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Black Hills National Forest

Draft 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 (Black Hills NF) 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) in order to guide management actions and decisions. The National Forest Management Act requires that forest plans be periodically updated. The current Black Hills NF forest plan was approved in 1997. Substantial plan amendments were last approved in March 2006 resulting in the Black Hills National Forest Land and Resource Management Plan. Relatively minor amendments have occurred through 2018 and the latest version can be found on the Black Hills NF website (USDA Forest Service 2006). In order to revise the current forest plan, the Black Hills NF 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 draft assessment report documents that work.

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 NF, 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 analyzes the effects of biological, hydrological, and anthropogenic factors 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 NF 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 NF. 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 (WBD) and the National Hydrography Dataset (NHD); U.S. Environmental Protection Agency's (USEPA) Assessment, Total Maximum Daily Load Tracking and Implementation System (ATTAINS) dataset for impaired waters; and Forest Service -provided Black Hills NF 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 (VIC) 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:

- Which nearby watersheds are most affected by forest activities
- WCF ratings were developed in 2010 and the indicators are based on 2010 data that have 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 biota
- Soil susceptibility and impacts from erosion; information about mass wasting events
- Aquatic refugia have not been mapped or documented
- Water rights data and information for the Black Hills

Watersheds Overview

River basins are delineated into a nested hierarchy represented by Hydrologic Unit Codes (HUCs) numbered with two to 12 digits, which are then categorized with names into regions, sub-regions, basins, sub-basins, watersheds, and sub-watersheds (USGS et al 2013). The Black Hills NF is located within the Cheyenne (HUC6: 101201) and Belle Fourche (HUC6: 101202) basins of the Cheyenne subregion (HUC4: 1012). The eight sub-basins (HUC8) the Black Hills NF lies within (table 1) are further divided into watersheds (HUC10: 40,000 to 250,000 acres) and sub-watersheds (HUC12: 10,000 to 40,000 acres). The Black Hills NF lands lie within 29 watersheds (HUC10) and 112 sub-watersheds (HUC12).

There are 13 HUC 8 watersheds surrounding those (table 1) that contain the Black Hills NF (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 to those encompassed in the Black Hills NF may have impacts on biotic and abiotic resources. Likewise, forest management activities may impact resources contained within nearby watershed areas.

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

HUC8 ID	HUC8 Name	Black Hills NF Geographic Area
10120107	Beaver	Elk Mountains
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 NF
10120202	Lower Belle Fourche	Bear Lodge Mountains, Strawberry Ridge
10120203	Redwater	Bear Lodge Mountains
10120201	Upper Belle Fourche	Bear Lodge Mountains

The Black Hills NF 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, MO, which enters the Gulf of Mexico at New Orleans, LA.

Watersheds adjacent to and overlapping with the Black Hills NF may influence conditions within the watersheds identified within the Black Hills NF. Likewise, watersheds within the Black Hills NF managed by the Forest Service may influence adjacent watershed conditions.

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

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 (6th level HUC, typically 10,000 to 40,000 acres) 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). The watersheds are scheduled for reassessment in 2025.

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 important 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 rated as "good" (Class 1), "fair" (Class 2), or "poor" (Class 3) according to a standardized rule set. 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 the 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 wildland conditions (USDA Forest Service 2011a). Class 2 and Class 3 watersheds have at risk or impaired function, respectively, because some 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, grazing by domesticated animals and wildlife, invasive species, recreational activities (dispersed camping) 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.
	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 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.
	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.
	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.
	Forest Cover	This indicator addresses the potential for altered hydrologic and sediment regimes because of the loss of forest cover on forest lands.
	Rangeland Vegetation	This indicator addresses effects on soil and water because of the vegetative health of rangelands.
	Terrestrial Invasive Species	This indicator addresses potential effects on soil, vegetation, and water resources because of terrestrial invasive species (including vertebrates, invertebrates, and plants).
	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 NF has 112 sub-watersheds. Of these, 43 are Class 1; 52 are Class 2, no sub-watersheds are Class 3, and 17 are 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. Over 90% of the sub-watersheds in the Beaver and Angostura Reservoir sub-basins are rated as Class 1, whereas none of the sub-watersheds within the Rapid sub-basin are rated as Class 1.

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

Sub-basin (HUC8) 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 are no sub-watersheds in the plan area with a Condition Class rating of 3 (poor/impaired), several sub-watersheds have condition indicators with poor/impaired ratings (table 5). Specifically, the Roads and Trails indicator is rated as poor across most of the Black Hills NF sub-watersheds, as is the Fire Regime/Wildfire indicator. Other indicators that are rated as poor/impaired in some of the Black Hills NF sub-watersheds include Aquatic Habitat, Aquatic Biota, and Forest Cover.

The percentage of sub-watersheds for that are Class 1, 2, or 3 for each watershed condition process category indicator is shown in table 5. Note that the sum of all classes 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 class 1, 2, and 3 sub-watersheds for each WCF indicator and sub-indicator

Process Category	Indicator	Class 1 (%)	Class 2 (%)	Class 3 (%)	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
	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

Process Category	Indicator	Class 1 (%)	Class 2 (%)	Class 3 (%)	Total (%)
Terrestrial Biological		17	71	13	100
	Fire Regime or Wildfire	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

The Forest Service uses the WCF to assess the overall functionality (condition) of a watershed based on physical and biological indicators. The indicators are classified under four primary categories that are each weighed toward the determination of overall watershed condition: Aquatic Physical (30%), Aquatic Biological (30%), Terrestrial Physical (30%), and Terrestrial Biological (10%).

Drivers of watershed processes, conditions, and change are typically created by disturbance regimes. Some disturbance regimes are natural, and others are anthropogenic. Climate change, weather, wildfire, insects, disease, animals, and humans are the most common disturbance regimes. 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 NF are listed below with associated ratings. Note that the WCF ratings were developed in 2010 and the indicators are based on 2010 data that have not yet been updated for all of these drivers except Roads and Trails and Soils. Further data collection efforts are needed to provide updated information on these drivers and ratings.

- 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 is rated "Fair" for almost all watersheds throughout the Black Hills NF (three are "Poor" and four are "Good").
- Roads and Trails – where roads and trails are rated Fair or Poor it is because road density is high, they are in close proximity to water, and outstanding maintenance. This is an indicator of hydrology and sediment regime changes from the natural baseline.
- Soils – Erosivity and productivity are "Good" throughout the sub-watersheds, but this indicator is low typically because erosion and chemical contamination are rated "Fair" in almost every sub-watershed (a few are "Poor", none are "Good").
- Fire Regime/Wildfire – Fire regime is 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 regime changes from the natural baseline.
- Forest Health – Invasive species, insects, disease, and air pollution contribute to the Fair and Poor ratings of Forest Health. This indicator is high in the Black Hills NF because the insects and disease sub-indicator is "Poor" in nearly every sub-watershed. Air quality is "Good" and invasive species is generally a mix of "Good" and "Fair."
- Invasive Species – This indicator assesses the effect of invasive species on soil, vegetation, and water resources. Invasive Species spread is a mix of "Good" and "Fair" for almost all watersheds throughout the Black Hills NF (two are "Poor").
- Aquatic Biota – Distribution, structure, and density of native and introduced aquatic fauna contribute to the overall rating of Aquatic Biota. The sub-indicator Lifeform Presence is "Good" throughout most of the Black Hills sub-watersheds, it is "Fair" in the middle region of the Forest.

The center region is also where the sub-indicators Native Species and Exotic/Aquatic Invasive Species are rated mostly “Poor” and some “Fair.”

Two sub-basins (Beaver and Angostura) have overall condition Class 1 while the other six sub-basins are rated Class 2 (table 4). Looking at the condition classes of the 12 indicators:

- Roads and Trails and Fire Regime/Wildfire are Class 3 (poor/impaired) in 72% of sub-watersheds
- Soils are rated Class 2 (Fair) in 100% of sub-watersheds
- Forest Health is rated Class 2 (Fair) in 94% of sub-watersheds
- Riparian/Wetland Vegetation is Class 2 in 93% of sub-watersheds

Roads and Trails, Fire Regime/Wildfire, Soils, Forest Health, and Riparian/Wetland Vegetation can and should be improved upon to the extent possible. However, these indicator classes do not push the majority of Beaver or Angostura sub-watersheds out of overall functionality Class 1 (“Good” or Functioning Properly) because the other indicators are functioning at a high enough level. One sub-watershed in Beaver and one in Angostura are Class 2 and they each have a Class 3 sub-indicator for Aquatic Biota.

