United States Department of Agriculture
Forest Service

Soil Resource Report

Colville National Forest Plan Revision
Draft Environmental Impact Statement

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Introduction

Soil resource information is a core component of National Forest Planning. Information about the soil resource provides planning teams with an understanding of the inherent capability of different portions of the landscape to meet a variety of land management objectives. Understanding the inherent soil capabilities and limitations of the landscape also assures that planned activities are both obtainable and sustainable over time.

Revision Topics Addressed in this Analysis

Old Forest Management and Timber Production

Old forest structure is more sustainable in areas of higher productivity soil types that can sustain that structure over the longer term. Soil resource information in combination with a stratification by plant association groupings can be used to better refine assessments of site productivity and the sustainability of old forest management areas.

Motorized Recreation Trails

Some soil types are less suited for motorized recreation trails because they are more sensitive to disturbances that can negatively affect important key soil functions.

Riparian and Aquatic Resource Management

Identification of areas having different levels of soil drought stress within riparian and aquatic resource management areas can be used to prioritize vegetation treatments. Adjusting vegetation density may promote soil properties that support healthy forest communities, providing desirable habitat attributes.

Identification of soils and landscapes that store large quantities of water that moderate peak flows and supply water for stream flows later in the summer months can also be used to prioritize vegetation treatments and other restoration activities that improve the functioning of these important areas.

Refer to hydrologist analysis for erosion and mass wasting potential. Soil information has been used extensively to determine erosion sensitive areas.

Relevant Laws, Regulations and Policy that Apply

Organic Administration Act of June 4, 1897 - Authorizes the President to modify or revoke any instrument creating a national forest; states that no national forest may be established except to improve and protect the forest within its boundaries, for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States. Authorizes the Secretary of Agriculture to promulgate rules and regulations to regulate the use and occupancy of the national forests

The Multiple-Use Sustained-Yield Act of 1960 - This act established that the sustained yield of goods and services must be conducted without resulting in permanent impairment of the productivity of the land.

The National Environmental Policy Act of 1969 - This act declares a national policy that encourages productive and enjoyable harmony between people and their environment, promotes efforts that will prevent or eliminate damage to the environment and biosphere, and enriches the understanding of the ecological systems and natural resources important to the nation.

Forest and Rangeland Renewable Resources Planning Act of August 17, 1974 - Directs the Secretary of Agriculture to prepare a Renewable Resource Assessment every ten years; to transmit a recommended Renewable Resources Program to the President every five years; to develop, maintain, and, as appropriate, revise land and resource management plans for units of the National Forest System; and to ensure that the development and administration of the resources of the National Forest System are in full accord with the concepts of multiple use and sustained yield. Organic Administration Act of June 4, 1897

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National Forest Management Act of October 22, 1976 - The National Forest Management Act reorganized, expanded, and otherwise amended the Forest and Rangeland Renewable Resources Planning Act of 1974, which called for the management of renewable resources on National Forest System lands. The National Forest Management Act requires the Secretary of Agriculture to assess forest lands, develop a management program based on multiple-use, sustained-yield principles, and implement a resource management plan for each unit of the National Forest System. It is the primary statute governing the administration of National Forests.

Travel Management Rule - On December 9, 2005 - the Forest Service published the TMR. The agency rewrote direction for motor vehicle use on National Forest Service lands under 36 CFR, Parts 212, 251, and 261, and eliminated 36 CFR 295. The rule was written to address at least in part the issue of unmanaged recreation. The rule provides guidance to the Forest Service on how to designate and manage motorized recreation on the Forests. The rule requires each National

Forest and Grassland to designate those roads, motorized trails, and Areas that are open to motor vehicle use.

Affected Environment

Introduction

The Colville National Forest has a wide diversity of soil types from the minimally-developed, nutrient poor soil and rock outcrop complexes of the steep mountain slopes and ridges to the deep, fertile soils of the lower valleys. Cooler temperatures, shorter growing seasons and steep topography are the prime factors behind the lack of soil development in the upper elevations of the Forest. Conversely, warmer temperatures, a longer growing season, and gentle topography found within the lower forest elevations provide more favorable conditions for soil development.

Soil Development

Soil development is dominated by five major soil formation factors: time, parent material, topography, climate, and biology. The two greatest influences on the development of the soils on the Colville National Forest are continental glaciation and distant volcanic activity.

During the Pleistocene Epoch (approximately 2.4 million to 18 thousand years ago), a continental glacier called the Cordilleran Ice Sheet built up, advanced and retreated several times covering much of western Canada as well as northern Washington and Idaho and northwestern Montana in the United States including the area covered by the Colville National Forest **(Figure 1)**. The ice sheets advanced and then retreated several times, according to the sequence of sediments that the ice sheets left behind. However, the most completely understood ice sheet advance is the one that occurred most recently, between 200,000 and 18,000 years ago. This most recent advance obscured much of the evidence of the earlier advances.

In places where the ice sheet flowed across bedrock, such as in eastern Washington, it smoothed the mountains and hills into more streamlined and rounded shapes. The highest peaks on the Colville National Forest remained unglaciated as the ice sheet moved around and not over them. The ice sheet valley fill and terraces of glacial outwash around its margins in the northern part of eastern Washington. Katabatic winds, driven by the temperature contrasts between the ice and the land, picked up and moved the finer-grained sediments from the outwash both out of and onto the area of the Colville National Forest.

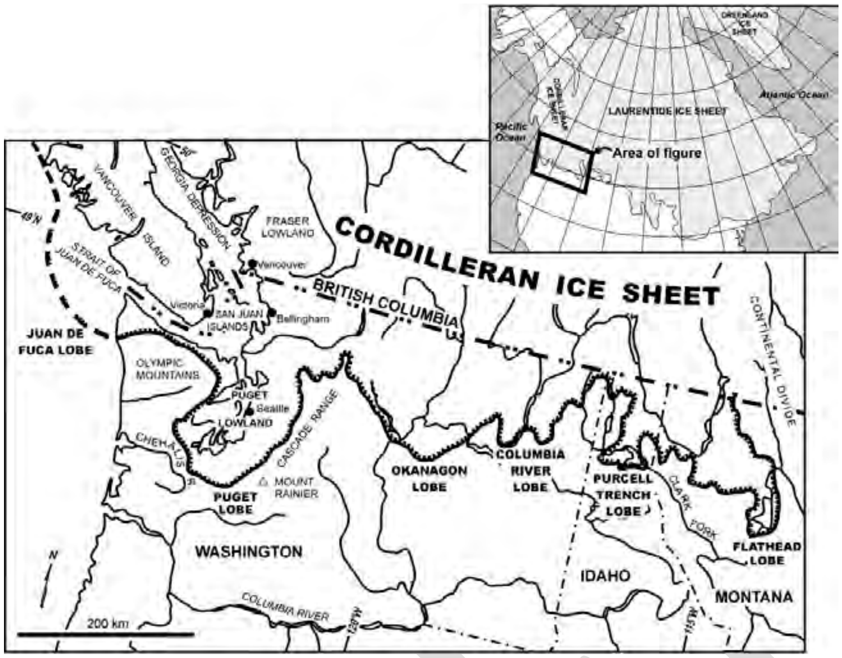

Figure 1. Extent of the Cordilleran Ice Sheet. (Booth et al., 2003)

Glacial soils fall into three, general categories: lacustrine, outwash and till. Lacustrine soils are derived from ancient glacial lakebeds. These soils are higher in silt or clay content than other glacial soils, resulting in higher water-holding capacities and higher fertility. Lacustrine soils are more susceptible to hillslope and wind erosion than till or outwash because of their fine texture. Streams flowing from glaciers deposited outwash soils. Water of varying speeds deposits particles of different sizes, sometimes resulting in distinct layers of gravel, sand, and rock in the soil profile. Usually, glacial outwash soils drain rapidly and have low organic matter content. Some glacial outwash soils contain a layer of wind deposited silt (loess) that increases their moisture-retaining capacity and fertility. Glacial till was deposited directly, mixed, deformed or compressed by glaciers and often results in a mixed particle size soil that is variably drained. Glacial till that was laid down beneath glaciers is known as basal till and has a dense, compacted layer, or densic layer, at a depth of about 18 to 36 inches that can extend more than 10 feet. This densic layer is often impenetrable to both plant roots and infiltrating water, forming a perched water table. Because of this, sites with basal till soils often drain poorly. If the densic layer is very shallow the soils may not be able to support trees or more deeply rooted plant species by virtue of wetland conditions.

Although lacking volcanoes, younger than 40 million years old within the Forest boundaries, many soils in the forest owe their productivity to volcanic activity. Volcanic ash from the eruption of Mount Mazama (now Crater Lake) 7,900 years ago has significantly influenced forested soils of the area. Additional volcanic ash and loess influenced by volcanic ash were deposited by eruptions of Mount Rainier, Mount St. Helens, and Glacier Peak. These ash-influenced soils can be found throughout the western United States **(Figure 2)**. Locally, these soils are characterized by a bright brown "cap" of volcanic ash 6 inches or more in thickness

(Figure 3). These ash-cap soils, in contrast to other soils, are important to forest management due to their low bulk density, high porosity, and high infiltration and water and nutrient retention capabilities. These soil properties reduce drought stress on plants during extended summer dry periods found in the forest. Given the distance from the volcanoes, the ash cap is much more stable, resistant to erosion, and greater bearing strength than the pumice based soils, closer to the sources.

Figure 2. Estimated spatial distribution of Mount Mazama volcanic ash.

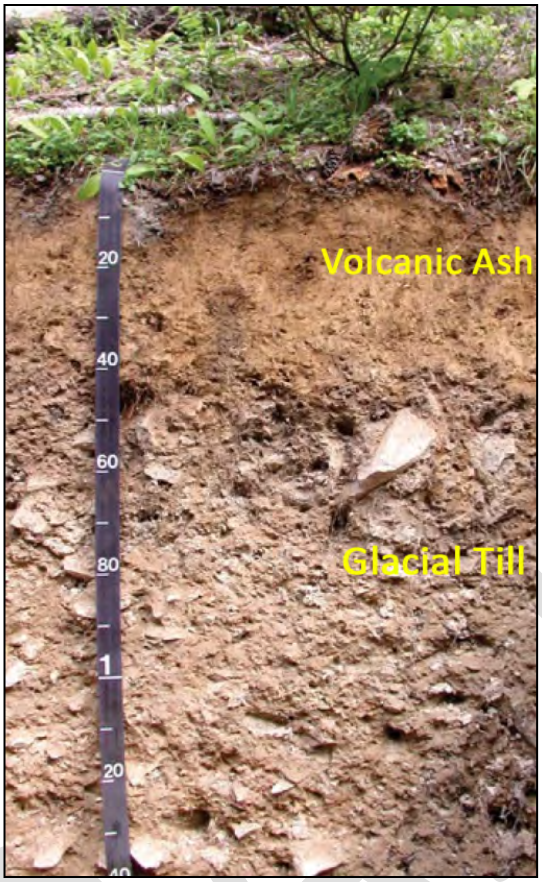

Figure 3. Typical ash-cap and glacial till soil profile (scale is in centimeters).

Landtypes

Soils of the Colville National Forest can be divided into five landform groups based on similar geomorphic processes (Davis et al., 2004)**(Figure 4)**:

- Soils on glaciated and scoured mountain slopes (673,990 acres)

Soils on glaciated and scoured mountain slopes are formed from metasedimentary, igneous, and pyroclastic geologies that have been shaped by continental glaciation. Scoured areas tend to have thin rocky soils. Lesser areas of deeper soil can be found in glacial till in draws and north facing slopes.

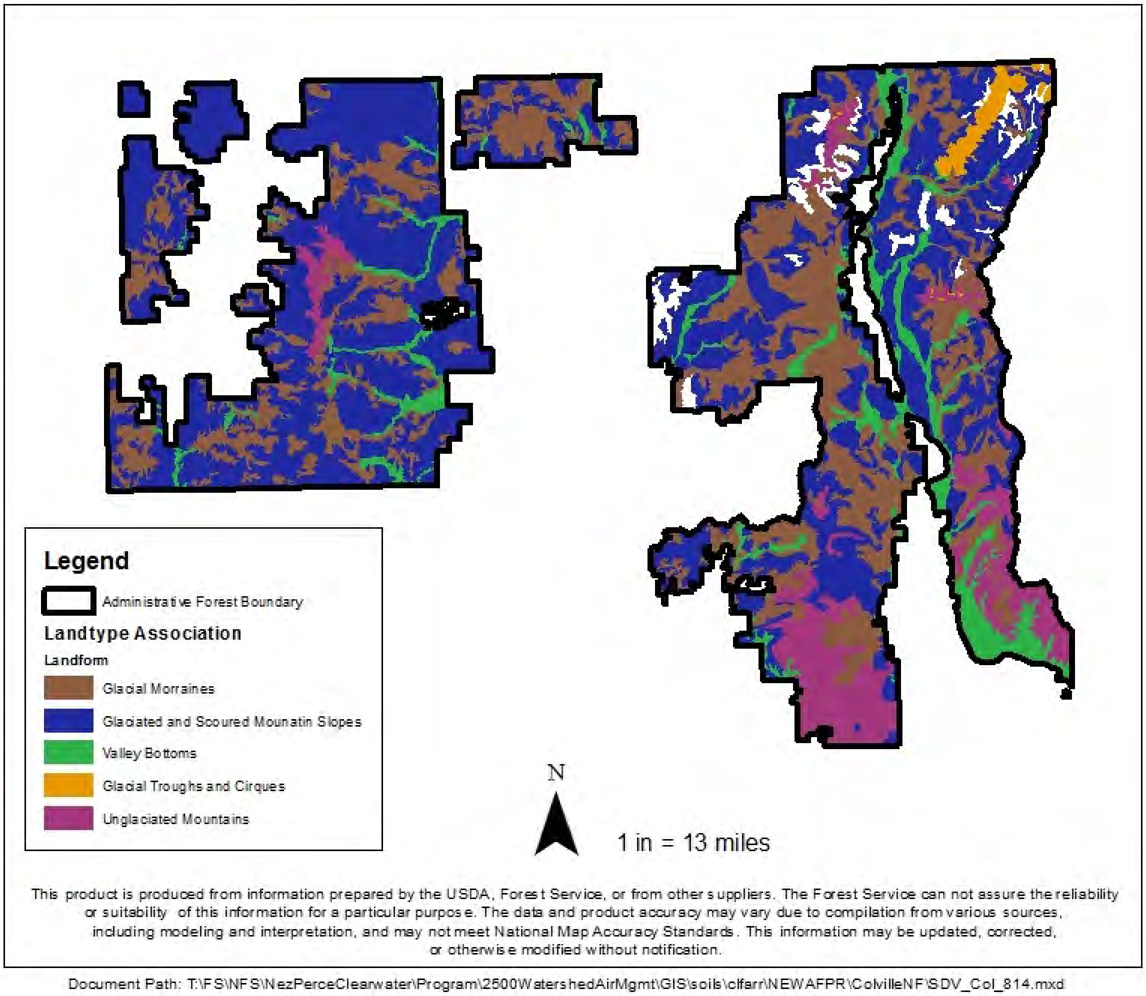

Figure 4. Landforms of the Colville National Forest.

- Soils on glacial moraines (397,794 acres)

Glacial deposition is the most common land forming process in glacial moraines. The most common rock types are metamorphic, intrusive, and volcanic. Springs, seeps, and pothole lakes are common.

- Soils on unglaciated mountains (120,144 acres)

This landform group consists of dissected and structure controlled mountain slopes and rounded ridge tops. These are the only landforms on the forest that are not glacially influenced. Moderately deep residual soils can be found on the ridge tops. Erosion and mass wasting are the primary landform drivers on the mountain slopes. These soils are formed from igneous intrusive and metasedimentary geologies.

- Soils on valley bottoms (120,036 acres)

These landforms are located in valley bottoms of varied size. Glacial meltwater, fluvial flooding, and glacial lake sedimentation are the major land forming factors. These soils are formed from relatively young surficial deposits of glacial till, alluvium, landslide debris, and glacial outwash. Rock types are mixed and varied in these landforms.

- Soils on glacial troughs and cirques (16,403 acres)

These landtypes are glacial valleys formed from alpine and continental glaciation. Ridges were scoured and slopes steepened by glacial erosion. Alluvial fans and glacial moraine deposits are found at the lower slopes. The most common rock type is metasedimentary.

Soil Taxonomy

The system of soil classification used by the National Cooperative Soil Survey has six levels. Beginning with the broadest, these categories are order, suborder, great group, subgroup, family, and series. Each level of taxonomy gives more detailed information about the soils. The dominant soil orders found in the Forest are Inceptisols and Andisols followed by Mollisols and Alfisols **(Table 1 and Figure 5)**.

Inceptisols are soils with poorly developed characteristics. Most Inceptisols occur under forested landscapes in a variety of climatic conditions. They tend to occur on steep slopes where erosion is continuously removing topsoil or convex toeslopes where colluvium is being deposited. Time tends to be the limiting factor of soil development in these soils.

Table 1. Soil Orders on the Colville National Forest.

Soil Order	Acres	% of Administrative Forest
Inceptisols	666,134	49%
Andisols	477,507	35%
Mollisols	64,416	5%
Alfisols	39,630	3%
Others (including Entisols, Histosols, and Spodosols)	110,462	8%

Andisols are soils that have formed from volcanic ash or other volcanic material. These soils have characteristic chemical and physical properties that include high water holding capacity and the ability to keep large quantities of phosphorus unavailable to plants. While volcanic ash plays an important role in the soils of the Forest, not all the soils have ash depths that would classify to Andisols. Many soils are within Andic and Vitrandic suborder, great group, or subgroups.

Mollisols are grassland soils with thick dark surface horizons. These dark surface horizons are the result of long-term additions of organic matter primarily through grass roots. These soils were formed in areas with a short fire return interval that prevented the growth of woody vegetation and stimulated the growth of native grasses. Some Mollisols may be relics of periglacial tundra.

