally good. Water quality tends to be best near outcrops and decreases with distance from outcrops. The only health-related constituents of concern in groundwater are naturally occurring radionuclides (i.e., radon, radium, thorium, and uranium) and manufactured radionuclides (i.e., technetium, plutonium, neptunium, and americium). Other constituents exist but they are either considered aesthetic rather than health related because they effect the taste of the water, or they are not present in quantities that are high enough to become a health concern. Constituents include dissolved sulfate (from anhydrite dissolution in the Minnelusa aquifer), common ions (i.e., calcium, magnesium, sodium, bicarbonate, and chloride), trace elements (i.e., arsenic, copper, iron, lead, manganese, mercury, selenium, zinc), nutrients (i.e., nitrogen and phosphorus) and hard water from carbonate (limestone) aquifers (Driscoll et al. 2002; 2020 water reports: City of Deadwood, City of Edgemont, Eagle Water Company, Green Acres Estates, High Meadows Water Company, Southern Black Hills Water, Terry Trojan Water District).

Surface water quality is dependent on geologic setting (Williamson and Carter 2001). Surface water quality is generally good, meeting all the quality standards established for beneficial water uses (Driscoll et al. 2002; 2020 water reports: City of Deadwood, City of Edgemont, Eagle Water Company, Green Acres Estates, High Meadows Water Company, Southern Black Hills Water, Terry Trojan Water District). However, on streams that do not have a significant groundwater influence (runoff-dominated streams), especially those in the exterior setting, water quality frequently exceeds temperature and dissolved oxygen standards.

The Black Hills National Forest works cooperatively with the states to conduct project-level monitoring and employ best management practices in compliance with state mandates and the Clean Water Act (USDA Forest Service 2009, USDA Forest Service 2013). Beyond the project-level practices employed to maintain water quality, the focus of water quality monitoring is on water bodies that may not be meeting established beneficial uses or that are listed as impaired (discussed further below). From the WCF (table 5), 86 percent of sub-watersheds had a Water Quality indicator rating of good in 2010, while 9 percent had a condition indicator rating of fair, and 4 percent had a condition indicator rating of poor.

The U.S. Environmental Protection Agency (USEPA) maintains an online system for accessing information about the conditions in the Nation’s surface waters called the Assessment, Total Maximum Daily Load Tracking and Implementation Systems, known as ATTAINS (https://www.epa.gov/waterdata/attains). According to ATTAINS there are six bodies of water (lakes, reservoirs) within the boundary of the Black Hills National Forest with an impaired designation (table 7). Two of the six are not located on National Forest System (NFS) lands, one is partially located on NFS lands and three are located wholly on NFS lands. All six are included in Table 7 because management on the forest may impact the water quality, even if the water bodies themselves are not located on NFS lands.

Table 7. USEPA Impaired Waters dataset from ATTAINS for lakes and reservoirs

	Iron Creek Lake (partially on NFS lands)	Stockade Lake (not located on NFS lands)	Sylvan Lake (not located on NFS lands)	Sheridan Lake (wholly on NFS lands)	Pactola Reservoir (wholly on NFS lands)	Deerfield Lake (wholly on NFS lands)
Overall Status	Not Supporting	Not Supporting	Not Supporting	Not Supporting	Not Supporting	Not Supporting
Assessed	Yes	Yes	Yes	Yes	Yes	Yes
Impaired	Yes	Yes	Yes	Yes	Yes	Yes
Threaten	No	No	No	No	No	No
On 303d List	Yes	Yes	Yes	Yes	Yes	Yes
TMDL	No	Yes	Yes	Yes	No	No
4b Plan	No	No	No	No	No	No
Alternative	No	No	No	No	No	No
Protection	No	No	No	No	No	No
Drinking water	No data	No data	No data	No data	Fully Supporting	No data
Ecological	Not Supporting	Not Supporting	Not Supporting	Not Supporting	Not Supporting	Not Supporting
Recreation	Insufficient Information	Not Supporting	Not Supporting	Not Supporting	Fully Supporting	Fully Supporting
Other Use	No data	No data	No data	No data	Fully Supporting	No data
Algal Growth	Insufficient Information	No data	No data	Meeting Criteria	Insufficient Information	Insufficient Information
Ammonia	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria
Mercury	No data	Cause Unknown		Cause Unknown	Meeting Criteria	Meeting Criteria
Nutrients	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria
Oxygen	Insufficient Information	Cause Unknown	Cause Unknown	Cause Unknown	Meeting Criteria	Meeting Criteria
Pathogens	No data	Meeting Criteria	No data	Meeting Criteria	Insufficient Information	Meeting Criteria
pH acidity	Insufficient Information	Meeting Criteria	Cause Unknown	Meeting Criteria	Meeting Criteria	Meeting Criteria
Solids Chlorine	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria
Temperature	Cause Unknown	No data	Cause Unknown	Cause Unknown	Cause Unknown	Cause Unknown

	Iron Creek Lake (partially on NFS lands)	Stockade Lake (not located on NFS lands)	Sylvan Lake (not located on NFS lands)	Sheridan Lake (wholly on NFS lands)	Pactola Reservoir (wholly on NFS lands)	Deerfield Lake (wholly on NFS lands)
Turbidity	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria

Table 8 displays six additional waterways that are within the boundary of the Black Hills National Forest and identified within ATTAINS as having an impaired waters designation. Again, some of these waterways are not located on NFS lands, but they are included because management on the NFS lands may affect the water quality (table 8).

Table 8. USEPA Impaired Waters dataset from ATTAINS for rivers and streams

	Spring Creek (partially on NFS lands)	Elk Creek (partially on NFS lands)	Cheyenne River (not on NFS lands)	Strawberry Creek (not on NFS lands)	Victoria Creek (partially on NFS lands)	Whitewood Creek (small portion on NFS lands)
Impaired	Yes	Yes	Yes	Yes	Yes	Yes
Threatened	No	No	No	No	No	No
Drinking Water	No data	No data	No data	No data	No data	No data
Ecological	Fully Supporting	Fully Supporting	Not Supporting	Not Supporting	Not Supporting	Fully Supporting
Recreation	Not Supporting	Not Supporting	Not Supporting	Insufficient Information	Not Assessed	Not Supporting
Other Use	Fully Supporting	Fully Supporting	Not Supporting	Insufficient Information	Not Assessed	Fully Supporting
Algal Growth	No data	No data	No data	No data	No data	No data
Ammonia	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria
Mercury	No data	No data	No data	Insufficient Information	No data	Meeting Criteria
Other Metals	No data	No data	Meeting Criteria	Impaired, Cause Unknown	No data	Meeting Criteria
Nutrients	Meeting Criteria	Meeting Criteria	Meeting Criteria	Insufficient Information	No data	Meeting Criteria
Oxygen	Meeting Criteria	Meeting Criteria	Meeting Criteria	Insufficient Information	No data	Meeting Criteria
Pathogens	Cause Unknown	Cause Unknown	Impaired, Cause Unknown	Insufficient Information	No data	Impaired, Cause Unknown
pH acidity	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria
Solids chlorinated	Meeting Criteria	Meeting Criteria	Impaired, Cause Unknown	Meeting Criteria	No data	Meeting Criteria
Temperature	Meeting Criteria	Meeting Criteria	Meeting Criteria	Insufficient Information	Impaired, Cause Unknown	Meeting Criteria

	Spring Creek (partially on NFS lands)	Elk Creek (partially on NFS lands)	Cheyenne River (not on NFS lands)	Strawberry Creek (not on NFS lands)	Victoria Creek (partially on NFS lands)	Whitewood Creek (small portion on NFS lands)
Toxic Inorganic	No data	No data	No data	Meeting Criteria	No data	Meeting Criteria
Turbidity	Meeting Criteria	Meeting Criteria	Cause Unknown	Meeting Criteria	No data	Meeting Criteria

The data (as displayed in table 7 and table 8) indicate whether the water body or waterway is threatened, whether or not the quality is supporting beneficial uses such as drinking water, ecological health, and recreation, as well as other water quality constituents. Ecological function and recreation are not supported by the impaired waters, and there is insufficient data to make a designation for drinking water. Many water quality constituents are "Meeting Criteria;" however, some constituents are noted as "Impaired, Cause Unknown."

The most recent report on water quality from the South Dakota Department of Agriculture and Natural Resources (SDDANR Integrated Report 2022) identified the reason two creeks that are partially on the Black Hills National Forest within the Belle Fourche River Basin are impaired. The following is clipped from that report:

- *Strawberry Creek is impacted by historic mining activity and acid mine drainage. One of the contributing sources of impairment was from Brohm Mining Corporation's Gilt Edge Mine. On December 1, 2000, the site was listed on the National Priorities List as a Superfund Site. Remediation activities at Gilt Edge Mine are contracted by EPA to HydroGeoLogic, Inc. Due to remediation activities, copper, low pH, and zinc were delisted as impairment causes in the 2010 cycle. Strawberry Creek continues to be nonsupporting for exceeding chronic cadmium levels. A cadmium TMDL was approved for Strawberry Creek in April 2010.*
- *Several segments of Whitewood Creek near Lead are nonsupporting for E. coli. Sources of the high bacteria numbers in the stream's middle reach may be due to aging septic and sewer systems, the combined sewer overflow in Lead, and wildlife and livestock. A SWD permit has been issued to the city of Lead for the combined sewer overflow, requiring compliance with EPA's minimum controls for the combined sewer overflow. The city of Lead continues to make progress to separate their sewer systems and eliminate the combined sewer overflow. TMDLs are currently being developed for the impaired segments of Whitewood Creek.*

The impaired water bodies and waterways identified above in Table 7 and Table 8 are located within six of the eight sub-basins occurring within the boundary of the Black Hills FS, as displayed in table 9.

Table 9. Summary of impaired waters in each HUC 8 sub-basin

Sub-basin (HUC8) ID	Sub-basin Name	Any Impaired Water Bodies or Waterways?
10120107	Beaver	No
10120106	Angostura Reservoir	Yes
10120109	Middle Cheyenne-Spring	Yes
10120110	Rapid	Yes
10120111	Middle Cheyenne-Elk	Yes

Sub-basin (HUC8) ID	Sub-basin Name	Any Impaired Water Bodies or Waterways?
10120202	Lower Belle Fourche	Yes
10120203	Redwater	Yes
10120201	Upper Belle Fourche	No

There is a possibility management activity on the Black Hills National Forest may also affect the sub-basins outside the proclaimed boundary of the Black Hills National Forest so the ATTAINS GIS dataset from the USEPA was used to assess the sub-basins that are adjacent to the Black Hills National Forest. All but three sub-basins (Upper Cheyenne, Lance, and Hat) have impaired surface waters (table 10).

