United States Department of Agriculture
Forest Service

Limestone/Silver Vegetation Management

Newport-Sullivan Lake Ranger District
Colville National Forest

Soil Resource Report

Prepared by:
Jason Jimenez
Soil Scientist
Colville National Forest
ARCPACS - Certified Professional Soil Scientist No. 37184

February 9th, 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

Date Last Saved: 6/27/2018 1:02 PM

1.0 – INTRODUCTION

The analysis will focus on the effects of mechanical treatments including timber harvest and fuel reduction to the soil resource and comparing anticipated soil effects to Regional and Forest Plan Soil Quality Standards and Guidelines. All proposed activities involving mechanical equipment will be analyzed in the soil resource report. Due to the temporary road construction, the soil report will also analyze its effects on soil productivity and function. The use of prescribed fire will also be analyzed in this report. The restoration treatments and the use of hand treatments is analyzed but not focused on due to the low contributions to detrimental soil conditions. The intent of the soil report is to detail effects of treatments on the soil resource, estimate anticipated amounts of detrimental soil condition caused by the proposed action, and develop design criteria that reduces the total extent of detrimental soil conditions from the proposed action.

The soil resource is not directly related to the purpose and need of the project and was not identified during scoping as a resource that should be included in the purpose and need. The restoration and improved functioning of watersheds and wetlands is directly related to the purpose and need of the project. Soil productivity can be related back to proper watershed and wetland function.

The Colville National Forest is proposing to conduct timber harvest, fuels treatment, and silvicultural management as well as temporary road construction and maintenance on 2,995 acres of an approximate 53,600 acre project area. The project is located on the Newport-Sullivan Lake Ranger District of the Colville National Forest within the Deep Creek, Slate Creek-Pend Oreille River, and Cedar Creek-Pend Oreille River (HUC 5) watersheds. Elevation in the project area range from 2,000 feet to 7,000 feet. The Pend Oreille River is located to the east and the Columbia River to the west. Tree species consists mainly of Douglas fir, western larch, western hemlock, and western red cedar with lesser amounts of lodgepole pine and grand fir.

2.0 – RELEVANT LAWS, REGULATION, AND POLICY – REGULATORY FRAMEWORK

The relevant laws, guidance, and direction for the proposed project in relation to the effects on soil quality, soil productivity, and watershed and wetland function are:

2.1 – COLVILLE NATIONAL FOREST - LAND AND RESOURCE MANAGEMENT PLAN - 1988

Directs managers to maintain soil productivity with an emphasis on protection over restoration and with detrimental soil conditions not to exceed 20% aerial extent with bounding by the treatment unit (defined as the activity area). The Colville National Forest Land and Resource Management Plan (USDA Forest Service, 1988a) discusses the effects of timber harvest on soil productivity (pages IV-5 through IV-10). In addition to the Regional 20% standard (described above), the Colville National Forest Land and Resource Management Plan provides three additional soil standards (pp. 4-50):

- Skid trail requirements must be specified in timber sale contracts that require tractor yarding.
- Identify areas of high soil erosion or mass failure potential and evaluate probable impacts of resource development.
- Retain organic matter to maintain site productivity.

2.2 – DESIRED CONDITION

The desired condition is for proper soil and watershed function across a majority of the landscape. Soils should have bulk densities within 20% of natural occurring densities for proper hydrologic function and soil productivity (tree root function). Soil cover should be maintained to an extent to prevent detrimental soil erosion and maintain soil stability. Soils should have a functional level of soil organic matter inputs with considerations to maintaining the soil nutrient status to continue ecological function. These conditions should be maintained across a landscape to maintain and support watershed function.

2.2.1 – Management Area

No management area specifically addresses management or desired conditions of the soil resource.

2.2.2 – Special Area Designations

No special area designations specifically address the soil resource or make special designations for the soil resource.

2.3 – FEDERAL LAW

The authorities governing Forest Service soil management are:

2.3.1 – The Organic Administration Act of 1897 (16 U.S.C. 473-475)

Authorizes the Secretary of Agriculture to establish regulations to govern the occupancy and use of National Forests and "…to improve and protect the forest within the boundaries, or 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."

2.3.2 – Bankhead-Jones Act of 1937

The Secretary of Agriculture is authorized and directed to develop a program of land conservation and land utilization to correct maladjustments in land use, and thus assist in controlling soil erosion (reforestation), preserving natural resources (protecting fish and wildlife, developing and protecting recreational facilities), mitigating floods (preventing impairment of dams and reservoirs, developing energy resources), conserving surface and subsurface moisture, protecting the watersheds of navigable streams, and protecting the public lands, health, safety, and welfare.

2.3.3 – The Multiple-Use, Sustained-Yield Act (MUSY) of 1960 (P.L. 86-517, 74 Stat. 215; 16 U.S.C. 528-531)

This Act directs the Secretary of Agriculture to manage resources in the combination that will best meet the needs of the American people; providing for periodic adjustments in use to conform to changing needs and conditions; and harmonious and coordinated management of the resources without impairment of the productivity of the land. Sustained yield means achieving and maintaining into perpetuity a high-level annual or regular periodic output of renewable resources without impairment of the productivity of the land.

2.3.4 – The National Environmental Policy Act (NEPA) of 1969 (16 U.S.C. 4321)

Established as the policy of the Federal Government to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans. The Act requires agencies to analyze the physical, social, and economic effects associated

with proposed plans and decisions, to consider alternatives to the action proposed, and to document the results of the analysis.

2.3.5 – The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 (16 U.S.C. 1600-1614) (as amended by National Forest Management Act (NFMA) of 1976 (16 U.S.C. 472a))

States that the development and administration of the renewable resources of the National Forest System are to be in full accord with the concepts for multiple use and sustained yield of products and services as set forth in the Multiple-Use Sustained Yield Act of 1960. It requires the Secretary of Agriculture to ensure, through research and monitoring, that forest management practices will not produce substantial and permanent impairment to the productivity of the land and water resources.

2.4 – EXECUTIVE ORDERS

2.4.1 – Executive Order 11988 (flood plains) - 1977

Requires federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative.

2.4.2 – Executive Order 11990 (wetlands) - 1977

The purpose of Executive Order 11990 is to "minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands."

2.5 – OTHER GUIDANCE AND RECOMMENDATIONS

2.5.1 – Forest Service Manual Direction 2500 - Watershed and Air Management - 2010

The objectives of the Forest Service's soil resource management policy are to contribute to agency goals for National Forest and Grassland management by:

1. Providing adequate soil resource information to help decision makers sustain ecological processes and functions so that desired ecosystem services are provided in perpetuity.
2. Maintaining and restoring soil quality and soil productivity on National Forest System lands in order to implement the Land and Resource Management Plan.
3. Ensuring all programs protect and maintain, or restore soil quality on National Forest System lands.

2.5.2 – Region 6 - Soil Quality Standards and Soil Quality Guidelines - 1998

The following regional soil standards are thresholds beyond which soil quality and productivity is adversely impacted (USDA Forest Service, 1998). Soil Quality Standards require that a minimum of 80% of an activity area is determined to have an acceptable soil quality condition. Detrimental soil quality conditions and the accompanying criteria for determining these conditions include:

- **Detrimental Compaction** – An increase in soil bulk density of 20% or more over an undisturbed level in volcanic ash soils or an increase in soil bulk density of 15% or more over an undisturbed level in other soil textures.
- **Displacement Puddling** – When the depth of ruts or imprints is six inches or more, soil deformation and loss of structure are observable and bulk density is increased.

- **Detrimental Displacement** – The removal of more than 50% of the topsoil, applies to an area greater than 100 square feet, which is at least five feet wide.
- **Detrimental Burning** – When the mineral soil surface has been dramatically changed in color, oxidized to a reddish color, and the next ½ inch blackened from organic matter charring by the heat conducted through the top layer, applies to an area greater than 100 square feet, at least five feet wide.
- **Detrimental Surface Erosion** – Evidence of surface soil loss in areas greater than 100 square feet including rills, gullies, and/or water quality degradations from sediment or nutrient enrichment.
- **Detrimental Mass Wasting** – Evidence of landslide associated with land management activities that degrades water quality.
- **Organic Matter** – 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 – plant litter, duff, and woody material less than three inches in diameter. (2) Coarse Woody Material – woody material greater than three inches in diameter.
- **Changes in Soil Moisture Regime** – Plan land management activities so that the soil moisture regime remains unchanged. Detrimental conditions are changes in soil drainage classes or aquic conditions that are incompatible with management objectives.