The sub-watersheds that have overall condition Class 2 have an additional majority of sub-watersheds rated Class 2 or 3 for Aquatic Biota and Riparian/Wetland Vegetation. Invasive species is “Fair” in approximately half of sub-watersheds throughout the Black Hills NF, indicating invasive species also contribute as a driver, but to a lesser extent than the indicators already noted.

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 vegetation communities 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 grazing, recreation, vehicular and foot traffic, and the effects of large-scale wildfires (e.g., runoff). Factors that contribute to soil productivity include organic matter availability and decomposition. 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 levels of forest litter, duff, and woody debris can improve conditions for conifers and other vegetation, but can build up over time with improper management. Inherent productivity of the soil is more a function of 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 community 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 72 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, Soil Condition Class evaluates alteration to natural soil conditions, including productivity, erosion, and chemical contamination (table 3). The Soils indicator is informed by the attributes: Soil Productivity, Soil Erosion, and Soil Contamination. All watersheds in the Black Hills NF are rated Class 2 (functioning at risk) for Soil Condition, indicating they are functioning, but at risk.

Soil Productivity is largely rated Class 1 (functioning) It is important to note that soil productivity is not the main factor contributing to the "functioning at risk" soils condition indicator classification.

Erosion and Sedimentation

The Soils indicator is informed by the attributes: Soil Productivity, Soil Erosion, and Soil Contamination. All watersheds in the Black Hills NF have a Soil Erosion sub-indicator rating of Class 2, indicating that they are functioning, but at risk. All sub-watersheds are rated Class 2 for Soil Erosion. The definition of Class 2 (functioning at risk) for Soil Erosion means up to 10% of the watershed shows evidence of accelerated erosion such as rills and gullies which are small and do not form a connective pattern (USDA Forest Service 2011b). Disturbances such as grazing, vehicular and foot traffic, recreation, logging, and wildfires are drivers of erosion in the Black Hills NF.

Another important indicator of erosion is the Roads and Trails indicator, which is rated as Class 3 for 72% of sub-watersheds, Class 2 for 24%, with only 4% in Class 1. A Class 3 (impaired function) rating is a combination of Class 3 ratings in all attributes (i.e., Open Road Density, Road and Trail Maintenance, Proximity to Water, Mass Wasting). Sub-watersheds in the northern half of the Black Hills NF are rated Class 2 for Mass Wasting, where the terrain is steeper. A small portion of watersheds in the northern half are rated Class 3. The southern half of the Black Hills NF watersheds are rated Class 1 for Mass Wasting. The following summarizes the Class 3 characteristics for each sub-indicator (USDA Forest Service 2011b):

- Open Road Density: more than 2.4 mi/mi^2,
- Road and Trail Maintenance: Best Management Practices (BMPs) for drainage applied to less than 50% of road, trails, and crossings,
- Proximity to Water: Greater than 25% of road and trail length is within 300 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 large quantities of debris to stream channels.

Because the Black Hills NF is, geologically, a dome of exposed bedrock, the steep and rocky terrain generally has soils that are more prone to mass wasting, landslides, and rock flows. These are primary factors in the increased Soil Erosion rating Class in the northern half of the Black Hills NF.

Shallow soils are defined as soils less than 20 inches deep. They are sensitive because they are susceptible to erosion. They are generally weakly developed, with relatively little organic matter, and therefore have low nutrient levels. Any soil displacement or loss can affect their productivity.

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. The soil erosion hazard ratings help classify soil erosion. The majority of soils (54%) are considered a slight erosion hazard, 28% have a moderate rating, and 12.4% range from severe to very severe.

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

Geologic Features and Hazards

The geology of the Black Hills NF is generally 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), Prominent hazards in the Black Hills NF 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 occur as a result of natural and anthropogenic disturbances as well. 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.

While data in the southern Black Hills NF is currently in progress, the same geologic formations exist, so the southern Black Hills NF are expected to mirror the north with respect to geologic hazards.

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 et al. (2002). The Black Hills are an important source of water 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 types. 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 NF is the headwater source for many municipal and public water supplies in the Black Hills NF region. The water sourced from the Back Hills NF provides water to the Cheyenne River (to the south) and Belle Fourche River (to the north) basins. 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. Together, these features allow surface water to recharge aquifers in places where the underlying rock otherwise has low permeability.

Surface water areas in the Black Hills NF 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, or 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 (Cox Lake and Crow Creek) 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.
- 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 may 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 50 cubic feet per second.
- The artesian spring area is defined by areas where the Madison Limestone and the Minnelusa outcrop, generally around the periphery of the Black Hills NF and where the Inyan Kara Group outcrops. Artesian springs are an important and substantial source of water for rivers and streams. Given the high loss rates in the area that springs occur, they are typically the reason streams have perennial flow in the area around the periphery of Black Hills NF exterior setting. Springs also are the sole source of many streams in the Black Hills NF including Fall River, Beaver Creek and Stockade Beaver Creek where spring flow is high and consistent. They also contribute substantially to base flow in several larger rivers, such as Redwater River in the northern Black Hills NF.
- 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 NF are relatively stable because they are driven by large-scale climatic and long-term geologic processes. However, population growth and increasing demand for water resources do have the potential to change this trend over time. The artesian springs are groundwater fed, so they are more stable. 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 NF 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 several 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 et al. 2002 study is nearly 20 years old, many of the large-scale precipitation and hydrogeologic patterns are likely still similar. Much of 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 et al. 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 et al. 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 et al. 2002, to the extent possible, but a number of the gages were no longer available or active. Neither of the gages used in Driscoll et al. 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 (cfs) was a few cfs 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).

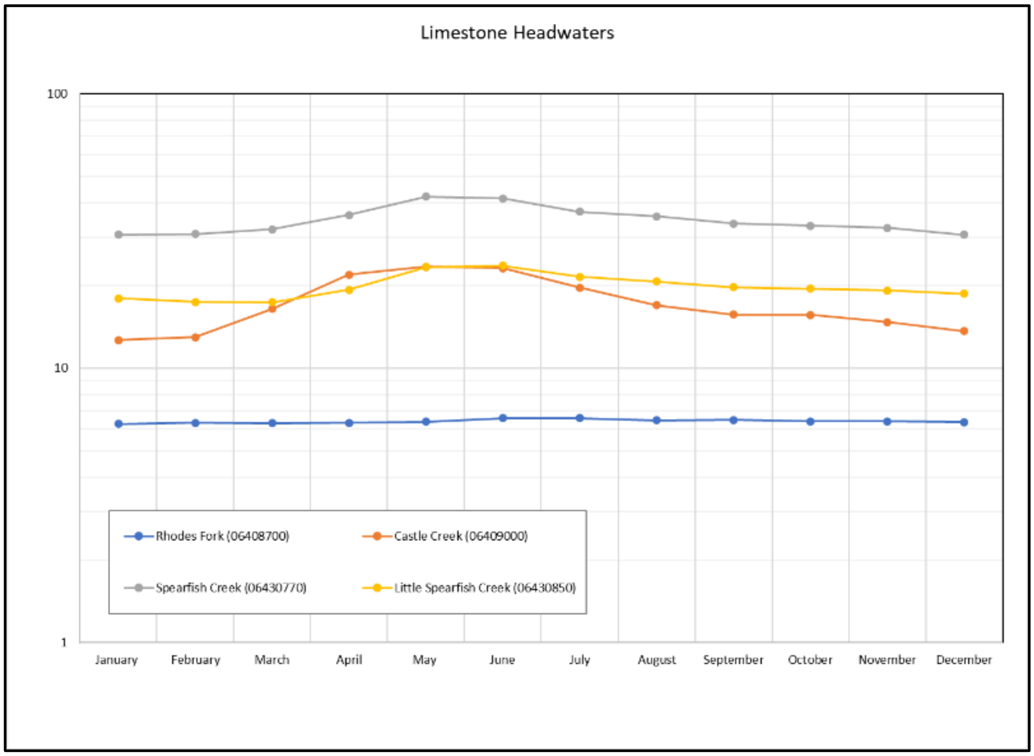

Figure 1. Hydrographs for the limestone headwaters basins based on monthly streamflow (cfs) data from 1995 to 2019