Each of the impaired waters is linked to a waterbody summary report. The main impairment for watersheds listed in table 10 are *E.coli*, fecal coliforms, and pathogens. Most are impaired with respect to recreational use and may or may not pertain to activities under the purview of the Forest Service.

Table 10. USEPA Impaired Waters dataset from ATTAINS for the HUC 8 sub-basins surrounding the Black Hills National Forest (USEPA 2020)

Sub-basin (HUC8) ID	Sub-basin Name	Any Impaired Water Bodies or Waterways?
10090208	Little Powder	Yes
10110201	Upper Little Missouri	Yes
10120103	Upper Cheyenne	No
10120104	Lance	No
10120108	Hat	No
10120112	Lower Cheyenne	Yes
10120113	Cherry	Yes
10130304	South Fork Moreau	Yes
10140102	Bad	Yes
10140201	Upper White	Yes
10140202	Middle White	Yes

Water Use

The Black Hills National Forest is the headwater source for municipal, industrial, and recreational water uses in western South Dakota. Water from the Black Hills National Forest is also an important source of recharge for aquifers in South Dakota and western Wyoming. Population growth can result in competing interests for water supplies, but overall water use in South Dakota is low compared to other states (Dieter et el. 2017, Dieter et al. 2018). Within the Black Hills National Forest there are consumptive water uses (public/municipal water supply, irrigation) and non-consumptive water uses (recreational including swimming, fishing, and boating).

There are numerous recreation sites throughout the Black Hills National Forest, including boat ramps, campgrounds, day use areas, fishing sites, horse camps, interpretive sites, visitor centers, lookouts, cabins, observation sites, picnic sites, snow parks, swimming sites, and trailheads. Recreational water uses, such as those listed, are considered non-consumptive water use, with the exception of some campgrounds that have their own public water supply (public water supply is water that is withdrawn to supply water for at least twenty-five people, or a minimum of fifteen connections). Non-consumptive water uses are an important part of recreation for fishing, swimming, and boating. The Black Hills National Forest has several reservoirs used for recreation as well as numerous rivers and streams.

Well water is used for most consumptive water uses. Consumptive uses from ground and surface water estimated by Driscoll and Carter (2001), include well withdrawals for agricultural, municipal and domestic use, reservoir evaporation, and consumptive withdrawals from streams. Consumptive withdrawals consist of irrigation withdrawals (not including unconsumed irrigation return flow). Most well withdrawals are consumed, however some municipal wells withdrawals may be unconsumed and returned to streams via wastewater.

In addition to some campgrounds, consumptive water uses in the Black Hills National Forest include small cities, towns, and communities that have public water supply wells. Every five years, the U.S. Geological Survey publishes a report of the estimated water use by state and county. The primary water use categories by county are irrigation, public supply, and industrial (Dieter et el. 2017, Dieter et al. 2018, Maupin et al. 2014, Kenny et al. 2009, Hutson et al. 2004). The primary water uses by county in 2000, 2005, 2010, and 2015 are shown in figure 7, figure 8, figure 9, figure 12, figure 11, figure 6, figure 10, and figure 12.

The South Dakota Department of Agriculture and Natural Resources (SDDANR) Drinking Water Program's mission is to protect public health and the environment. According to SDDANR Drinking Water Program, there are approximately 150 public drinking water systems in the Black Hills National Forest (2021). The majority of these public water systems are privately owned and operated. They are used for campgrounds, summer camps, horse and other recreational camps, ranches, and stores. There are several small municipal water systems as well, which typically provide more information in a formal annual water report. Information about the municipal water systems, their source water, and the most recent (2020) water quality report is provided in table 11. These reports can provide a snapshot of the water quality of other public water supplies throughout the Black Hills National Forest and the factors that contribute to that water quality. For instance, alpha emitters, and radium are the product of natural erosion and may be found within a certain distance of a particular geologic formation, while copper and lead are typically from corrosion of pipes and may be found almost anywhere there is water infrastructure (2020 water reports: City of Deadwood, City of Edgemont, Eagle Water Company, Green Acres Estates, High Meadows Water Company, Southern Black Hills Water, Terry Trojan Water District). There are other cities within the Black Hills National Forest, including Rapid City, Spearfish, Sturgis, Custer, Hill City, Hot Springs and many other communities, however those listed here were most readily available through SDDANR. The United States Department Environmental Protection Agency and the Wyoming Association of Rural Water Systems are sources of water use information for the communities of Newcastle and Sundance. Wyoming Department of Environmental Quality (DEQ) may also have additional information.

Table 11. Municipal public water supply information

City	Year of Report	Customers	Average use (gallons of water per day)	Source	Relative Susceptibility	Contaminants Detected	Contaminant Sources
City of Deadwood	2020	1,270	348,000	Surface water purchased (river, lake, stream, ponds, reservoirs, springs, wells)	medium	Copper, Lead below action level by order of magnitude; Barium, Fluoride, Haloacetic Acids Total trihalomethanes below Maximum Contaminant Level by order of magnitude or more	Copper/lead = corrosion of household pipes; Barium = discharge of drilling waste, metal refineries, erosion of natural deposits; Fluoride = erosion of natural deposits, discharge from fertilize, additive; by products of drinking water chlorination
City of Edgemont	2020	774	262,000	Groundwater from local wells	low	Copper, lead below action level by order of magnitude; alpha emitters, combined radium, fluoride, nitrate, total trihalomethanes below MCL	Copper/lead = corrosion of household pipes; Alph emitters and combined radium = erosion of natural deposits; Fluoride = SAA; Nitrate = runoff from fertilizer use, leaching from septic tanks, sewage, erosion from natural deposits; RAA = by product of drinking water chlorination
Eagle Water Company	2020	25	2,000	Surface water sources river, lake, stream, ponds, reservoirs, springs, wells)	low	Copper, lead below AL; Alpha emitters, Fluoride, RAA below MCL	
Green Acres Estates	2020	31	2,325	Groundwater from local wells	medium	Copper, lead below AL; Alpha emitters, Combined Radium below MCL	
High Meadows Water Company	2020	140	2,000	Groundwater from local wells	medium	Copper, lead below AL; Fluoride, nitrate below MCL	
Southern Black Hills Water	2020	492	32,000	Groundwater from local wells	low	Copper, lead below AL; Alpha emitters, fluoride, nitrate below MCL	
Terry Trojan Water District	2020	400	29,000	Groundwater from local wells		Copper, lead below AL; Alpha emitters, barium, combined radon, fluoride, nitrate below MCL	

Irrigation is the highest form of consumptive water use in Crook, Custer, Fall River, Meade and Weston Counties (Figure 6, figure 7, figure 8, Figure 10 and Figure 12), although values are considerably lower than many other states (Dieter et el. 2017, Dieter et al. 2018, Maupin et al. 2014).

In Lawrence and Pennington Counties, public supply water is the highest form of consumptive water use (figure 9 and figure 12). Pennington County, which is the largest of the seven counties, saw increased public supply water with an expected increase in population. However, all other counties except Crook and Meade saw decreased use of public supply despite population increases (Fall River's population declined slightly from 2000-2015). Where irrigation withdrawals are high compared to public supply use, overall irrigation withdrawals decreased as irrigated acres decreased. In Lawrence and Pennington Counties, irrigated acres were constant from 2000-2010 and then decreased in 2015, while withdrawals saw increases through 2005 (Lawrence County) or 2010 (Pennington County) and then a sharp decrease.