Alfisols are soils that have clay-enriched subsoils and high base saturation. These soils have typically formed in forested ecosystems and tend to have high soil fertility.

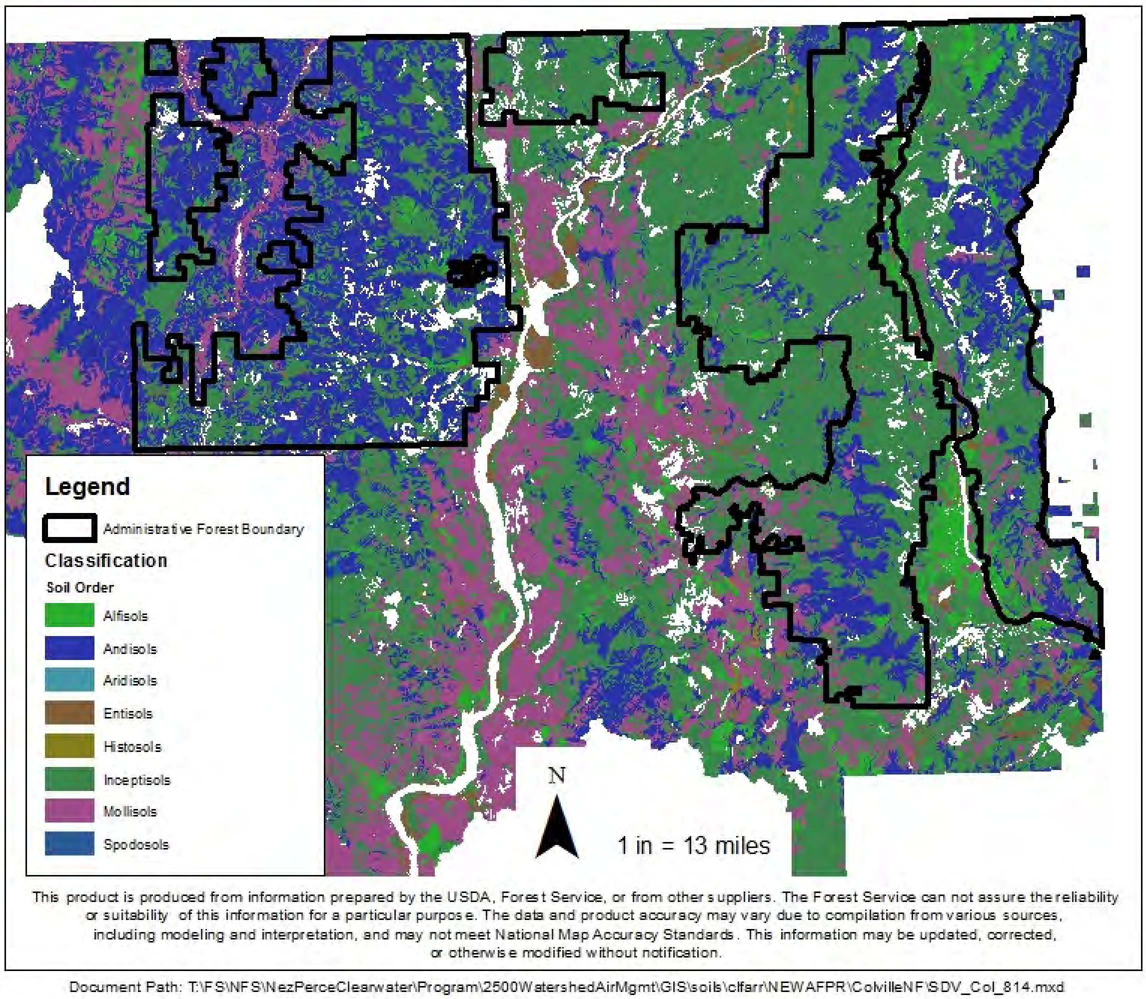

Figure 5. Soil Orders on the Colville National Forest.

Current Conditions and Trends

Soil Quality

Soil is the foundation of the ecosystem. Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation and ecosystem health. Soil productivity is the inherent capacity of the soil resource to support appropriate site-specific biological resource management objectives, which include the growth of desirable plant species, plant communities, or a sequence of plant communities, all to support multiple land uses.

Forest Service Manual (FSM) Chapter 2550 Soil Management directs soil resource management on National Forest System lands. The objectives of the national direction are 1) to maintain or restore soil quality on National Forest System lands and 2) to manage resource uses and soil resources on National Forest System lands to sustain ecological processes and function so that desired ecosystem services are provided in perpetuity. Soil function is any ecological service, role, or task that soil performs.

The FSM identifies six soil functions: soil biology, soil hydrology, nutrient cycling, carbon storage, soil stability and support, and filtering and buffering. In order to provide multiple uses and ecosystem services in perpetuity, these six soil functions need to be active and effectively working. Each of these six soil functions are discussed in the following sections. Interpretive maps have been developed to assist in understanding how these functions are operating within different ecosystems. These soil functions and the interpretive maps are also referenced in the discussion of "Environmental Consequences."

Soil Biology

Soil biology is the ability to provide habitat for a wide variety of organisms including plants, fungi, microorganisms and macro-organisms in the upper sections of the soil. Diversity of soil biology is beneficial for several reasons:

The complex process of decomposition and nutrient cycling requires a varied set of organisms.

- An intricate group of soil organisms can compete with disease-causing organisms and prevent a problem-causing species from becoming dominant.
- Several organisms are involved in creating and maintaining the soil structure important to water dynamics in soil.
- Many antibiotics and other drugs and compounds used by humans come from soil organisms.
- Most soil organisms cannot grow outside of soil, so it is necessary to preserve healthy and diverse soil ecosystems to preserve beneficial microorganisms.

The major drivers of soil biological function are presence of organisms and thermodynamics. The organism influences on the soil include plant and animal actions from root growth and distribution to macro pore creation by small mammals. The thermodynamics of the site control moisture and temperature of the soil profile. Vegetation canopy and soil cover (forest floor, fine and coarse woody debris) provide macro and microhabitat and climate conditions on-site in order to support the soil organisms. Important characteristic soils are formed on unglaciated areas with remnant plant communities; these are typically older, well developed soils.

Soil Hydrology

Soil hydrology is the ability of the soil to absorb, store, and transmit water, both vertically and horizontally. Soil hydrology is extremely important on the Forest, because the ecosystem productivity is typically limited by water. Soil can regulate the drainage, flow, and storage of water and solutes, including nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water. With proper functioning, soil partitions water for groundwater recharge and use by plants and animals. Sensitive soils for the hydrologic function are soils with volcanic ash deposits, soils susceptible to drought, and hydric soils (wetlands).

Volcanic Ash Soils

The surficial volcanic ash deposits, or ash cap, of the soils on the Forest are instrumental to the high productivity of the Forest. The ash-cap on the Forest is characterized by a low bulk density, high water holding capacity, and a high cation exchange capacity that can lead to a concentration of nutrients. The ash-caps found on the Forest are in varying forms from thick mantles of pure ash to layers of ash mixed with weathered mineral soil.

The ash deposited on the Forest tends to be fine particles forming loam and silt loam textured soils. The high water holding capacity of the ash-cap is arguably the most important feature of the ash-cap locally. The ash was deposited over rocky and sandy coarse textured soils with relatively low water holding capacities in northeastern Washington and therefore the majority of the plant-available water in this landscape is held in the ash cap.

Ash-caps are extremely susceptible to decreased soil quality due to compaction, erosion, and soil mixing. Ashy soils have low soil bearing capacity and therefore compact very easily within a large range of soil moisture levels. Compaction causes a restriction to plant rooting, lowered water-holding capacity, and lowered infiltration rates. Ashy soils also do not recover from compaction as quickly as other soil types. Several hypotheses exist regarding the slower recovery times; including the low amounts of clay and therefore limited natural shrink and swell cycles or the possible physical locking of jagged edge ash particles during compaction.

Ash-cap layers tend to be resistant to erosive forces when fully vegetated due to high infiltration rates and strong soil structure. When vegetation and litter layers are removed, the ashy surface is highly susceptible to severe erosion. Loss of the ash-cap layer would reduce the water-holding capacity and increase the overall soil bulk density. These effects would decrease available soil moisture and tree root penetrability. The effects of mixing the ash-cap with subsoil are similar and would result in comparable productivity decreases. Since volcanic ash is not replaced, the effects of erosional losses of the ash-cap would be long term. Areas with ground disturbance may become more favorable for weed invasion, which could reduce overall soil productivity.

A map of areas and types of ash-cap soils on the Colville Forest was created using the Natural Resources Conservation Service SSUGRO soil data layer **(Figure 6)**. The purpose of this interpretive map is to show where ash-cap soils occur and the relative thickness and makeup of the different volcanic ash soils. Four categories were identified based on whether or not an ash-cap was present and soil taxonomic classification of the ash-caps(Soil Survey Staff, 2014). Andisols include soils in the Andisols soil order that have an ash-cap at least 24 inches thick. Ash-cap soils in the Andic subgroup have at least eight inches of ash-cap and contain minerals weathered from volcanic ash. Ash-cap soils in the Vitrandic subgroup also have at least eight inches of ash-cap and have higher volcanic glass content compared to Andic subgroups.

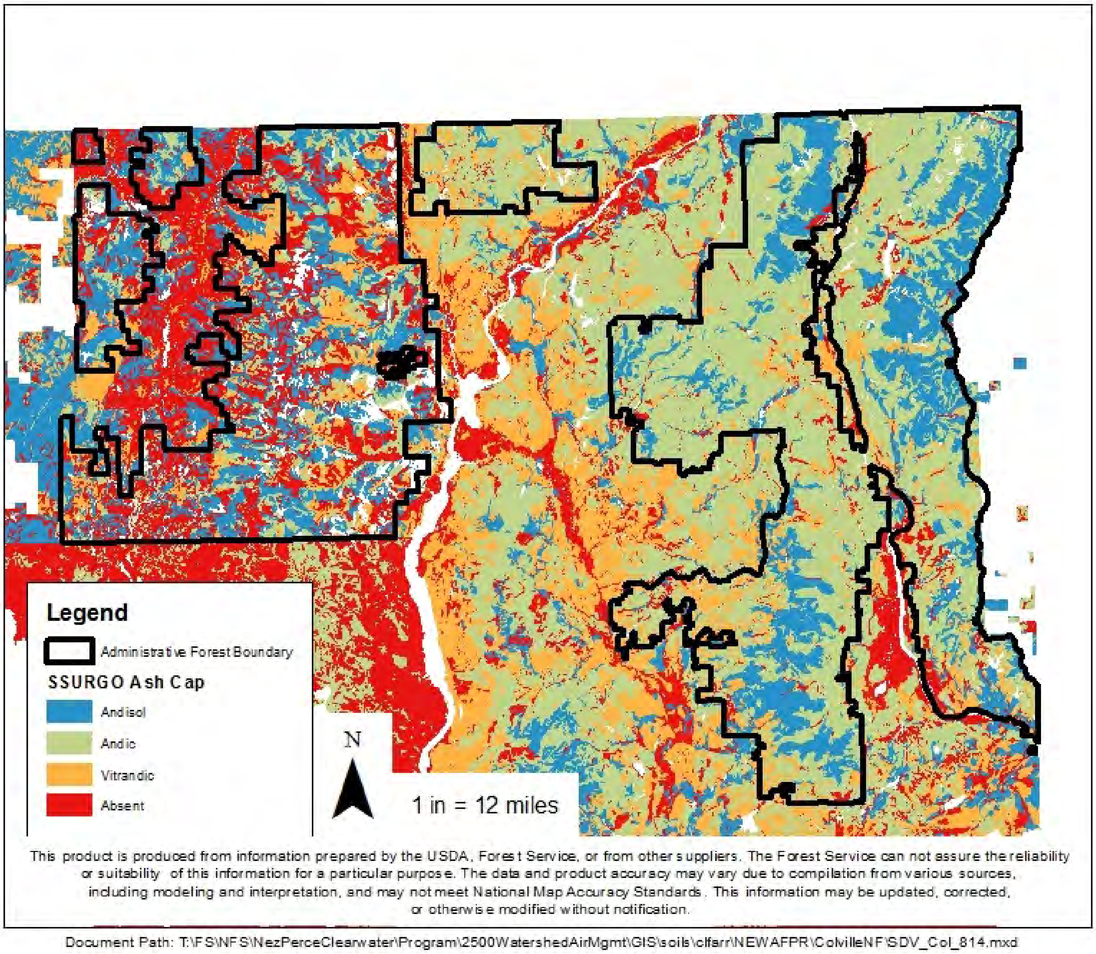

Figure 6. Map of Volcanic Ash Deposits.

Droughty Soils

Drought affects trees directly by slowing or arresting growth, and causing injury or death. It also affects them indirectly, by increasing their susceptibility to wildfire, insect pests and disease. A drought may be short-lived, perhaps lasting one growth season, but its impact on a tree's health—and, ultimately, a forest's—can last much longer. Trees have evolved protective mechanisms to deal with water stress, but there are many external factors that determine the effects of drought, including soil composition and topography, as well as the species mix, age and density of trees. These soils that are susceptible to drought can inform management as to desired tree density and areas at risk to insect and disease outbreaks.

Oregon State University has created a soil drought index layer for the Pacific Northwest Region of the Forest Service (**Table 2 and Figure 7**). This layer represents an initial approximation of the potential for droughty soil conditions in forested landscapes in Washington and Oregon. The index is based upon best-available soils data and satellite-derived estimates of actual and potential evaporation. Potential evapotranspiration (PET) is an estimate of the evaporation and transpiration that would occur if an adequate supply of moisture were available. Actual evapotranspiration (AET) measures the actual loss of moisture from soil and plant surfaces, and so the degree to which AET falls below PET may be interpreted an indicator of moisture limitation. Some studies have found that prolonged periods of low AET to PET ratio (AET/PET) during a growing season are highly correlated with reduced dryland crop yields. AET/PET has been used as a broad-scale indicator of potential drought stress.

Table 2. Droughty Soil Index for the Colville National Forest.

	April, May, June		July, August, September	
Droughty Soil Index	Acres	% of Administrative Forest	Acres	% of Administrative Forest
Low	5915	0%	7374	1%
Low to Moderate	546,751	41%	464,796	35%
Moderate	643,988	48%	644,360	48%
Moderate to High	147,427	11%	182,961	14%
High	840	0%	45,432	3%

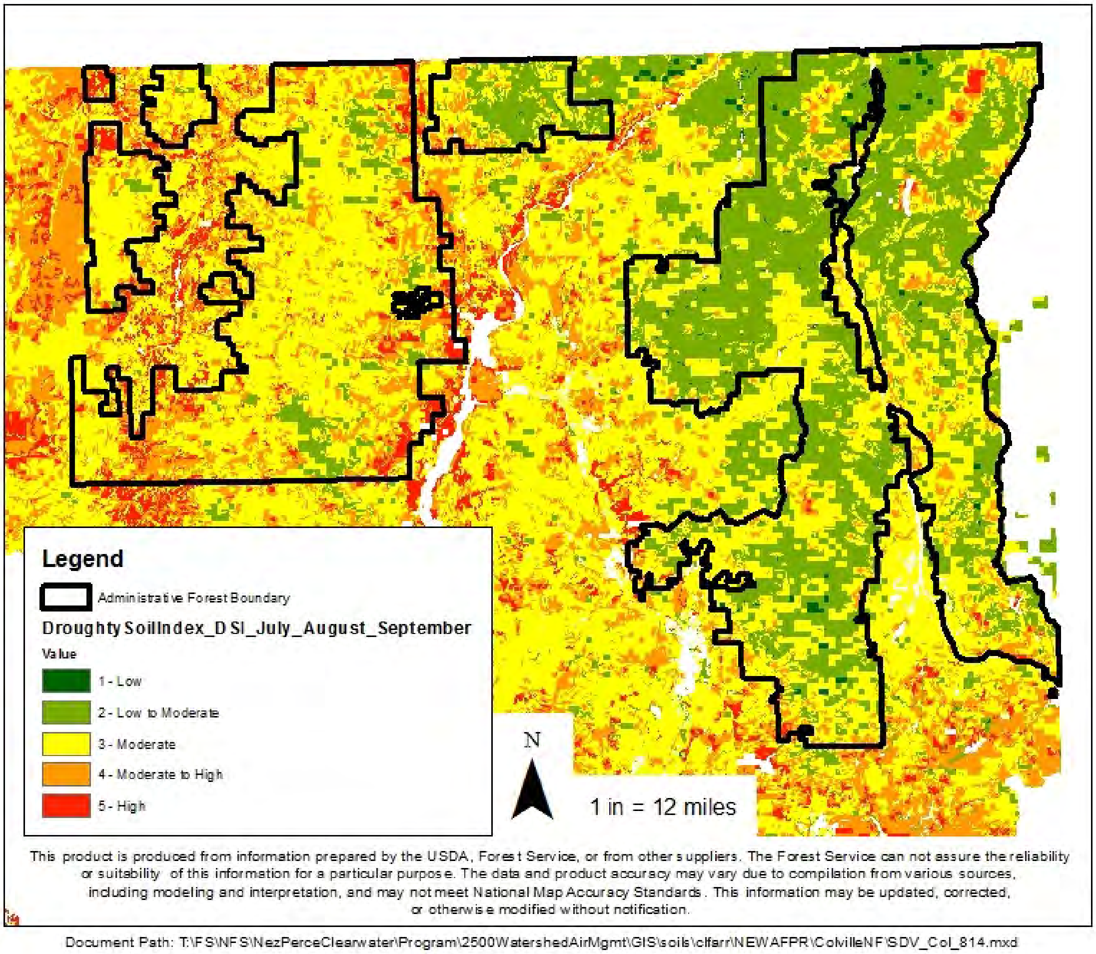

Figure 7. Droughty Soil Index Map for July, August and September.