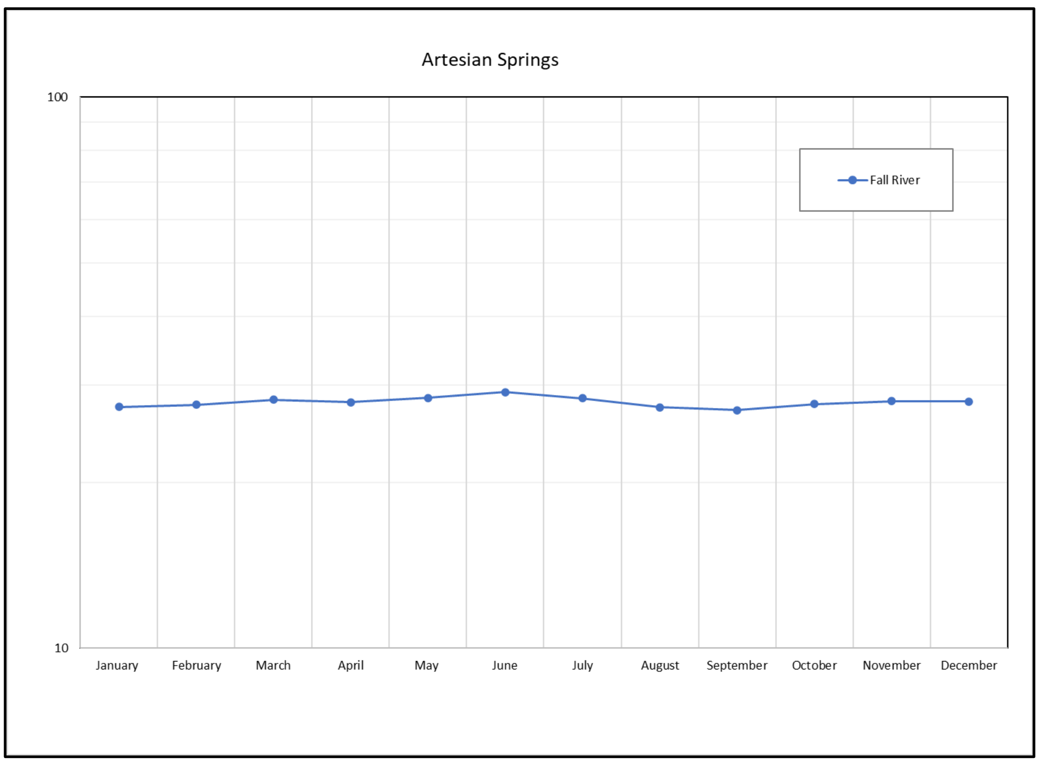

Figure 2. Hydrographs for the artesian springs basins based on monthly streamflow (cfs) data from 1995 to 2019

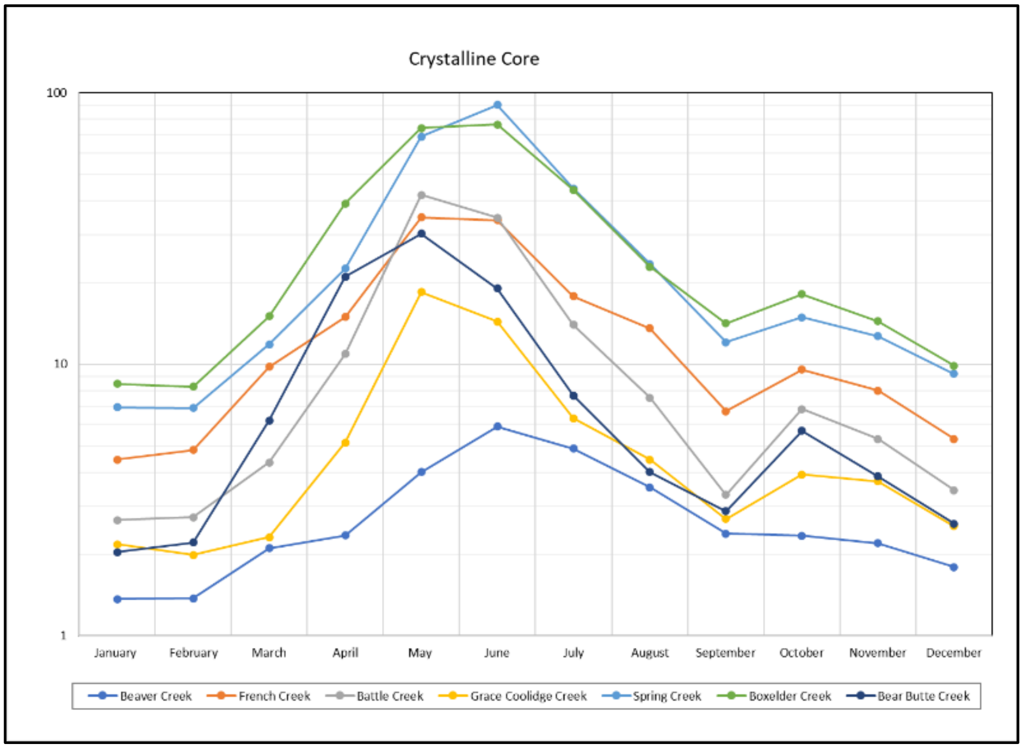

Figure 3. Hydrographs for the crystalline core basins based on monthly streamflow (cfs) data from 1995 to 2019

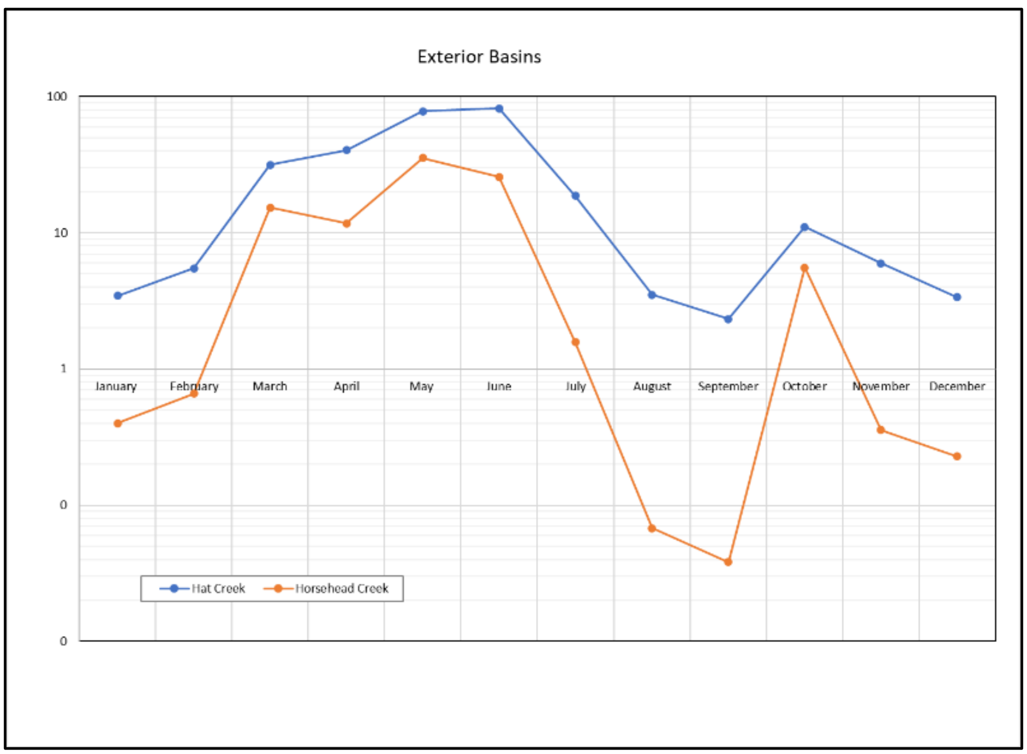

Figure 4. Hydrographs for the exterior basins based on monthly streamflow (cfs) data from 1995 to 2019

Aquatic species typically utilize a variety of microhabitat features for spawning, rearing, feeding, and refuge from predators or inclement conditions such as high flows or extreme temperatures. While these refugia undoubtedly exist within the aquatic ecosystems of the Black Hills NF, they have not been mapped or documented.

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 invasive species, fire suppression, or other unintended management consequences. Each of these changes are discussed in greater detail in the respective assessment documents.

Precipitation patterns across the Black Hills (figure 5) 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).