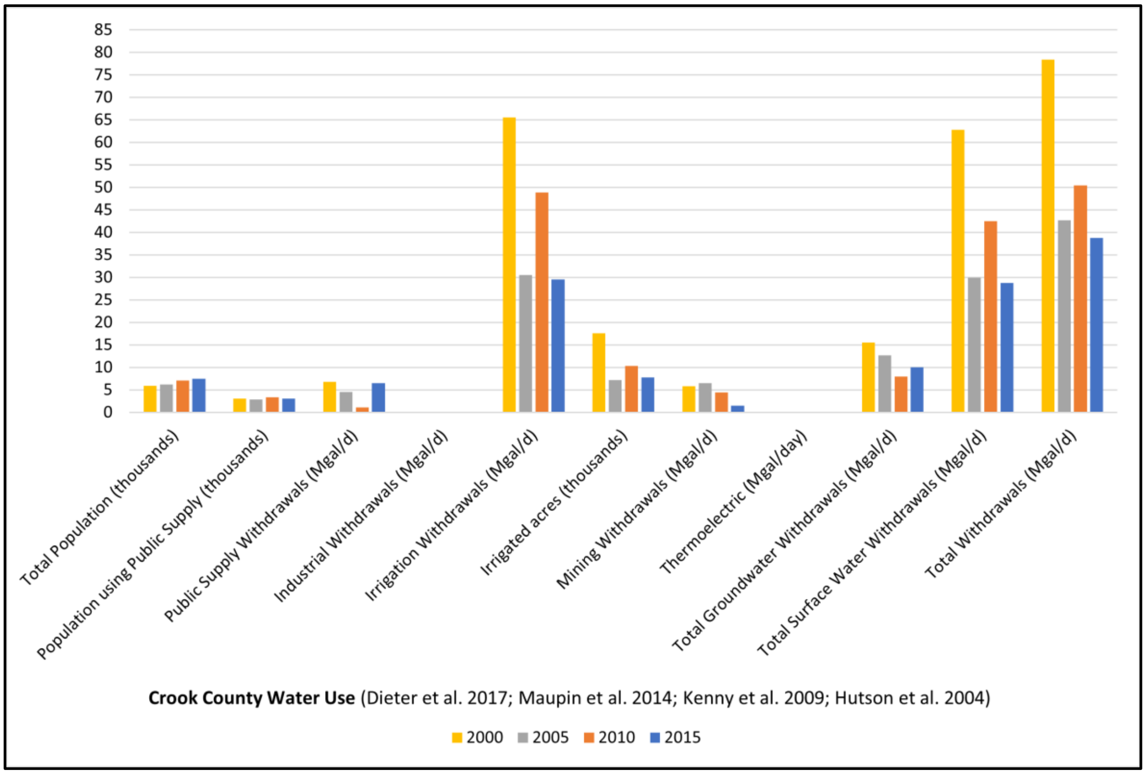

Figure 6. Water use in Crook County

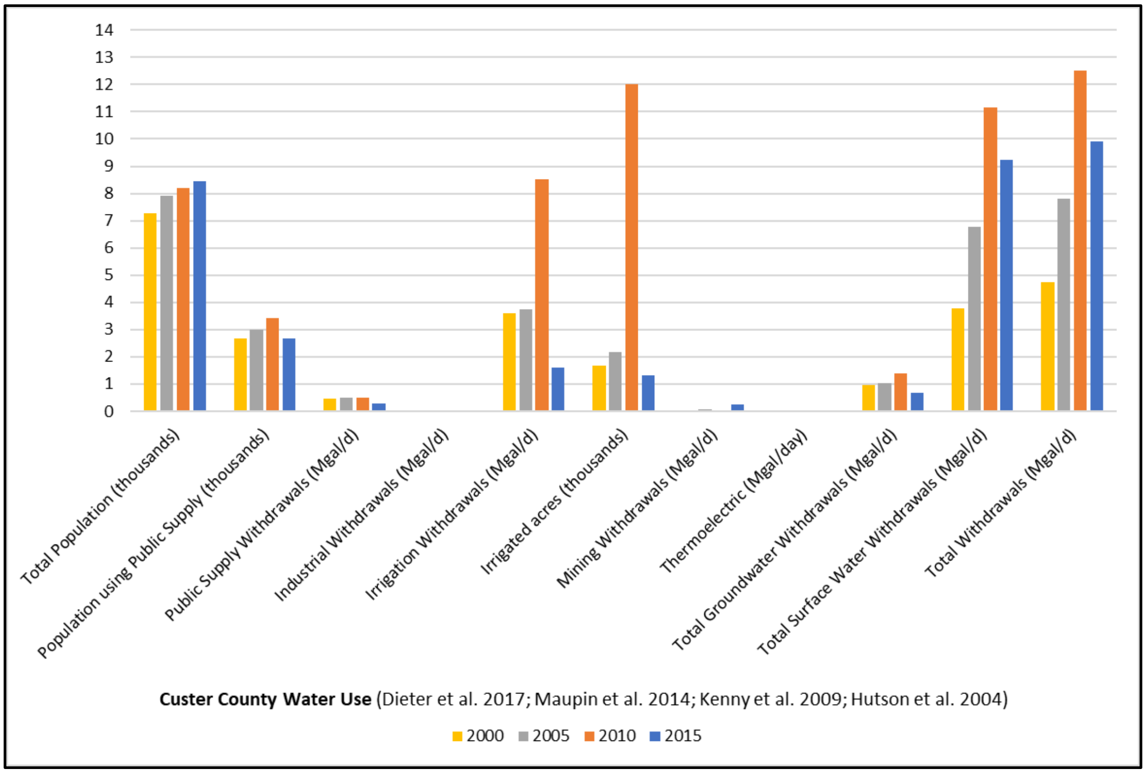

Figure 7. Water use in Custer County

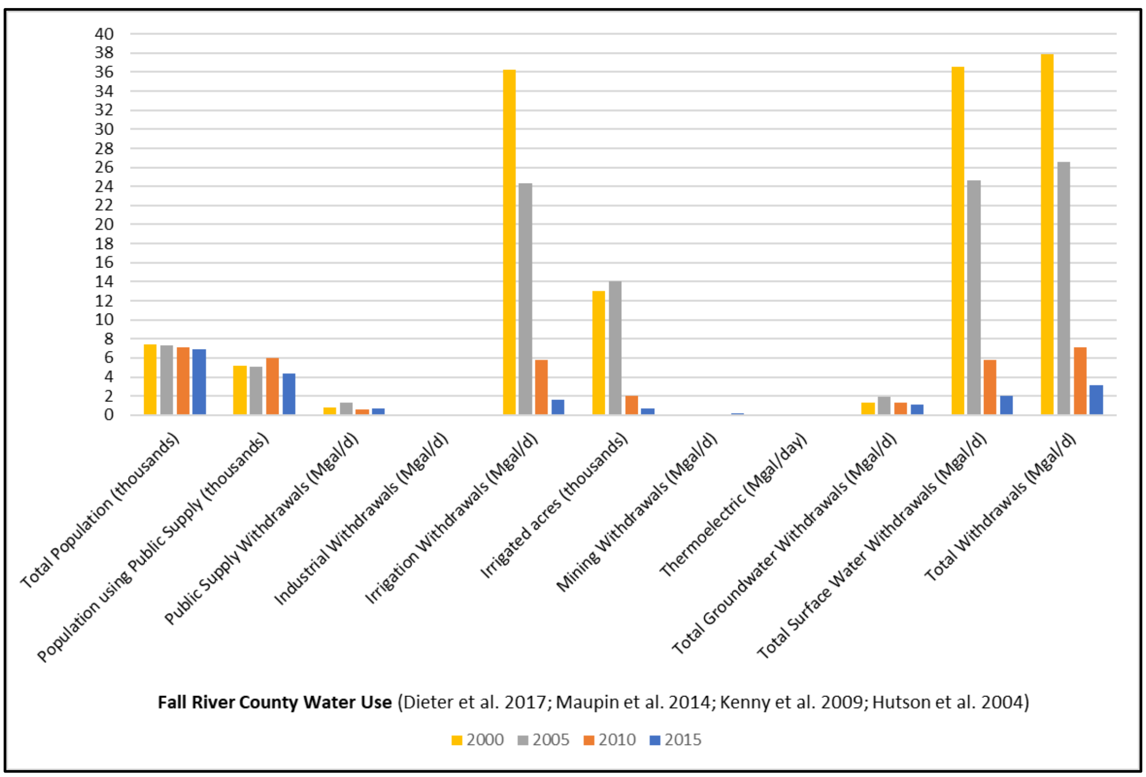

Figure 8. Water use in Fall River County

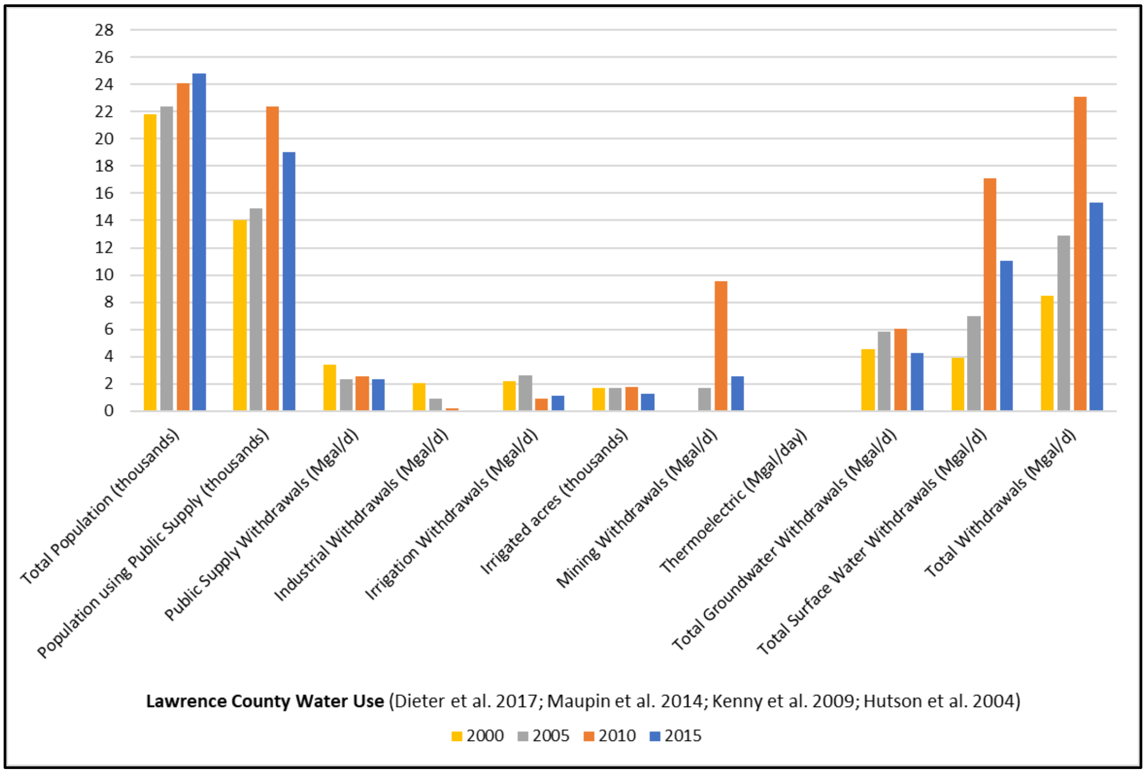

Figure 9. Water use in Lawrence County

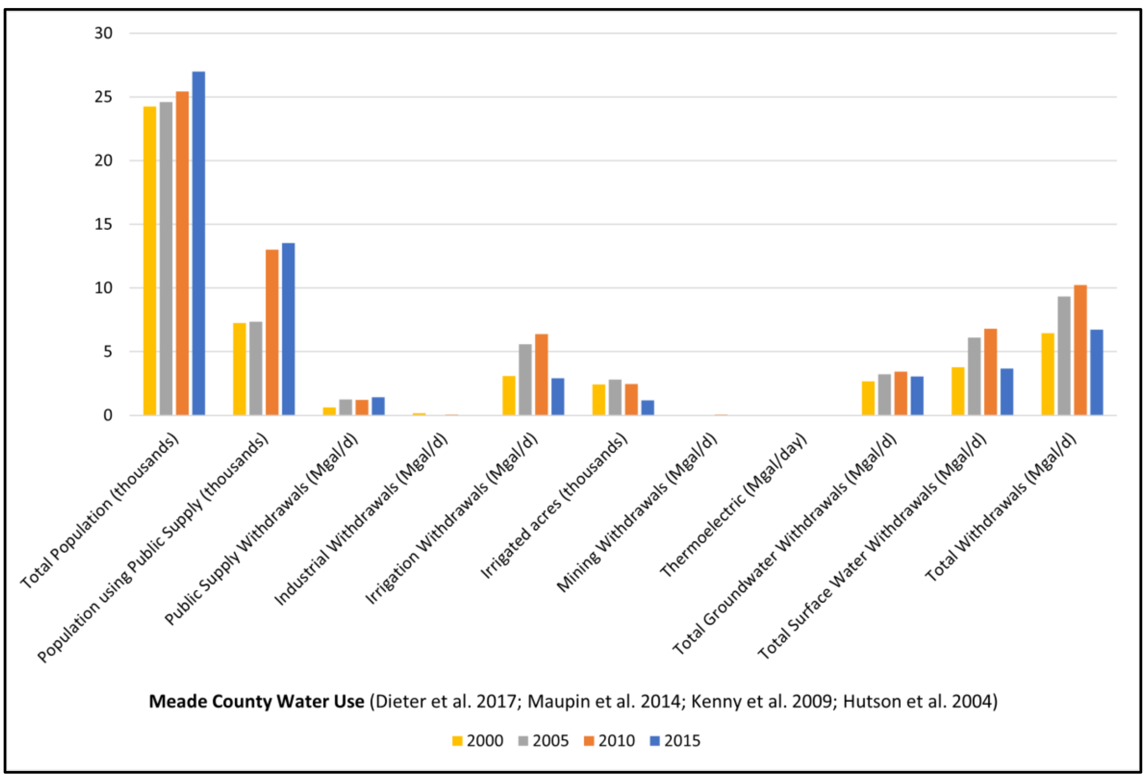

Figure 10. Water use in Meade County

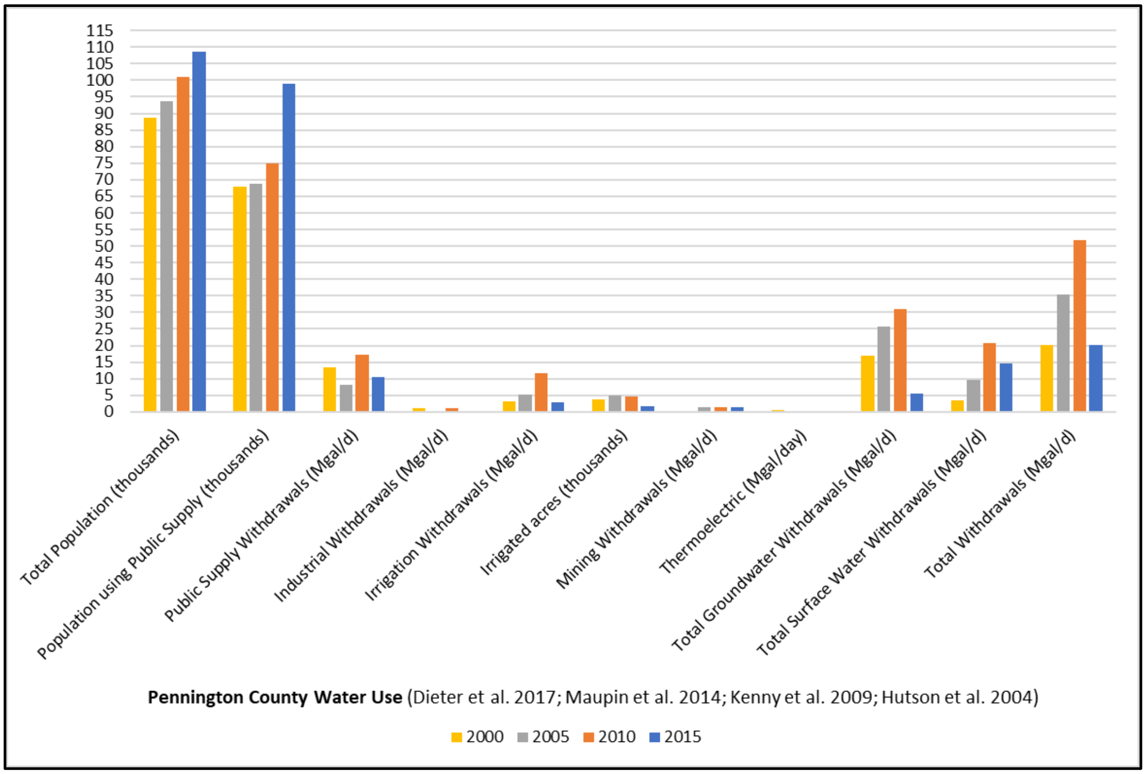

Figure 11. Water use in Pennington County

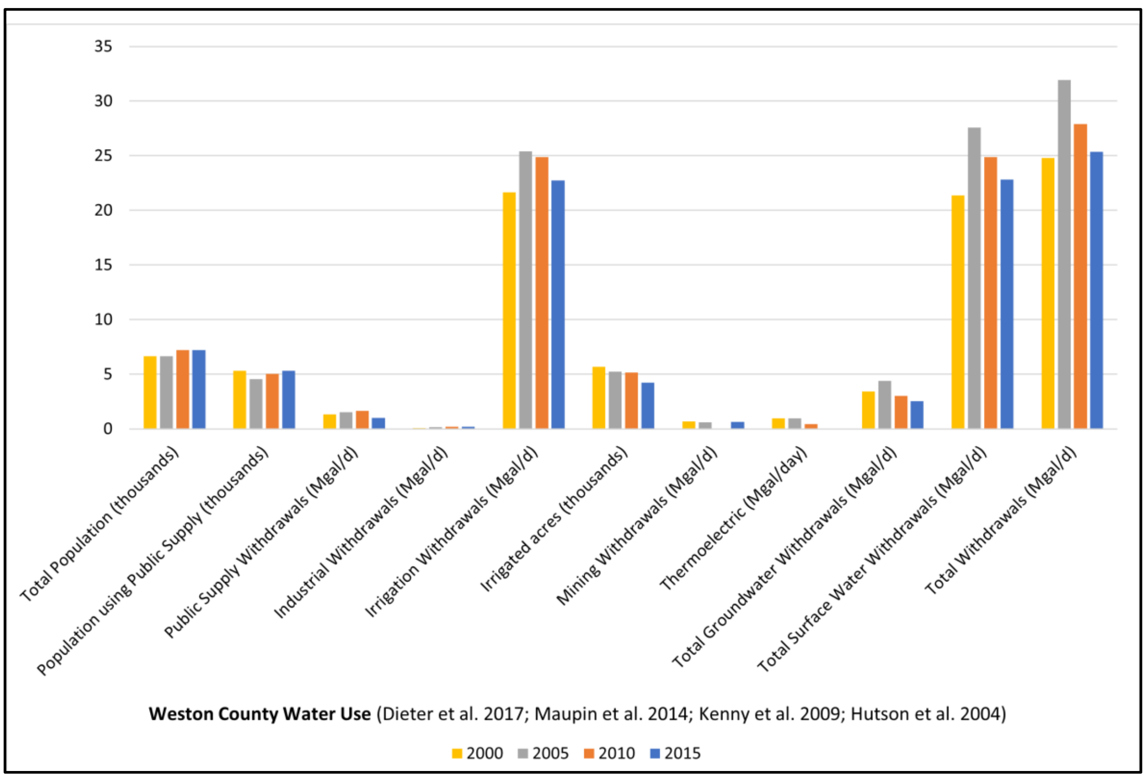

Figure 12. Water use in Weston County

Water is used for mining in all the counties except Meade, but it is exceedingly small amount in five of the counties. Mining use is higher in Lawrence County, which showed a spike in use in the year 2010. The spike in use was accompanied by increased surface water withdrawals that same year.

The water use data presented by Dieter et al. 2017, Maupin et al. 2014, Kenny et al. 2009, and Hutson et al. 2004 indicates that surface water withdrawals were higher than groundwater withdrawals, except in Pennington County from 2000 to 2005. It appears that irrigation, and mining primarily use surface water, while public supply water is sourced primarily from groundwater.

There are eighteen active large dams and reservoirs within the proclaimed boundary of the Black Hills National Forest. Two of those dams, Deerfield Lake and Pactola Reservoir, are managed and operated by the U.S. Bureau of Reclamation. Hemler Dam is privately owned, Sylvan Lake Dam is state owned, and Lower Homestake Reservoir has no designation. The other thirteen dams are operated by the Forest Service. The U.S. Bureau of Reclamation provides data on daily reservoir levels for water year (October through September). Pactola and Deerfield reservoirs were at or above average reservoir storage and precipitation in 2020 and in 2021, except October through January in both years which were below average precipitation.

Water Availability

From 1931 to 1998, the average annual precipitation was approximately eighteen inches. That average varies with altitude as lower altitudes receive sixteen inches annually and higher altitudes receive twenty-eight inches of annual precipitation. The 1990s were wetter than other decades and the averages presented by Carter and others (2002) are high. Precipitation from 2000 to 2020 may be lower, but more data on this is needed. Additionally, potential evaporation exceeds precipitation in the Black Hills National Forest. Approximately 92 percent of annual precipitation becomes evapotranspiration, 3.5 percent recharges aquifers, and 4.5 percent is runoff (Carter et al. 2002).

The National Climate Change Viewer (NCCV; Alder and Hostetler 2013) climate change predictions for precipitation and runoff for the period 2025-2049 were made on the spatial level of the HUC 8 watersheds. Predictions for precipitation and runoff were made using the Mean Model for 2025 to 2049.