2.5.3 – National Best Management Practices for Water Quality Management on Forest System Lands - 2012

Best management practices (BMP's) designed to protect water quality, soil quality, and watershed condition are derived from the National Best Management Practices for Water Quality Management on National Forest System Lands (USDA Forest Service, 2012). BMP's protect the beneficial traits of water, soil productivity, and soil quality, which prevent or minimize the threat of discharge of pollutants of concern. Similar projects have used BMP's in the past and been proven effective in protecting water quality, soil quality, tree productivity, and watershed condition.

3.0 – Topic and Issues Addressed in This Analysis

3.1 – Purpose and Need

3.1.1 – Purpose

- Reduce the risk and extent of insect and/or disease infestation.
- Increase resilience to potential insect and/or disease infestation.
- Reduce wildfire risk to the local communities and surrounding federal lands.

3.1.2 – Need

The project area currently has acres of vegetation that are overstocked and susceptible to uncharacteristically high levels of insects and disease. Overstocking creates more inter-tree competition which in turn increases stress on individual trees. Existing stand composition and structure put the project area at risk to these disturbance agents over the foreseeable future.

There is a need to restore stands towards historic levels of stand density and species composition in order to improve sustainability and resiliency in this ecosystem. Under historic fire regimes, species such as western larch, Ponderosa pine, Douglas-fir, and western white pine would have played a more dominant role on the landscape on dry to moist sites. Red cedar and hemlock would have been more dominant on wet sites, but are currently establishing on drier sites due to lack of fire disturbance.

3.1.3 – Proposed Action

The proposed action is 2,096 acres of shelterwood treatment and 899 acres of commercial thinning in the project area. There is will also be 0.5 miles of temporary road construction and 25 acres of soil decompaction.

3.2 – ISSUES

There were no issues from the purpose and need that directly relate to the soil resource, watershed function, or wetlands. There were no soil resource or watershed issues that led to the development of additional alternatives.

3.3 – OTHER RESOURCE CONCERNS

Heavy equipment from legacy logging has resulted in detrimental compaction in two of the proposed units. These units were identified and discussed during the collaboration process and were recommended for restoration.

3.4 – RESOURCE INDICATORS AND MEASURES

Table 1. Resource indicators and measures for assessing effects

Resource Element	Resource Indicator	Measure	Used to Address Purpose and Need or Key Issue?	Source from Law, Policy, Standards and Guidelines, or Best Management Practices
Soil Function	Detrimental Soil Conditions	Extent of Detrimental Soil Conditions in Activity Areas	No	National Forest Management Act of 1976; Regional and Forest Plan Soil Quality Standards and Guidelines
Soil Erosion	Surface Soil Erosion and Landslide Potential	Potential for Detrimental Surface Soil Erosion and Detrimental Mass Soil Movement	No	National Forest Management Act of 1976; Regional and Forest Plan Soil Quality Standards and Guidelines
Soil Organic Matter Soil Nutrients	Depth of Forest Floor, Quantity of Fine and Coarse Wood	Potential for Soil Nutrients and Soil Function Issues Due to Lack of Organic Matter Inputs	No	National Forest Management Act of 1976; Regional and Forest Plan Soil Quality Standards and Guidelines
Wetland Function	Status of Function (*properly functioning, functioning at risk, and nonfunctional*)	Number of Surveyed Wetlands Rated as Properly Functioning	Yes	Executive Order 11990 (wetlands) – 1977; Forest Service Manual Direction 2500 - Watershed and Air Management

4.0 – METHODOLOGY

4.1 – INFORMATION SOURCES

The project area was evaluated using current soil maps and geology maps as well as historical and current aerial imagery. Existing soil mapping presents a relatively accurate description of the project area.

Existing soil survey information (USDA National Resource Conservation Service, 1992) was used unless field survey revealed significant differences between mapped soils and field survey findings. Other outstanding risks to soil and/or watershed values are also evaluated. The Soil Scientist focused field time and Soil Crew survey on units proposed for ground based mechanical treatment and wetlands within the project boundary. The Soil Crew surveyed **37** units using the National Soil Disturbance Monitoring Protocol in the proposed treatment area in summer 2016. Soil compaction was identified by use of a spade to evaluate alteration of soil structure and other factors. Extent of compaction is determined through transects and use of visual disturbance classes (Page-Dumroese et al., 2009a, 2009b). Skyline units were not surveyed due to the lower risk of detrimental soil impacts. Most all units showed evidence (old tree stumps, skid trails, and roads) of past logging operations. At minimum, 30 point surveys were completed in each unit with photos and a GPS track being taken during each transect. Field sheets and field notes are available in the project file. Sampling with National Soil Disturbance Monitoring Protocol as well as additional reconnaissance level evaluation by the Soil Scientist and Soil Crew provides a representative baseline of the project area for the understanding of the landscape, potential effects, and cumulative effects. A summary of disturbance is found in **Section 5.3** and **Appendix A**.

Using the Proper Functioning Condition Protocols (Department of Interior, Bureau of Land Management, 2003, 1998) and a modified Army Corps of Engineers wetland survey protocol the Soil Crew surveyed selected mapped wetlands on Forest Service lands within the analysis area. Wetlands were also surveyed to determine if they meet criteria for hydric plants, hydric soils, and wetland hydrology. The Soil Crew conducted the surveys instead of an interdisciplinary team, as the protocol is intended, due to resource constraints. A total of **20** wetlands; approximately **53** acres of wetland were surveyed. Results are reported in **Section 5.3** and **Appendix B**.

The analysis is based on the above-described review of geographic information, field data collection, and an analysis of past and current scientific literature in relation to soil formation, soil quality, soil compaction, and the effects of treatments on soil function. A review of Colville National Forest soil monitoring data as well as soil monitoring conducted on other National Forest Units also informs the analysis and conclusions. Field-notes, transect data, unit descriptions, maps, and references are contained in the soils project file.

4.2 – INCOMPLETE AND UNAVAILABLE INFORMATION

There is no incomplete or unavailable information that would substantially change or modify the analysis or conclusions provided.

4.3 – SPATIAL AND TEMPORAL CONTEXT FOR EFFECTS ANALYSIS

Direct/Indirect/Cumulative Effects Boundaries

Area – Effects on soil productivity are site specific and not spatially mobile over the project area. The analysis area for effects to soils is the treatment unit or activity area. The activity area is defined in Region 6 Soil Quality Standards as, "The total area of ground impacting activity, and is a feasible unit for sampling and evaluating" (p.6). 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.

The area effected by the construction of new temporary roads is defined as a zone hydrologically disconnected by the road construction as well as areas of detrimental disturbance between the cut and fill slopes.

Time – The time bounding for 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. No projects and treatments in addition to the proposed action is anticipated within the activity areas. Continued cattle grazing, road maintenance, and recreational activities are anticipated to be the reasonably foreseeable future events. Other activities that do not detrimentally impact soil productivity or soil function is also anticipated.

5.0 – AFFECTED ENVIRONMENT – EXISTING CONDITION

5.1 – RESOURCE INDICATOR AND MEASURES

Table 2. Resource indicators and measures for the existing condition

Resource Element	Resource Indicator	Measure	Existing Condition
Soil Function	Detrimental Soil Conditions	Extent in Activity Areas	170 acres
Soil Erosion	Surface Soil Erosion and Landslide Potential	Potential for Detrimental Surface Soil Erosion and Detrimental Mass Soil Movement	Low
Soil Organic Matter Soil Nutrients	Depth of Forest Floor, Quantity of Fine and Coarse Wood	Potential for Soil Nutrient and Soil Function Issues Due to Lack of Organic Matter Inputs	Low
Wetland Function	Status of Function (*properly functioning, functioning at risk, and nonfunctional*)	Number of Surveyed Wetlands Rated as Properly Functioning	13 Wetlands

5.1.1 – Soil Function – Detrimental Soil Condition

Table 3. Estimated detrimental soil condition in proposed treatment units

Percent Detrimental Soil Condition[1]	Number of Units Sampled	Corresponding Percentage of Detrimental Soil Conditions (Approximate Acres[2])
0-3%	23	30
7-10%	12	100
10>%	2	40

Notes: [1]Estimated approximately 3,000 acres surveyed of the approximately 54,000 acre project area, all of the units with treatments by ground based mechanical equipment were surveyed.