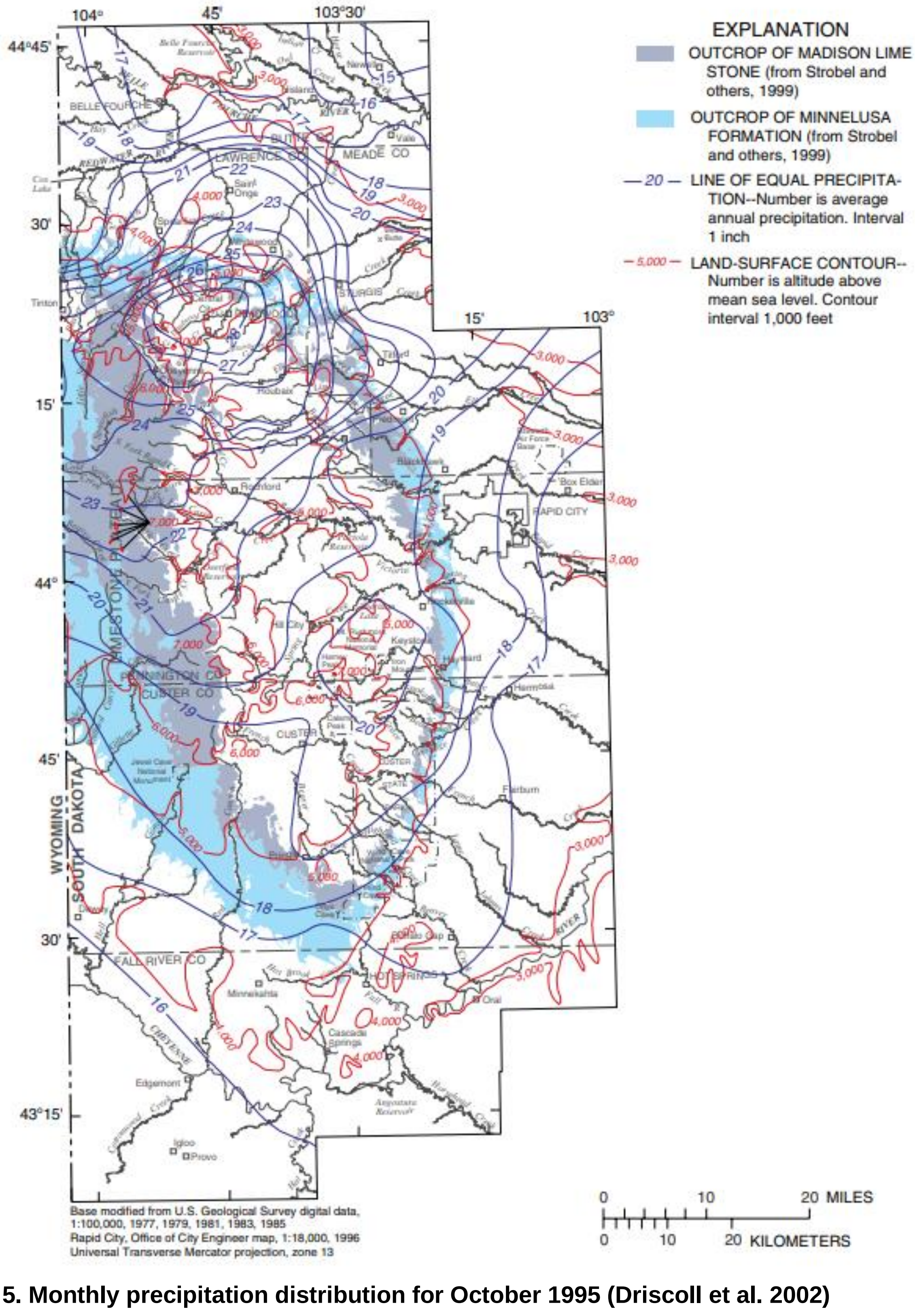

Figure 5. Monthly precipitation distribution for October 1995 (Driscoll et al. 2002)

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 et al. 2002 evaluated water resources including surface and ground water budgets and quality. The study used data from 71 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 4 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 et al. 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 NF.

Water Quality

Groundwater quality 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 also generally good, meeting all the quality standards established for beneficial water uses. 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.

Work is in progress to address the impaired waters, especially those related to mining. With awareness of water quality issues and the activities that can lead to degraded water quality, and implementation of measures to remove risks to water quality or use of BMPs, water quality can be improved in the future.

The water quality in each watershed is generally good for most uses. From the WCF (table 5), 86% of sub-watersheds have a Water Quality rating of Class 1, while 9% are Class 2, 4% are Class 3, and only 4% of watersheds are rated “Poor” or impaired (table 7).

The majority of water, including source water areas, groundwater, and public supply water, in the Black Hills NF is in good condition. There are six bodies of water (lakes, reservoirs) with an impaired designation, according to the U.S. Environmental Protection Agency (USEPA) impaired waters dataset (USEPA 2020; table 8). There are 14 additional waterways (streams, rivers, reservoirs, and lakes) with a USEPA impaired waters designation (USEPA 2020; table 9 and table 10). The data acquired from the USEPA impaired waters datasets for the Black Hills NF through 2020 are presented in table 8, table 9, and table 10. The USEPA impaired waters dataset used slightly different categories to describe water quality for water bodies than for waterways and lakes and reservoirs in both datasets. For that reason, the lakes and reservoirs are repeated in table 8, table 9, and table 10. A summary by watershed of impairment status is presented in table 7.

The data also 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 (table 8, table 9, and table 10). For the most part, 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.”

Additionally, all watersheds in the Black Hills NF, regardless of USEPA listing status, have a Soil Contamination rating of Class 2 except for two sub-watersheds that are Class 3 in the southern most Black Hills NF. This impairment results from abandoned mines and polluted waters associated with mine reclamation sites.

Table 7. 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
10120202	Lower Belle Fourche	Yes
10120203	Redwater	Yes
10120201	Upper Belle Fourche	No

Table 8. USEPA Impaired Waters dataset from ATTAINS for lakes and reservoirs

	Iron Creek Lake	Stockade Lake	Sylvan Lake	Sheridan Lake	Pactola Reservoir	Deerfield Lake
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
Turbidity	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria	Meeting Criteria

Table 9. USEPA Impaired Waters dataset from ATTAINS for rivers, streams, and lakes (part 1)

	Stockade Lake	Sylvan Lake	Spring Creek	Iron Creek Lake	Sheridan Lake	Elk Creek	Pactola Reservoir
Impaired	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Threatened	No	No	No	No	No	No	No
Drinking Water	No data	No data	No data	No data	No data	No data	Fully Supporting
Ecological	Not Supporting	Not Supporting	Fully Supporting	Not Supporting	Not Supporting	Fully Supporting	Not Supporting
Recreation	Not Supporting	Not Supporting	Not Supporting	Insufficient Information	Not Supporting	Not Supporting	Fully Supporting
Other Use	No data	No data	Fully Supporting	No data	No data	Fully Supporting	Fully Supporting
Algal Growth	No data	No data	No data	Insufficient Information	Meeting Criteria	No data	Insufficient Information
Ammonia	Meeting Criteria	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria
Mercury	Cause Unknown	No data	No data	No data	Cause Unknown	No data	Meeting Criteria
Other Metals	No data	No data	No data	No data	No data	No data	No data
Nutrients	Meeting Criteria	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria
Oxygen	Cause Unknown	Cause Unknown	Meeting Criteria	Insufficient Information	Cause Unknown	Meeting Criteria	Meeting Criteria
Pathogens	Meeting Criteria	No data	Cause Unknown	No data	Meeting Criteria	Cause Unknown	Insufficient Information
pH acidity	Meeting Criteria	Cause Unknown	Meeting Criteria	Insufficient Information	Meeting Criteria	Meeting Criteria	Meeting Criteria
Solids chlorinated	Meeting Criteria	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria
Temperature	No data	Cause Unknown	Meeting Criteria	Cause Unknown	Cause Unknown	Meeting Criteria	Cause Unknown
Toxic Inorganic	No data	No data	No data	No data	No data	No data	No data
Turbidity	Meeting Criteria	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria	Meeting Criteria

Table 10. USEPA Impaired Waters dataset from ATTAINS for rivers, streams, and lakes (part 2)