Overall, runoff and precipitation patterns are predicted to be slightly elevated in the winter and spring months relative to the 1981-2010 mean and lower during the summer months. The net yearly precipitation predictions are higher than the mean, but the timing of precipitation shifts. The summer months are predicted to receive less precipitation than average, which is likely to increase evapotranspiration rates and decrease water availability. The watersheds with higher elevations (Rapid, Middle Cheyenne Elk, Lower Belle Fourche, and Redwater), are predicted to have up to 0.2 inches more precipitation per month from October to November.

The NCCV predicts temperatures to increase from 2-4°F over the next 25 years in all watersheds. The Black Hills National Forest climate change vulnerability assessment predicts increases of between 4.3 and 5.3°F by mid-century.

The future of surface and ground water for both consumptive and non-consumptive water use is optimistic based on the climate predictions by Alder and Hostetler (2013). The major aquifers in the Black Hills area are the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers (Carter et al. 2002). The Madison and Minnelusa aquifers are used extensively and heavily influence the surface-water resources of the area (Carter et al. 2002). These aquifers have high recharge rates and have a history of rebounding quickly after irrigation season. Since climate projections for the Black Hills National Forest watersheds do not appear to predict substantial decreases in precipitation or runoff and water uses are not likely to increase either to substantial population growth or increased need for special use permits, it is likely the water resources will remain stable into the near future. Changes to the predicted timing of precipitation and runoff could require changes to water management strategies and reservoir operations.

Water Infrastructure

There are hundreds of small dams/ponds that are used for livestock watering, wildlife habitat, and scenic/visual uses. Many of these structures are undocumented in Wyoming and South Dakota State databases. Some information can be found in the Black Hills National Forest GIS databases for water rights, structural range improvements and dam location notice databases. The agency-wide Infrastructure database identifies sixty-three water structures as ‘dams. While many are small, they can still have important impacts on the aquatic resources in the Black Hills National Forest as described in this section.

In addition to many smaller structures, there are eighteen active large dams and reservoirs within the proclaimed boundary of the Black Hills National Forest that are operated by State or Federal agencies. Two of the large dams, Deerfield Lake and Pactola Reservoir, are managed and operated by the U.S. Bureau of Reclamation. Hemler Dam is privately owned, Sylvan Lake Dam is state owned (and on state-owned land), and Lower Homestake Reservoir has no designation. The other thirteen dams are operated by the Forest Service. Only two are listed as constructed of something “other” than earthen materials. The name, ownership, and maximum storage capacity of each of these facilities is provided in table 12.