[2]More acres were surveyed than are proposed for mechanical treatment due to draft units being dropped.

5.1.2 – Soil Erosion – Surface Soil Erosion and Mass Wasting

Field surveys conducted by the Soil Crew 2016 did not detect the presence of significant soil erosion across the landscape. National Soil Disturbance Monitoring Protocol surveys conducted within treatment units recorded data on over 2,000 points.

Recent aerial photos were reviewed for the presence of substantial soil mass movement (i.e., landslides and debris flows) and active soil movement was not observed.

5.1.3 – Soil Organic Matter

Field surveys conducted by the Soil Crew in 2016 show the presence of sufficient forest floor depth, averaging 6 cm (2.4 inches) across all units, as well as the presence of fine and coarse wood that will sustain soil organic matter inputs and soil nutrient status over the short- and long-term.

5.1.4 – Wetland Function

Twenty-five wetland areas were identified for survey to determine existing conditions using the information from the National Wetlands Inventory shapefile for the Colville National Forest. Five mapped wetlands were not surveyed due to difficult access (greater than 2 miles from a road). Three mapped wetlands were determined not to have hydric soils or hydric hydrology that would classify the mapped area as a wetland (US Army Corps of Engineers, 2010). Twenty wetlands were surveyed and rated. Additional descriptions can be found in **Appendix B** and in the soils project file.

Table 4. Wetlands surveyed

Category	Number of Wetlands
Isolated – Did Not Survey	5
Mapped Wetland Did Not Met Wetland Criteria	3
Non-Functional	1
Functional at Risk	3
Properly Functioning	13
Total Number of Mapped Wetlands	25
Total Wetlands Surveyed and Rated	**20**

5.2 – SOILS IN THE PROJECT AREA

The soils in the project area are grouped into four main categories based on their parent material and distribution of volcanic ash. Volcanic ash content has strong implications for soil productivity and sensitivity to management actions. The soils within these groups (volcanic ash-cap, admixture, no volcanic ash-cap, wetlands) have similar properties and implications for management.

5.2.1 – Volcanic Ash-Cap Soils

Soils influenced by volcanic ash dominate the soils of the Colville National Forest. Volcanic ash comes from the Cascade volcanoes, including Mt. Mazama, which is estimated to have deposited about six to twelve inches of volcanic ash in eastern Washington. In this area, the volcanic ash is generally silt-size particles. In general, the volcanic ash

component is deeper on north aspects, higher elevations, in moist vegetation associations, and in draws and convex landscape positions.

About 90% of the project area has volcanic ash-cap soils. In this area, the volcanic ash layer generally ranges from 4 inches to 18 inches. The presence of volcanic ash strongly influences many of the management interpretations for these soils. Volcanic ash-cap soils have higher water holding capacity, increased soil fertility, and resilience to disturbance than otherwise similar soils.
Compaction: Due to fine textures, loams and silt loams in the surface horizons, volcanic ash-cap soils have a high potential for compaction.
Erosion: Soils with volcanic ash-caps are not highly erodible because the ash forms water stable soil aggregates and the soil has high infiltration rates. However, when dry, these soils are dusty and non-cohesive and can be susceptible to wind erosion if large areas of bare soil are exposed. The soil erosion hazard for volcanic ash-cap soils within the project area would be moderate. This conflicts with the erosion sensitivity ratings in the soil survey, which lists volcanic ash-capped soils as having a high erosion hazard. The ratings are based on soil texture and do not account for the high infiltration rates and strong soil structure development.

5.2.2 – Soils with an Admixture of Volcanic Ash and Other Parent Materials

About 5% of the project area has soils that have an admixture (something that is produced by mixing) of volcanic ash in the surface horizon. Typically admixture soils have a greater bulk density and soil strength than volcanic ash-cap soils, and surface textures of loam, sandy loam, gravelly sandy loam or cobbly sandy loam. The coarse fragments in the surface horizons vary considerably among these soils.
Compaction: Because of the higher initial bulk density and the greater soil strength, admixture soils do not compact as easily as volcanic ash-cap soils. Compaction potential is typically moderate.
Erosion: These soils do not form the water stable aggregates seen in volcanic ash soils and are less cohesive. The erosion potential is high.

5.2.3 – Soils with No Appreciable Volcanic Ash

About 5% of the project area has soils that have no appreciable volcanic ash in the surface horizon, mainly alluvial soils adjacent to streams channels.
Compaction: Because of the higher initial bulk density, high rock fragment content, and the greater soil strength, these soils do not compact as easily as ash-cap soils. Compaction potential is typically low to moderate.
Erosion: On the soils formed in sandy glacial outwash, erosion hazard is high and slope stability can be problematic.

5.2.4 – Wetland Soils – Soils with Hydric Properties

Less than 1% of the project area consists of wetland soils. There are also small-unmapped wetlands and seeps scattered throughout the project area. Wetlands are universally sensitive to machine traffic due to saturation throughout the growing season and high organic matter content of the soils.
Compaction: Due to high moisture content across the growing season, wetlands have a very high soil compaction hazard and are at high risk for detrimental soil conditions from mechanical equipment and concentrated grazing use
Erosion: Wetlands are generally in low gradient, low landform positions with extensive vegetation cover. Wetlands have a low soil erosion hazard.

5.3 – EXISTING CONDITION - EFFECTS OF PAST ACTIVITIES

5.3.1 – Timber Harvest

Table 5. Summary of past timber harvest on National Forest land in project area

Decade[1]	Acres[2]
1960-1970	900
1971-1980	800
1981-1990	1800
1991-2000	100
2001- current	0

Notes: [1]Past logging was estimated using Colville National Forest records and are reported by fiscal year.
[2]Numbers are rounded to the nearest 100 and are approximate.

Stumps and old roads, indicative of past timber harvest, are found intermittently throughout the project area. Forest Service records and aerial photos indicate that some of the National Forest land in the project area has had timber harvest since 1930. Logging prior to the 1930s occurred in conjunction with homesteading and settlement of the area. Harvested areas have often been logged more than once. Repeated entries, especially where new roads, skid trails, and landings are used instead of existing ones, can create legacy soil compaction and soil disturbance. The length of time required for compacted soil to de-compact and recover its full function varies depending on the type of soil, the degree of compaction, and a number of other factors, and can range from 20 to over 60 years (Miller et al., 2004).

Information from the **37** field surveys for detrimental soil condition using the National Forest Service Soil Disturbance Monitoring Protocol found varied results of detrimental soil condition from past harvests. Approximately two-thirds of the units were found to have minor amounts (less than 3%). The remaining third was found to have greater detrimental soil conditions (7-10%), of these units two had higher amounts of 11% and 16%.

5.3.2 – Past Wildfire

The western portion of the project area burned in the 1930's and the eastern portion burned in the 1920's. Evidence of these fires was seen in scattered parts of the project area as burned snags and coarse woody debris, and charcoal in the soil profile. Potential wildfire effects to soils include soil erosion, compromise of soil structure and infiltration rates, as well as reductions in soil carbon, soil organic matter, and certain soil nutrients (Bormann et al., 2008; Certini, 2005; Mataix-Solera et al., 2011; Neary et al., 2005). It is anticipated that detrimental soil conditions from those fires have recovered and is no longer contributing to current detrimental soil conditions in the project area.

5.3.3 – Fire Exclusion

The absence of fire lowers rates of nutrient cycling and decomposition due to cooler soil temperature, lower microbial metabolism and the buildup of thicker duff/litter layers (DeLuca and Zouhar, 2000; Neary et al., 1999). Higher leaf coverage areas that have resulted from fire exclusion reduce soil water and solar radiation, which slows nutrient cycling and decomposition. Fire exclusion has also allowed grass and shrub plant communities to become forested, which reduces organic matter input (Biswell, 1989; Sugihara, 2006). A review of literature suggests that periodic low intensity fires do not deplete forest nutrients but enhances soil nutrient pools and soil organic matter (Johnson et al., 2013; Johnson and Curtis, 2001; Stark, 1977). Fire exclusion has altered soil properties and the soil forming factors in certain vegetation types in the project area but these changes are not considered to create detrimental soil conditions.