	Cheyenne River	Strawberry Creek	Victoria Creek	Whitewood Creek	Deerfield Lake
Impaired	Yes	Yes	Yes	Yes	Yes
Threatened	No	No	No	No	No
Drinking Water	No data	No data	No data	No data	No data
Ecological	Not Supporting	Not Supporting	Not Supporting	Fully Supporting	Not Supporting
Recreation	Not Supporting	Insufficient Information	Not Assessed	Not Supporting	Fully Supporting
Other Use	Not Supporting	Insufficient Information	Not Assessed	Fully Supporting	No data
Algal Growth	No data	No data	No data	No data	Insufficient Information
Ammonia	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria
Mercury	No data	Insufficient Information	No data	Meeting Criteria	Meeting Criteria
Other Metals	Meeting Criteria	Impaired, Cause Unknown	No data	Meeting Criteria	No data
Nutrients	Meeting Criteria	Insufficient Information	No data	Meeting Criteria	Meeting Criteria
Oxygen	Meeting Criteria	Insufficient Information	No data	Meeting Criteria	Meeting Criteria
Pathogens	Impaired, Cause Unknown	Insufficient Information	No data	Impaired, Cause Unknown	Meeting Criteria
pH acidity	Meeting Criteria	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria
Solids chlorinated	Impaired, Cause Unknown	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria
Temperature	Meeting Criteria	Insufficient Information	Impaired, Cause Unknown	Meeting Criteria	Impaired, Cause Unknown
Toxic Inorganic	No data	Meeting Criteria	No data	Meeting Criteria	No data
Turbidity	Cause Unknown	Meeting Criteria	No data	Meeting Criteria	Meeting Criteria

There are contaminated surface waters within and adjacent to the Forest (table 8, table 9, and table 10). The ATTAINS GIS dataset from the USEPA was used to assess the watersheds that are adjacent to the Black Hills NF. All but three watersheds (Upper Cheyenne, Lance, and Hat) have impaired surface waters (table 11).

Each of the impaired waters is linked to a waterbody summary report. The main impairment listed in the watersheds listed in table 11 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 11. USEPA Impaired Waters dataset from ATTAINS for the HUC 8 sub-basins surrounding the Black Hills NF (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 NF is the headwater source for municipal, industrial, and recreational water uses in western South Dakota. Water from the Black Hills NF 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 NF 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 NF, 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 25 people, or a minimum of 15 connections). Non-consumptive water uses are an important part of recreation for fishing, swimming, and boating. The Black Hills NF 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, 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 NF 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 6, figure 7, figure 8, and figure 9.

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 NF (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 12. These reports can provide a snapshot of the water quality of other public water supplies throughout the Black Hills NF 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 numerous other cities within the Black Hills NF, including Rapid City, Spearfish, Sturgis, Custer, Hill City, Hot Springs and many other communities, however those listed here were most readily available through SDDANR. Wyoming Department of Environmental Quality (DEQ) may also be a source of water use information for the communities of Newcastle and Sundance.

Table 12. 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 Custer and Fall River Counties (figure 6 and figure 7), 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 8 and figure 9). Pennington County, which is the largest of the four counties, saw increased population using public supply water with increased population, which is expected. However, all other counties saw decreased population using public supply with increasing population (Fall River's population declined slightly from 2000-2015). Where irrigation withdrawals are high compared to public supply use (Custer and Fall River Counties), overall irrigation withdrawals generally decreased as irrigated acres decreased. In Lawrence and Pennington Counties, irrigated acres were nearly constant from 2000-2010 and then decreased in 2015, while withdrawals saw increases through 2005 or 2010 and then a sharp decrease.