Hydric Soils

Hydric soils and wetlands are areas on the landscape that tend to retain moisture on the landscape and are sensitive to human activities. There are very limited amounts of hydric soils on the Colville National Forest. The NRCS classifies map units in the Soil Survey program as to the amount of the map unit that is hydric. There are 2,989 acres of soils mapped as 100% hydric on the forest and 2,247 acres of soils mapped as predominately hydric (66 to 99% hydric) (Table 3). This combines to less than one percent of the Forest land base. Map units that are made up of hydric soils may have small areas, or inclusions, of non-hydric soils in the higher positions on the landform, and map units made up of non-hydric soils may have inclusions of hydric soils in the lower positions on the landform. Map units that are not listed do not meet the definition of hydric soils because the dominant soil component does not have one of the hydric soil indicators. A portion of these map units, however, may include hydric soils. There are inclusions in most map units that can be hydric, therefore the total land base on the forest that have hydric soils is likely underestimated due to the level of mapping and classification. In all soil surveys, every map unit includes areas of soil components or miscellaneous areas that are not identified in the name of the map unit. Many areas of these components are too small to be delineated separately. Generally in these soil surveys, inclusions can make up to 20% of a map unit.

Table 3. Map Unit Hydric Ratings on the Colville National Forest.

Hydric Class	Acres	Percent of Administrative Forest
Non Hydric (0%)	1,181,432	87%
Predominately Non Hydric (1-32%)	171,480	13%
Predominately Hydric (66-99%)	2247	0.17%
Hydric (100%)	2989	0.22%

Hydric soils are defined as soils formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions within the upper part. A soil is defined as saturated when all pores are filled with water, excluding all air. The saturated soil closest to the soil surface indicates the level of the water table. Anaerobic conditions exist when biologically available oxygen is absent from the soil.

Positions in the landscape that have high water tables are more likely to have wet and potentially hydric soils. The same is true for soils that are prone to flooding or ponding. The following landscape positions are locations that may contain hydric soils, based on the timing and duration of saturation and anaerobic soil conditions.

- Depressional areas collect and store runoff water from the surrounding landscape after rain events. Saturation is not sustained for long periods after rain events. Mineral soils are likely to be present and may or may not be hydric. Vegetation can consist of trees, shrubs and herbs.
- Flood plains that are seasonally flooded may contain hydric soils. Hydric soils usually form in the backwater area, where water is retained for extended periods of time. Soils are typically mineral with trees and shrubs being the dominant vegetation.
- Seeps occur at the bases of slopes where the groundwater table intersects the soil surface. They are often found where a slope grades into flat land. The high water table in seeps is sustained by groundwater discharge. There can be mineral or organic soils, and the vegetation in and around the seep can consist of trees, shrubs and herbs.

In hydric soils, soil organic matter accumulates because the microorganisms decompose plant and animal material more slowly than in anaerobic soils. This decrease in decomposition causes organic matter to build up at the surface. As a result, anaerobic soils usually have a dark or almost black surface. Common rates of organic accumulation may average 2 inches every 100 years. A dark surface horizon, underlain by a gray horizon is one common indicator. Another indicator of a hydric soil is a horizon that is predominantly gray with accumulations of iron along root channels or in masses. In the horizons with accumulated iron, there are also areas that are depleted, making them lighter than the main horizon color (Hurt et al., 1996).

The presence of hydric soils is one third of the requirements needed to meet a jurisdictional wetland. The two other requirements include wetland hydrology and hydrophytic vegetation. Hydrology refers to the movement of water in the environment. However, wetland hydrology specifically implies the soil is saturated to the surface for approximately five percent of the growing season, or is frequently flooded or ponded. Hydrophytic vegetation is adapted to survive in saturated and anaerobic soils. Wetlands are universally sensitive to machine traffic due to saturation throughout the growing season and high organic matter content of the soils.

Nutrient Cycling

Nutrient cycling is the movement and exchange of organic and inorganic matter back into the production of living matter. Soil stores, moderates the release of, and cycles nutrients and other elements. In contrast to the annual harvests associated with agriculture, forest harvest— and hence nutrient removal— typically occurs only once per rotation or every 40 to 120 years. This not only reduces the rate of removal, but the long-time interval makes natural additions of nutrients by atmospheric deposition and by weathering of soil minerals very important in maintaining nutrient status. Sensitive soil attributes for nutrient cycling include the forest floor vegetation quantity composition, and coarse soil texture subject to leaching. Soils formed on quartzite are problematic, in that they are very low in nutrients from parent material and have little capacity for retaining deposited nutrients.

During these biogeochemical processes, analogous to the water cycle, nutrients can be transformed into plant available forms, held in the soil, or even lost to atmosphere or water. Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled through soil. Decomposition by soil organisms is at the center of the transformation and cycling of nutrients through the environment. Decomposition liberates carbon and nutrients from the complex material making up life forms and puts them back into biological circulation so they are available to plants and other organisms. Decomposition also degrades compounds in soil that would be pollutants if they entered ground or surface water. Nutrient cycling can be assessed by considering organic matter composition on a site (forest and rangeland floor, fine and coarse woody material) and the nutrient availability (topsoil horizons and nutrient deficiencies).

Nearly all the nitrogen in forest systems is bound to organic matter. Very little of the total pool of nitrogen is available to plants; only about 2.5% of total organic nitrogen is released annually (Grigal and Vance, 2000). The rate of nitrogen release from organic matter (mineralization) is controlled by microbial decomposition, which in turn is controlled by environmental factors as well as the amount and chemical composition of organic matter (Grigal and Vance, 2000). Rates of nitrogen mineralization are highly spatially variable within stands (Johnson and Curtis, 2001). The availability of nitrogen from organic matter has been said to "most often limit the productivity of temperate forests" (Hassett and Zak, 2005). Logging residues are a source of nitrogen during early periods of stand growth after harvest (Hyvönen et al., 2000)(Mälkönen, 1976). Dead woody material left after logging provides carbon-rich material for microbes to feed upon; and typically microbial populations increase after forest harvests due to the input of logging residues. Microbes immobilize nitrogen in their tissues and limit losses that could otherwise occur through leaching or volatilization. As dead woody material gradually decomposes during the 15–20 years following harvest, microbial populations decline and slowly release the nitrogen to growing vegetation. One research study found that nearly all the nitrogen and much of the phosphorous that moved down through the litter layer into mineral soil was in organic forms as a result of microbial transformations of organic matter in the forest floor (Qualls et al., 1991). This indicates that some nitrogen and phosphorous can be moved from the litter layer into mineral soil where it may be stable for a longer period. Phosphorus is another essential nutrient that is mainly supplied, in forms available to plants, by the microbial breakdown of organic materials. A deficiency of available phosphorus can limit plant metabolism of nitrogen, and some forests may be limited by phosphorus availability (Trettin et al., 2003). Inorganic phosphorus is often present in soil minerals, but under low-pH conditions often found in forest soils; soluble aluminum and iron react with inorganic phosphorus to form insoluble compounds that are unavailable to most plants (Pritchett, 1979). Sulfur like nitrogen, occurs in soil primarily as organic compounds and is made available for plant growth through oxidation by microbes to sulfate forms (Fisher and Binkley, 2000). Carbonic acid weathering of the feldspathinc, ferro-magnesian igneous rocks, very common on the Forest yields aluminum, iron, calcium, and magnesium ions in low soil pH.

Soil Organic Matter

The soil organic layer is extremely important to all soils on the Forest, especially those formed from low-nutrient geology like granite and quartzite which weathers slowly. Soil organic matter is fundamentally important to sustaining soil productivity. Soil organic matter is influenced by fire, silviculture activities, and decomposition/accumulation rates. The organic component of soil is a large reserve of nutrients and carbon and is the primary site for microbial activity. Forest soil organic matter influences many critical ecosystem processes, including the formation of soil structure. Soil structure influences soil gas exchange, water infiltration rates, root penetration, and water-holding capacity. Soil organic matter is also the primary location for nutrient recycling and humus formation, which enhances soil cation exchange capacity and overall fertility. Soil organic matter depends on inputs of biomass (e.g., vegetative litter, fine and coarse woody debris) to build and maintain the surface soil horizons, support soil biota, enhance moisture-holding capacity, and prevent surface erosion. Nevertheless, in natural systems organic matter fluctuates with forest growth, mortality, fire, and decay.

Low-Nutrient Soils

A rating on soil nutrient availability based on geology types has been developed by the Intermountain Tree Nutrient Cooperative at the University of Idaho **(Table 4 and Figure 8)**. Tree nutrition value is an interpretation of rock geochemistry and its nutritive status. Soils formed from quartzite geologies tend to be very nutrient poor. This is especially true when the volcanic ash layer is no longer on site. Soil wood loss may alter processes of forest regeneration and growth, favoring species requiring lower soil moisture and lower nutrient levels, and provide for a greater potential for soil erosion. Potential loss or reduction of organic matter can lead to a decline in several key soil and foliar nutrients (Powers et al., 2005). Further effects also include a reduction of habitat for species requiring soil wood as dens or as substrate for invertebrates, bacteria and fungi, which affect food availability for small rodents and their predators.

Table 4. Geologic Tree Nutrition Values for the Colville National Forest.

Geology Tree Nutrition Value	Acres	% Administrative Forest
High	50,075	4%
Moderate	922,817	68%
Low	278,203	20%
Very Low	104,050	8%

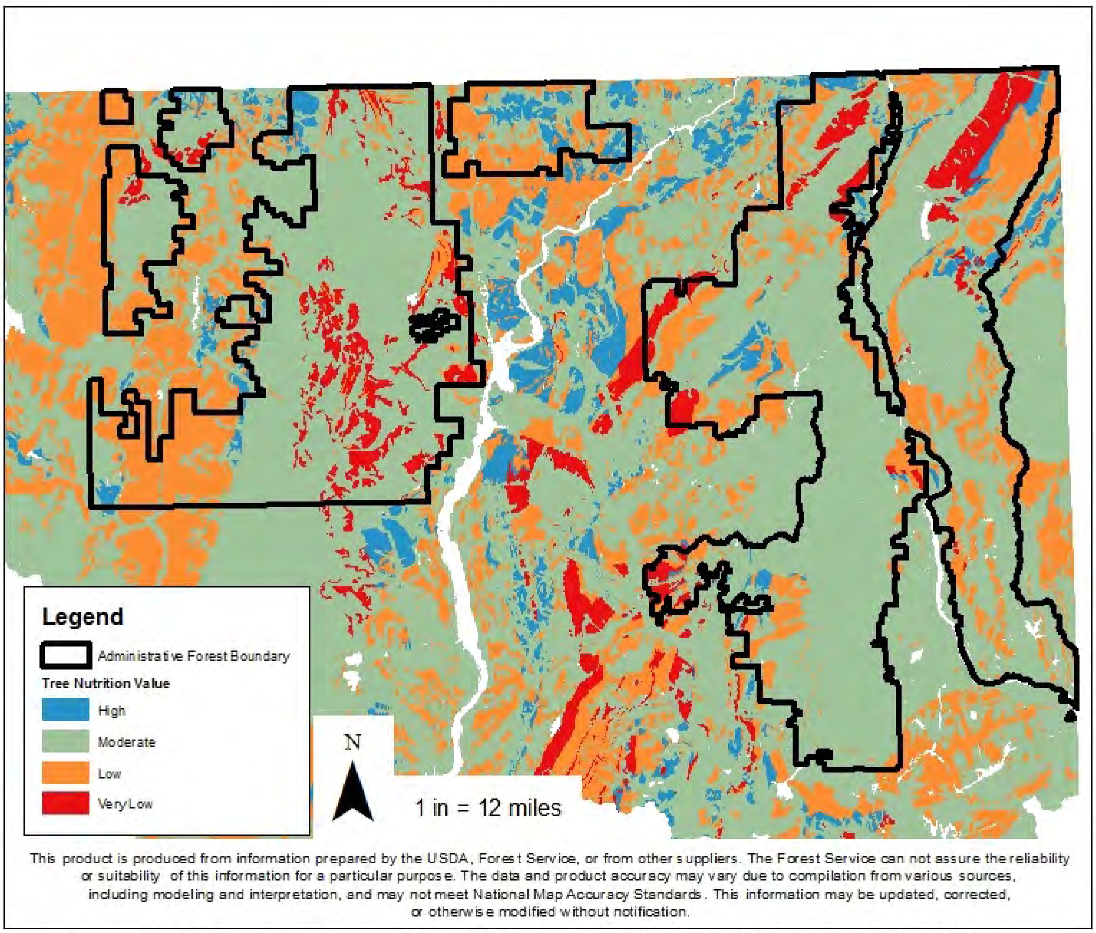

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Figure 8. Geologic Tree Nutrition Values for the Colville National Forest.

Carbon Storage

The carbon storage function is defined as the ability of the soil to store carbon (**Figure 9**). The carbon cycle illustrates the role of soil in cycling nutrients through the environment. Globally more carbon is stored in soil than in the atmosphere and above-ground biomass combined. Limiting factors of soil carbon storage are depth and rockiness. Carbon compounds are inherently unstable and owe their abundance in soil to biological and physical environmental influences that protect carbon and limit the rate of decomposition (Schmidt et al., 2011). Soil organic matter is formed by the biological, chemical, and physical decay of organic materials that enter the soil system from sources aboveground (e.g., leaf fall, crop residues, animal wastes and remains) or belowground (e.g., roots, soil biota). The organic compounds enter the soil system when plants and animals die and leave their residue in or on the soil. Immediately, soil organisms begin consuming the organic matter; extracting energy and nutrients; and releasing water, heat, and carbon dioxide back to the atmosphere. Thus, if no new plant residue is added to the soil, soil organic matter would gradually disappear. If plant residue is added to the soil at a faster rate than soil organisms convert it to carbon dioxide, carbon would gradually be removed from the atmosphere and stored (sequestered) in the soil. Large quantities of soil organic matter accumulate in environments such as wetlands, where the rate of decomposition is limited by a lack of oxygen, and high-altitude sites where temperatures are limiting to decomposition. Most carbon in mineral soil comes from root turnover (Schmidt et al., 2011), although some is moved from the forest floor into upper mineral soil layers (Qualls et al., 1991).

A soil carbon stock was determined for the forest using local data from the soil surveys of the area and local research. The soil carbon stock includes carbon compounds in the forest floor litter layer and the mineral soil to a depth of one meter (or depth to bedrock if the soil is shallower than one meter). Forest floor carbon numbers were generated using data from the National Cooperative Soil Survey, research data as analyzed by (Smith et al., 2006), and regional data collected by (Page-Dumroese et al., 2006). Soil organic carbon (SOC) was estimated for the Colville National Forest using data from the National Cooperative Soil Survey. A modified equation following the methods of (Batjes, 1996) was used to calculate the total SOC to a depth of one meter for the mineral soil. This results in a forest floor carbon stock of 103 Tg (113.5 million tons) with and average density of 103 Mg C/ha (46.0 tons/acre) and a mineral soil carbon stock of 172 Tg (189.6 million tons) SOC in the top one meter of soil with an average carbon density of 127 Mg C/ha (56.7 tons/acre). The total soil carbon stock, organic and mineral layers, for the Colville National Forest is approximately 275 Tg (303.1 million tons)C with a density of 203 Mg C/ha (90.6 tons/acre). This carbon density is within the ranges found in several research projects **(Table 5)**.

The carbon storage potential **(Figure 9)** was determined for the forest. The factors used to develop this map include the inherent soil productivity **(Figure 13)**, soil depth, and percent rock fragments in the soil profile.

Table 5. Soil Carbon Densities from Research.

Environment	SOC (Mg C/ha)	Source
Cool, conifer forests of U.S.	403-494	(Kern, 1994)
Cool, temperate forests of Maine	130	(Davidson and Lefebvre, 1993)
Global temperate forests	118	(Schlesinger, 1977)
Cool, temperate forest of north central U.S.	84-152	(Franzmeier et al., 1985)

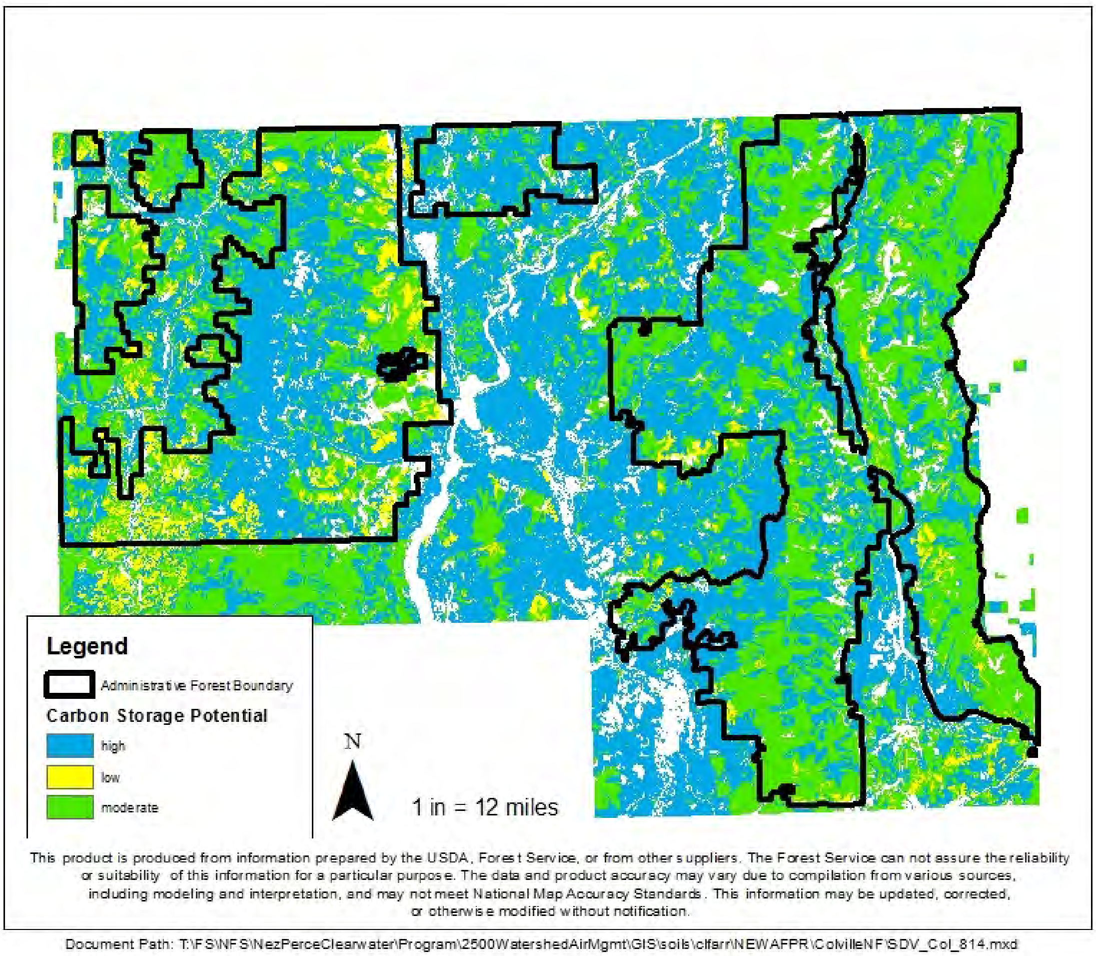

Figure 9. Soil Carbon Storage Potential on the Colville National Forest.