5.3.4 – Grazing Allotments

Livestock trails were observed throughout the project area and within some proposed treatment units. Monitoring indicates that grazing allotments add 1 to 2% detrimental soil conditions typically concentrated in riparian areas and areas of low canopy cover. There are two active allotments, Z canyon and Silver creek, in the project area.

5.3.5 – Recreation

Most of this area receives a low level of dispersed camping. The impacts of dispersed camping on soil and vegetation are considered to be substantial but very limited, and of limited significance at the project and landscape scale. Off highway vehicle (OHV) use was observed on open roads, and closed roads. OHV use of a closed road does not increase detrimental soil conditions. Roads have been designated for travel and not the growing of vegetation so soil productivity standards do not apply. Some user-created roads and trails were observed in the project area. The OHV use in the project area is not extensive and does not threaten soil productivity. Detrimental soil condition from recreation would be much less than 1% of the project area.

6.0 – PROPOSED ACTION

6.1 – PROJECT DESIGN FEATURES

6.1.1 – General Project Design Features

- The total acreage of all detrimental soil conditions should not exceed 20% of the total acreage within the activity area including landings and system roads. The desired outcome is to limit detrimental soil conditions to preserve soil productivity and comply with Regional Soil Quality Guidelines and Forest Plan Standards. Applies to all management activities: timber harvest, fuel reduction, and prescribed fire.

- Skid trail spacing must be specified in the timber sale/stewardship contract as follows. Applies to timber harvest and fuel reduction activities.
    - Skid Trail Spacing: 100 feet apart edge to edge, except when converging at landings or avoiding obstacles.
    - Forwarder Trails: 40 feet apart edge to edge except when converging at landings or avoiding obstacles. Four to eight inches of un-compacted slash should cover forwarder trails.

- Skidding equipment must travel on designated trails. When feasible re-use old skid trails. Feller-bunchers should concentrate use on skid trails and should travel in an efficient manner with limited passes off skid trails. The desired outcome is to limit detrimental soil conditions to preserve soil productivity and comply with Regional Soil Quality Guidelines and Forest Plan Standards. Applies to timber harvest and fuel reduction activities.

- Slope limitations for ground-based equipment as follows. The desired outcome is to limit detrimental soil conditions to preserve soil productivity and reduce erosion potential. Applies to timber harvest and fuel reduction activities using mechanical equipment.
    - Tractor and skidder yarding would be limited to slopes less than 35%. Short slope lengths may be steeper.
    - Feller bunchers, harvester-forwarder systems, and other tracked heavy equipment would be limited to slopes less than 40%. Short slope lengths may be steeper.

- Minimize compaction, rutting, and erosion by avoiding activities during wet conditions. Ground-based equipment would operate on relatively dry soils of high soil strength or bearing capacity. Rutting exceeding soil quality standards should be remediated. The Field Guide to Soil Moisture Conditions Relative to Operability of Logging Equipment (Rust, 2005) should be used to determine soil trafficability. The desired outcome is to limit detrimental soil conditions and comply with Forest Plan and Regional Soil Quality Standards.

- Winter logging requires that skid trails are buffered by at least 8 inches of compacted snow or frozen ground or a combination of the two that exceeds 8 inches. If cut to length equipment is to be used, a combination of slash, compacted snow, and/or frozen ground that exceed 8 inches can be used to buffer forwarder trails. The desired outcome is to limit detrimental compaction and rutting to preserve soil productivity and soil quality. Applies to timber harvest and fuel reduction activities using mechanical equipment.

- De-compact landings and temporary roads to restore hydrologic function. The desired outcome is to restore infiltration, provide soil cover, and stabilize soils to prevent erosion and loss of soil productivity. Applies to all timber harvest activities.

- In units that have had commercial harvest, keep follow up fuel treatment machinery to designated skid trails except for limited passes off designated skid trails. Fuel reduction machinery (i.e., masticators and piling equipment) should be tracked equipment having a ground pressure rating of 8 psi or less and with an articulating arm capable of reaching 15 feet. The desired outcome is to prevent detrimental soil conditions and prevent harvest/fuel treatment units from exceeding 20% detrimental soil conditions per Regional and Forest Plan Soil Quality Standards. Applies to fuel reduction and silvicultural activities.

- Retain fine and coarse organic matter on top of the soil. Soil cover should exceed 35%, preferably 50%. The desired outcome is to maintain sufficient amounts of organic matter to prevent short- or long-term nutrient and carbon cycle deficits and to avoid detrimental physical and biological soil conditions. Maintain soil cover amounts to prevent soil erosion. Treatment units should be maintained with between 6 to 20 tons per acre of coarse woody material (defined as woody material greater than 3 inches in diameter). Applies to all timber harvest, fuel reduction, and silvicultural activities.

- Target machine pile size to 15 feet in diameter and 10 feet in height **outside of landings**. The desired outcome is to maintain sufficient amounts of organic matter and to avoid detrimental physical and biological soil conditions. Smaller piles allow for re-colonization by soil organisms and prevent excess tracking from mechanical equipment when creating piles. Applies to all fuel reduction and silvicultural activities.

- Adequately drain firelines including machine and hand line. Waterbars would be installed during fire line construction following guidelines in Fireline Waterbar Guidelines for Prescribed Fires (Jimenez, 2013a) and would be described in Element 5 and Element 9 of the burn plan(s). The desired outcome is to prevent soil erosion from firelines, preserve soil organic matter, and allow for re-vegetation of firelines. Applies to prescribed fire operations.

6.1.2 – Unit Specific Design Features

- For ground based units with 7- 10% detrimental soil conditions practices would be included for certain units to ensure that cumulative detrimental soil conditions would remain at or below 20%.

- Conduct timber harvest when soil is covered by 8 inches of compacted snow or 8 inches of frozen soil or a combination of two that totals 8 inches. This condition should be present on approximately 90% of the timber harvest unit **or**
- Conduct timber harvest using cut to length logging systems where stand density supports covering forwarder trails with 8 inches of uncompacted slash **or**
- Conduct timber harvest during summer dry conditions **and**
- Reuse any existing skid trails, landings, and road templates.

Units where these practices should be implemented: **6,7,9,11,15,17,24,25,26,32,40,44**

- For ground based units greater than 10% detrimental soil conditions, the practices would be included for select units to ensure that cumulative detrimental soil conditions would remain at or below 20%.
  - Follow practices detailed above **and**
  - De-compact areas identified with pre-existing detrimental soil conditions. Area to be de-compacted will be approximately 10% to 20% of the unit. Areas will be de-compacted post treatment.

Units where these practices should be implemented: **2, 13**
Unit 2 has an area of prominent main skid trails in the north-east section of the unit. Unit 13 was previously dozer thinned and shows detrimental soil conditions from that treatment as well as a prominent legacy skid trail network.

6.2. – REQUIRED MONITORING

There is no required monitoring related to soil resource for the Limestone/Silver Vegetation Management Project.

6.3 – DIRECT AND INDIRECT EFFECTS FOR THE PROPOSED ACTION

Table 6. Resource indicators and measures for the Proposed Action – direct and indirect effects

Resource Element	Resource Indicator	Measure	Alternative 2 - Proposed Action Direct and Indirect Effects
Soil Function	Detrimental Soil Conditions	Extent in Activity Areas	300 Acres
Soil Erosion	Surface Soil Erosion and Landslide Potential	Potential for Detrimental Surface Soil Erosion and Detrimental Mass Soil Movement	Moderate (short-term 0 to 5 years) Low (long-term 5 to 50 years) with recovery of soil cover.
Soil Organic Matter Soil Nutrients	Depth of Forest Floor, Quantity of Fine and Coarse Wood	Potential for Soil Nutrient and Soil Function Issues Due to Lack of Organic Matter Inputs	Low
Wetland Function	Status of Function (*properly functioning, functioning at risk, and nonfunctional*)	Number of Surveyed Wetlands Move to Properly Functioning Condition	13 Wetlands

6.3.1 - Spatial and Temporal Context for Effects Analysis

The spatial context for the effects analysis for soil function, soil erosion, and soil organic matter would be the activity area of the proposed actions as defined by Region 6 Soil Quality Standards and Guidelines (USDA Forest Service, 1998, p. 6). Watershed function is analyzed on the HUC 6 watershed scale. Wetland function is analyzed on the mapped boundary of the wetland.