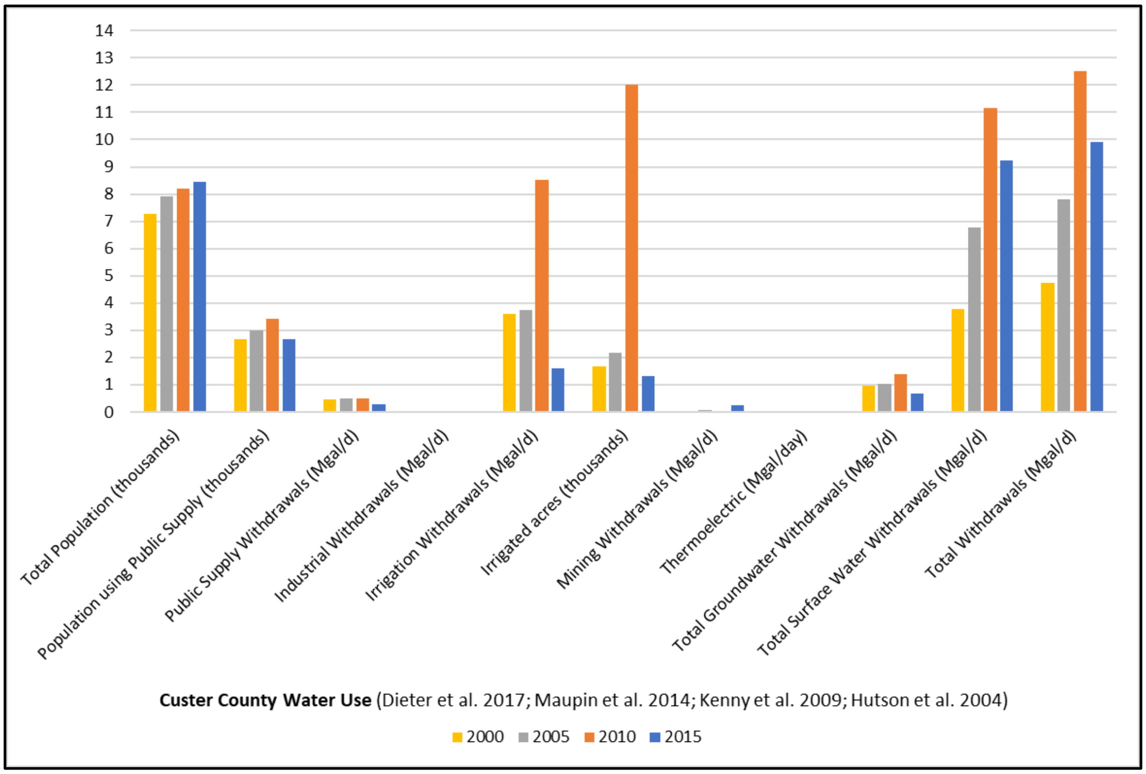

Figure 6. Water use in Custer County

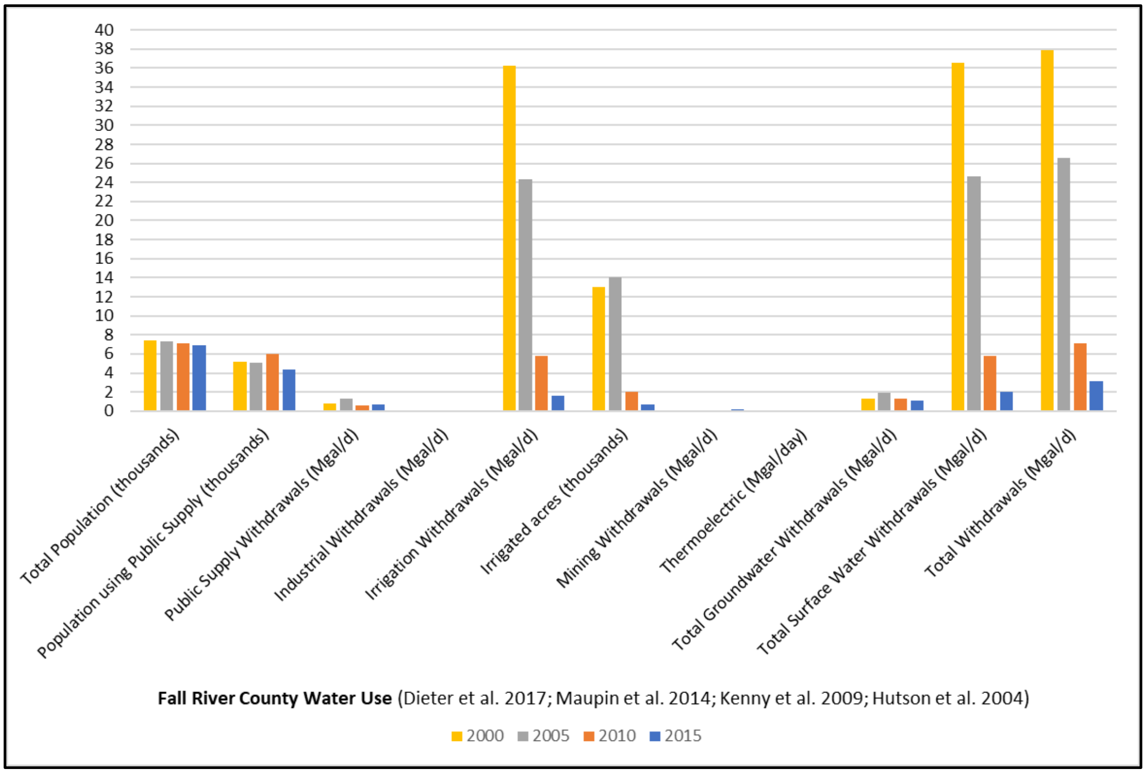

Figure 7. Water use in Fall River County

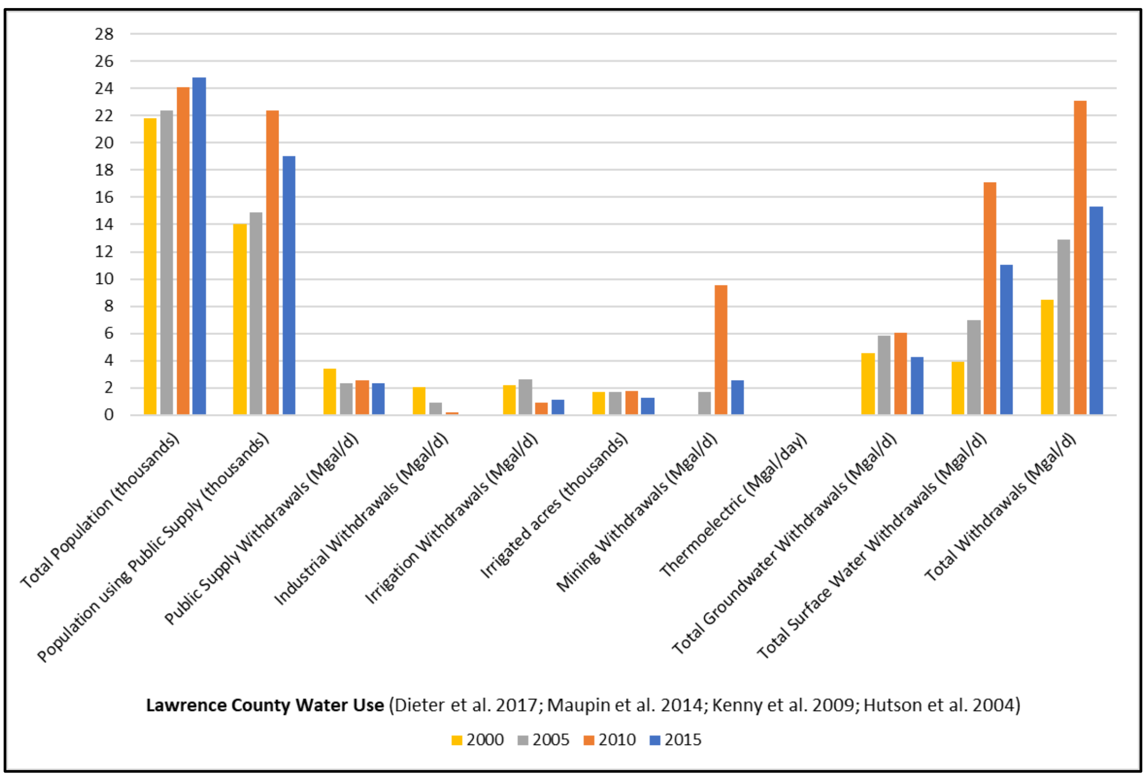

Figure 8. Water use in Lawrence County

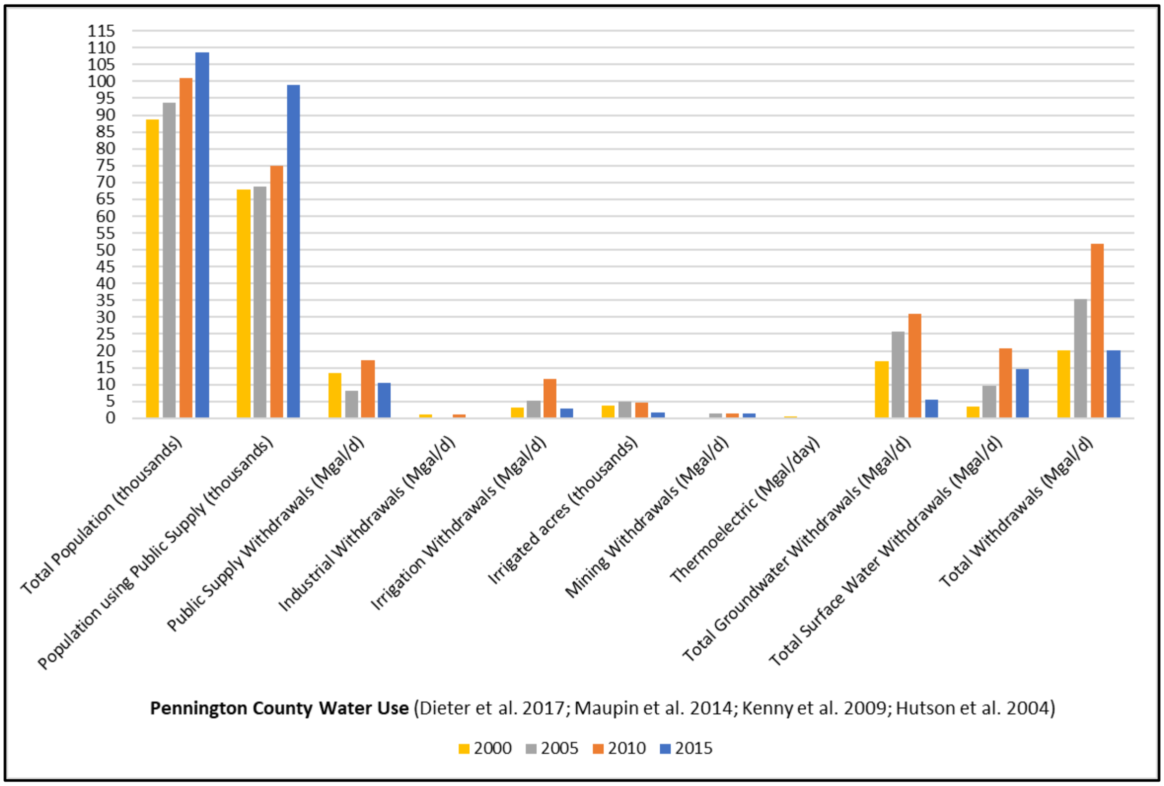

Figure 9. Water use in Pennington County

In all the counties shown above (Custer, Fall River, Lawrence, Pennington), water is used for mining, but it is very small in three 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 generally higher than groundwater withdrawals, except in Pennington County from 2000 to 2005. It appears that irrigation, mining, and thermoelectric water users primarily use surface water, while public supply water is sourced primarily from groundwater. Since public supply is generally lower than the other uses combined, surface water withdrawals are higher than groundwater withdrawals in most counties.

There are 18 active large dams and reservoirs in the Black Hills NF. 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 13 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) 2020 and 2021 through January. 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 18 inches. That average varies with altitude as lower altitudes receive 16 inches annually and higher altitudes receive 28 inches of annual precipitation. The 1990s were wetter than other decades and the averages presented by Carter et al. 2002 are likely 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 NF. Approximately 92% of annual precipitation becomes evapotranspiration, 3.5% recharges aquifers, and 4.5% 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 (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 Black Hills NF 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 NF 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 that are used for livestock watering, wildlife habitat, and scenic/visual uses. Many of these dams are undocumented in Wyoming and South Dakota State databases. Some information about some of the small dams can be found in the Black Hills NF GIS databases for water rights and dam location notice databases, however, some of these sources are currently being brought up to date. While many dams are small, they can still have important impacts on the aquatic resources in the Black Hills NF as described in this section.

In addition to the small dams, there are 18 active large dams and reservoirs in the Black Hills NF 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 Lower Homestake Reservoir has no designation. The other 13 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 13.