Table 12. Active dams in the Black Hills National Forest

Dam Name	Owner	Construction Materials	Maximum Storage Capacity (acre-ft)
Lower Homestake	Not Listed	Other	8
Cook Lake	Forest Service	Earth	805
Iron Creek Lake	Forest Service	Earth	517
Hanna	Forest Service	Earth	27
Rod and Gun	Forest Service	Earth	29
Lakota	Forest Service	Earth	240
Bismark Lake	Forest Service	Earth	626
Major Lake	Forest Service	Earth	73
Mitchell Lake	Forest Service	Earth	181
Horsethief Lake	Forest Service	Earth	590
Dalton Lake	Forest Service	Earth	41
Roubaix Lake	Forest Service	Earth	92
Strawberry	Forest Service	Earth	6
Sheridan Lake	Forest Service	Earth	22,043
Deerfield Lake	U.S. Bureau of Reclamation	Earth	14,969
Pactola Reservoir	U.S. Bureau of Reclamation	Earth	52,186
Hemler Reservoir	Private	Earth	8
Sylvan Lake	State	Other	0

Infrastructure associated with water diversions are authorized by special use permits by the Forest Service. There are forty-three water use pipelines in the Black Hills National Forest, and six water conveyance easements that have been granted (USFS 2021c). Given the number of water users in the Black Hills and the fact that most public supply water is derived from wells, it is not likely these numbers will increase substantially.

A hydraulic study by Hoogestraat (2011) looked at four dams (Horsethief Lake, Mitchell Lake, Iron Creek Lake, and Lakota Lake) within the Black Hills National Forest and their risk profile if a dam breach or failure occurred. Only Horsethief Lake was rated a significant hazard because there are structures downstream and considerable economic loss is probable from a dam failure. Mitchell Lake, Iron Creek Lake, and Lakota Lake are all rated as low hazards because there are no structures at risk if a dam breach occurred during a 100-year or 500-year 24-hr storm. As mentioned previously, there are sixty-three dams (not all are managed by the Black Hills FS) identified in the agency-wide database. Ten of the dams managed by the forest have been rated as High Hazard Dams in accordance with “Federal Guidelines for Dam Safety – Hazard Potential Classification System for Dams” (U.S. Department of Homeland Security and Federal Emergency Management Agency 2004). In the event of failure or mis-operation of High Hazard Dams the “probable loss of one or more human lives is expected.” All ten of those high-risk dams have emergency action plans in place, have monitoring devices and are inspected annually.

While the Forest Service does not manage all the dams and reservoirs in the Black Hills, they provide \benefits including flood control and storage, water for irrigation, and recreational opportunities such as camping, boating, fishing, water skiing etc. Dams and reservoirs also inherently alter the aquatic ecosystem by reducing, and at times, eliminating flow, all of which affects aquatic resources. Interruption of river continuity may result in inhibiting fish migration, stopping or limiting sediment flow and nutrient transport, hydrologically disconnecting the river and floodplain, and water quality changes (Schmutz and Moog 2018). Typically, the impacts on aquatic resources occur fairly rapidly and the ecosystems can adjust. If major changes to aquatic resources have not already occurred, they are not likely to occur unless substantial changes in reservoir storage occur (such as drastically reduced reservoir levels compared to historic levels) or changes in operations occur (such as releasing more or less water than usual). Additionally, if uses in or around the reservoir change, such as increased recreational activities, water quality could be altered. Limiting or tracking recreational uses in and around reservoirs would be prudent if such actions do not already exist.

Withdrawals do not seem to have a significant impact on aquatic resources. Much of the Black Hills National Forest is groundwater or spring fed and aquifers bounce back quickly after depletion. Some streams have little water because their recharge rate is so high. The larger reservoirs that are managed by the U.S. Bureau of Reclamation are managed and operated to ensure appropriate flows for fish and other species.

Water Rights

The use of water within a state is defined by state laws, and state courts. In most western states (South Dakota and Wyoming included) water rights are based on priority of prior appropriation; that is whoever first put the water to beneficial use has the priority right to the water (Jacobs et al. 1995). In South Dakota, a water right is needed for all uses except domestic uses up to 25,920 gallons per day or a maximum pumping rate of twenty-five gallons per minute. Domestic uses that exceed these volumetric limits, and all other uses require water rights. Domestic uses include ordinary household uses, irrigation of noncommercial gardens and trees not exceeding one acre in size, stock watering, and eighteen gallons per minute of use in schools, parks, and public recreation areas. Water rights are granted, regulated, and administered by the State. For dams, the State of South Dakota also has a type of water right called Location Notice which is used primarily for dams on ephemeral drainages. The South Dakota Department of Agriculture and Natural Resources maintains a database of all of the state's water rights allocations. Water rights in Wyoming are regulated by the State Engineer's Office, which maintains a database of the state's water rights allocations.

The Forest Service has the authority to grant special use authorizations, which are legal documents (e.g., permit, term permit, lease, easement) that allow occupancy, use, rights, or privileges on National Forest lands. The implementing regulations that guide how the Forest Service administers special use authorizations can be found in the Code of Federal Regulations (CFR) at 36 CFR Parts 25, 261, and 295. However, the states grant the right to use water. All federal agencies, including the Black Hills National Forest, must comply with applicable federal and state laws regarding the use of water from water sources on federal land when administering and managing federal land.

The US Forest Service has an agency-wide water rights database which is being updated to reflect water uses on NFS lands and to correct inconsistencies between Black Hills National Forest records and state data. Efforts to verify and update water rights in the water rights database are increasingly more important as demand in the Black Hills National Forest increases.

Wildland Fire Regimes

Effects of Wildland Fire on Watersheds

The Forest Service's WCF was used to assess the fire regime and effects of wildfire in the Black Hills National Forest in 2010. The Fire Regime condition indicator is included within the Terrestrial Biological set of indicators, along with Forest Cover, Rangeland Vegetation, Terrestrial Invasive Species, and Forest Health. The Fire Regime condition indicator was rated poor in 84 percent of HUC 12 sub-watersheds and as fair in 16 percent of sub-watersheds (table 13). The Beaver sub-basin had five out of 11 HUC-12 sub-watersheds that were rated as fair, and the Rapid sub-basin had five out of 12 sub-watersheds rated as fair. All other sub-basins had one or two sub-watersheds rated fair and the rest were poor. Note that the WCF indicators are based on 2010 data and have not yet been updated, hence are not reflective of the changed conditions resulting from the mountain pine beetle epidemic and timber management since 2010.

Table 13. Fire Condition Rating in each sub-watershed, base on 2010 WCF evaluation

HUC8 ID	HUC8 Name	HUC 12 Name	Fire Condition Rating
10120107	Beaver	Line Creek-Beaver Creek	Poor
		Beaver Creek-Bear Run	Poor
		Beaver Creek-Rats Valley Creek	Poor
		Upper Spearfish Creek	Poor
		Beaver Creek-Rock Canyon	Poor
		Lower Pass Creek	Fair
		Middle Pass Creek	Poor
		Pass Creek-East Pass Creek	Poor
		Roby Canyon	Poor
		Teepe Canyon	Poor
10120106	Angostura Reservoir	Cheyenne River-Little Tepee Creek	Fair

HUC8 ID	HUC8 Name	HUC 12 Name	Fire Condition Rating
		Cheyenne River-Moss Agate Creek	Fair
		Cheyenne River-Tepee Creek	Fair
		Chilson Canyon	Fair
		Craven Canyon	Fair
		Fourmile Creek	Poor
		Hawkwright Creek	Poor
		Lightning Creek-Red Canyon Creek	Poor
		Nitche Spring-Red Canyon Creek	Poor
		Pleasant Valley-Red Canyon Creek	Poor
		Whoopup Creek	Poor
10120109	Middle Cheyenne-Spring	Grizzly Bear Creek-Battle Creek	Poor
		Cottonwood Springs Creek	Poor
		Glen Erin Creek-French Creek	Poor
		Headwaters Spring Creek	Poor
		Hot Brook	Poor
		Iron Creek	Fair
		Johnson Gulch-Spring Creek	Poor
		Lower Cold Brook	Poor
		Lower Grace Coolidge Creek	Poor
		Middle Beaver Creek	Fair
		Newton Fork	Poor
		Newton Fork-Spring Creek	Poor
		Rockerville Gulch-Spring Creek	Poor
		Ruby Creek-French Creek	Poor
		Sheridan Lake-Spring Creek	Poor
		Stockade Lakes-French Creek	Poor
		Upper Beaver Creek	Poor
		Upper False Bottom Creek	Poor
		Deadman Gulch Creek-Battle Creek	Poor
		Highland Creek	Poor
		South Fork Lame Johnny Creek	Poor
10120110	Rapid	Canyon Lake-Rapid Creek	Poor
		Deerfield Lake-Castle Creek	Poor
		Lower Castle Creek	Fair
		North Fork Castle Creek	Fair
		North Fork Rapid Creek	Poor
		Pactola Reservoir-Rapid Creek	Fair
		Silver Creek-Rapid Creek	Fair
		Slate Creek	Poor
		South Fork Castle Creek	Poor
		South Fork Rapid Creek	Fair
		Upper Cold Brook	Poor

HUC8 ID	HUC8 Name	HUC 12 Name	Fire Condition Rating
		White Draw-Red Canyon Creek	Poor
10120111	Middle Cheyenne-Elk	Blackhawk Creek-Boxelder Creek	Poor
		Estes Creek-Boxelder Creek	Poor
		Jim Creek-Boxelder Creek	Poor
		Little Elk Creek-Elk Creek	Poor
		Morris Creek	Poor
		North Boxelder Creek-Boxelder Creek	Poor
		Pleasant Valley Creek	Poor
		South Boxelder Creek-Boxelder Creek	Poor
		Stagebarn Canyon Creek	Poor
		Town of Roubaix-Elk Creek	Poor
10120202	Lower Belle Fourche	Arnold Creek-Belle Fourche River	Poor
		Boulder Creek	Poor
		Deep Creek	Poor
		Headwaters Alkali Creek	Poor
		Park Creek	Poor
		Victoria Creek-Rapid Creek	Fair
10120203	Redwater	Bear Gulch	Poor
		Cold Springs Creek	Poor
		Crow Creek-Redwater Creek	Poor
		Grand Canyon	Poor
		Little Spearfish Creek	Poor
		Lower Spearfish Creek	Poor
		Middle Spearfish Creek	Poor
		North Fork Hay Creek	Poor
		North Redwater Creek-Redwater Creek	Poor
		Polo Creek	Poor
		Red Canyon Creek	Poor
		Sand Creek	Poor
		South Fork Hay Creek	Poor
		South Redwater Creek	Poor
		Sundance Creek	Poor
		Upper Whitewood Creek	Poor
		Upper Pass Creek	Poor
10120201	Upper Belle Fourche	Blacktail Creek	Poor
		Houston Creek	Poor
		Lower Beaver Creek	Poor
		Lytle Creek	Poor
		Miller Creek	Poor
		Spring Creek-Belle Fourche River	Poor
		Upper Castle Creek	Fair

The 2010 WCF showed 84 percent of sub-watersheds were rated as poor condition for the Fire Regime condition indicator and 16 percent of sub-watersheds were rated as fair when assessed in 2010. A rating of poor for this indicator means there is a “high likelihood of losing defining ecosystem components because of the presence or absence of fire” (USDA Forest Service 2011b), A fair rating means there is a moderate likelihood, and good rating means there is a low likelihood. A Fire Regime condition indicator rating of poor indicates there is a significant departure in the majority of the watershed from reference conditions. This includes changes to vegetation type and cover, fire frequency, severity, and pattern, and fuel accumulation (USDA Forest Service 2011b). In the WCF, either Fire Regime or Wildfire Effects are rated for any one watershed. Watersheds that experienced a significant wildfire with the past five years are rated only for Wildfire Effects during the initial 5-year recovery period, and then rated only for Fire Regime after the initial recovery period. Note that the WCF indicators are based on 2010 data and have not yet been updated, hence are not reflective of the changed conditions resulting from the mountain pine beetle epidemic and timber management since 2010. Please see the *Fire and Fuels Assessment* for more information regarding the fire regime.