The temporal context for effects is short-term relative to soil productivity and soil quality, ranging from five to twenty years. This time frame pertains to soil erosion and soil cover replacement. Long-term temporal effects ranges from 20 to 100 years and pertain to soil compaction, soil displacement, soil nutrient status, and coarse woody material recovery. Short- and long-term timeframes apply to both watershed function and wetland function.

6.3.2 – Soil Function - Detrimental Soil Conditions

Mechanical Vegetation Treatments (Including Road Construction)

Soil compaction would increase over the short-term and long-term but remain within Regional Soil Quality Standards and Guidelines with project design features presented in **Section 7.1**. Commercial timber harvest with ground-based equipment would increase soil compaction (Alexander and Poff, 1985) but management requirements would limit the extent increases. Decreases in soil porosity from compaction should not negatively affect tree productivity (Powers, 2002).

An increase in soil erosion and loss over the short-term (less than 2 years) is expected but with project design features dictated in **Section 7.1**, soil erosion would return to background levels within 3 years (Elliot, 2005). Soil Disturbance Monitoring Protocol surveys show a low occurrence of bare soil and forest floor depths that average 2 inches or greater in a majority of the units. Detrimental erosion from timber harvest units is not frequent or widespread with current harvest practices and best management practices (Litschert and MacDonald, 2009). Field observations and monitoring on the Colville National Forest has not identified substantial erosion from recent timber harvest units (Jimenez, 2013b).

Temporary road construction would remove soil from productivity on approximately 2 acres.

Prescribed Fire

Monitoring of twelve prescribed fires in 2013-2016 show less than two percent detrimental soil conditions. High and moderate soil burn severity is typically less than 3% of measured transects and does not represent a threat to soil productivity or soil quality. Existing roads and natural features are typically used as control lines as well as hand line. Hand line and machine line typically represents less than 1% of the unit. Water control structures would be installed on hand line to prevent soil erosion.

Other Proposed Actions

Other proposed actions will not measurably increase detrimental soil conditions in the project area.

6.3.3 – Soil Erosion – Surface Soil Erosion and Landslide Potential

Mechanical Vegetation Treatments (Including Road Construction)

When trees are cut, the root system begins to decay, and the soil-root fabric progressively weakens. The loss of root strength or increased soil moisture or both after tree removal can lower the slope safety factor sufficiently enough that a moderate storm with an associated rise in pore water pressure can result in slope failure (Swanson, 1974). After trees are removed, the frequency of landslides can increase (Ziemer, 1981). Steep slopes (greater than 35%) with shallow soils and heavy removal of the overstory vegetation increase the risk for landslides. Partial cutting, the provision of leave areas (skips), and the retention of understory vegetation help minimize landslide potentials (Dhakal and Sidle, 2003). Areas of high potentials for slope stability failures have been reviewed and evaluated for the treatment units, there is a low potential risk for slope stability failures to exceed Regional Soil Quality Standards and Guidelines or Forest Plan standards. This is due to the soils and geology of the project area and the lack of large group selection treatments. The project area has a moderate historic occurrence of landslide and debris flows.

Prescribed Fire

Prescribed fire is not expected to influence slope stability. Fires are prescribed at low to moderate severities, tree mortality and enhanced soil moisture from reduced vegetation is not expected to increase to a degree at which the potential for landslides or debris flows is increased. Tree mortality would also not be substantial enough to affect root structure across the landscape. Understory vegetation recovery would support slope stability.

Other Proposed Actions

Other proposed actions will not measurably increase surface soil erosion and landslide potential in the planning area. These other proposed actions include hand piling, aquatic restoration activities, recreation changes, and proposed Forest Plan Amendment.

6.3.4 – Soil Organic Matter

Mechanical Vegetation Treatments (Including Road Construction)

Mechanical vegetation treatments will displace, lower, and remove accumulations of soil organic matter through disturbance and increase soil respirations due to bare soil, high soil temperatures, and increased solar radiation into stands and the forest floor. Depending on stand conditions some treatment may add additional fine and coarse wood to the forest floor. These effects will not be outside the thresholds for Forest Plan and Regional Soil Quality Standards.

Road construction would displace topsoil for the footprint of the road and remove soil organic matter. Road footprint would be removed from soil productivity and the growing of vegetation. This will be a long-term effect to soil organic matter in these areas.

Prescribed Fire

In the short-term, forest floor depth and fine wood would be reduced but monitoring indicates that level is not outside of thresholds for Forest Plan and Regional Soil Quality Standards. Long-term addition of carbon to the soil in the form of charcoal and nutrients are cycled through prescribed fire. Areas of fire dependent ecosystems would be returned to conditions more within the historic range of variability for organic matter deposition and amounts on the

landscape. Overall, amounts of organic matter would be reduced but soil nutrient cycling and soil function would be improved by restoring stands to within their historic range of variability.

Other Proposed Actions

Other proposed actions will not measurably increase or decrease soil organic matter in the project area. These other proposed actions include hand piling, aquatic restoration activities, recreation changes, and proposed Forest Plan Amendment.

6.3.5 – Wetland Function

Wetland function would improve over the short- and long-term due to restoration actions proposed and protection of wetlands designated in project design features. Wetlands are areas of exclusion for mechanical treatment.

6.3.6 – Other - Nutrient Cycling, Filtering and Buffering, and Soil Carbon Storage

Mechanical Vegetation Treatments (Including Road Construction)

With commercial timber harvest, there is a potential for losses in soil organic carbon and soil organic matter but not in amounts that would reduce soil quality and soil productivity (Johnson and Curtis, 2001; Powers, 2002). Treatments would increase decomposition and facilitate increased inputs of soil organic matter into the soil profile through slash, coarse woody material, and root decomposition with design criteria in **Section 3.4** (Brown et al., 2003).

Prescribed Fire

Soil nutrient status would be increased and soil acidity decreased, both of which are positive effects. Approximately 10% of soil nitrogen would be lost through prescribed fire; research has shown no significant impact to forest productivity with these losses from prescribed fire (Johnson et al., 2005). There would be a short-term reduction of soil organic matter, approximately 5% decrease (Johnson and Curtis, 2001). There will be an increase in stable carbon from the flux of charcoal added to the soil surface and forest floor. This short-term reduction is within Soil Quality Analysis Standards and would have no effect on long-term soil productivity and soil quality. Over the long term, prescribed fire would increase soil organic matter and nutrient cycling over pre-fire levels (Certini, 2005). Prescribed fire has minimal effects on soil or water quality (Murphy et al., 2006). Soil carbon is increased in the short- and long-term as well as carbon being protected in large tree boles created by prescribed fire treatments.

Other Proposed Actions

Other proposed actions will not measurably increase or decrease nutrient cycling and filtering and buffering in the project area.

6.4 – CUMULATIVE EFFECTS FOR THE PROPOSED ACTION

Table 7. Resource indicators and measures for the Proposed Action – cumulative effects

Resource Element	Resource Indicator	Measure	Alternative 2 - Proposed Action Cumulative Effects
Soil Function	Detrimental Soil Conditions	Extent in Activity Areas	No Cumulative Effects
Soil Erosion	Surface Soil Erosion and Landslide Potential	Potential for Detrimental Surface Soil Erosion and Detrimental Mass Soil Movement	Low – (No Change)
Soil Organic Matter	Depth of Forest Floor, Quantity of Fine and Coarse Wood	Potential for Soil Fertility and Soil Function Issues Due to Lack of Organic Matter Inputs	Low – (No Change)
Wetland Function	Status of Function (*properly functioning, functioning at risk, and nonfunctional*)	Number of Surveyed Wetlands Rated as Properly Functioning	Not Applicable

6.4.1 – Past, Present, and Reasonably Foreseeable Activities Relevant to Cumulative Effects Analysis

Effects of past and present activities are discussed in the existing condition, **Section 5.0**. The existing condition described in the analysis incorporates all past actions that have occurred within the project area as described in Summary of Past, Present, or Reasonably Foreseeable Activities Within and Adjacent to the Limestone-Silver Vegetation Management project area document present in the project file.

6.4.2 – Cumulative Effects of Alternative 2 – The Resource Elements and Resource Indicators

There are no other activities in the reasonable foreseeable future (defined for this analysis as projects decided and waiting for implement, in any stage of planning, or listed on the out year plan, or listed in the Schedule of Proposed Actions on the Colville National Forest website) that are expected to substantially increase the detrimental soil condition in the project area. There is no overlap in time and space. Effects are described in the direct and direct effects in the previous sections.