Table 13. 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 & 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

No information was found or provided about water diversions specifically, but associated infrastructure was obtained from the special use permits provided by the Forest Service. There are 43 water use pipelines in the Black Hills NF, 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 within the Black Hills NF and their risk profile if a dam breach or failure occurred. Only Horsethief Lake was rated a significant hazard because there are numerous structures downstream and considerable economic loss is probable from a dam failure. Michell Lake, Iron Creek, 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. Dam breach studies have not been performed on all the dams in the Black Hills NF, but the four studied by Hoogestraat (2011) are some of the bigger reservoirs and were identified by Forest Service as those with a need for the assessments at the time of the study. Potential structural and economic damages may exist at the other 14 dams, but studies to evaluate this have not been performed.

While the Forest Service does not manage the dams and reservoirs in the Black Hills, these provide a number of 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 substantially 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 large impact on aquatic resources. Much of the Black Hills NF is groundwater or spring fed and aquifers bounce back quickly after depletion. Some streams have very 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

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 25 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 18 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.

In Wyoming, water rights are similar to those of many western states where the right is based on priority or prior appropriation; that is, whoever first put the water to beneficial use has the priority right to the water (Jacobs et al. 1995). Water rights in Wyoming are regulated by the State Engineer. 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.

Water rights is a known data gap for the Black Hills NF. Efforts to verify and update water rights in the water rights database are increasingly more important as demand in the Black Hills NF 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 NF. The Fire Regime indicator is included within the Terrestrial Biological set of indicators, along with Forest Cover, Rangeland Vegetation, Terrestrial Invasive Species, and Forest Health. Fire Regime is rated “Poor” in 84% of HUC 12 sub-watersheds and “Fair” in 16% of sub-watersheds (table 14). The Beaver watershed has five out of 11 HUC-12 sub-watersheds rated “Fair” and the Rapid watershed has five out of 12 rated “Fair”. All other watersheds have one or two sub-watersheds rated Fair and the rest are Poor. Note that the WCF indicators are based on 2010 data and have not yet been updated.

Table 14. Fire Condition Rating in each sub-watershed

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
		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

HUC8 ID	HUC8 Name	HUC 12 Name	Fire Condition Rating
		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
		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

HUC8 ID	HUC8 Name	HUC 12 Name	Fire Condition Rating
		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 WCF shows 84% of sub-watersheds are Class 3 for the sub-indicator Fire Regime or Wildfire and 16% of sub-watersheds are Class 2. Class 3 means there is a "high likelihood of losing defining ecosystem components because of the presence or absence of fire" (USDA Forest Service 2011b), Class 2 means there is a moderate likelihood, and Class 1 means there is a low likelihood. A Fire Regime rating of Class 3 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, fuel accumulation, loss of soil organic matter, and poor protection to soil and water resources (USDA Forest Service 2011b). In terms of Wildfire Effects, Class 3 indicates that increased flooding and erosion are likely for more than 5 years post-fire because soil and ground cover conditions have been altered significantly enough to increase erosion and runoff. 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.

Watershed Adaptation to Wildland Fire Behavior

The WCF indicates that watershed adaptation to fire regime has been difficult based on Fire Regime and Wildfire indicators (USDA Forest Service 2011a, USDA Forest Service 2011b). It recommends 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. Community Wildfire Protection Plans report that fires are burning hotter and more acres are being burned than in the past (Mattox 2009, Mattox 2012). These observations, as well as the fire regime condition class (Poor/Impaired; table 14) indicate that the watersheds are undergoing a transition and their adaptation at this stage has resulted in poor/at risk functionality. In terms of how fire regime impacts the overall watershed condition ratings, 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 to prescribed fire include hazardous fuels reduction, minimized insect infestations and disease, increased forage for game, improvements to endangered and threatened species habitat, and recycling of nutrients back into the soil.

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 NF. 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, since insects and disease increase tree mortality, the resulting reductions of the forest canopy result in an earlier snow melt and some degree of increased runoff (Sheppard and Battaglia 2002).

As stated in the Insects, Disease, and Invasive Species Assessment, MPB populations explode approximately every twenty years in the Black Hills NF 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 in the understory in the years following the outbreak, can result in an increase in fire risk due to an increased number of snags and deadfall (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. In snow-influenced watersheds, this will 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 includes a condition indicator for Terrestrial Invasive Species within the Terrestrial Biological process category. Watersheds are primarily functioning properly or functioning at risk (Class 1 and Class 2), which accounts for 98% of the watersheds in the Black Hills NF. More specifically, there are 54 watersheds out of a total of 95 with assessments (57%) in the Black Hills NF that are functioning properly (Class 1) with regards to terrestrial invasive species. An additional 39 watersheds (41%) are functioning at risk with regards to invasive species. Only 2% of watersheds are classified as impaired function regarding invasive species.

The Aquatic Biological process category includes a sub-indicator called Aquatic Biota for exotic and/or invasive species. Based on this sub-indicator, 53% of watersheds (50 of 95) are functioning while 27% of watersheds (26 of 95) are functioning at risk and 20% of watersheds (19 of 95) are impaired. Thus, aquatic invasive species are a greater source of impairment than terrestrial invasive species, with 20% of sub-watersheds impaired with respect to aquatic invasive species versus 2% for invasive terrestrial species.

For more detailed discussion on this topic, reference the Insects, Disease, and Invasive Species Assessment report.

While some watersheds are impaired with respect to aquatic and terrestrial invasive species, many watersheds are still Class 1 and Class 2 even with these impairments. As noted earlier, the vast majority of sub-watersheds are classified as functioning or functioning at risk. Invasive species status is likely a portion of the cause for impairment or functioning at risk ratings; however, because there are several other indicators it is difficult to pinpoint which one has the higher impact on watershed functioning status.

Invasive species have become well-established in the Black Hills NF and the Forest Service has been implementing a Noxious Weed Management Plan for 20 years. 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 (ANS) 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 NF, but it's difficult to tease out the influence of that specific factor. See the Insects, Disease, and Invasive Species Assessment report.

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 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 watersheds. The following discussion refers to projections for precipitation and runoff made using the Mean Model for 2025 to 2049 (table 15).

Overall, runoff and precipitation patterns appear to be 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 watersheds, the watersheds with higher elevations (Beaver, Rapid, Middle Cheyenne Elk, Lower Belle Fourche, and Redwater), are also 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 NF 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 15. Projections based on increase (+) or decrease (-) from 1981-2010 average (NCCV 2014)

HUC8 ID	HUC8 Name	Black Hills NF Geographic Area	Runoff Predictions 2025-2050 (inches/month)	Precipitation Predictions 2025-2050 (inches/month)
10120107	Beaver	Elk Mountains	(+) 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
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-burning 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

Human influences on the watershed include effects from mining, timber harvest, infrastructure, recreation, and tourism as well as effects on the fire regime, habitat, and climate change. Numerous activities have caused disruption of the natural forest patterns compared to a reference condition (Weins et al. 2012) with varied outcomes from fire suppression, timber harvesting, livestock grazing, establishment of exotic plant species, insects and disease, and past management activities.

Recreation

Recreational activities such as camping, hiking, picnicking, swimming, fishing, boating, and rockhounding can lead to erosion, especially near waterways, and reduce water quality.

Infrastructure

The Watershed Condition Class for Roads and Trails is primarily Class 3 (at risk), indicating that maintenance and density of trails and roads contributes substantially to the overall erosion class.

Infrastructure includes dams, water systems, buildings, railroads, and transmission lines. Dams and water systems can rapidly induce changes to water resources and aquatic habitat on an ecosystem level. Electric transmission lines have caused several wildfires in western states in recent years, and buildings and railroads can be sources of erosion as well as impact wildlife.

The WCF shows that the Roads and Trails indicator is Class 3 for 72% of sub-watersheds, and Class 2 for 24%, and only 4% are Class 1. The Class 2 and 3 rating are related to high road or trail density, close proximity to water bodies, and road maintenance concerns, which also includes a risk factor for mass wasting. These ratings indicate that Roads and Trails are contributing to the impaired state of most watersheds. The Class 1 and Class 2 ratings indicate that some watersheds are currently withstanding impairment caused by roads and trails. There may be certain locations where the condition of roads and trails has a higher impact on the overall Watershed Condition rating when combined with other indicators, such as an area prone to mass wasting or very near a water body. Details about trends are not possible from the WCF data currently collected.