Watershed Adaptation to Wildland Fire Behavior

To a large extent, watershed condition is controlled by the composition and density of vegetative cover and the amount of bare soil resulting from anthropogenic or natural disturbances that affect the watershed. Fire primarily alters vegetation and soil properties, changing hydrologic and geomorphic processes. In general, the effects of fire are increased soil water and overland flow that result in accelerated erosion by a variety of surface and mass movement processes (USDA Forest Service 2011b). The WCF ratings of poor for the Fire Regime indicator suggests a need for the implementation of management activities focused on improving watershed health conditions, including restoring fire-adapted ecosystems. Management activities posed in the WCF include reduction of hazardous fuels, erosion control, reforestation, and improvements to soil and water resources. In addition to the WCF ratings, local Community Wildfire Protection Plans report that fires are burning hotter, and more acres are being burned than in the past (Mattox 2009, Mattox 2012). The fire regime impacts the overall watershed condition ratings because it is a factor in the decreased overall functionality of each watershed and sub-watershed.

Fire Management – Preventing extreme wildfires is key to helping achieve fire resilient ecosystems. Extreme fires can also have lasting impacts on all WCF indicators. Thinning and prescribed fires are the two main treatments to help achieve these goals. Both of these treatments help remove buildup of excessive woody debris and over-crowded vegetation. The benefits of prescribed fire include hazardous fuels reduction, minimized insect infestations and disease, increased forage for game and livestock, improvements to endangered and threatened species habitat.

Effects of Insects, Disease, and Invasive Species on Watersheds

The mountain pine beetle (MPB) (*Dendroctonus ponderosae*) has minimal effects on the watersheds of the Black Hills National Forest in the long term, as most effects are transitory. Although MPB increases tree mortality, this is offset by increases in understory vegetation and tree regeneration, which filters run-off and minimizes changes to streamflow during normal or dry climactic conditions in watersheds that are not snow influenced (Thom et al. 2020). In watersheds that are snow influenced, insects and disease increase tree mortality, which results in the reduction of the forest canopy causing an earlier snow melt and some degree of increased runoff (Sheppard and Battaglia 2002).

As stated in the I*nsects, Disease, and Invasive Species Assessment*, MPB populations explode every twenty years in the Black Hills National Forest in periodic epidemics, the last of which lasted from approximately 1996 through 2016 (Graham et al. 2021). During times of drought, the pine engraver (*Ips pini*) can cause high mortality in unthinned young stands (Sheppard and Battaglia 2002). The increased tree mortality associated with these insect outbreaks, and the significant increase in seedling and sapling densities and herbaceous cover in the understory in the years following the outbreak, can result in an increased risk of high intensity fires that have the potential to damage soils and affect the watershed (Sheppard and Battaglia 2002, Parrish et al. 1996, Graham et al. 2021). This will bring about the stressors related to fire as mentioned in the sections above and result in increased runoff until understory vegetation and tree regeneration can mitigate the effects of the decrease in overstory (Sheppard and Battaglia 2002, Thom et al. 2020).

As stated above, during years when insect epidemics are experienced, watersheds that are snow influenced will experience some degree of increased runoff due to reductions in the forest canopy (Sheppard and Battaglia 2002). In the years since the end of the MPB epidemic, there has been an increase in forest structures comprised of young forest seedlings and saplings. Sapling densities in some areas range from 5,000 to 10,000 per acre (Graham et al. 2021, USDA Forest Service 2013). This regeneration will help filter runoff and minimize changes in streamflow (Thom et al. 2020).

The WCF used to evaluate watersheds in 2010 includes an aquatic biological indicator, which includes a sub-indicator for exotic and/or invasive species. In 2010 the sub-indicator ratings indicated 53 percent of watersheds (50 of 95) were functioning properly, 27 percent of watersheds (26 of 95) were functioning at risk, and 20 percent of watersheds (19 of 95) were impaired. Based on the 2010 data, aquatic invasive species are potentially more of an impairment than terrestrial invasive species, given that 20 percent of sub-watersheds were rated as impaired with respect to aquatic invasive species versus 2 percent for terrestrial invasive species. It must be noted again these ratings are based on data collected in 2010, they do not account for the increase in terrestrial invasives plants that has occurred, nor the recent finding of zebra mussels (*Dreissena polymorpha*) on the Black Hills National Forest.

Invasive species have become well-established in the Black Hills National Forest despite ongoing treatment. The weed-management plan directs the forest to implement prevention, education, administration, planning, and integrated control in the weed-management effort. The forest plan was amended in 2005 to include additional management direction related to noxious weeds and non-native pests. In the intervening years, this has been broadened to include aquatic nuisance species on National Forest System lands. The presence of invasive species is just one of the current stressors and drivers affecting watershed function in the Black Hills National Forest, but it is difficult to tease out the influence of that specific factor. For more detailed discussion on this topic, reference the *Insects, Disease, and Invasive Species Assessment*.

Effects of Climate Change on Watersheds

Climate change in the Rocky Mountain region is expected to impact watershed scale processes through earlier spring runoff, lower baseflows, and greater precipitation occurring as rainfall rather than snow (Halofsky 2018). The *Climate Change Vulnerability in the Black Hills Assessment* (CCVA) projects more frequent and extreme precipitation events, with increased precipitation, especially in winter and spring. These changes are likely to result in increased water temperatures, decreased snowpack, increased variability in streamflow each year, and greater potential for flooding in spring and early summer. These impacts will alter aquatic habitats, affect forest vegetation, and change ecological processes.

The National Climate Change Viewer (NCCV) developed by the U.S. Geological Survey (Alder and Hostetler 2013) uses various climate models to predict climate variables such as precipitation, temperature, runoff, vapor pressure deficit, and soil water storage throughout the US. NCCV results are available for several future periods, including 2025-2049, 2050-2074, and 2075-2099. Predictions are made on the spatial level of the HUC 8 sub-basins. The following discussion refers to projections for precipitation and runoff made using the Mean Model for 2025 to 2049 (table 14).

Overall, runoff and precipitation patterns are slightly elevated between January and June relative to the 1981-2010 mean. That increase is sometimes offset by an equal or decreased level of precipitation and runoff in the summer months (June to September). Predicted runoff increases range from 0.05 inches per month to 0.2 inches per month. Predicted precipitation increases range from 0.1 inches per month to 0.5 inches per month. Five sub-basins, with higher elevations (Beaver, Rapid, Middle Cheyenne Elk, Lower Belle Fourche, and Redwater), are predicted to have up to 0.2 inches more precipitation per month from October to November.

The NCCV predicts temperatures to increase from 2-4°F over the next 25 years in all watersheds. The CCVA indicates the average temperature in the Black Hills National Forest has risen around 2°F. It projects a rise in temperatures of around 4 to 5°F by mid-century.

Given that the majority of precipitation is lost to evapotranspiration, summers could become drier with the predicted decrease in runoff. Although winter precipitation and runoff are predicted to be higher than the current running average and reservoirs and aquifers could have an increased opportunity to replenish, population growth and increased demands on groundwater could offset those changes. Many streams are spring or groundwater fed in the Black Hills, which means more water will be available for recharge in the winter months, an ideal time to keep those sources flowing. Changes to timing of precipitation and runoff could, however, change water management strategies, including when and how irrigation occurs.

Table 14. Projections based on increase (+) or decrease (-) from 1981-2010 average (NCCV 2014)

HUC8 ID	HUC8 Name	Black Hills National Forest Geographic Area	Runoff Predictions 2025-2050 (inches/month)	Precipitation Predictions 2025-2050 (inches/month)
10120107	Beaver	Elk Mountain	(+) 0-0.1 February-April (-) 0-0.1 May- July	(+) 0-0.3 March-May (-) 0-0.2 July-August (+) 0.1 October-November
10120106	Angostura Reservoir	Pleasant Valley, Red Canyon	(+) 0-0.05 February-April	(+) 0-0.4 March-June (-) 0-0.2 July -August
10120109	Middle Cheyenne-Spring	Seven Sisters Range	Negligible change (less than 0.05 inches/month)	(+) 0-0.4 inches January-June (-) 0-0.2 July -September
10120110	Rapid	Rapid Creek	(+) 0-0.1 inches per month Feb – May (-) 0-0.2 May-August	(+) 0-0.4 inches February-June (-) 0-0.2 June-September (+) 0.1 October
10120111	Middle Cheyenne-Elk	Sheridan Lake	(+) 0-0.1 February – July	(+) 0-0.4 February-June (-) 0-0.2 June-August (+)0.1 October-November
10120202	Lower Belle Fourche	Bear Lodge Mountains, Strawberry Ridge	(+) 0-0.1 February – July	(+) 0-0.4 inches February-June (-) 0-0.2 June-August (+) 0-0.2 October

HUC8 ID	HUC8 Name	Black Hills National Forest Geographic Area	Runoff Predictions 2025-2050 (inches/month)	Precipitation Predictions 2025-2050 (inches/month)
10120203	Redwater	Bear Lodge Mountains	(+) 0-0.2 January – April (-) 0-0.2 May-August	(+) 0-0.5 inches Jan-June (-) 0-0.1 July-August (+) 0.2 September-December
10120201	Upper Belle Fourche	Bear Lodge Mountains	(+) 0-0.1 inches per month February – April (-) 0-0.1 May-August	(+) 0-0.4 inches January-July

Increasing temperatures and altered precipitation events could result in increased drought and wildfires. While having adapted to a wide range of conditions, the ponderosa pine forest could experience issues stemming from increased drought. Drought would increase the forest stands susceptibility to insects and disease and make it vulnerable to larger high-intensity fires. Post-wildfire effects would be exacerbated by increased human populations within forest boundaries and downstream. Post-fire watershed responses include flooding waters containing ash and debris causing damage to infrastructure, posing threats to water quality and municipal water supplies, threatening human life and property. Post-fire flooding also causes loss of habitat for aquatic and riparian species. The CCVA anticipates that other species such as white spruce and paper birch will continue to persist, although they are likely to be vulnerable to warming temperatures. Additional information about climate change conditions can be found in the CCVA.