Support and Stability

Soil stability and support is necessary to anchor plants and structures. Inherent soil properties, like soil texture and particle size distribution, play a major role in physical stability. Soil has a porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots. Soils also provide anchoring support for human structures and protect archeological artifacts. The need for structural support can conflict with other soil uses. For example, soil compaction may be desirable under roads and houses, but it can be detrimental for the plants growing nearby. The conflict of stability and support with plant growth capabilities is constant when dealing with roads, skid trails, recreation trails, and forest productivity. Sensitive soils for the support and stability function are soils with high erosion hazards and soils with high mass wasting hazards. Support and stability can be assessed by evaluating risk of erosion and mass wasting and observing soil deposition.

Highly Erosive Soils

The susceptibility of soil to erosion, or the relative loss of exposed soil to erosional forces, is expressed by soil erosion ratings. Surface erosion risk was developed for the Landtype Associations of North Central Washington (Davis et al., 2004). This rating represents the susceptibility of the bare, un-vegetated surface to erosion by wind and water. Approximately 37% of the forest has a high risk for surface erosion **(Table 6 and Figure 10)**. Basically, if practices or conditions occur that remove vegetative cover and expose the surface soil layer to erosional forces, then the erosion susceptibility rating applies. Skid trails, fire lines, machine piles areas, and severely burned areas are examples of practices and conditions that expose soils to erosional forces such as wind and rain.

Table 6. Surface Erosion Risk.

Surface Erosion Risk	Acres	Percent of Forest Administrative Boundary
Low	220,237	16%
Moderate	629,664	46%
High	507,295	37%

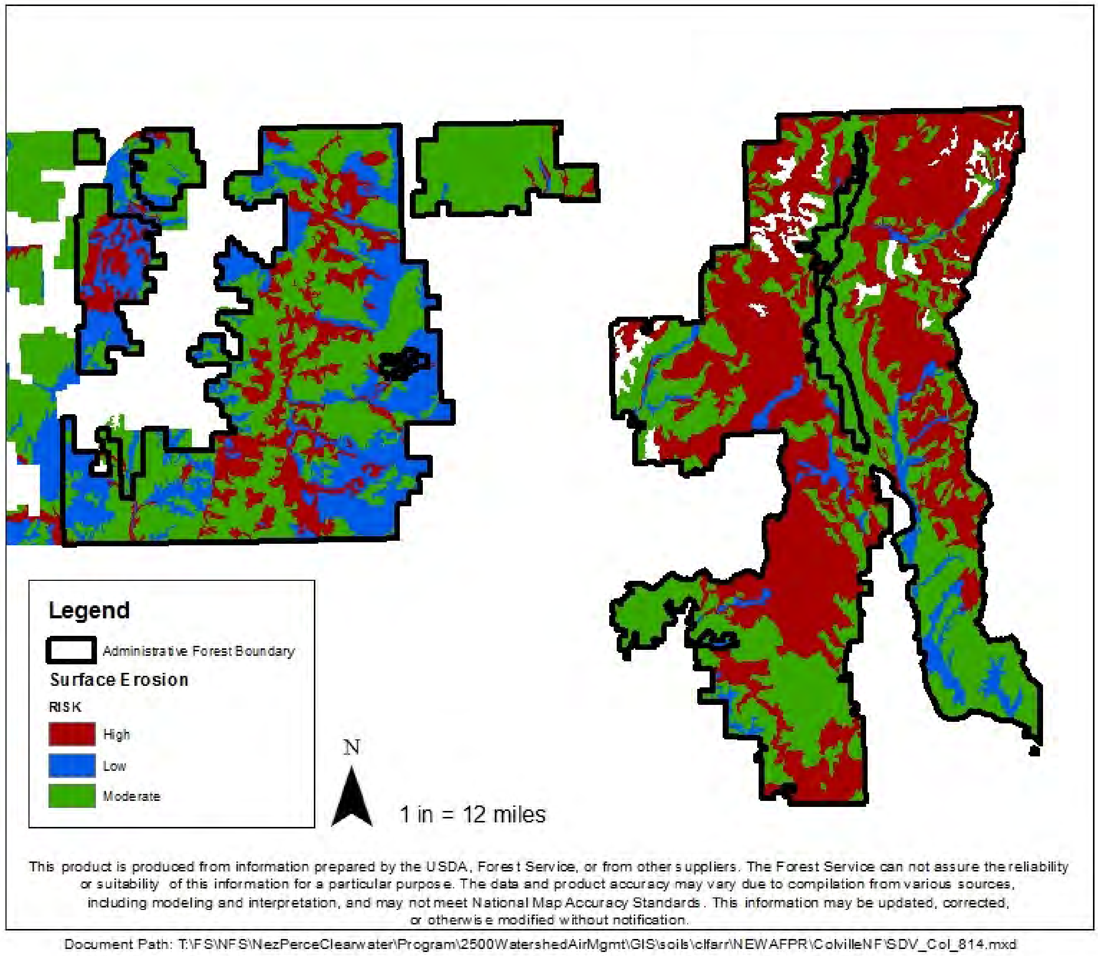

Figure 10. Map of Surface Erosion Risk.

Landslide Prone Soils

Forest soils that have high mass wasting hazards are considered landslide prone. Landslide or mass wasting are terms used to describe the downslope movement of material under the influence of gravity. Water is usually only a minor part of the moving material. A slide is a rapid, planar movement of a large mass of earth and other debris down a hill or a mountainside. Slumps involve a mass of soil or other coherent material sliding along a curved surface (shaped like a spoon). Slumps and planar slides form crescent-shaped cliffs, or abrupt scarps at the top of the slide slope. More than one scarp can exist down the slope. Slumps form a depression or back slope, between the scarp and the mass that moved. Soil creep is a long-term process. The combination of small movements of soil or rock in different directions over time are directed by gravity gradually downslope. The slumps and soil creep make trees and shrubs curve to maintain their perpendicularity. The surface soil can migrate under the influence of cycles of freezing and thawing, or hot and cold temperatures, inching its way toward the bottom of the slope forming terracettes. Flows are movement of earth materials and vegetative debris that more resemble fluid behavior. Water, air, and ice are often involved in enabling fluid-like motion of the material. Falls, including rockfalls and topples are where rock cascades down a slope, but without fluid or sufficient volume to behave as a flow. The accumulation of fallen rock material residing at the base of the slope is known as talus.

Landslides are likely to occur in areas near where they have occurred in the past or as reactivation of older mass wasting. In many cases, the landscape features provide evidence of past and ongoing landslide activity. Mass wasting is part of the evolution of the landscape, delivering material to be carried away by streams. Landslides are triggered by earthquakes, major storms, volcanic activity, or human activities that may cause slopes to become unstable. The additional weight of rains or snow melt can cause slopes to fail or reactivate older landslides. The most significant factors were: steepness of the original slope angle, undercutting of the toe of the slope by erosion or excavation, and height of saturation of the slope (Jones et al., 1961).

Landslide hazards ratings for the Colville National Forest were developed for the Landtype Associations of North Central Washington (Davis et al., 2004). (Landslide hazard ratings are currently being developed for Forest Service Region 6, including adjustments for smaller subsets. These ratings would not be available, until after this Plan is finalized.) There are ratings for both deep seated and shallow rapid landslides. Deep-seated landslides include rotational slumps and other mass movement that is sporadic or slow and involves thick masses of material over a relatively large area. Factors used to assess deep seated landslide risk were:

- Easily weathered bedrock high in clays
- Geologic structural features such as folding and faulting
- Geomorphic shape features such as escarpments and concave topography
- Fine textured surficial deposits
- Slope gradients greater than 20%
- Indications of concentrated groundwater
- Indications of surface and subsurface water

Approximately 3% of the forest has a high risk for deep seated landslides **(Table 7 and Figure 11)**. The only area on the forest that was determined to have a high risk at the landtype classification scale is the Pend Oreille River Valley.

Table 7. Deep-Seated Landslide Risk.

Deep Seated Landslide Risk	Acres	Percent of Forest Administrative Boundary
Low	837,452	62%
Moderate	483,928	36%
High	35,817	3%

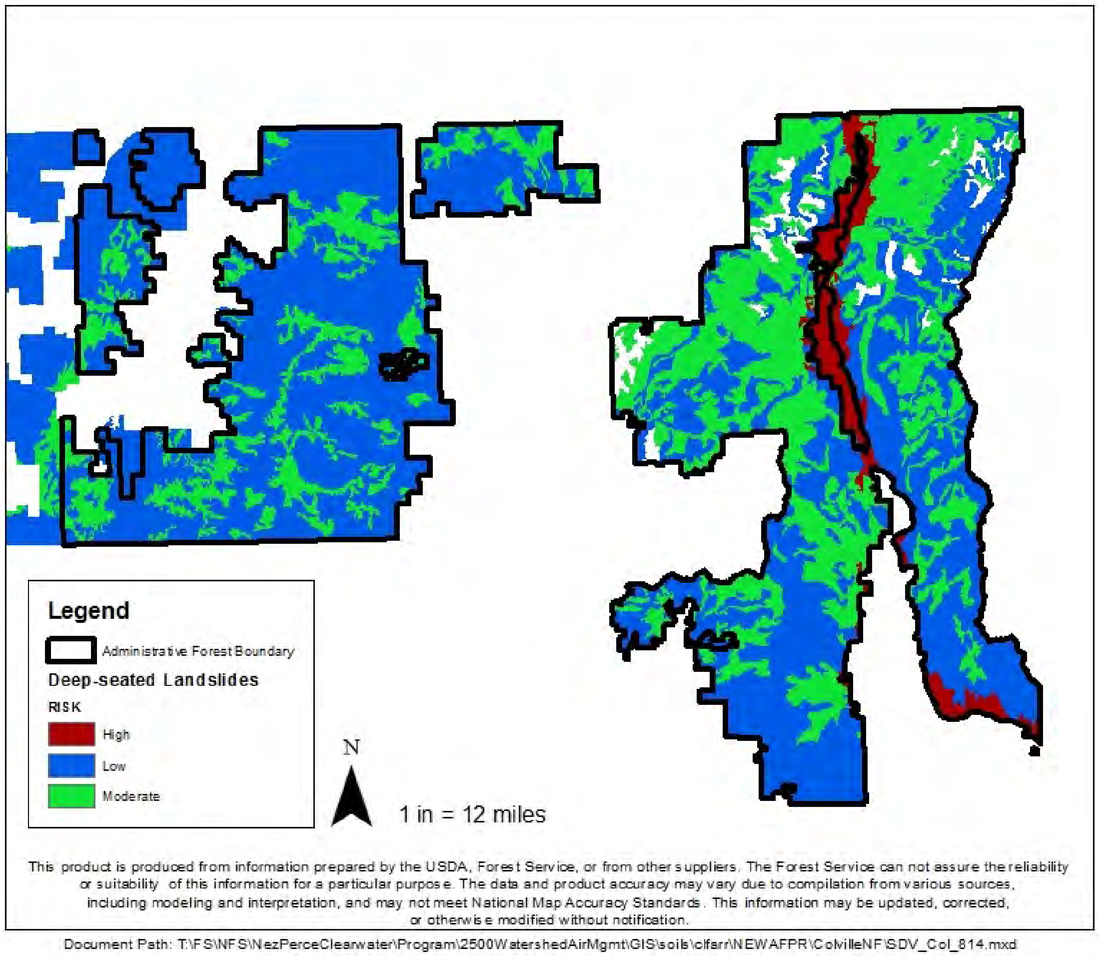

Figure 11. Map of Deep-Seated Landslide Risk.

Shallow rapid landslides include debris slides such as debris avalanches, flows and torrents. These slides are relatively small and shallow. Seven factors were used to develop this risk rating:

- Slope gradients greater than 40%
- Convergent drainages and/or catchment basins
- Unconsolidated coarse textured soils
- Interface of materials with discontinuous hydrologic properties
- Sparse vegetation patterns
- Geomorphic features such as debris chutes or alluvial fans
- High low order drainage density especially with parallel patterns

Approximately 1% of the forest has a high risk for shallow rapid landslides **(Table 8 and Figure 12)**. The only area of the forest with a high risk of deep-seated landslides at the landtype scale occurs in the Salmo-Priest area of the Selkirk Mountains. For information on the impacts of these landslides on water quality and fisheries see the sediment delivery risk analysis discussed in the fisheries and the hydrology report.

Table 8. Shallow Rapid Landslide Risk.

Shallow Rapid Landslide Risk	Acres	Percent of Forest Administrative Boundary
Low	581,955	56%
Moderate	759,961	43%
High	15,280	1%

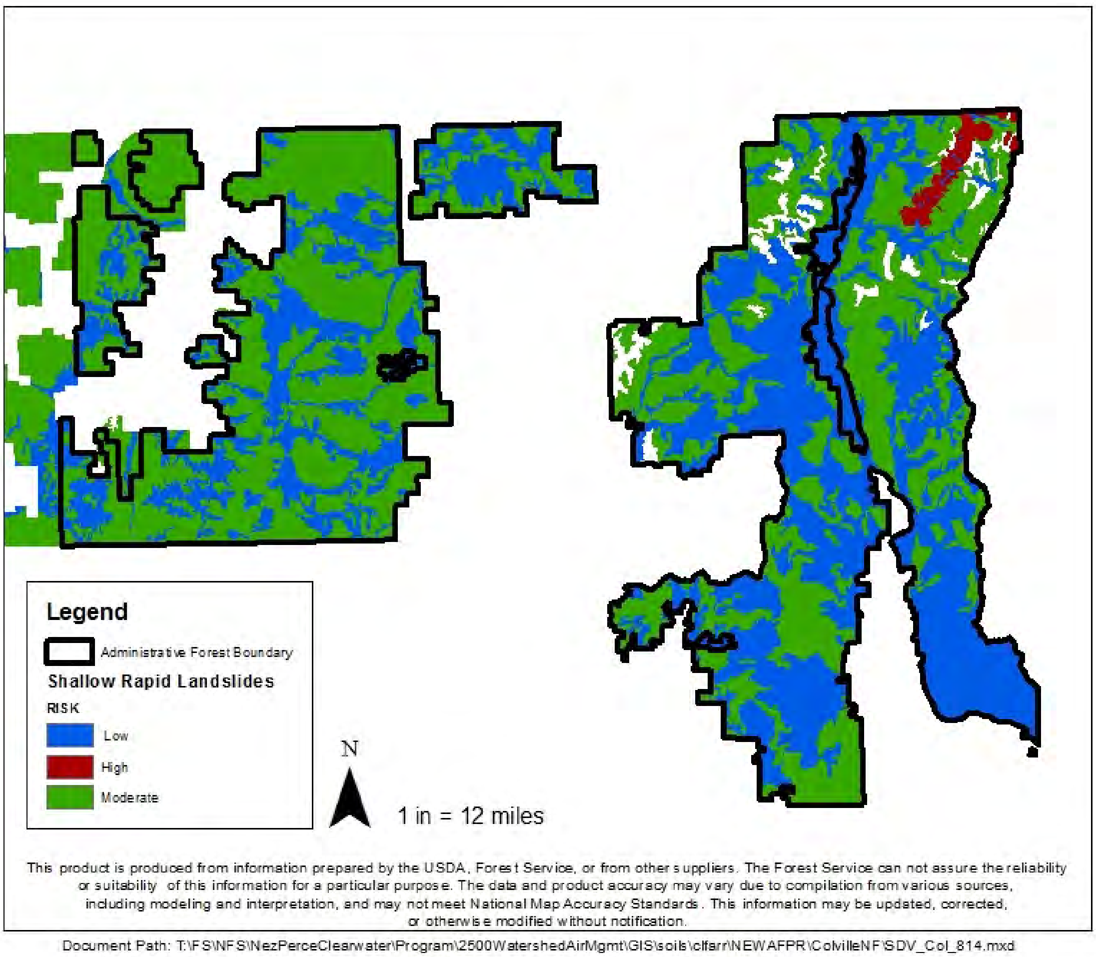

Figure 12. Map of Shallow Rapid Landslide Risk.

Filtering and Buffering

Soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals. The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits. Soil absorbs contaminants from both water and air. Microorganisms in the soil degrade some of these compounds; others are held safely in place in the soil, preventing contamination of air and water. Wetlands soils especially function as nature's filters. Filtering and buffering on the Forest is impacted by chemical pollutants and industrial contamination at a very small scale. Wetlands are also discussed in the hydrology report.