There are no quantifiable cumulative effects as a result of the proposed action in terms of Soil Function, Soil Erosion, Soil Organic Matter, and Wetland Function resource elements.

7.0 – SUMMARY

7.1 – DEGREE TO WHICH THE PURPOSE AND NEED FOR ACTION IS MET

The soil resource is not directly related to the purpose and need of the project and was not identified during scoping as a resource that should be included in the purpose and need.

7.2 – DEGREE TO WHICH THE PROPOSED ACTION ADDRESSES THE ISSUES

No alternatives were selected for detailed analysis other than the no action alternative and the proposed action. There are no issues related to the soil resource.

7.3 – SUMMARY OF ENVIRONMENTAL EFFECTS

Detrimental soil conditions are expected to increase to thresholds that are below Regional and Forest Plan Soil Quality Standards. Ground based timber harvest units with grapple piling treatments will approach 18% detrimental soil conditions that will recover over the short- and long-term depending on the degree of site specific disturbance. Most units of mechanical treatment will remain under 15% detrimental soil condition with the majority of the detrimental disturbance from soil compaction followed by soil rutting (conditions defined by Soil-Disturbance Field Guide (Napper et al., 2009)). Soil erosion will not increase in a measurable way. There will be short-term negative effects to soil function and soil productivity but overall soil conditions and long-term effects will be beneficial as forest stands return to historic and natural range of variability via thinning and prescribed fire treatments.

The construction of 0.5 miles of new temporary roads will inhibit soil productivity on approximately 2 acres (estimated 30 feet impact width) for the long term; >50 years. The new temporary roads will also disconnect hillslopes from hydrologic function across the landscape as the road prism interrupts and diverts horizontal flow of water through the soil pedon. The new temporary roads will also create areas of detrimental soil erosion as flows are concentrated and then diverted off the road prism. These effects are long term on the landscape; 20 to 100 years depending on site specific attributes.

8.0 – COMPLIANCE WITH COLVILLE NATIONAL FOREST LAND AND RESOURCE MANAGEMENT PLAN AND OTHER RELEVANT LAWS, REGULATIONS, POLICIES, AND PLANS

The proposed action would meet soil management goals, maintenance of soil quality, and limit of detrimental soil condition. The proposed project action complies with the standards and guidelines described in the Forest Service Manual and Handbook, General Water Quality - Best Management Practices – Pacific Northwest Region (1988), Region 6 Soil Quality Standards (1999), and Colville National Forest – Land Management Plan (1988).

It is my determination that the proposed action would not detrimentally degrade soil resources beyond above stated guidelines due to treatment prescriptions and characteristics of the landscape involved. Negative direct, indirect, and cumulative effects would be limited with the design criteria and best management practices. This analysis and report represents my best professional judgment based on my observations of the project area, quantitative and qualitative data collection, and a review of the best available science.

9.0 – OTHER RELEVANT MANDATORY DISCLOSURES

Intensity Factors for Significance (FONSI) (40.CFR 1508.27(b))

1) Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.

The no action or proposed action alternatives **do not** exceed a threshold for direct, indirect, or cumulative effects that would be significant for soil quality, soil function, or soil productivity as well as watershed function.

3) Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses. The land could be cropland, pastureland, rangeland, forestland, or other land, but not urban built-up land or water. Prime farmland has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed according to modern farming methods. Prime farmlands do not need to be currently under cultivation or have a history of cultivation. Prime farmland is defined by a criterion of nine different soil characteristics including soil moisture regime, soil temperature regime, soil texture, soil chemistry, and others (*Soil Survey Manual*, 1993).

There are approximately 380 acres of Prime farmland within the Limestone-Silver Vegetation Management project area. Of these area, 12 acres lay within unit boundaries. Anglen silt loam, a designated prime farmland soil, covers 0.5 acres of the east corner of unit 38, 0.5 acres of the southeast corner of unit 39, and 11 acres of the northern edge of unit 40. There is little concern of major degradation of soil productivity within these areas due to the small size and the absence of proposed temporary roads in areas of prime farmland.

Wetlands throughout the project area were surveyed and current condition data collected. This data is described in the existing condition section and **Appendix B**. Project design criteria will limit detrimental effects to wetlands and provide buffers and protection from fuel reduction and timber harvest work. Several wetlands are designated for restoration treatments. These treatments will restore function and protect the long term integrity of the wetland. Overall function and conditions will improve in those wetlands despite having mechanical equipment work in the meadows/wetlands.

10) Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

There is no action related to or effecting the soil resource or watershed function that threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment.

11.0 – REFERENCES CITED

Alexander, E.B., Poff, R., 1985. Soil Disturbance and Compaction in Wildland Management, Earth Resources Monograph 8. USDA Forest Service, Pacific Southwest Region.

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

Biswell, H., 1989. Prescribed Burning - In California Wildlands Vegetation Management. University of California Press, Berkeley, CA.

Bormann, B.T., Homann, P.S., Darbyshire, R.L., Morrissette, B.A., 2008. Intense forest wildfire sharply reduces mineral soil C and N: the first direct evidence. Can. J. For. Resour. 38, 2771–2783.

Brown, J.K., Reinhardt, E.D., Kramer, K.A., 2003. Coarse Woody Debris: Managing Benefits and Fire Hazard in the Recovering Forest (General Technical Report No. RMRS-GTR-105). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Odgen, UT.

Certini, G., 2005. Effects of fire on properties of forest soils: a review. Oecologia 143, 1–10. doi:10.1007/s00442-004-1788-8

DeLuca, T.H., Zouhar, K.L., 2000. Effects of selection harvest and prescribed fire on the soil nitrogen status of ponderosa pine forests. For. Ecol. Manag. 138, 263–271. doi:10.1016/S0378-1127(00)00401-1

Department of Interior, Bureau of Land Management, 2003. A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lentic Area (Riparian Area Management No. TR 1737-16).

Department of Interior, Bureau of Land Management, 1998. A User Guide to Assessing Proper Functioning Condition and Supporting Science for Lotic Area (Riparian Area Management No. TR 1737-15).

Dhakal, A.S., Sidle, R.C., 2003. Long-term modelling of landslides for different forest management practices. Earth Surf. Process. Landf. 28, 853–868. doi:10.1002/esp.499

Elliot, W.J., 2005. Water Erosion Prediction Project (WEPP) - Soil Erosion and Sediment Delivery Modeling.

Jenny, H., 1941. Factors of Soil Formation: A System of Quantative Pedology. McGraw-Hill, New York.

Jimenez, J., 2013a. Fireline Waterbar Guidelines for Prescribed Fire (Unpublished Forest Service Report). USDA Forest Service, Colville National Forest, Kettle Falls, WA.

Jimenez, J., 2013b. Soil Erosion and Timber Harvest on the Colville National Forest (Unpublished Forest Service Report). Colville National Forest, Kettle Falls, WA.

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

Johnson, D.W., Murphy, J.F., Susfalk, R.B., Caldwell, T.G., Miller, W.W., Walker, R.F., Powers, R.F., 2005. The effects of wildfire, salvage logging, and post-fire N-fixation on the nutrient budgets of a Sierran forest. For. Ecol. Manag. 220, 155–165. doi:10.1016/j.foreco.2005.08.011

Johnson, D.W., Walker, R.F., McNulty, M., Rau, B.M., Miller, W.W., Johnson, B.G., 2013. Dale W. Johnson, et al. The Long-Term Effects of Wildfire and Post-Fire Vegetation on Sierra Nevada Forest Soils. Forests 2012, 3, 398-416. Forests 4, 517. doi:http://dx.doi.org/10.3390/f4020517

Litschert, S.E., MacDonald, L.H., 2009. Frequency and characteristics of sediment delivery pathways from forest harvest units to streams. For. Ecol. Manag. 259, 143–150. doi:10.1016/j.foreco.2009.09.038

Mataix-Solera, J., Cerda, A., Arcenegui, V., Jordan, A., Zavala, L.M., 2011. Fire effects on soil aggregation: A review. Earth-Sci. Rev. 109, 44–60.