Watershed management must adapt to the changing climate, including wetter conditions and more extremes between dry and wet cycles. Ensuring stream connectivity for flows and for habitats during dry periods, and developing resilient, well-located infrastructure to withstand flooding events will be critical to adaptively managing for climate change.

Human Influences on Watersheds

Numerous human activities have caused disruption of the natural forest patterns compared to a reference condition (Weins et al. 2012) with varied outcomes. These influences are manifested across different geographic and temporal scales. While a comprehensive list of these human influences is not possible due to their pervasiveness, the general categories include water use, mineral extraction, transportation, recreation, biological changes (invasive species, beaver removal), vegetation management (timber harvest, livestock grazing, wildland fire management), and urbanization. The current forest plan has components (see *Chapter 3. Current Management Direction*) designed to help manage the impacts of management actions on soils and water.

The number and placement of roads required for many of the uses of the forest has resulted in a poor rating for the WCF Roads and Trails indicator in 72 percent of sub-watersheds, during the 2010 evaluation. With the increased use of the forest since 2010, that indicator will remain as poor when the WCF is updated.

There is a well-established history of mining in the Black Hills National Forest. While mining brought economic prosperity and towns were built to accommodate the influx of mine workers, it also resulted in abandoned mines and acid mine drainage issues that have negative impacts on watershed health. Acid mine drainage requires substantial efforts and funds to remediate. The negative impacts include contaminated soil and water that negatively impact human health and the health of rivers, fisheries, and ecosystems. The impacts from acid mine drainage can spread many miles from the source mine, especially if it is located on or near a waterway. It can also contaminate groundwater. In the Black Hills National Forest, the Gilt Edge Mine and the Richmond Hill mine both have or have had acid mine drainage issues.

The Gilt Edge Mine, previously a gold mining operation, is an USEPA Superfund site. It is located in Lawrence County, South Dakota, approximately six miles south of Lead and Deadwood, SD. The mine was abandoned in 1989 and was listed on the USEPA's National Priorities List in 2000. It is located near the headwaters of Strawberry Creek, Terrible Gulch, and Ruby Gulch, all of which drain to Bear Butte Creek. Bedrock and alluvial aquifers also underly the mine area. The most significant health risks from the site are the release of metals to the downstream fisheries and water users, and the potential for contaminated soil to impact human health and the environment (USEPA 2017). Remediation is on-going to address acid mine drainage from the Gilt Edge Mine sites and is expected to continue for several years (USEPA 2017).

The southwestern most area of the Black Hills National Forest has 26 documented abandoned mines, each with multiple related hazards. All of these mines were uranium and vanadium mines, and none are currently active. The abandoned mine related hazards vary and include issues with subsidence, highwalls, trenches, horizontal openings, waste rock piles and pits. Abandoned mines discovered throughout the forest are assessed for safety, rehabilitation as appropriate, and closure needs such as fencing, filling in, and gating for bats. The Forest Service hosts a mine database documenting information about abandoned mines, but it is not a complete inventory.

The watersheds are withstanding and recovering from the influences of mining activities. There are impaired waters associated with acid mine drainage from the Gilt Edge Mine and the Richmond Hill mine, and there are numerous impaired waters throughout the Black Hills National Forest, but most impaired listings are a result of *E.coli*, fecal coliforms, and pathogens as well as temperature-related impairments. Given all the mining that has occurred in the Black Hills National Forest, and all the efforts to reclaim mine lands, the watersheds are experiencing recovery.

The dominant characteristics of each watershed are terrestrial and aquatic biota and vegetation (including rangeland vegetation), water quantity and quality, soils, fire regime, forest cover, invasive species, and forest health. These dominant characteristics are perturbed by both natural environmental dynamics (fire, insects, disease) and human influence (infrastructure, roads, recreation, land use). According the 2010 WCF, these characteristics are either withstanding or recovering from perturbations, given that watershed conditions are all Class 1 or Class 2. They are still functioning properly, although the majority (80 percent) are functioning at risk.

Ecosystem Services

Ecosystem services are defined by the planning rule as benefits people obtain from ecosystems (36 CFR 219.19). Humans benefit from and depend on watersheds in a variety of ways. Some forest ecosystem services and multiple uses, including timber production, carbon storage, water regulation, aesthetic amenities, recreation, and wildlife and their ecosystem requirements (including soil, water, and vegetation) are discussed below.

Timber Production – Timber production requires soil productivity levels high enough to support tree species of interest for timber production, soil and slope stability (reduced erosion), and the availability of adequate water resources. Harvest requires the associated infrastructure (particularly roads). Timber production should be balanced with reducing fuel load to decrease wildfire risks. (See *Timber* assessment for more information).

Carbon Storage (in soil and biomass) – Storage occurs in live trees, standing dead trees, understory vegetation, down dead wood, the forest floor, and soil. Some requirements include limiting soil erosion, sustaining high soil productivity, and adequate water resources. This should be balanced with reducing fuel load to decrease wildfire risks.

Water Regulation – Water regulation includes direct regulation through changes in flow regime, thermal and light inputs, sediment flux, chemicals, nutrients, and pathogens and indirect regulation through practices such as forest management (Binder et al. 2017).

- The flow regime can change dramatically in both the short and long term when vegetation changes occur (clear-cutting, roads and infrastructure, fire, land use changes), reflecting the importance of timber harvest and stand management as a regulation tool.
- Vegetation is also critical in a stream's thermal load. Vegetation can affect the stream's temperature and water oxygen, which can impact stream habitat. Increased vegetation lowers the thermal load by providing shade and regulates the temperature and flow of groundwater flow (Binder et al. 2017).
- Sediment and organic matter from stream and riparian habitats increase soil nutrients and rebuild wetlands (Binder et al. 2017). Sediment flux can occur because of deforestation, roads, and fire. Too much or too little sediment can alter habitat areas, choke vegetation, and damage spawning habitat (Binder et al. 2017). Land use changes, fire regime, and erosion/soil quality can impact sediment flux.
- Chemicals, Nutrients, and Pathogens, especially nutrients from agriculture, are the second leading cause of impaired waters in the US (Binder et al. 2017). Vegetation is important to help remove nitrates in water. Water temperature and sediment flux can also exacerbate nutrient loads in water.

Aesthetic Amenities – The condition of the soil and water resources contribute to directly to the aesthetic amenities of a watershed. As Binder and others note (2017) the color, size, texture and shape of forests, trees and vegetation are all important to the aesthetic amenities of forests. Those attributes are reliant on healthy soils and water.

Recreation requires roads, trails and other access points (for water or views). Many recreation sites also require clean water, if not for human consumption, then at least for aesthetic quality and recreational use. Recreation activities are also directly impactful to

Wildlife can benefit recreation by adding aesthetic and spiritual values, as well as playing an important role in disease control, pest control, pollination, nutrient cycling and soil formation (Binder et al. 2017). Requirements include, forest habitat, adequate water resources including clean water, and safe passage across roads or safety buffer zones. Where hunting is permitted, limits may also be required for certain species. Hunting may also help to control populations of certain species to maintain overall ecosystem function. Land use is also an important factor in wildlife benefits and multiple use because changes could reduce or encroach on wildlife habitat.

Chapter 3. Current Management Direction

The current, as amended, Black Hills National Forest Land and Resource Management Plan contains management direction to manage soils and water, including these standards and guidelines:

Soil Productivity

- When doing projects, analyze the cumulative effects of disturbances on long-term soil productivity (Forestwide Standard 1101).
- Maintain or improve long-term levels of organic matter and nutrients on all lands. On soils with surface soil (A-horizon) thinner than one inch, topsoil organic matter less than 2%, or effective rooting depth less than 15 inches, retain 80-90% of the fine (less than 3 inches in diameter) post treatment logging slash in the stand after each clearcut and seed-tree harvest. Consider need for retention of coarse woody debris slash in each activity area to balance soil quality requirements and fuel loading concerns (Forestwide Standard 1102).

Soil Disturbance

- Manage land treatments to limit the sum of severely burned and detrimentally compacted, eroded, and displaced land to no more than 15 percent of any land unit. “Land treatments” are human actions that disturb vegetation, ground cover or soil. “Land unit” is a mapped land-type polygon or a mapped soil unit (Forestwide Standard 1103).
- Minimize soil compaction by reducing off-road vehicle passes, by skidding on snow, frozen or dry soil conditions, or by off-ground logging systems (Forestwide Guideline 1104).
- Limit roads and other disturbed sites to the minimum feasible number, width, and total length consistent with the purpose of specific operations, local topography and climate (Forestwide Standard 1105).
- Stabilize and maintain roads and other disturbed sites during and after construction to control erosion (Forestwide Standard 1106).
- Where there is potential for toxic contamination of soil from ground disturbing activities (e.g., oil or gas drilling or mineral exploration), a contingency plan to prevent or rehabilitate soil contamination shall be developed (Forestwide Standard 1107).

Slope Stability

- Perform an on-site slope-stability examination on slopes over 55 percent prior to design of roads or activities that remove most or all of the timber canopy on all other soil types. Limit intensive ground-disturbing activities on unstable slopes identified during slope-stability exams (Forestwide Guideline 1108.b).

Soils and Surface Water Runoff

- Manage land treatments to maintain enough organic ground cover in each land unit to prevent harmful increased runoff (Forestwide Standard 1112).
- Construct roads and other disturbed sites to minimize sediment discharge into streams, lakes and wetlands (Forestwide Standard 1113).

- When construction of maintenance level 1 roads, temporary roads, skid trails and landings occur, install structures to divert runoff when needed (Forestwide Standard 1114).
- Manage land treatments to conserve site moisture and to protect long-term stream health from damage by increased runoff (Forestwide Standard 1116).