Inherent Soil Productivity

Inherent soil productivity can be described as a summation of the six ecological soil functions. The main function drivers of inherent soil productivity on the Colville are soil hydrology and nutrient cycling. Inherent soil productivity influences what plant communities can grow on the forest and how well they grow. Maintaining soil productivity is an important consideration in determining the level of natural resource extraction, like timber harvest, the forest can sustain, as well as other forest values, such as wildlife habitat and biodiversity. **Table 9** provides a soil function evaluation matrix that can be used to evaluate whether or not one of the six key soil functions have been affected or impaired as a result of soil disturbances.

Table 9. Soil Function Evaluation Matrix.

Soil Function	Selected Attributes	Soil Quality Indicator	Forest Plan Desired Future Condition	Affected, but Not Impaired	Impaired Function
Biological	Roots and Aeration	Root growth	Root growth, both vertically and laterally, is unimpeded by compaction.	Compaction evident but does not significantly affect root growth. Roots can penetrate and/or grow around compacted structure.	Compaction limits root growth. Roots are not able to penetrate the compacted structure.
		Root Distribution	Root distribution and depth is as expected for vegetation type and successional stage or desired plant community.	Root distribution and depth has been reduced or changed from the expected on the site.	There are few/very few roots in the surface horizons as compared with expected.
		Porosity	Macro and micro-pores are as expected for soil texture and type.	Movement of air and water in the root zone has been affected but not impeded by compaction.	Movement of air and water in the root zone has been obstructed by compaction. Anaerobic properties may have formed.
	Plant Community Potential and Thermo-dynamics	Plant Community Composition	The soil is capable of supporting a distribution of desirable plant species by vegetative layer (i.e. trees, shrubs, herbaceous) as identified in the potential vegetation. The site has not transitioned to an undesirable state.	Changes in soil or site characteristics indicate a shift towards a less productive (desired) plant community. There may be an increase in invasive plants or other undesirable species.	Site is unlikely to support the desired plant community or vegetation is absent, sparse or with layers missing.
		Canopy Cover and Soil Cover	Soil temperature and moisture regimes are maintained in conditions to support desired plant communities.	Canopy and soil cover changed enough to effect soil temperature and moisture, but not enough to affect regimes.	Canopy and soil cover changed enough to result in changes in soil temperature and moisture regimes.

Soil Function	Selected Attributes	Soil Quality Indicator	Forest Plan Desired Future Condition	Affected, but Not Impaired	Impaired Function
Hydrologic	Infiltration	Surface Structure	Surface structure is as expected for the site (e.g. granular, sub angular blocky, single grain).	Surface structure effected, but not impairing hydrologic function. (Sub angular blocky parting to platy soil structure.)	Surface structure platy, strongly compacted, or massive.
		Surface Pore Space	There are common to many tubular pores with high vertical continuity.	Common to few tubular pores.	Few tubular pores with low vertical continuity.
		Surface Crusting	Surface crusting is as expected for the soil type and landform.	Water compacted or non-biotic surface is abundant. Surface crust is thin and easily dispersed or broken.	Water compacted or non-biotic surface crust extensive. Non-biotic surface crust is thick and not easily dispersed or broken.
	Water Absorption and Storage	Available Water	Site water is as expected for the soil type and landform or has been improved.	Site water has been reduced but is able to support the desired vegetation community. Compaction is limited to the upper 12 inches of the soil.	Site water has been reduced and is unable to support the desired vegetation community. Compaction is deep into the soil profile, greater than 12 inches.
	Water Transmission	Subsurface Flow Connectivity *	Maintain subsurface flow connectivity with the streams (i.e. subsurface flow is not obstructed or intercepted).	Subsurface flow has been partially obstructed or intercepted.	Subsurface flow has been completely obstructed or intercepted.
Nutrient Cycling	Organic Matter Composition	Forest or Rangeland Floor	Forest and rangeland floor is distributed and the composition is appropriate for vegetation type and successional stage. Rangeland to be determined by Ecological Site Descriptions (ESD) specific to soil type.	Forest and rangeland floor on-site is at undesirable levels (low or high). If low, there is potential on-site for recruitment of the litter and duff layers.	Forest and rangeland floor is missing from the site. There is little potential on-site for recruitment of the litter and duff layers.

Soil Function	Selected Attributes	Soil Quality Indicator	Forest Plan Desired Future Condition	Affected, but Not Impaired	Impaired Function
		Fine Woody Material (less than 3 inches)	Fine woody material is on site in various stages of decay in amounts appropriate for habitat type.	Fine woody material is on-site in undesirable levels (low or high). If low, there is potential on-site for recruitment of fine woody material.	Fine woody material is absent from the site and there is little potential on-site for recruitment of fine woody material.
		Coarse Woody Material (Greater than 3 inches)	Coarse woody material is on site in various stages of decay and size classes in amounts appropriate for habitat type.	Coarse woody material is on-site in undesirable levels (low or high). If low, there is potential on-site for recruitment of coarse woody material.	Coarse woody material is absent from the site and there is little potential on-site for recruitment of coarse woody material.
	Nutrient Availability	Surface (A) horizon or mollic layer	"A" horizon is present, well distributed, not fragmented. The depth of the A horizon is within soil type expected range.	"A" horizon is present, but not evenly distributed. Changes in physical properties exist.	"A" horizon is absent or present in association with prominent plants. Properties are similar to those of the underlying subsoil.
		Nutrient Deficiency	Soil nutrients are maintained at levels to support desired vegetation.	Decreased vigor evident only in combination with other stressors (i.e. drought, pathogens).	Soil nutrients are below levels needed to support desired vegetation.
		Ash-cap	Soil ash-cap is intact and as expected for the site.	Ash-cap is partially missing or locally mixed within the root zone.	Ash-cap is absent from the site or mixed with subsoil deeper than the root zone.
Carbon Storage	Carbon Storage	Carbon Storage	The ability of the soil to store carbon has not been impaired.		The ability of the soil to store carbon has been impaired.
Support and Stability	Stability	Surface erosion (wind, rill, or sheet)	Erosion is occurring at natural levels or not evident. Bare ground is within expected ranges.	Erosion is discontinuous, poorly defined & not connected into any pattern. Effective ground cover is greater than 60%	Erosion actively expanding, well-defined, continuous & connected into a definite pattern. Effective ground cover is less than 60%

Soil Function	Selected Attributes	Soil Quality Indicator	Forest Plan Desired Future Condition	Affected, but Not Impaired	Impaired Function
		Site stability (mass erosion, landslide prone)	Site stability potential is unchanged, by human activity or stability has been improved.	Site stability potential is decreased for a short time in order to realize or improve resource values long-term.	Site stability potential is decreased.
	Deposition	Soil deposition	Deposition is at natural levels and recent depositional material is vegetated.	Soil and/or litter deposition is present. Fine litter may be patterned as small debris accumulations. Some recent depositional material is vegetated.	Soil and/or litter are deposited on the uphill side of logs, brush piles, etc. Soil may be moving from activity site. Recent depositional material is non-vegetated.
Filtering and Buffering	Filtering	Soil contamination	Soil is free of chemical or industrial contamination.	Minor, local soil contamination can be expected to dissipate naturally.	Soil is contaminated by chemical or industrial pollutants.

Soil productivity sustains forest soils in a condition that favors regeneration, survival, and long-term growth of desired forest vegetation and is critical to sustainable forest management. Maintaining forest soil productivity is less costly than correction or mitigation, such as trying to fix damaged soils after the fact.

The Forest has been classified into five categories of soil productivity from very low to very high **(Table 10 and Figure 13)**.

Areas of the Forest with high and very high productivity are the sites most likely to be able to support sustained timber production with minimal resource inputs. Twenty-one percent (21%) of the forest is in high and very high productivity.

Areas of the Forest with moderate productivity are able to support sustained timber production with a limited amount of resource inputs and a focus on maintaining soil productivity. Thirty-four percent (34%) of the forest is in moderate productivity.

Areas with low and very low productivity would require a high amount of resource inputs in order to be able to sustain long-term timber production. Forty-four percent (44%) of the forest is in low and very low productivity.

Table 10. Inherent Soil Productivity on the Colville National Forest.

Soil Productivity Class	Acres	Percent of Administrative Forest
Very High	54,056	4%
High	211,003	17%
Moderate	424,388	34%
Low	399,347	32%
Very Low	151,648	12%

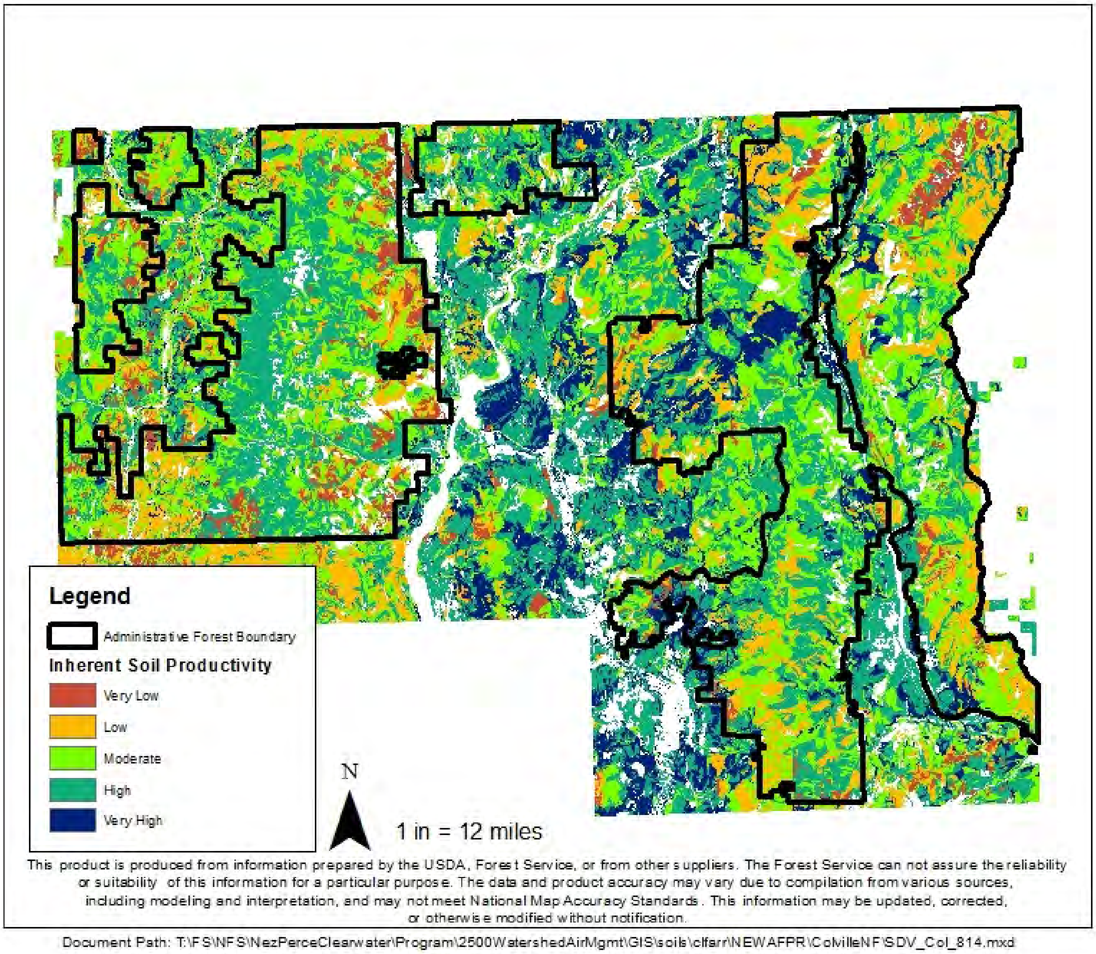

Figure 13. Map of Inherent Soil Productivity.

Maintaining soil productivity is critical to sustainable forest management. A decrease in soil productivity could affect the level of harvesting the forest can sustain, as well as other forest values, such as wildlife habitat and populations, and biodiversity. Certain attributes associated with the soils in the forest make them susceptible to reduced productivity. Ash-cap soils are susceptible to compaction, erosion, and soil mixing. Compaction restricts plant rooting, lowers water-holding capacity and decreases infiltration. Loss of surface soil through displacement and mixing decreases soil productivity. Displacement can result from temporary road construction, excavation and some ground-based harvest activities. Because volcanic ash is not replaced, the effects of any erosional or displacement losses of the ash-cap would be permanent.

The soil organic layer is extremely important to soils. Soil organic matter is fundamentally important to sustaining long-term soil productivity and is influenced by fire, harvest activities, decomposition and accumulation rates. The organic component of soil is a large reserve of nutrients and carbon and is the primary site for microbial and mycorrhizal activity. Soil organic matter influences many critical ecosystem processes, including the formation of soil structure and water stable aggregates. Soil organic matter is also the primary location for nutrient recycling and humus formation, which enhances nutrient storage and overall fertility. Soil organic matter depends on inputs of biomass (e.g., vegetative litter, fine woody debris and root abandonment) to build and maintain the surface soil horizons, support soil biota, enhance soil moisture-holding capacity, and prevent surface erosion.

Some controversy has emerged in recent years over the role of coarse woody debris in maintaining long-term soil productivity. The controversy involves the fact that coarse wood contains very little in the way of nutrients. Regardless, recent research still recommends leaving enough of this material on the ground after treatment to encourage biodiversity and ecological function (e.g., microbial action, mushroom production) (Page-Dumroese et al., 2006).

Forest-Wide Desired Conditions – Landscape Character and Dynamics

SOIL

Background Information for Soils
Soils are an integral part of ecosystems, their function, and the above and below ground interaction of organisms. These functions all contribute to ecological resilience. Soil conservation and protection is needed to effectively maintain soil quality and productivity and improve or protect watershed conditions. Generally, soil productivity standards and guidelines are not applied to administrative sites or dedicated use areas (such as roads, recreation sites, fuel breaks).

PLAN COMPONENTS

Soil Desired Condition - 1

Soil Productivity and Function

Soil productivity and function contributes to the long-term resilience of ecosystems. Management activities occur on soils with the inherent capability to support those activities.

Table 11. Soil Ecological Functions with Attributes and Indicators for Long-term Soil Productivity.

Soil Function	Selected Attributes	Soil Quality Indicator	Desired Condition

Soil Function	Selected Attributes	Soil Quality Indicator	Desired Condition
Biological	Roots	Root growth and distribution	Root growth, both vertically and laterally, is unimpeded. Root distribution and depth is expected for vegetation type and successional stage.
	Plant Community Potential and Thermodynamics	Plant Community Composition	The soil is capable of supporting a distribution of desirable plant species by vegetative layer (i.e. trees, shrubs, herbaceous) as identified in the potential plant community.
		Canopy Cover and Soil Cover	Soil temperature and moisture is maintained in conditions to support desired floral and faunal communities.
Hydrologic	Infiltration	Surface Structure	Surface structure is as expected for the site (e.g. granular, subangular blocky, single grain).
	Water Absorption and Storage	Available Water	Site water is as expected for the soil type or has been improved.
		Ash Cap	Soil ash cap is intact and as expected for the site.
	Water Transmission	Subsurface Flow Connectivity	Maintain subsurface flow connectivity (i.e. subsurface flow is not obstructed or intercepted).
Nutrient Cycling	Organic Matter Composition	Surface Organic Matter	The amount of organic material on top of the mineral soil is maintained at levels to sustain soil microorganisms and provide for nutrient cycling. The size, amount, and distribution of organic matter maintained on the mineral soil on a long term basis is consistent with the amounts that occur given the local ecological type, climate, and normal fire return interval for the area.
		Fine Woody Material	Fine woody material is on site in various stages of decay in amounts appropriate for habitat type.

Soil Function	Selected Attributes	Soil Quality Indicator	Desired Condition
		Coarse Woody Material	See Vegetative Systems - Biological Legacies Desired Condition - 3 Snags and coarse woody debris
	Nutrient Availability	Surface (A) horizon or mollic layer	The amount of organic matter within the mineral soil, indicated by the color and thickness of the upper soil horizon, is within the normal range of characteristics for the site, and is distributed normally across the area.
		Nutrient Deficiency	Soil nutrients are maintained at levels to support desired vegetation.
Carbon	Carbon Storage Potential		The soil's ability to store carbon is maintained.
Support and Stability	Stability	Surface erosion (wind, rill, or sheet)	Erosion is occurring at natural levels or not evident and an adequate level of soil cover is maintained to prevent accelerated erosion.
	Support	Site support (mass erosion, landslide prone)	Site stability potential is unchanged or stability has been improved. Soil stability varies from minor soil creep to active land flows according to soil characteristics, soil moisture, and triggers. Management activities avoid or do not accelerate underlying soil movement rates.
	Deposition	Soil deposition	Deposition is at natural levels and recent depositional material is vegetated.
Filtering and Buffering	Filtering	Soil contamination	The soil acts as a filter and buffer to protect the quality of water, air, and other resources by immobilizing, degrading or detoxifying chemical compounds or excess nutrients.

Soil Desired Condition - 2

Detrimental soil conditions

Surface erosion rates are within the natural range of variation for a given biophysical setting. There is no degradation of aquatic habitat and water quality from surface erosion rates resulting from permitted uses and management actions. Ecological and hydrologic functions are not impaired by soil compaction.

Soil Desired Condition - 3

Soil stability varies from minor soil creep to active land flows according to soil characteristics, soil moisture, and triggers. Management activities avoid or do not accelerate underlying soil movement rates.

Forest-Wide Objectives – Landscape Character and Dynamics

Soil Objective - 1

Within 5 years of plan implementation, stabilize, rehabilitate, or restore natural processes that support soil productivity and function on approximately 50 acres per year.

Forest-Wide Standards and Guidelines – Soil

Soil Guideline - 1

Total Soil Resource Commitment

The Total Soil Resource Commitment (TSRC) is no more than 5% of the forest. Inventoried roads are currently approximately 1.5%.

The soil stability and support function is maintained within the TSRC.