Wildfire

Eighty-four percent of sub-watersheds are Class 3 for Fire Regime based on the 2010 WCF ratings. Currently, sufficient data does not exist to fully inform whether or not watersheds are recovering from wildfire regime changes as long-term trends are difficult to discern; however current data does indicate that the watersheds are not recovering quickly, and more data collection is needed. While fire regime accounts for a small portion of the overall Watershed Condition Class, it is still a contributing factor toward watershed condition ratings.

Mining

Mining in the Black Hills NF, especially gold mining, began in the late 1800s. 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 NF, 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 Richmond Hill Mine, located approximately four miles northwest of Lead, SD, was an open pit heap leach gold mine. In the 1990s the mine developed an acid-mine drainage problem, which was remediated using a pit impoundment backfilled with acid generating rock and covered by a low permeability capping system, South Dakota Department of Environment and Natural Resources (SDDENR 2011). The mine has been continuously monitored to ensure the remedial efforts are still effective at reducing water infiltration into the ore. Cleopatra Creek, located downstream of the mine, has no contamination issues and can still be used as a fishery (SDDENR 2011).

The southwestern most area of the Black Hills NF 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, adits, berits, 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 generally seem to be withstanding and recovering from the influences of mining activities. There are some 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 NF, 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 NF, 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 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%) are functioning at risk. Further data collection is needed to evaluate trends and assess conditions and response after the 2010 ratings.

Watershed Considerations

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. This should be balanced with reducing fuel load to decrease wildfire risks.

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 flow regime, thermal and light inputs, sediment flux, and chemicals, nutrients, and pathogens (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).
- 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 by providing a buffer (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 color, size, texture and shape of forests, trees and vegetation are all important to the aesthetic amenities of forests (Binder et al. 2017).

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

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.

Management

The Black Hills National Forest 1997 Land and Resource Management Plan contains management direction to manage soils, water, fires and fuel, as listed below.

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 1 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

- 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).
- 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

- 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).

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).

Potential Needs for Change

Where there are stressors and drivers for soils and watersheds, there are potential needs for change. Below, those needs for change are briefly discussed.

1. Roads and Trails – The WCF shows that 72% of watersheds are rated Class 3 and 24% are Class 2 for roads and trails. Since roads and trails are an indicator for changes to the hydrologic and sediment regimes, 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.
2. Fire Regime – The Fire Regime is Class 3 in 84% of sub-watersheds. Since Class 3 for Fire Regime indicates "altered hydrologic and sediment regimes because of departures from historical ranges of variability in vegetation, fuel composition, fire frequency, fire severity, and fire pattern" (USDA Forest Service 2011b), 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.
3. Climate change – Climate Change in the Black Hills is predicted to be warmer and drier than currently in the summers (CCVA). While winters are expected to receive more precipitation that may help to restore aquifer levels, the hotter summers with lower than average precipitation could increase wildfire risk and may also prolong the peak wildfire season.

   More water is expected to be lost than average to evapotranspiration during warmer summers, further stressing ecosystems. Since most water resources in the Black Hills NF 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. Continued population increase, resulting in increased demand for water use may offset or further decline water tables.
4. Mining - Mining operations and prospecting are not as prevalent as they once were, but they are still ongoing. Mining has a high risk of permanent ecosystem disruption including vegetation eradication, wildlife habitat disruption or displacement, and water contamination. Mines today must follow stricter laws and regulations to remain in operation and they must operate in such a way that they have less impacts on an ecosystem. Remediation for the acid mine drainage that has occurred is progressing and on-going. The need for on-going remediation serves as a reminder of what could happen, even when regulations are in place. Mining remains a high-risk activity. The projected economic benefit needs to be balanced with the ecological damage and the costs incurred for damages.
5. Water Infrastructure and Aquatic Needs – Is the current plan adequate to manage water infrastructure and aquatic needs? In addition to the small dams, there are 18 active large dams and reservoirs in the Black Hills NF 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 Lower Homestake Reservoir has no designation. The other 13 dams are operated by the Forest Service. Only two are listed as constructed of something other than earthen materials. There are also numerous other smaller dams that are not as well documented. Future water operations, which includes benefits for coping with climate change and helping keep the aquatic ecosystems balanced, would benefit from a complete listing of all infrastructure and water uses.
6. Aquatic Habitat – Climate change could potentially reduce flows in the summer months and impair aquatic habitat. There are opportunities to remove instream barriers at road stream crossings to promote stream connectivity over a range of flows and environmental

conditions. These actions can improve aquatic habitat by creating passage for fish and suitable habitat at a range of flow conditions. More information about climate change and its potential impacts is available in the Climate Change Vulnerability in the Black Hills National Forest assessment.

7. Wetland Restoration – Protect, restore, and/or reconnect degraded wetlands adjacent to or connected to stream systems for improved stability and to improve favorable water flows, habitat quality and water quality. Examples include fencing to exclude livestock; stream restoration to restore channelized flows to natural stream dimensions, pattern, and profile; enhance in-stream habitat for fisheries; and wetland restoration such as restoring water tables and wetland vegetation through arresting head cutting that is dewatering wetlands and peatlands, and vegetation plantings; and relocation or reclamation of roads and trails that cross or are immediately adjacent to springs, streams, and wetlands.

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 NF 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 and work to mitigate impacts to the riparian ecosystems. States are in charge of regulating water rights and consumptive uses. It is expected that many of these activities will continue in the future.

Chapter 3. Public Participation in the Planning Process

This section may have some placeholders until after the public has had chance to review the assessment reports and the Black Hills NF has completed other public engagement activities.

Public Interest

The most likely to be interested in this topic are those currently who live or recreate in or near the Black Hills NF, those who rely on the resources for their livelihoods, and those whose water supply depends on the Black Hills NF. Pending additional outreach, this section will be revised to reflect current interest and comments.

Future Involvement

Pending additional outreach, this section will answer how do stakeholders want to be informed about this topic as the planning process proceeds.

Public Information Needs

Pending additional outreach, this section will answer what is confusing about this topic and what follow-up could improve understanding?

Chapter 4. Conclusions

Based on the findings and discussion in this section, the greatest needs of the watersheds are summarized in the following list. These needs occur in areas that were rated lowest overall among the watersheds/sub-watersheds by the WCF. In these watersheds, some functions are either impaired, declining, or affecting the impairment of other watershed indicators. The impairment status results in an unsustainable management situation.

- Riparian/Wetland Vegetation and Aquatic Biota – Sediment and organic matter from stream and riparian habitats increase soil nutrients and rebuild wetlands (Binder et al. 2017). However, sediment flux can increase 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. Improving the fire regime could improve erosion in some areas and riparian and wetland vegetation. Since land use changes can also impact riparian and wetland vegetation (by increased erosion or soil or water contamination), using appropriate BMPs for new projects such as new buildings, recreation areas, renewable energy, and grazing activities would be prudent. Improving passage under, over, or crossings around water bodies could improve aquatic habitat (see Roads and Trails below).
- Roads and Trails – Most roads and trails are rated “Fair” or “Poor”. Many are rated Poor because they may not have BMPs for drainage at roads, trails, and crossings. There is opportunity here to not only apply BMPs, but to design them such that they can create habitat and allow fish passage for a range of flow conditions. Designing and implementing BMPs may improve road condition ratings and sustain aquatic species habitat as the climate changes.
- Fire Regime/Wildfire – Fire regime is 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 regime changes. The Forest Service is already involved in fuel reduction practices such as thinning and prescribed fire. Many communities have been negatively impacted by large wildfires and are interested in adopting programs to better understand the risk factors and target the highest risk areas. There may be opportunity to collaborate with local communities to address their needs and concerns. Also, this rating could change with a reassessment of the watersheds once the MPB epidemic has subsided.
- Forest Health – Invasive species, insects, disease, and air pollution contribute to the Fair and Poor ratings of Forest Health. This indicator is low in the Black Hills NF because the insects and disease sub-indicator is “Poor” in nearly every sub-watershed. The current fire regime has been linked to increased invasive species, insect, and disease. An improvement in the fire regime could improve the status of Forest Health indicators. Once the WCF ratings have been updated to reflect post-MPB conditions, this status will likely change.
- Invasive Species – This indicator assesses the effect of invasive species on soil, vegetation, and water resources. Invasive Species spread is a mix of “Good” and “Fair” for almost all watersheds throughout the Black Hills NF (two are “Poor”). This may be linked to fire regime. Improving fire regime could improve the invasive species effects on soil, vegetation, and water resources, by making the ecosystem more resilient to disturbance regimes, including climate change. The ratings may change once 2010 WCF ratings have been updated.

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