Stream Channels

- Conduct actions so that stream pattern, geometry, and habitats are maintained or improved toward robust stream health (Forestwide Standard 1201),
- Move stream channels only if all other practical alternatives to protect critical resources or capital investments have been exhausted and other legal requirements have been met. If streams are put in channels:
  - a. Use methods that create stable beds and banks and beneficial aquatic habitat features, and
  - b. Use stream geometry relationships to reestablish meanders, width/depth ratios, etc. consistent with each major stream type (Forestwide Guideline 1202).
- Design and construct all stream crossings and other instream structures to provide for passage of flow and sediment, withstand expected flood flows, and allow free movement of resident aquatic life (Forestwide Standard 1203).
- Naturally occurring debris shall not be removed from stream channels unless it is a threat to life, property, crucial resource values, or otherwise covered by legal agreement (Forestwide Guideline 1204).
- When projects are implemented which can affect large, woody debris, retain natural and beneficial volumes of large, woody debris for fish habitat, stream energy dissipation, and as sources of organic matter for the stream ecosystem (Forestwide Guideline 1205).
- When stabilizing damaged stream banks, preferentially use methods that emphasize vegetative stabilization. Use native vegetation for streambank stabilization whenever possible (Forestwide Guideline 1206).
- Manage water-use facilities to prevent gully erosion of slopes and to prevent sediment and bank damage to streams (Forestwide Standard 1207).
- Design water developments to minimize damage to channel capacity, aquatic habitat and riparian vegetation (Forestwide Guideline 1208).

Instream Flows

- Manage vegetation treatments so that stream flows are not changed to the extent that long-term stream health is degraded (Forestwide Standard 1209).
- Maintain enough water in perennial streams to sustain existing stream health. Return some water to dewatered perennial streams when needed. Comply with Section 505 of the FLPMA and 36 CFR 251.56 when issuing and re-issuing authorizations for water storage and diversion facilities (Forestwide Standard 1210).

Water Quality

- Place new sources of chemical and pathogenic pollutants where such pollutants will not reach surface or ground water (Forestwide Standard 1211).

- Apply runoff controls to disconnect new pollutant sources from surface and ground water (Forestwide Standard 1212).
- Apply chemicals using methods which minimize risk of entry to surface and ground water (Forestwide Standard 1213).
- Where natural background water pollutants cause degradation, it is not necessary to implement improvement actions. Short-term or temporary failure to meet some parameters of the applicable federal or state standard, such as increased sediment from road crossing construction or water resource development, may be permitted in exceptional cases (Forestwide Guideline 1214).

Water Influence Zone

- In the water influence zone next to perennial and intermittent streams, lakes, and wetlands, allow only those actions that maintain or improve long-term stream health and riparian ecosystem condition (Forestwide Standard 1301).
- Maintain long-term ground cover, soil structure, water budgets, and flow patterns in wetlands to sustain their ecological function, per 404 regulations (Forestwide Standard 1302).
- Vegetative type conversion should only be done in riparian areas to reestablish riparian vegetation for the protection and/or enhancement of those ecosystems (Forestwide Guideline 1303).
- As opportunities arise, and need dictates, relocate or implement mitigation measures for roads, trails, watering tanks, ponds, water catchments, and similar facilities currently located within the Water Influence Zone (Forestwide Standard 1304).
- Locate camping sites for contractual purposes (e.g., mining, logging, etc.) such that channel and riparian areas are not impacted (Forestwide Standard 1305).
- Prohibit log landing, decking areas and mechanical slash piling within riparian areas unless the integrity of the riparian area can be protected (e.g., frozen, snow-covered ground conditions) (Forestwide Standard 1306).

Mineral and Energy Resources

- A Plan of Operations shall contain proposed reclamation objectives and practices to maintain water quality and soil stability during mining and exploration activities, including post mining and exploration, and any temporary shutdowns. Reclamation objectives should include the planned uses of the management area or reasons why these uses can no longer be achieved. (Forestwide Standard 1501)
- For all operating plans or leasing activities proposed within two miles of Jewel Cave National Monument, or any known passageway that extends outside the Monument boundary, coordinate environmental assessment and operating plan approval with Monument personnel to assure protection of the cave complex. (Forestwide Standard 1503)
- In karst areas (Minnelusa and Paha Sapa or Madison Limestone), consider special precautions in operating plans to avoid damage to significant cave resources. (Forestwide Standard 1504)
- Utilize existing regulations and policies to minimize effects of mineral extractions in riparian areas. If reclamation is not done concurrently, reclamation of mined areas will begin immediately following mining activity. Reclamation will follow existing landform

and vegetative characteristics as much as feasible, unless management objectives require otherwise. (Forestwide Standard 1505)

- Minimize disturbance to the riparian area by mineral activities. Initiate timely and effective rehabilitation of disturbed areas and restore riparian areas to a state of productivity comparable to that before disturbance.
    - a. Prohibit the depositing of material from drilling, processing or site preparation in natural drainages.
    - b. Locate the lower edge of disturbed or deposited soil banks outside of natural drainages and riparian areas.
    - c. Prohibit stockpiling of topsoil or any other disturbed soil in natural drainages or riparian areas.
    - d. Prohibit mineral processing (milling) activities within natural drainages or riparian areas. (Forestwide Guideline 1506)
- Confine heavy equipment use in riparian areas to areas necessary for mineral extraction. (Forestwide Guideline 1507)
- Require monitoring of mining mitigative measures in riparian areas to insure that the measures are effective and in compliance with applicable water quality standards. (Forestwide Guideline 1508)
- Include stipulations for floodplains and wetlands in all leases that contain floodplains or wetlands that exceed two hundred meters in width. (Forestwide Standard 1513)

Fire and Fuels

- Use the appropriate suppression response for each management area as shown in the fire management direction summary table (Forestwide Standard 4101).
- Discourage the application of fire-retardant chemicals over riparian areas, wetlands and open waters. Avoid applications in these areas in the Wilderness and RNAs (Forestwide Standard 4102.b).
- To prevent soil erosion, re-vegetate burned areas that will not naturally revegetate quickly. See Management Area 1.1A for re-vegetation in the Wilderness. No re-vegetation efforts will occur within designated RNAs (Forestwide Standard 4102.c).
- Utilize prescribed fire through planned and natural ignitions to achieve management objectives for each management area as shown in the fire management direction summary table (Forestwide Standard 4103).
- When feasible and appropriate use broadcast burning to dispose of slash in order to return the inorganic and organic chemicals in the foliage and small woody material to the soil, to reduce fire hazard, and to provide seed beds for natural regeneration (Forestwide Standard 4105).
- In areas identified as having high rating for risk, hazard or value: Reduce or otherwise treat all fuels (activity fuels within three years of cutting) so the potential fireline intensity does not exceed 200 BTUs/second/foot on 90 percent of the days when fires occur, or break up continuous fuel concentrations exceeding the above intensity into units 30 to 40 acres maximum size, surrounded by fuel breaks (Forestwide Guideline 4110.a(1)).
- Locate slash piles that are scheduled for burning out of meadows that contribute to Waters of the United States. Use a buffer distance designed to keep sediment, ash and debris out of channels (Forestwide Guideline 4111).

Actions of Others

Currently, there are numerous other local, state, and federal entities as well as private landowners involved in taking action within the watersheds in the Black Hills National Forest to improve conditions related to wildfire, erosion, water quality, and water quantity. Like the Forest Service, these stakeholders are subject to federal, state, and local regulations and authorities. Communities are invested in better understanding the past and present wildfire regime (Mattox 2009, Mattox 2012) and counties are actively working in cooperation with governmental agencies such as the Forest Service. The USEPA is also actively involved in remediation of impaired waters, especially the Gilt Edge Mine and the Richmond Hill sites. The U.S. Bureau of Reclamation and the Forest Service work to regulate water in reservoirs and downstream to mitigate impacts to the riparian ecosystems. States are in charge of regulating water rights and consumptive uses. It is expected these activities will continue in the future.

Chapter 4. Potential Needs for Change

The current forest plan direction (as outlined above) is fairly strong for soils and water, yet some updates may be beneficial. The focus should be on managing to maintain resiliency to provide for ecosystem services and buffer anticipated impacts from climate change. Potential changes to consider:

- Current forest plan standard 1103 (Maintain enough water in perennial streams to sustain existing stream health. Return some water to dewatered perennial streams when needed. Comply with Section 505 of the FLPMA and 36 CFR 251.56 when issuing and re-issuing authorizations for water storage and diversion facilities) might not be attainable when the use of water is managed by the state. Consider evaluating this standard and rewriting as needed.
- Current forest plan standard 1103 (Manage land treatments to limit the sum of severely burned and detrimentally compacted, eroded, and displaced land to no more than 15 percent of any land unit. "Land treatments" are human actions that disturb vegetation, ground cover or soil. "Land unit" is a mapped land-type polygon or a mapped soil unit) might need to be edited to reflect the current Forest Service directives that apply the '15 percent rule' to 'activity areas'.
- Consider incorporating forest plan components that would protect vulnerable karst features from ground-disturbing, or potentially groundwater contaminating, activities.
- Consider incorporating forest plan components that recognize the need to protect soil and water from the increased pressure from recreation.
- Consider incorporating forest plan components to address the uncertainty accompanying climate change.
  - For example, the Black Hills is predicted to be warmer and drier than currently in the summers, which could result in more water loss via evapotranspiration during warmer summers, further stressing ecosystems. Since most water resources in the Black Hills National Forest are groundwater fed, there may be opportunities for water managers to alter current water operations. If water is conserved more in the winter, when precipitation is expected to increase, it may be possible to balance the decreased runoff expected in the drier summer months and keep rivers and streams wetter for longer.
  - While winters are expected to receive more precipitation that may help to restore aquifer levels. Hotter summers with lower-than-average precipitation could increase wildfire risk and may also prolong the peak wildfire season. An increased wildfire risk could adversely impact watershed conditions.
- Consider if forest plan components are needed to address the effects from a continued population increase, resulting in increased demand for water use, as well as the potential for ground water contamination from an increase in the number of septic systems.
- Zebra mussels are a new occurrence on the forest, consider the need for forest plan components to help limit their spread.
- Consider if additional forest plan components are needed for roads and trails. Roads and trails are an indicator for changes to the hydrologic and sediment regimes, so the addition of roads or trails and neglect of maintenance would exacerbate the impacts roads and trails are currently having on the overall watershed condition. On the other hand, BMPs and actions taken to improve road conditions, locations, density, and maintenance concerns may improve conditions and, by extension, may improve areas with hydrologic and sediment concerns as well.

- Consider additional forest plan components to address an altered fire regime. The impact of fire regime changes on the watersheds could be profound. If improved, the whole ecosystem could improve including water quality, erosion, and aquatic and terrestrial vegetation.
- Consider if additional forest plan components are needed to address continued population increase, which could result in increased demand for water or declined water tables.
- Consider if additional forest plan components are needed to address mining. Mining has an elevated risk of permanent ecosystem disruption including vegetation eradication, wildlife habitat disruption or displacement, and water contamination.

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