TSRC is the conversion of a productive site to an essentially non-productive site (0 to 40 percent of natural productivity) for a period of more than 50 years. Examples include system roads, administrative sites, developed campgrounds, rock quarries, mine sites, livestock watering facilities.

Soil Guideline - 2

Effective Ground Cover

Minimum effective ground cover following any soil disturbing management activity should be as shown in the following table.

Table 12. Minimum Effective Ground Cover Following Any Soil Disturbing Activity.

	Minimum percent effective ground cover	
Erosion hazard class	**1st year**	**2nd year**
Low (very slight)	20-30	30-40
Medium (moderate)	30-45	40-60
High (severe)	45-60	60-75
Very High (very severe)	60-75	75-90

Soil Guideline - 3

Native Topsoil

Native topsoil should be used where practical to meet restoration project objectives.

Past Management Impacts on Soil Quality and Productivity

Historically (pre-European settlement) and without anthropogenic (man-caused) disturbances, soil loss, soil compaction and nutrient cycling would probably have been within functional limits to sustain soil function and maintain soil productivity for most soils. The exception to this could be relatively short term effects of wildfire during times of drought. Since there were no political boundaries historically, soil condition would have been similar on similar soils throughout the range of the vegetation types.

Much of the current soil condition on the Colville National Forest is related to past management. Soil condition is affected by activities that occur or re-occur at the same place over time. Permanent loss of soil productivity has and could affect the level of goods and beneficial use of the forests in the future. Management activities that have affected soil condition include timber harvesting, site preparation, mechanical fuels treatments, prescribed fires, wildfires, road construction and use, recreation facility maintenance and use, grazing, and special uses. Some examples of impacts that have affected current soil condition include:

- Heavily compacted soils from forest vegetation treatments, grazing and recreation activities have caused or may cause reduced productivity for decades (Burger and Kelting, 1999).
- Land disturbing activities caused erosion of topsoil at rates greater than the soils natural ability to replace it, referred to as soil loss tolerance rate. This has resulted in permanent loss of soil productivity, as soils are considered a non-renewable resource.

- During the 19th and 20th centuries as more livestock numbers and acres were grazed over long seasons, range condition (and soil condition) declined. The effects of this early, heavy livestock use can still be seen on the ground.
- Road corridors that make up the forests' road system resulted in loss of soil productivity.
- Mineral extraction pits and mines resulted in permanent loss or reduction in soil productivity.
- Uncharacteristic wildfire resulted in erosion rates well beyond tolerance erosion rates.
- Footprints of administration and recreation sites, such as developed campgrounds, have reduced soil productivity.
- Permanent special use sites, such as communication towers and buildings eliminated soil productivity.

There are activities that have improved soil condition, as well as removing risk to soil productivity such as:

- Prescribed fire has removed fuels and undesirable plant material which impede vegetation growth and condition
- Thinning dense forest, woodland and invaded grassland have increased light and reduced water competition for desired understory grasses and shrubs.
- Channel restoration projects have restored bank and vertical stream bed stability to and have re-established water table levels on floodplains and terraces that result in increased vegetation/soil productivity.
- Decommissioning of unneeded roads has returned old roadbeds back to producing vegetation.
- Implementation of INFISH, Washington State Forest Practice Rules, Washington State Surface Mining Act, and USDA Forest Service Best Management Practices has resulted in decreased erosion and sedimentation from roads and timber harvests.

Need for Change

Old Forest Management and Timber Production

In the revision of the Forest Plan, three broad-scale concerns drove the need to consider how we address old forest management, especially the current reserve system approach at the landscape scale. These are:

- The recent history of uncharacteristic levels of disturbances resulting from fire and insect and disease activity that would likely continue into the future.
- The interaction between disturbances and climate change that elevates the importance of restoring landscape resiliency.

- Uncertainty about the recovery and viability of old forest-dependent species given the increased risk of uncharacteristically severe disturbances that is likely to be exacerbated by climate change impacts.

Motorized Recreation Trails

The current land management plans provide direction for summer and winter motorized uses, including identifying areas where such use may not be authorized or is limited, mainly for protection of aquatic, plant, and wildlife habitats.

The goal for recreation settings and experiences would include providing a spectrum of high quality, nature-based outdoor recreational settings where visitors access the Forest, including access to the biological, geological, scenic, cultural, and experiential resources of the Forest. Where the visitor's outdoor recreational experience involves few conflicts with other users, access is available for a broad range of dispersed recreation activities such as dispersed camping, rock climbing, boating, mushroom and berry picking, hunting, and fishing and these experiences are offered in an environmentally sound manner, are within budget limits, and contribute to the local economy.

Access

Three broad concerns drove the need to address road density:

1) the Forest can no longer afford to properly maintain the road system at current operational maintenance levels,

2) the current road system is not aligned with current and future resource management objectives, and

3) the existing road management direction is confusing and difficult to follow because it is scattered throughout current Forest Plan (Colville National Forest Land and Resource Management Plan), Forest Plan amendments (East-side Screens, Interim Inland Native Fish Strategy for the Intermountain, Northern, and Pacific Northwest Regions), national-level decisions (the Roadless Rule), and interim policy (e.g., Grizzly Bear No-Net-Loss, Lynx Agreement, the Interior Columbia Basin Strategy).

Recommended Wilderness Areas

By law, all National Forest System lands must be evaluated for possible wilderness recommendation during the plan revision process. The result of that evaluation shows whether a need exists for additional wilderness and what trade-offs may exist if the area is eventually designated part of the National Wilderness Preservation System.

Currently, the Salmo-Priest Wilderness covers about three percent of the Colville National Forest and evaluation showed a need for additional wilderness opportunities on the Forest. A review of possible areas showed some are available to fill this need.

Wildlife

The current Forest Plan provides limited protection for habitat connectivity, providing wildlife and aquatic crossing structures, and managing activities adjacent to the structures so they are used by wildlife.

Riparian and Aquatic Resource Management

The current Forest Plan includes riparian management direction from the Inland Native Fish Strategy. This approach appears to have either maintained or improved riparian and aquatic habitat conditions at the watershed and larger scales.

Objectives for Riparian Management Areas would give emphasis to maintaining or restoring the riparian and aquatic structure and function of intermittent and perennial streams, confer benefits to riparian-dependent plant and animal species, enhance habitat conservation for organisms that are dependent on the transition zone between upslope and riparian areas, contribute to improved water quality and flows, and contribute to a greater connectivity of the watershed for both riparian and upland species.

Desired conditions for Riparian Management Areas within any given watershed are to have compositions of native flora and fauna and a distribution of physical, chemical, and biological conditions commensurate with natural processes.

Environmental Consequences

Methodology

Old Forest Management

Plant water availability is the resource most limiting productivity within different plant associations groups on the Forest. Information about the soil resource combined with climate can be used to identify different soil drought stress levels and their ability to support dense old forest vegetation structure into the future.

Assumptions

Plant water availability is the resource most limiting productivity within different plant associations groups on the Forest. Information about the soil resource combined with climate can be used to identify different soil drought stress levels and their ability to support dense old forest vegetation structure into the future.

Methods of analysis

Four classes of suitability for old growth management areas (not suited, low, medium, and high suitability) was developed to assist in analyzing placement of old growth management areas.

- Step 1: For each alternative the analysis unit was identified. For example, No Action is the fixed old growth management areas while the proposed action is all actively managed portions of the forest = management areas 3A, 5, 6, 7, and 8.
- Step 2: The droughty soils layer was overlaid to provide an estimate of potential productivity and the percentage of each management area in each productivity class was determined based on the droughty soil index map.

Table 13. Area Extent of Site Productivity Ratings for Old Forest Management Areas by Alternative.

Alternative	Management Areas	Acres/ % Area	High	Moderate	Low	Unsuited	Total
No Action	Focused and General Restoration	Acres	5735	15,533	4165	4717	30,150
		Area	19%	51%	14%	16%	
Proposed Action	Focused and General Restoration	Acres	189,998	390,736	77,417	90,602	748,753
		Area	25%	53%	10%	12%	
Alternative R	Focused and General Restoration Late Forest	Acres	191,708	397,065	80,121	94,909	763,803
		Area	25%	52%	11%	12%	
Alternative P	Focused and General Restoration	Acres	189,998	390,736	77,417	90,602	748,753
		Area	25%	53%	10%	12%	
Alternative B	Restoration area Active Management	Acres	193,154	399,338	80446	95105	768,043
		Area	25%	52%	11%	12%	
Alternative O	Restoration area Responsible	Acres	190,759	394,059	78,872	93,692	757,382
		Area	25%	52%	11%	12%	

Alternative	Management Areas	Acres/ % Area	High	Moderate	Low	Unsuited	Total
	Management						

Timber Production

Assumptions

- Timber suitability and rangeland capability
  - Lands suitable for timber production are the land base used to calculate timber production harvest levels. Lands are removed from the timber production base for six reasons.
    - Statute, Executive Order, or regulation has withdrawn the land from timber production.
    - The Secretary of Agriculture or the Chief has withdrawn the land from timber production.
    - Timber production would not be compatible with the achievement of the desires conditions and objectives established by the plan for those lands.
    - The technology is not currently available for conducting timber harvest without causing irreversible damage to soil, slope, or other watershed conditions.
    - There is no reasonable assurance that such lands can be adequately restocked within 5 years after final regeneration harvest.
    - The land is not forest land.

Methods of Analysis

- Timber suitability and rangeland capability
  - Areas on the Colville that are considered unsuitable for timber production from a soils perspective fall into these three groupings:
    - Areas that are generally not forested because the site is too hot and dry (Mollisols). This condition is more common on the western part of the forest and generally corresponds to low elevation sites on south and west facing slopes.

- Areas that are generally not forested and areas that are generally forested but would be difficult to regenerate artificially because the soil is extremely shallow and/or rocky.
- Areas where the water table is at or near the surface either permanently or seasonally. These conditions typically occur near streams and many of these mapping units would probably be excluded in RHCAs.

Motorized Recreation Trails

Assumptions

Motorized access in areas of sensitive soils has the potential to effect soil erosion and soil productivity potentials. Some soil types have low bearing strength when wet and would not support motorized access during periods of high soil moisture. Thin ash-cap soils are easily displaced by motorized equipment negatively affecting the functioning of these soils. The hydrologic functioning of soils that store large quantities of water within the landscape can be disrupted by trails that cause excessive drainage of water in these areas.

Methods of Analysis

Each alternative, which varies in where it allows motorized access, has a different potential to negatively affect key soil functions.

- Step 1: The analysis unit for each alternative was determined based on areas of allowable motorized recreation trails.
- Step 2: Was repeated three times, once for each bullet below:
  - Soils having ash-caps with silt and silt loam soil textures and those in the medial soil taxonomic particle size classes are considered to have low bearing strength when moist.
  - Soil taxonomy was used to identify different soil sensitivities to displacement. Andic and vitrandic subgroups are sensitive due to their thin (<13 inches depth) ash-caps, Andisols soil orders with thicker ash-caps were identified as moderately sensitive and soil with no ash-cap were considered not sensitive.
  - Soil that store large quantities of water include soils having a hydric soil rating, soils having aquic soil moisture regimes, and flooded/occasionally flooded, poorly and somewhat poorly drained soils.

- Step 3: The percentage of each Back County Management allocation that has sensitive soils was then determined (i.e. low bearing strength, sensitive ash-caps, or water storing soils).

Riparian and Aquatic Resource Management

Assumptions

Soil drought index can be used to identify riparian and aquatic resource management areas that may be overstocked and a higher priority for restoration treatments. Areas of high water storage capacity on the landscape can hold large quantities of water to moderate peak flows and supply water for stream flows later in the summer months.

Methods of Analysis

Identifying high priority areas for restoration treatments based on soil drought stress.

- Step 1: Riparian and Aquatic Resource Management areas were identified.
- Step 2: These polygons were overlaid with the soil drought index map.
- Step 3: The percentages of five soil drought stress classes (Low, Low to Moderate, Moderate, Moderate to High, and High) were identified.

Identifying where areas of high water storage capacity are on the landscape.

- Step 1: Riparian and Aquatic Resource Management areas were identified.
- Step 2: These polygons were overlaid with the water storage and transmission layer map.
- Step 3: The percentage area of soils having high water storage capacity were identified.

Summary of Effects Common to All Alternatives

Timber suitability and rangeland capability

Lands suitable for timber harvest includes lands suitable for timber production as well as lands where timber harvest can be used as a tool for reasons other than timber production, such as wildlife habitat improvement or thinning to reduce wildfire risk. Areas of the Colville National Forest that have been identified as suitable for timber harvest but not timber production from a soils perspective are soils classified as Mollisols and mollic subgrades. These soils were developed in a grassland or savannah type ecosystem and would provide opportunity to restore these ecosystems with the use of timber harvest.

An assessment of range capability has been completed for the forest as well. As defined in 36 CFR 219.3, capability refers to the potential of an area of land to produce resources, supply goods and services, and allow resource uses under an assumed set of management practices and at a given level of management intensity. Capability depends upon current resource conditions and site conditions, such as climate, slope, landform, soils, and geology, as well as the application of management practices, such as silviculture or protection from fire, insects, and disease. Capable range on the Colville National Forest does not include lands considered rock outcrops, very wet and rubble-land. This category includes lands classified as rock outcrop, rubble-land, lithic, serpentinitic, river-wash, very wet or badlands in the soil resource coverages for the National Forest. Lands classified as shallow soils were removed from capable range as well because of inherent productivity limitations. Because slope limits the accessibility of livestock to potential forage, steep slopes need to be withdrawn from the capable land base. A 40 percent slope was determined to be a reasonable threshold for cattle and a 70 percent slope threshold was considered appropriate for sheep on the Forest. Lands steeper than these thresholds were removed from the land base.

Motorized Recreation Trails

Table 14 shows the percentage area identified for motorized recreation trails having silty ash-cap soils by alternative. When soil moistures are high these silty ash-cap soils would have low equipment bearing strengths. Off road vehicle use in these areas under moist soil conditions are expected to result in excessive rutting and soil puddling that can both reduce water infiltration into the soil and result in channeled runoff and accelerated soil erosion.

Table 14. Area Extent of Silty Ash-Cap Soils that are Sensitive to Motorized Recreation Trails due to Bearing Strength under Higher Soil Moisture Conditions by Alternative.

Alternative	Management Area	Acres/ % Area	Silty Ash-cap soils (sensitive)	Totals
No Action	Semi-primitive Motorized	Acres	10,979	26,399
		Area	42%	
Proposed Action	Backcountry Motorized	Acres	11,203	37,802
		Area	30%	
Alternative R	Backcountry Motorized	Acres	1891	6060
		Area	31%	
Alternative P	Backcountry Motorized	Acres	10,671	36,308
		Area	29%	
Alternative B	Backcountry Motorized	Acres	1873	6031
		Area	31%	

Alternative	Management Area	Acres/ % Area	Silty Ash-cap soils (sensitive)	Totals
Alternative O	Backcountry Motorized	Acres	10,485	35,553
		Area	29%	

Table 15 shows the percentage of the area identified for motorized recreation trails having different sensitivities to soil displacement of ash-caps by alternative. Displacement of these highly productive ash-cap soil layers would have negative effects to inherent site productivity.

Table 15. Area Extent of Soils having Different Sensitivities to Soil Displacement by Equipment Operations due to Presence or Absence of Ash-Cap and Ash-Cap Depth by Alternative.

Alternative	Management Area	Acres/ % Area	No Ash-cap (low sensitivity)	Thick Ash-cap (moderate sensitivity)	Thin Ash-cap (high sensitivity)	Totals
No Action	Semi-primitive Motorized	Acres	231	8510	17658	26,399
		Area	1%	32%	67%	
Proposed Action	Backcountry Motorized	Acres	38	16,575	21,189	37,802
		Area	>1%	44%	56%	
Alternative R	Backcountry Motorized	Acres	35	177	5848	6060
		Area	>1%	3%	97%	
Alternative P	Backcountry Motorized	Acres	38	15,771	20,499	36,308
		Area	>1%	43%	57%	
Alternative B	Backcountry Motorized	Acres	35	159	5837	6031
		Area	>1%	3%	97%	
Alternative O	Backcountry Motorized	Acres	138	15,539	19,876	35,553
		Area	>1%	44%	56%	

Table 16 shows the percentage of the area identified for motorized recreation trails having water storing soils by alternative. These soils are sensitive to motorized recreation trail use due

to soil disturbances that could negatively affect the soil hydrologic function, disrupting water flow in the soil and causing ground water to become surface flow.

Table 16. Area Extent of Water Storing Soils that are Sensitive to Motorized Recreation Trails due to Soil Disturbances that Could Negatively Affect the Soil Hydrologic Function by Alternative.

Alternative	Management Area	Acres/ % Area	Wet soils (sensitive)	Totals
No Action	Semi-primitive Motorized	Acres	3525	26,399
		Area	13%	
Proposed Action	Backcountry Motorized	Acres	1343	37,802
		Area	4%	
Alternative R	Backcountry Motorized	Acres	1338	6060
		Area	22%	
Alternative P	Backcountry Motorized	Acres	1343	36,308
		Area	4%	
Alternative B	Backcountry Motorized	Acres	1332	6031
		Area	22%	
Alternative O	Backcountry Motorized	Acres	1343	35,553
		Area	4%	

Riparian and Aquatic Resource Management

Table 17 shows acres of riparian and aquatic resource management areas over the whole Forest and discloses the number of acres or percentage of the riparian and aquatic resource management areas that have different soil drought index ratings. Areas having a moderate or high drought index rating should be a higher priority for vegetation management treatments that can help to preserve forest health and promote shading potential in these droughty soil areas.

Table 17. Area Extent of Soils having Different Levels of Drought Stress within Riparian and Aquatic Resource Management Areas.