Miller, R.E., Colbert, S.R., Morris, L.A., 2004. Effects of Heavy Equipment on Physical Properties of Soils and on Long-Term Productivity: A Review of Literature and Current Research. (Technical Bulletin No. 887). National Council for Air and Stream Improvement.

Murphy, J.D., Johnson, D.W., Miller, W.W., Walker, R.F., Blank, R.R., 2006. Prescribed fire effects on forest floor and soil nutrients in a Sierra Nevada Forest. Soil Sci. 171, 181–199. doi:10.1097/01.ss.0000193886.35336.d8

Napper, C., Howe, S., Page-Dumroese, D., 2009. Soil Disturbance Field Guide. 0819 1815 - SDTDC 103.

Neary, D.G., Klopatek, C.C., DeBano, L.F., Ffolliott, P.F., 1999. Fire effects on belowground sustainability: a review and synthesis. For. Ecol. Manag. 122, 51–71. doi:10.1016/S0378-1127(99)00032-8

Neary, D.G., Ryan, K.C., DeBano, L.F., 2005. Effects of Fire on Soil and Water (General Technical Report No. RMRS-GTR-42-volume 4), Wildland Fire in Ecosystems. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Page-Dumroese, D.S., Abbot, A.M., Rice, T.M., 2009a. Volume I: Rapid Assessment (General Technical Report No. WO-82a), Forest Soil Disturbance Monitoring Protocol. USDA Forest Service.

Page-Dumroese, D.S., Abbot, A.M., Rice, T.M., 2009b. Volume II: Supplementary Methods, Statistics, and Data Collection (General Technical Report No. WO-82b), Forest Soil Disturbance Monitoring Protocol. USDA Forest Service.

Powers, R.., 2002. Effects of Soil Disturbance on Fundamental, Sustainable, Productivity of Managed Forests (General Technical Report No. PSW-GTR-183). USDA Forest Service.

Rab, A., Bradshaw, J., Campbell, R., Murphy, S., 2005. Review of factors affecting disturbance, compaction, and trafficability of soils with particular reference to timber harvesting in the forests of south-west western Australia (Technical Report No. 2). Department of Conservation and Land Management, SFM.

Rust, B., 2005. The Field Guide to Soil Moisture Conditions Relative to Operability of Logging Equipment (Unpublished Forest Service Report). Shasta Trinity National Forest, Redding, California.

Soil Survey Manual, 1993. . U.S. Department of Agriculture.

Stark, N.M., 1977. Fire and Nutrient Cycling in a Douglas-Fir/Larch Forest. Ecology 58, 16–30.

Sugihara, N.G., 2006. Fire in California's Ecosystems. University of California Press.

Swanson, D.N., 1974. Slope stability problems associated with timber harvesting in mountainous regions of the Western United States. (General Technical Report No. PNW-21). USDA Forest Service.

Taskey, R.D., Arroues, K.D., 2006. Soil Survey of Yosemite National Park, California.

US Army Corps of Engineers, 2010. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region (Version 2) (Regional Supplement No. ERDC/EL TR-10-3). US Army Corps of Engineers - Engineer Research and Development Center.

USDA Forest Service, 2012. National Best management Practices for Water Quality Management on National Forest System Lands - Volume 1: National Core BMP Technical Guide (Technical Guide No. FS-990a).

USDA Forest Service, 1998. Region 6 Soil Quality Standard and Guidelines (No. FSM 2520), R-6 Supplement 2500.98-1.

USDA Forest Service, 1988a. Colville National Forest Land Resource Management Plan.

USDA Forest Service, 1988b. Region 6 - Water Quality Best Management Practices.

USDA National Resource Conservation Service, 1992. Soil Survey of Pend Oreille County Area, Washington (Soil Survey).

Ziemer, R.R., 1981. The role of vegetation in the stability of forested slopes. USDA Forest Service, Pacific Southwest Research Station, Arcata, CA.

APPENDIX A – SUMMARY OF DETRIMENTAL SOIL CONDITIONS (D0, D1, D2, D3) PER STAND/TIMBER UNIT

Unit ID	Detrimental Soil Condition	Total Points Collected	D0	D1	D2	D3	Forest Floor Depth (cm)	Fine Wood	Coarse Wood	Live Plant	Bare Soil
1	3%	32	78%	19%	3%	0%	8.7	97%	16%	63%	0%
2	11%	102	73%	20%	4%	2%	6.7	96%	16%	80%	2%
5	3%	30	90%	7%	0%	3%	5.2	87%	10%	67%	0%
6	8%	39	56%	36%	8%	0%	2.8	100%	3%	90%	0%
7	10%	50	80%	10%	10%	0%	0.5	92%	12%	96%	0%
9	7%	30	73%	20%	3%	3%	5.3	100%	0%	63%	0%
11	7%	30	87%	7%	7%	0%	6.1	97%	23%	77%	0%
12	0%	30	87%	13%	0%	0%	5.8	100%	7%	63%	0%
13	16%	62	58%	26%	16%	0%	5.6	100%	3%	87%	0%
14	3%	30	83%	13%	3%	0%	3.5	90%	0%	90%	3%
15	7%	30	87%	7%	7%	0%	4.3	93%	3%	40%	0%
16	0%	30	93%	7%	0%	0%	6.5	93%	17%	70%	0%
17	9%	35	86%	6%	0%	9%	6.5	100%	9%	74%	0%
22	0%	30	100%	0%	0%	0%	5.7	100%	27%	27%	0%
23	3%	30	77%	20%	3%	0%	4.9	97%	40%	87%	3%
24	7%	30	80%	13%	0%	7%	6.8	97%	27%	67%	3%
25	7%	30	47%	47%	7%	0%	5.3	97%	10%	70%	0%
26	7%	30	57%	37%	3%	3%	4.6	100%	10%	77%	0%
27	0%	30	80%	20%	0%	0%	5.2	100%	3%	60%	0%
29	0%	30	97%	3%	0%	0%	7.8	100%	47%	53%	0%
32	10%	30	83%	7%	10%	0%	5	93%	33%	63%	0%
33	0%	30	100%	0%	0%	0%	6.5	100%	37%	70%	0%
34	0%	30	100%	0%	0%	0%	8	97%	50%	33%	0%
35	3%	30	70%	27%	3%	0%	5	100%	23%	73%	0%
36	0%	30	87%	13%	0%	0%	4.1	100%	27%	87%	0%
37	0%	30	97%	3%	0%	0%	5.1	100%	30%	60%	0%
38	0%	30	90%	10%	0%	0%	5.5	93%	17%	73%	0%
39	3%	30	80%	17%	3%	0%	7.3	100%	27%	80%	0%
40	7%	30	77%	17%	7%	0%	3.6	100%	7%	53%	0%
41	3%	30	80%	17%	3%	0%	7.8	100%	43%	50%	0%
43	3%	119	64%	29%	7%	1%	6.6	97%	21%	61%	4%
44	8%	40	80%	10%	8%	3%	7.8	100%	20%	45%	30%
46	3%	30	87%	10%	0%	3%	5	97%	7%	47%	0%
47	0%	30	90%	10%	0%	0%	8.4	100%	20%	73%	0%
48	3%	30	80%	17%	3%	0%	5.1	100%	7%	60%	0%
49	3%	30	87%	10%	0%	3%	8.5	100%	7%	70%	3%
50	0%	60	85%	15%	0%	0%	4.6	100%	8%	75%	0%

APPENDIX B – SUMMARY OF WETLAND SURVEY

Wetland ID	Acres	Functional Rating	Trend	Issues
LSW02	2	Not a wetland	N/A	N/A
LSW05	<1	Properly Functioning Condition	N/A	N/A
LSW11	3	Properly Functioning Condition	N/A	N/A
LSW14	2	Not a wetland	N/A	N/A
LSW15	<1	Functional At Risk	Undetermined	Herbs encroaching on formerly ponded area
LSW17	<1	Properly Functioning Condition	N/A	N/A
LSW18	2	Functional At Risk	Downward	Mapped as open water but no surface water present. Appears to be shrinking. Inside unit 47.
LSW19	<1	Not a wetland	N/A	N/A
LSW20	4	Properly Functioning Condition	N/A	N/A
LSW23	<1	Properly Functioning Condition	N/A	N/A
LSW26	12	Non-Functional	Undetermined	Human alterations: berm blocking flow to main potential wetland flow. Half of wetland is out of the FS boundary.
LSW27	<1	Properly Functioning Condition	N/A	N/A
LSW28	<1	Properly Functioning Condition	N/A	N/A
LSW48	<1	Properly Functioning Condition	N/A	Fresh beaver activity. Beaver dropping trees downstream. Flooding and ponding increasing downstream of main pond.
LSW50	<1	Properly Functioning Condition	N/A	N/A
LSW54	<1	Not a wetland	N/A	N/A
LSW55	3	Properly Functioning Condition	N/A	N/A
LSW56	5	Functional At Risk	Undetermined	Half of wetland is out of the FS boundary.
LSW65	<1	Properly Functioning Condition	N/A	N/A
LSW66	15	Properly Functioning Condition	N/A	N/A