Management	Acres/ %	Drought Index

Area	Area	Low	Low to Moderate	Moderate	Moderate to High	High	Total
Riparian and Aquatic Resource Management Areas	Acres	1664	67,415	74,709	12,716	2787	159,291
	% Area	1%	42%	47%	8%	2%	

Table 18 indicates acres of riparian and aquatic resource management areas over the whole Forest and discloses the number of acres or percentage of the riparian and aquatic resource management areas that have water storing soils. Recognition of these important water storing areas can help managers highlight and prioritize restoration opportunities in degraded areas. Management opportunities include managing these areas to increase water tables to historic levels, restoration of riparian vegetation in disturbed areas, and identifying mitigation measures and project design criteria to help assure soil disturbances are not affecting soil hydrology.

Table 18. Area Extent of Water Storing Soils within Riparian and Aquatic Resource Management Areas.

Management Area	Acres/ % Area	Water Storage Areas	Total
Riparian and Aquatic Resource Management Areas	Acres	89,984	159,291
	% Area	56%	

Alternative 1 – No Action

This is the current Colville Forest Plan as amended. No action means the current management direction would continue.

Summary of Effects

Old Forest Management

No Action – "Old Forest Management"

- The current forest plan identifies fixed old growth reserves on about three percent of the total Forest land base and the Eastside Screens provide management direction for their management.
- Approximately 16% of the current Old Forest Management areas are unsuited for timber production and another 14% of these areas have a low site productivity that is likely marginal for supporting Old Forest Management.

Motorized Recreation Trails

No Action – "Motorized and Non-motorized Recreation"

- Off road vehicle use is allowed in designated areas and trails in Management Areas 3A (Recreation), 3C (Downhill Skiing), 5 (Scenic/Timber), 7 (Wood/Forage), and 10 (Semi-Primitive Motorized Recreation). These Management areas cover 26,399 acres within the Colville National Forest.
- Approximately 42% of the motorized off road vehicle use areas have silty ash-cap soils that are expected to have low equipment bearing strength under higher soil moisture conditions. Approximately 67% of this area has highly sensitive thin ash-cap soils that are easily displaced by motorized equipment operations. And approximately 13% of this area has water storing soils on which soil disturbance could result in negative effects to soil hydrology.

Alternative 2 – Proposed Action

Summary of Effects

Old Forest Management and Timber Production

Proposed Action – “Old Forest Management”

- The proposed action uses a “whole landscape” approach for providing late forest structure, allowing late structure forests to shift location in response to ecological process. These types of management enables closer approximation of natural disturbance regimes by allowing closer approximation of natural disturbance regimes that can move around the landscape with disturbance.

- While under the Proposed Action restoring late forest structure can occur within all management areas across the Forest. This analysis was limited to management areas that allow active management.

- Within managed land allocations approximately 78 % of the land base consists of high or moderate site productivity, thus allowing a substantial land base for restoring and maintaining Old Forest Management.

Motorized Recreation Trails

Proposed Action – “Backcountry and Backcountry Motorized Management Areas”

- The Proposed Action has two Backcountry management areas, motorized and non-motorized. Backcountry (BC) Management Areas (MAs) emphasize non-motorized recreation opportunities while Backcountry Motorized (BCM) management areas support motorized backcountry recreation opportunities. In the proposed Action, approximately 6% (37,802 acres) of the Forest is allocated to Backcountry Motorized management and approximately 8% is allocated to Backcountry non-motorized.

- Approximately 30% of the BCM Management Areas have silty ash-cap soils that are expected to have low equipment bearing strength under higher soil moisture conditions. Approximately 56% of this area has highly sensitive thin ash-cap soils that are easily displaced by motorized equipment operations. And approximately 4% of this area has water storing soils on which soil disturbance could result in negative effects to soil hydrology.

Alternative R

Summary of Effects

Old Forest Management and Timber Production

Alternative R – "Old Forest Management"

- Alternative R uses a fixed reserve management approach to maintain late forest structure habitats which covers about 44 percent of the Forest. These reserves are called "late forest structure emphasis areas" and overlay other management areas. Although similar to the Proposed Action the key difference between the Proposed Action and Alternative R for late forest structure is that late forest structure areas in the Proposed Action are managed dynamically at the landscape scale whereas Alternative R proposes management of static reserves for late forest structure areas.

- Similar to the Proposed Action approximately 77 percent of the late forest structure emphasis areas land base consists of high or moderate site productivity, thus allowing a substantial land base for identifying Old Forest Management areas.

- An important difference between Alternative R and the Proposed Action is that once late forest structure emphasis areas are identified they would be static and subject to changes in their conditions as a result of management and or disturbance.

Motorized Recreation Trails

Alternative R – "Backcountry and Backcountry Motorized Management Areas"

- Alternative R has two Backcountry management areas, motorized and non-motorized. Under alternative R the 6060 acre Lost Creek Potential Wilderness Area (PWA) makes up the single BCM management area for this alternative.

- Approximately 31% of the Lost Creek Potential Wilderness Area, BCM Management Area, has silty ash-cap soils that are expected to have low equipment bearing strength under higher soil moisture conditions. Approximately 97% of this area has highly sensitive thin ash-cap soils that are easily displaced by motorized equipment operations. And approximately 22% of this area has water storing soils on which soil disturbance could result in negative effects to soil hydrology.

Alternative P

Summary of Effects

Old Forest Management and Timber Production

Alternative P

- Alternative P uses the same "whole landscape" approach as the Proposed Action for providing late forest structure, allowing late structure forests to shift location in response to ecological process. Thus the effects of Old Forest Management would be the same as the Proposed Action.

Motorized Recreation Trails

Alternative P – "Backcountry and Backcountry Motorized Management Areas"

- Alternative P has two Backcountry management areas, motorized and non-motorized. Under alternative P, approximately 5% (36,308 acres) of the Forest is allocated to Backcountry Motorized management and approximately 5% is allocated to Backcountry non-motorized.
- Approximately 29% of the BCM Management Areas have silty ash-cap soils that are expected to have low equipment bearing strength under higher soil moisture conditions. Approximately 57% of this area has highly sensitive thin ash-cap soils that are easily displaced by motorized equipment operations. And approximately 4% of this area has water storing soils on which soil disturbance could result in negative effects to soil hydrology.

Alternative B

Summary of Effects

Old Forest Management and Timber Production

Alternative B

- Alternative B uses a fixed reserve management approach to maintain late forest structure habitats which covers about 31 percent of the Forest. These reserves are called "late forest structure emphasis areas" and overlay other management areas.

- Within managed land allocations approximately 77% of the land base consists of high or moderate site productivity, thus allowing a substantial land base for restoring and maintaining Old Forest Management.

Motorized Recreation Trails

Alternative B – "Backcountry and Backcountry Motorized Management Areas"

- Alternative B has two Backcountry management areas, motorized and non-motorized. Under alternative B the 6031 acre Lost Creek Potential Wilderness Area (PWA) makes up the single BCM management area in this alternative.
- Approximately 31% of the Lost Creek Potential Wilderness Area, BCM Management Area, has silty ash-cap soils that are expected to have low equipment bearing strength under higher soil moisture conditions. Approximately 97% of this area has highly sensitive thin ash-cap soils that are easily displaced by motorized equipment operations. And approximately 22% of this area has water storing soils on which soil disturbance could result in negative effects to soil hydrology.

Alternative O

Summary of Effects

Old Forest Management and Timber Production

Alternative O

- Alternative O uses a fixed reserve management approach to maintain late forest structure habitats which covers about 33 percent of the Forest. These reserves are called "late forest structure emphasis areas" and overlay other management areas.
- Within managed land allocations approximately 77% of the land base consists of high or moderate site productivity, thus allowing a substantial land base for restoring and maintaining Old Forest Management.

Motorized Recreation Trails

Alternative O – "Backcountry and Backcountry Motorized Management Areas"

- Alternative O has two Backcountry management areas, motorized and non-motorized. Under alternative O, approximately 5% (36,308 acres) of the Forest is allocated to Backcountry Motorized management and approximately 16% is allocated to Backcountry non-motorized.

- Approximately 29% of the BCM Management Areas have silty ash-cap soils that are expected to have low equipment bearing strength under higher soil moisture conditions. Approximately 56% of this area has highly sensitive thin ash-cap soils that are easily displaced by motorized equipment operations. And approximately 4% of this area has water storing soils on which soil disturbance could result in negative effects to soil hydrology.

Cumulative Effects – Common to All Alternatives

Bounding of the Cumulative Effects

Area - Effects on soil productivity are site specific and not spatially mobile over the analysis area. The analysis area for cumulative effects to soils is the treatment unit or activity area. The activity area as defined in Region 6 Soil Quality Standards as "The total area of ground impacting activity, and is a feasible unit for sampling and evaluating." The effects of past, present, and reasonably foreseeable future actions to soils typically involve the area of disturbance itself and does not move outside the area disturbed. The development and movement of soils occurs on a geologic time scale and this area bounding reflects cumulative effects to soils.

Time - The time bounding for cumulative effects encompasses previous disturbances from prior wildfire, timber harvest, and grazing as detailed in the existing condition. Disturbance to soil can last for decades and even centuries (Amundson and Jenny, 1997; Jenny, 1941). For reasonably foreseeable future actions, the bounding is five years in the future.

Past, Present, and Foreseeable Activities Relevant to Cumulative Effects Analysis

Past management activities and disturbance on Colville National Forest lands including timber harvest, silvicultural activities, grazing, road building and wildland fire can have cumulative effects on the soil resource. Limited mining and special uses have also occurred on the Colville National Forest. Impacts to soil productivity and soil quality from past management include soil compaction, soil erosion and topsoil loss, soil puddling, soil displacement, and detrimental soil burning (typically from high severity wildland fires). Grazing, fire suppression, and other activities such as road building have cause detrimental effects to soil moisture regimes including down cutting and dewatering of meadows and wetlands.

There are no foreseeable activities that would vary from present activities. Present activities include timber harvest, fuel reduction (prescribed fire and mechanical), road construction and maintenance, silvicultural treatments, grazing (including llamas), special use permits, and providing recreational opportunities. There is also the potential for wildland fires (suppression and for resource benefit). Foreseeable and present actions also include stream, meadow, and wetland restoration as well as road decommissioning and obliteration.

All alternatives would maintain or improve soil function, soil productivity, and soil quality.

No Action Alternative Cumulative Effects

Within the projected 15 or 20 year life of the Forest Plan, areas of mechanical treatment are possible to be returned to within that time frame, especially fuel break treatments. The no action alternative includes a 20% percent detrimental soil disturbance threshold to limit the cumulative effects to soils if multiple treatments across multiple timeframes are placed on the landscape.

Action Alternatives (Proposed Action, R, P, B, O) Cumulative Effects

The action alternatives would continue to improve soil conditions on the landscape. Placed within all these alternatives is the restoration of 50 acres of detrimental soil condition per year. This would decrease detrimental soil condition and remediate some of the cumulative effects created from placing multiple treatments across the same activity area. Additional desired conditions, goals, objectives, standards, and guidelines in the action alternatives would improve and preserve soil function and soil quality.

When analyzed with past, present, and reasonably foreseeable future activities, the action alternatives would improve soil reliance and low risk to damage from high severity wildfire and be responsive to climate change. Due to the funding and staff forecast and the reality that timber harvest, silvicultural treatments, and prescribed fire treatments would be the same extent across action alternatives

Compliance with Relevant Laws, Regulations, Policies and Plans

The proposed action and the alternatives would meet soil management goals, maintenance of soil quality, and limit of detrimental soil condition. The proposed action and alternatives comply with the standards and guidelines described in the Forest Service Manual and Handbook, Region 6 Soil Quality Standards and Guidelines (1999), and National Best Management Practice for Water Quality Management on National Forest Systems Lands (2012).

Other Agencies and Individuals Consulted

Jason Jimenez – Forest Soil Scientist – Colville National Forest

William Swartz – Soil and Hydrology Technician – Colville National Forest

Acronyms

AET – Actual Evapotranspiration

FSM – Forest Service Manual

NCSS -National Cooperative Soil Survey

NRCS – National Resource Conservation Service

PET - Potential Evapotranspiration

PWA – Potential Wilderness Area

SOM – Soil Organic Matter

SSUGRO – Soil Survey Geographic Database

TSRC – Total Soil Resource Commitment

Glossary

Activity area: An activity area is the area extent of a treatment unit, excluding system roads, as well as landings and temporary roads, outside the treatment unit boundary. An activity area may also be a prescribed burn unit or any area delineated on the ground for a specific treatment.

Alfisols: A soil order in USDA soil taxonomy. Alfisols form in semiarid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility.

Andisols: A soil order in USDA soil taxonomy. Andisols are soils formed in volcanic ash and defined as soils containing high proportions of glass and amorphous colloidal materials, including allophane, imogolite, and ferrhydrite.

Areal extent: The measured area (length times width or diameter) affected by an activity.

Biological indicators of soil quality: Biological indicators include measures of living organisms or their activity used as indicators of soil quality.

Chemical indicators of soil quality: Indicators that include tests of organic matter, pH, electrical conductivity, heavy metals, cation exchange capacity, and other parameters.

Compaction: Soil compaction, also known as soil structure degradation, is the increase of bulk density or decrease in porosity of soil due to externally or internally applied loads. Soil compaction can adversely affect nearly all physical, chemical and biological properties and functions of soil.

Dynamic soil quality: An aspect of soil quality relating to soil properties that changes as a result of soil use and management or over the human time scale.

Erosion: Soil erosion is the detachment and movement of soil or rock by water, wind, ice, or gravity.

Effective Soil Cover: Material that will protect the soil from raindrop impact and/or resist the accumulation and channelization of water. Material includes surface rocks, vegetation, wood shreds, straw, or native plant materials.

Forest floor: The forest floor includes all organic soil horizons consisting of dead plant material on the surface of the mineral soil surface.
Glacial cirques: A cirque (French, from the Latin work, circus) is an amphitheater like valley head, formed at the head of a valley glacier by erosion.
Glacial outwash: is a plain formed of glacial sediments deposited by meltwater outwash at the terminus of a glacier.
Glacial moraines: Is a material transported by a glacier and then deposited. There are eight types of moraines, six of which form recognizable landforms, and two of which exist only while the glacier exists.
Glacial till: Glacial till is unsorted glacial sediment derived from the erosion and entrainment of material by the moving ice of a glacier. It is deposited some distance down ice to form terminal, lateral, medial and ground moraines.
Glacial troughs: A valley shaped by valley glaciers and ice streams within ice sheets that has a distinct trough form.
Hydric soil: A soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.
Inherent soil quality: An aspect of soil quality relating to a soil's natural composition and properties as influenced by the factors and processes of soil formation in the absence of human effect.
Lacustrine deposits: Sediments and chemical precipitates deposited in lakes.
Lacustrine soils: Soil formed on or from lacustrine deposits.
Mollisols: A soil order in USDA soil taxonomy. Mollisols form in semi-arid to semi-humid areas, typically under a grassland cover. Their parent material is typically base-rich and calcareous and includes limestone, loess, or wind-blown sand.
Nutrient cycling: The soils storing, moderating the release of, and cycling of nutrients and other elements.
Periglacial: geomorphic environments were located at periphery of past Pleistocene glaciers. In these environments, the landscape is dominantly influenced by frost action.
Physical indicators of soil disturbance: Indicators of soil disturbances that may vary with management and that include bulk density, aggregate stability, infiltration, hydraulic conductivity, and penetration resistance.
Pleistocene epoch: A time period that spanned from 2.6 million to 11,700 years ago.
Soil drought index: Indices for objectively quantifying the severity of drought on different soils and landscapes.
Soil fertility: The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops.
Soil function: Includes any service, role, or task that soil performs including sustaining biological activity, regulating and partitioning water and solute flow, filtering, buffering, degrading, and detoxifying pollutants, storing and cycling nutrients, and providing support to vegetation.
Soil organic matter: Soil organic matter is the component of soil, consisting of plant and animal residues at various stages of decomposition.

Soil quality: The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation and ecosystem health.

Soil quality indicator: A quantitative or qualitative measure used to estimate soil functional capacity. Indicators should be adequately sensitive to change, accurately reflect the processes or biophysical mechanisms relevant to the function of interest, and be cost effective and relatively easy and practical to measure. Soil quality indicators are often categorized into biological, chemical, and physical indicators.

Soil quality monitoring: The act of tracking trends in quantitative indicators or the functional capacity of the soil to determine the success of, or change associated with, management practices (land uses or disturbances) or the need for additional management changes. Monitoring involves the orderly collection, analysis, and interpretation of data from the same locations over time.

Total Soil Resource Commitment: Total amount of area that is dedicated to other uses other than growing vegetation. TSRC is the conversion of a productive site to an essentially non-productive site (0 to 40 percent of natural productivity) for a period of more than 50 years. Examples include system roads, administrative sites, developed campgrounds, rock quarries, mine sites, livestock watering facilities.

References

Amundson, R., Jenny, H., 1997. On a State Factor Model of Ecosystems. BioScience 47, 536–543. doi:10.2307/1313122

Batjes, N.H., 1996. Total carbon and nitrogen in the soils of the world. Eur. J. Soil Sci. 47, 151–163.

Booth, D.B., Troost, K.G., Clague, J.J., Waitt, R.B., 2003. The Cordilleran Ice Sheet, in: A.R. Gillespie, S.C.P., and B. F. Atwater (Ed.), Developments in Quaternary Sciences, The Quaternary Period in the United States. Elsevier, pp. 17–43.

Burger, J.A., Kelting, D.L., 1999. Using soil quality indicators to assess forest stand management. For. Ecol. Manag. 122, 155–166.

Davidson, E.A., Lefebvre, P.A., 1993. Estimating regional carbon stocks and spatially covarying edaphic factors using soil maps at three scales. Biogeochemistry 22, 107–131.

Davis, C., Karver, M., Kovalchik, B., Lillybridge, T., Narisco, C., 2004. Landtype Associations of Northcentral Washington.

Fisher, R.F., Binkley, D., 2000. Ecology and Management of Forest Soils, John Wiley & Sons. N. Y.

Franzmeier, D.P., Lemme, G.D., Miles, R.J., 1985. Organic carbon in soils of north central United States. Soil Sci. Soc. Am. J. 49, 702–708.

Grigal, D.F., Vance, E.D., 2000. Influence of soil organic matter on forest productivity., in: New Zealand Journal of Forestry Science. New Zealand Forest Research Institute, pp. 169–205.

Hassett, J.E., Zak, D.R., 2005. Aspen Harvest Intensity Decreases Microbial Biomass, Extracellular Enzyme Activity, and Soil Nitrogen Cycling. Soil Sci. Soc. Am. J. 69, 227. doi:10.2136/sssaj2005.0227

Hurt, G.W., Whited, P.M., Pringle, R.F., 1996. Field indicators of hydric soils in the United States: A guide for identifying and delineating hydric soils.

Hyvönen, R., Olsson, B.A., Lundkvist, H., Staaf, H., 2000. Decomposition and nutrient release from Picea abies (L.) Karst. and Pinus sylvestris L. logging residues. For. Ecol. Manag. 126, 97–112.
Jenny, H., 1941. Factors of Soil Formation: A System of Quantative Pedology. McGraw-Hill, New York.
Johnson, D.W., Curtis, P.S., 2001. Effects of forest management on soil C and N storage: meta analysis. For. Ecol. Manag. 140, 227–238. doi:10.1016/S0378-1127(00)00282-6
Jones, F., Embody, D., Peterson, W., 1961. Landslides along the Columbia River Valley, Northeastern Washington (US Geological Survey Professional Paper No. 367).
Kern, J.S., 1994. Spatial patterns of soil organic carbon in the contiguous United States. Soil Sci. Soc. Am. J. 58, 439–455.
Mälkönen, E., 1976. Effect of whole-tree harvesting on soil fertility.
Page-Dumroese, D.S., Jurgensen, M.F., Tiarks, A.E., Ponder, J., Sanchez, F.G., Fleming, R.L., Kranabetter, J.M., Powers, R.F., Stone, D.M., Elioff, J.D., 2006. Soil physical property changes at the North American Long-Term Soil Productivity study sites: 1 and 5 years after compaction. Can. J. For. Res. 36, 551–564.
Powers, R.F., Andrew Scott, D., Sanchez, F.G., Voldseth, R.A., Page-Dumroese, D., Elioff, J.D., Stone, D.M., 2005. The North American long-term soil productivity experiment: Findings from the first decade of research. For. Ecol. Manag. 220, 31–50. doi:10.1016/j.foreco.2005.08.003
Pritchett, W.L., 1979. Properties and management of forest soils. John Wiley & Sons.
Qualls, R.G., Haines, B.L., Swank, W.T., 1991. Fluxes of dissolved organic nutrients and humic substances in a deciduous forest. Ecology 254–266.
Schlesinger, W.H., 1977. Carbon balance in terrestrial detritus. Annu. Rev. Ecol. Syst. 51–81.
Schmidt, M.W., Torn, M.S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I.A., Kleber, M., Kögel-Knabner, I., Lehmann, J., Manning, D.A., 2011. Persistence of soil organic matter as an ecosystem property. Nature 478, 49–56.
Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A., 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States.
Soil Survey Staff. 2014. Keys to Soil Taxonomy, 12th ed. USDA-Natural Resources Conservation Service, Washington, DC.
Trettin, C.C., Jurgensen, M.F., Kimble, J.M., 2003. Carbon cycling in wetland forest soils. Lewis Publishers, Boca Raton, London, New York, Washington, DC.

Appendices

Appendix A – Monitoring

Management actions that have potential to detrimentally affect soil quality, soil productivity, and soil function shall be monitored. Monitoring of soils prior to management activities allow for determination of the existing condition and sets a baseline to determine the change in condition post management activity. Detrimental soil conditions have been proven in literature to affect soil function and soil productivity. Monitoring would be conducted typically using the Forest Service National Soil Disturbance Monitoring Protocol (Page-Dumroese, 2009).

The objective is to answer the monitoring question "Are the long term soil health and productivity desired conditions being met or is improvement being made to attain desired conditions?"

The following effectiveness monitoring would be conducted:

- Ground based timber harvest has the greatest potential to detrimentally affect soil function and soil productivity (Page-Dumroese, 2010). To monitor soil conditions post ground based timber harvest, the Forest Service National Soil Disturbance Monitoring Protocol should be conducted on 10 units per year post harvest. Some units should receive monitoring pre-treatment. The monitoring should occur at a 5% margin of error and a 90% confidence interval.
- Mechanical based fuel reduction can include mechanical pilling, mastication, and biomass removal. Due to the use of heavy equipment with these treatments, they have potential to increase detrimental soil condition above Regional Soil Quality Standards (USDA, 1998). The Forest Service National Soil Disturbance Monitoring Protocol should be conducted on 5 units per year post treatment. Some units should receive monitoring pre-treatment. The monitoring should occur at a 5% margin of error and a 90% confidence interval.
- Prescribed Fire has the potential to remove large amounts of vegetation and soil cover creating a potential hazard for soil erosion and top soil loss. At moderate and high soil burn severities, soil organic matter can be lost, soil hydrologic function can be compromised, and long term soil productivity negatively affected (Parsons et al, 2010 and Neary et al, 2005). A protocol for the Colville National Forest has been develop in collaboration with silviculture and fuels staff and can be found in Jimenez, 2014. This protocol should be conducted on 5 prescribed broadcast burn units per year. Monitoring should occur on spring and fall burns.

National Best Management Practices Monitoring is sufficient to determine if other activities are having prolonged detrimental effects to soils or if best management practices designed to protect soil resources are not being implemented for those activities.

Monitoring conducted would be documented with methodology, summary of results, and recommendations. A summary of all monitoring would be provided to Line Officers. Specific monitoring reports should be provided to the relevant Forest staffs.

Appendix B – Tools and Techniques

Management activities include both passive and active restoration to maintain and improve soil productivity, soil hydrologic function, soil carbon storage, and soil quality. The below is a list of possible techniques that can protect the soil resource from detrimental soil conditions, repair detrimental soil conditions like compaction and displacement of topsoil, and maintain or enhance important soil attributes like hydric conditions and soil carbon.

- Soil Cover Additions
    - Mulching bare soil or areas of unnaturally low soil cover
    - Planting and re-vegetation of disturbed areas (not for silviculture purposes)
- Soil Decompaction
    - Subsoiling of:
        - Decommissioned roads
        - Skid trails
        - Landings
        - Unauthorized roads
- Reclaiming Topsoil
    - Spreading windrows of soils or piles from silvicultural operations
    - Obliterations of road beds
- Soil Carbon Enhancement
    - Burying excess slash and logging debris (non-merchantable material) in on contour swales
    - Production and spreading of biochar in forest stands
    - Prescribed fire – produces stable charcoal (carbon) in the soil and on the landscape.
- Restoration and Maintenance of Hydric Soil Conditions
- Restoration and Maintenance of Hardwood Stands

FOREST SERVICE MANUAL
PORTLAND, OREGON

TITLE 2520 - WATERSHED PROTECTION AND MANAGEMENT

R-6 Supplement No. 2500.98-1

Effective

POSTING NOTICE.Supplements are numbered consecutively by title and calendar year. Post by document name. Remove entire document, if one exists, and replace with this supplement. The last R-6 Supplement to this manual was R-6 Supplement No. 2600-96-2.

This supplement supersedes Supplement 2600-96-2.

Document Name	Superseded (Number of Pages)	New (Number of Pages)
2520	5	6

Digest:

This supplement clarifies direction for planing and implementing activities in areas where soil quality standards are exceeded from prior activities; re-defines soil displacement; provides guidance for managing soil organic matter and moisture regimes.

ROBERT W. WILLIAMS
Regional Forester

Thomas J. Mills
Station Director

FSM 2500 - WATERSHED AND AIR MANAGEMENT
R6 SUPPLEMENT 2500-98-1
Effective

CHAPTER 2520 - WATERSHED PROTECTION AND MANAGEMENT

2520.2 - Objective. To meet direction in the National Forest Management Act of 1976 and other legal mandates. To manage National Forest System lands under ecosystem management principles without permanent impairment of land productivity and to maintain or improve soil and water quality.

1. Plan and conduct land management activities so soil and water quality are maintained or improved.

   a. Soil quality is maintained when soil compaction, displacement puddling, burning, erosion, loss of organic matter and altered soil moisture regimes are maintained within defined standards and guidelines.

   b. Water quality is maintained when sedimentation and nutrient enrichment from surface erosion and mass wasting processes is within ranges of natural variability.

2. The Pacific Northwest Region shall have implementable, measurable soil quality standards and guidelines that can be monitored and are supportive of land management objectives.

2520.3 - Policy. Design and implement management practices which maintain or improve soil and water quality. Emphasize protection over restoration.

When initiating new activities:

1. Design new activities that do not exceed detrimental soil conditions on more than 20 percent of an activity area. (This includes the permanent transportation system.)

2. In areas where less than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effect of the current activity following project implementation and restoration must not exceed 20 percent.

3. In areas where more than 20 percent detrimental soil conditions exist from prior activities, the cumulative detrimental effects from project implementation and restoration must, at a minimum, not exceed the conditions prior to the planned activity and should move toward a net improvement in soil quality.

2521 - WATERSHED CONDITION ASSESSMENT

2521.03 - Policy. Assess current Forest-wide soil quality conditions and trends. Conduct monitoring activities to determine if soil quality objectives, standards and guidelines are met and are in accord with current scientific knowledge.

1. Soil Quality Standards: The following regional standards are thresholds beyond which soil quality is adversely impacted.

Leave a minimum of 80% of an activity area in an acceptable soil quality condition. Detrimental conditions, as defined below, also include landings and system roads. Detrimental soil quality conditions and the accompanying criteria for determining when and where these conditions occur include:

a. Compaction, Displacement, Puddling, Severely Burned.

(1) Detrimental Compaction.

(a) Volcanic Ash/Pumice Soils (Soils with Andic Properties). An increase in soil bulk density of 20 percent, or more, over the undisturbed level.

(b) Other Soils. An increase in soil bulk density of 15 percent, or more, over the undisturbed level, a macropore space reduction of 50 percent or more, and/or a reduction below 15 percent macro porosity.

Assess changes in compaction by sampling bulk density, macro porosity, or penetration resistance in the zone in which change is relatively long term and that is the principal root development zone. This zone is commonly between 4 to 12 inches in depth.

(2) Detrimental Puddling. Detrimental puddling is when the depth of ruts or imprints is six inches or more. Soil deformation and loss of structure are observable and usually bulk density is increased.

(3) Detrimental Displacement. Detrimental displacement is the removal of more than 50 percent of the A horizon from an area greater than 100 square feet, which is at least 5 feet in width.

(4) Detrimental Burned Soil. Soils are considered to be detrimentally burned when the mineral soil surface has been significantly changed in color, oxidized to a reddish color, and the next one-half inch blackened from organic matter charring by heat conducted through the top layer. The detrimentally burned soil standard applies to an area greater than 100 square feet, which is at least five feet in width.

b. Erosion

(1) Detrimental Surface Erosion. For effectiveness monitoring, detrimental erosion is visual evidence of surface loss in areas greater than 100 square feet, rills or gullies and/or water quality degradation from sediment or nutrient enrichment. (See FSM 2532)

For planning or implementation monitoring to meet acceptable levels of soil loss and soil management objectives, the minimum percent effective ground cover following cessation of any soil-disturbing activity should be:

Minimum Percent Effective Ground Cover

Erosion Hazard Class	1st Year	2nd Year
Low (Very slight-slight)	20-30	30-40
Medium (Moderate)	30-45	40-60
High (Severe)	45-60	60-75
Very High (Very Severe)	60-90	75-90

The above erosion hazard classes are from Soil Resource Inventories, ecological unit inventories, the Region 5 Erosion Hazard Rating System (R5-2500-14) and locally adapted standard erosion models and measurements.

(2) Detrimental Soil Mass Wasting. Detrimental mass wasting is visual evidence of landslides associated with land management activities and/or degrades water quality. (See FSM 2532)

Plan activities to avoid acceleration of natural landslide rates. Make Level I, II, or III stability analyses as appropriate. (Ref. USDA FS EM-7170-13 Vol. 1-3)

2. Soil Quality Guidelines:

a. Organic Matter. Organic matter is critical for long-term site productivity and ecosystem sustainability. It should be maintained in amounts sufficient to prevent short or long-term nutrient and carbon cycle deficits and to avoid detrimental physical and biological soil conditions.

(1) Fine Organic Matter - Fine organic matter includes plant litter, duff, and woody material less than 3 inches in diameter. Determine minimum organic layer thickness and distribution locally according to groups of similar soils or ecological types (FSH 2090.11).

(2) Coarse Woody Material - Coarse woody material is greater than 3 inches in diameter. Management of coarse woody material has different

degrees or standards depending on specific multi-resource objectives. The direct benefits to soils vary widely, depending on ecological type.

Adjust the minimum logs, or branches, per acre according to potential for ecological type, or groups of similar types.

b. Soil Moisture Regime. Plan land management activities so that the soil moisture regime remains unchanged (except for activities that restore natural water tables). Detrimental conditions are changes in soil drainage classes (Soil Survey Manual and Handbook) or aquic conditions (Soil Taxonomy Handbook) that are incompatible with management objectives.

Evaluate the effect of management induced water table or subsurface flow changes on plant growth or potential community composition.

3. Application of Soil Quality Standards

The standards and guidelines apply to lands where vegetation and water resource management are the principal objectives. (For example, timber sales, grazing pastures or allotments, wildlife habitat, riparian reaches, and burn areas.) These standards and guidelines do not apply to intensively developed sites such as mines, developed recreation sites, administrative sites, or rock quarries.

a. Planning. Use soil quality standards to guide the selection and design of management practices and prescriptions on a watershed scale. Evaluate existing soil conditions on all ownerships within the watershed and consider cumulative effects with the addition of proposed actions on ecosystem sustainability and hydrologic function. On a planned activity area, evaluate existing soil conditions and design activities to meet soil quality standards. Document adjustments to management practices, soil conservation practices or restoration techniques necessary to meet threshold values for the affected soil properties and watershed conditions.

b. Monitoring.

(1) Watershed Condition Classes. Each forest needs to monitor watershed condition (FSM 2521.1) and track trends in overall soil quality over time through landscape scale assessments such as watershed analysis (MAR 82.5, 82.6, 82.7.)

(2) Implementation Monitoring. During and following completion of projects, document whether management practices are, or were, implemented as prescribed.

(3) Effectiveness Monitoring. Document if the cumulative effects from applied management practices within an activity area met soil quality

standards as defined. Base assessments on appropriate sampling design and procedures. For example: R6-RWM-146-1983, "Sampling Some Physical Conditions of Surface Soils." Appropriate quantitative or qualitative techniques may be used.

(4) Validation Monitoring. Where there are significant gaps in knowledge, collaborate with research organizations, adjoining Forests, Universities, Private Industry and other local interested groups to establish studies to fill the knowledge gaps.

2521.04 - Responsibilities

2521.04c - Forest Supervisors.

1. Forest Supervisors are responsible for:

a. Ensuring Forest Plans include soil quality standards and guidelines and setting local surface organic matter standards and guidelines.

b. Assessing current Forest-wide soil quality conditions relative to watershed condition classes I, II and III. (Ref. MAR 82.5, 82.6, 82.7 and FSM 2521.1)

c. Providing training for application of soil management prescriptions, standards and objectives to forest personnel.

d. Evaluating the effectiveness of soil quality standards and procedures, measuring them through monitoring and periodic reviews, and recommending adjustments to the Regional Forester.

e. Reporting monitoring results to the Regional Forester.

2. District Rangers are responsible for:

a. Ensuring that land management activities are consistent with soil quality standards and guidelines.

b. Implementing measures necessary to meet soil quality standards in environmental documents.

c. Conducting post activity evaluations to determine if soil quality standards have been met.

2521.05 - Definitions.

Activity Area. The total area of ground impacting activity, and is a feasible unit for sampling and evaluating. Some examples are: a sale contract unit, pasture, allotment, meadow, riparian reach, burned area.

Bulk Density. The mass of dry soil per unit volume. Determine volume before drying to a constant weight at 105 degrees C. Correct this figure for weight and volume of coarse fragments greater than 2 mm in diameter.

Ecological Type. A category of land having a unique combination of potential natural plant community, soil, landscape features, climate, and differing from other ecological types in its ability to produce vegetation and respond to management. (Ref. FSH 2090.11)

Project Area. The area in which project analysis occurs for proposed specific activities.

Restoration. Treatments that restore vital soil functions to inherent range of variability. It is recognized that treatments may need to occur over a period of years and may need to be maintained.

Soil Compaction. Compaction of soil increases soil bulk density and soil strength and decreases porosity as a result of the application of forces such as weight and vibration.

Soil Displacement. Soil displacement is the lateral movement of soil from one place to another by mechanical forces such as equipment blades, vehicle traffic, or logs being yarded.

Soil Mass Wasting. Soil mass wasting is the detachment and movement of soil or surface mantle material by gravity. Some landslides fail in a single mass or single event and move downslope to cause debris slides and avalanches. Other landslides detach and move slowly over a period of years.

Soil Puddling. Soil puddling is a physical change in soil properties, under moist conditions, due to shearing forces that destroy soil structure and reduce porosity. It occurs in slightly plastic, plastic, and very plastic soils.

Soil Quality. The capacity of a specific soil to function within natural or altered land use boundaries to sustain or improve plant or animal productivity, water quality and flows, air quality, and human health and habitation.

Surface Erosion. Surface erosion is the detachment and transport of individual soil particles by wind, water, or gravity. Surface erosion can occur as the loss of soil in a fairly uniform layer (sheet erosion, dry ravel) or rills or gullies.

Water Quality. (For these purposes) Changes in water conditions from erosion, sedimentation and nutrient enrichment.