APPENDIX C – SUMMARY OF SOIL SERIES IN PROJECT AREA

Soil Type	Volcanic Ash Present	Acres	% of Project Area
Ahren loam, 2 to 20 percent slopes	Volcanic Ash-cap	492	1%
Ahren loam, 20 to 40 percent slopes	Volcanic Ash-cap	486	1%
Ahren loam, 40 to 65 percent slopes	Volcanic Ash-cap	369	1%
Aits loam, high precipitation, 0 to 15 percent slopes	Volcanic Ash-cap	23	<1%
Aits loam, high precipitation, 25 to 40 percent slopes	Volcanic Ash-cap	210	<1%
Aits loam, high precipitation, 40 to 65 percent slopes	Volcanic Ash-cap	468	1%
Aits stony loam, high precipitation, 0 to 40 percent slopes	Volcanic Ash-cap	19	<1%
Aits stony loam, high precipitation, 40 to 65 percent slopes	Volcanic Ash-cap	143	<1%
Aits, high precipitation-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	120	<1%
Anglen silt loam, 0 to 7 percent slopes	Volcanic Ash-cap	319	1%
Anglen silt loam, 7 to 15 percent slopes	Volcanic Ash-cap	114	<1%
Belzar silt loam, 25 to 40 percent slopes	Volcanic Ash-cap	1181	2%
Belzar silt loam, 40 to 65 percent slopes	Volcanic Ash-cap	3548	7%
Belzar silt loam, 5 to 25 percent slopes	Volcanic Ash-cap	763	1%
Belzar-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	3565	7%
Belzar-Rock outcrop complex, 5 to 40 percent slopes	Volcanic Ash-cap	2072	4%
Bonner gravelly sandy loam, 30 to 65 percent slopes	Volcanic Ash-cap	78	<1%
Bonner silt loam, 0 to 10 percent slopes	Volcanic Ash-cap	203	<1%
Bonner gravelly silt loam, 0 to 10 percent slopes	Volcanic Ash-cap	167	<1%
Borosaprists, ponded	Wetland	51	1%
Bossburg muck	Wetland	20	3%
Brickel stony loam, 20 to 60 percent slopes	No Volcanic Ash	416	1%
Bridgeson silt loam	Volcanic Admixture	12	6%
Buhrig very stony loam, 25 to 40 percent slopes	Volcanic Ash-cap	299	2%
Buhrig very stony loam, 40 to 65 percent slopes	Volcanic Ash-cap	1352	<1%
Buhrig-Rock outcrop complex, 25 to 40 percent slopes	Volcanic Ash-cap	288	<1%
Buhrig-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	3002	<1%
Dufort silt loam, 0 to 15 percent slopes	Volcanic Ash-cap	906	<1%
Dufort very stony silt loam, 0 to 40 percent slopes	Volcanic Ash-cap	38	<1%
Hartill silt loam, 15 to 25 percent slopes	Volcanic Ash-cap	84	1%
Hartill silt loam, 40 to 65 percent slopes	Volcanic Ash-cap	32	1%
Hartill-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	12	<1%
Histosols, ponded	Wetland	11	5%
Huckleberry silt loam, 0 to 15 percent slopes	Volcanic Ash-cap	38	9%
Huckleberry silt loam, 15 to 25 percent slopes	Volcanic Ash-cap	276	1%
Huckleberry silt loam, 25 to 40 percent slopes	Volcanic Ash-cap	347	1%
Huckleberry silt loam, 0 to 40 percent slopes	Volcanic Ash-cap	262	<1%
Huckleberry-Rock outcrop complex, 25 to 65 percent slopes	Volcanic Ash-cap	2815	2%
Huckleberry silt loam, 40 to 65 percent slopes	Volcanic Ash-cap	4754	1%
Huckleberry-Rock outcrop complex, 30 to 65 percent slopes	Volcanic Ash-cap	643	8%
Inkler-Rock outcrop complex, 20 to 40 percent slopes	Volcanic Admixture	162	3%
Inkler-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Admixture	172	<1%
Kaniksu sandy loam, 0 to 15 percent slopes	Volcanic Admixture	249	<1%
Kaniksu sandy loam, 15 to 40 percent slopes	Volcanic Admixture	216	<1%

Soil Type	Volcanic Ash Present	Acres	% of Project Area
Kegel loam	No Volcanic Ash	167	<1%
Kiehl gravelly silt loam, 0 to 10 percent slopes	Volcanic Ash-cap	392	1%
Manley silt loam, 0 to 20 percent slopes	Volcanic Ash-cap	86	<1%
Manley silt loam, 0 to 40 percent slopes	Volcanic Ash-cap	1206	<1%
Manley silt loam, 20 to 40 percent slopes	Volcanic Ash-cap	716	<1%
Manley silt loam, 40 to 65 percent slopes	Volcanic Ash-cap	4141	1%
Manley-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	1831	2%
Martella silt loam, 0 to 5 percent slopes	Volcanic Ash-cap	183	<1%
Martella silt loam, 15 to 25 percent slopes	Volcanic Ash-cap	25	<1%
Merkel stony sandy loam, 0 to 40 percent slopes	No Volcanic Ash	214	<1%
Newbell silt loam, 0 to 25 percent slopes	Volcanic Ash-cap	151	<1%
Newbell silt loam, 25 to 40 percent slopes	Volcanic Ash-cap	16	<1%
Newbell silt loam, 40 to 65 percent slopes	Volcanic Ash-cap	282	2%
Newbell stony silt loam, 0 to 40 percent slopes	Volcanic Ash-cap	204	1%
Newbell-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	218	5%
Orwig sandy loam, 0 to 20 percent slopes	Volcanic Admixture	73	1%
Pits	No Volcanic Ash	108	4%
Rock outcrop	No Volcanic Ash	844	1%
Rock outcrop-Huckleberry complex, 30 to 65 percent slopes	No Volcanic Ash	1537	1%
Rock outcrop-Orthents complex, 50 to 90 percent slopes	No Volcanic Ash	814	1%
Rubble land	No Volcanic Ash	34	<1%
Rufus channery loam, 30 to 65 percent slopes	Volcanic Admixture	35	<1%
Rufus-Rock outcrop complex, 30 to 65 percent slopes	Volcanic Admixture	25	1%
Scotia fine sandy loam, 7 to 15 percent slopes	Volcanic Admixture	72	<1%
Smackout loam, 0 to 5 percent slopes	Volcanic Ash-cap	28	<1%
Smackout loam, 20 to 40 percent slopes	Volcanic Ash-cap	374	<1%
Smackout loam, 40 to 65 percent slopes	Volcanic Ash-cap	874	1%
Smackout loam, 5 to 20 percent slopes	Volcanic Ash-cap	207	<1%
Threemile silt loam, 25 to 40 percent slopes	Volcanic Ash-cap	162	2%
Typic Xerorthents, 30 to 65 percent slopes	Volcanic Admixture	166	7%
Uncas muck	Volcanic Ash-cap	68	1%
Uncas variant muck	Volcanic Ash-cap	17	7%
Waits loam, 0 to 15 percent slopes	Volcanic Ash-cap	62	4%
Waits loam, 15 to 25 percent slopes	Volcanic Ash-cap	1228	<1%
Waits loam, 25 to 40 percent slopes	Volcanic Ash-cap	638	<1%
Waits loam, 40 to 65 percent slopes	Volcanic Ash-cap	2425	<1%
Waits-Rock outcrop complex, 25 to 40 percent slopes	Volcanic Ash-cap	278	1%
Waits-Rock outcrop complex, 40 to 65 percent slopes	Volcanic Ash-cap	2262	3%
Water	No Volcanic Ash	495	1%