Soil Resource Report
Norse Peak and American Fire

Mt. Baker-Snoqualmie National Forest
and
Okanogan-Wenatchee National Forest
Ignition Date: August 11, 2017

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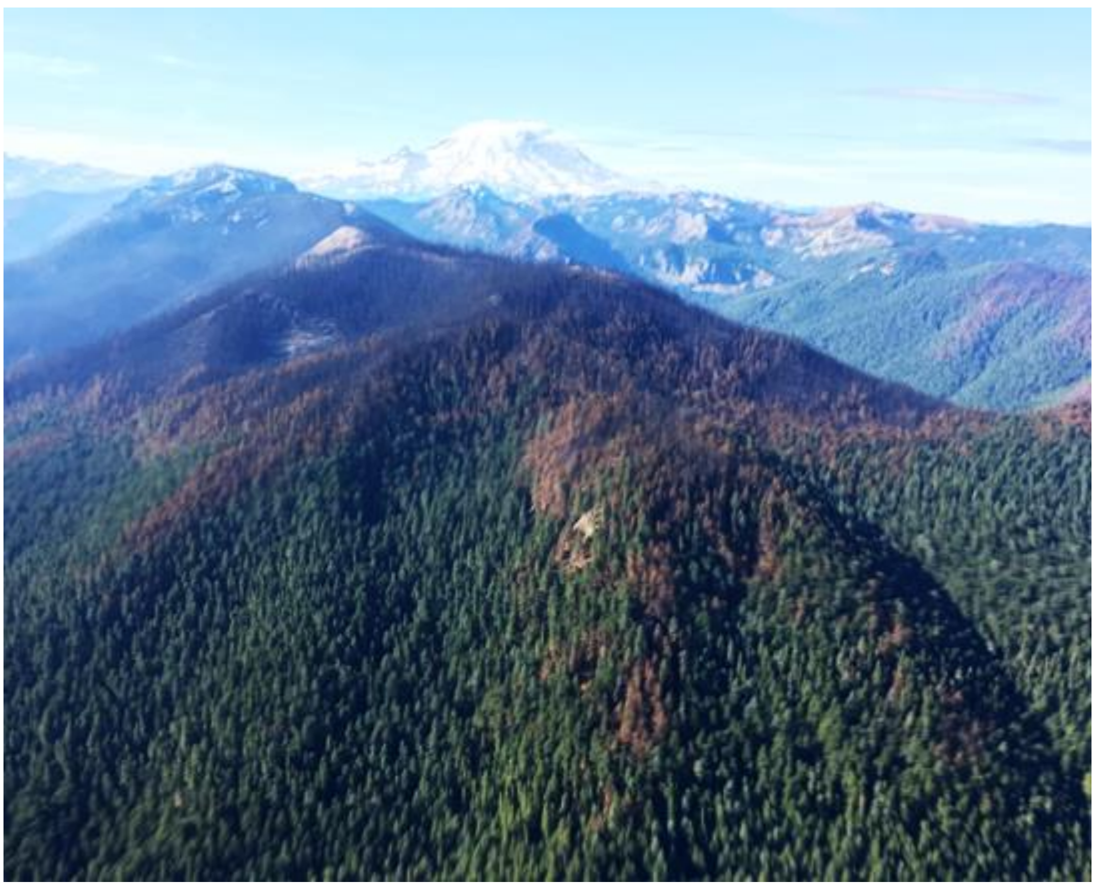

Objectives:

This purpose of this soil assessment is to:

- Summarize the soil types within in the fire and briefly discuss the management importance of each type
- Describe the Soil Burn Severity (SBS) within the fire area
- Estimate soil erosion in watersheds determined sensitive to erosion and sediment transport
- Determine whether threat to soil productivity and threat of erosion constitute an emergency
- Determine any needed treatments
- Make recommendations to Forest management

I. Potential Values at Risk and Threats

The NFS values potentially at risk were initially identified by an interdisciplinary group of employees from various National Forest units, with additional input from the Washington Geological Survey, a component of the Washington Department of Natural Resources. A final list of values with associated threats was refined by the Norse Peak BAER team resource specialists. Overall, minor direct threats exist for soil resources themselves from the fire. Locally, however, moderate to high risk may be present due to indirect effects to fisheries, recreation, and cultural resources. Additionally, deposited sediment can add to material carried downstream during debris flows. The threats likely affecting soil resources and level of risk are listed in Table 1. Debris flow risks and recommendations are discussed in the Geology Report (Slaughter and Contreras, 2017).

Table 1. Risks to Soils and Related Values, with Associated Threats.

Risk of Damage	Resource	Description of Threat
Low	Soil Erosion	The loss of overstory vegetation, ground cover, and organic matter will leave the soil resource susceptible to erosive forces for 5 to 7 years. Likelihood of detrimental soil displacement and loss of soil productivity.
Generally Moderate; locally High	Fisheries	Sediment and ash deposition downstream are expected from the erosion of exposed soil and nutrient-rich ash off-site, causing reduced dissolved oxygen levels and reduced quality of critical habitat for T&E species.
Varies; generally Moderate	Trails and Roads	Increased probability for localized erosion and overland debris flows that could result in damage to road and trail prisms.
Generally Moderate; locally High	Loss of Life or Property	Debris flows, floods, and road washouts may cause damage to or destruction of recreational residences downstream.
Low	Hydrologic Function	An increase in soil erosion could cause a loss of stream channel function with excessive gully formation, stream aggrading, and/or channel widening.
Moderate	Cultural Resources	Soil erosional events may affect cultural resource sites within the burn perimeter.
Low	Loss of Native Plant Cover	Increased potential for the spread of invasive & noxious weeds from known populations from within & adjacent to fire could lead to high erodibility of soil resource.

II. Resource Condition Assessment:

A. Resource Setting

Thirteen fires were ignited by lightning on August 10th and 11th, in the vicinity of the William O. Douglas and Norse Peak Wilderness Areas on the Naches Ranger District of the Okanogan-Wenatchee National Forest. The fires were burning in steep rocky terrain, with difficult access. Two of the fires reached significant size: the Norse Peak (north of State Route [SR] 410) and American Fires (south of SR 410). By early September, the Norse Peak Fire had spread across to the Snoqualmie District of the Mt. Baker-Snoqualmie National Forest, and the two fires had essentially merged across SR 410. The two fires will be collectively referred to as the Norse Peak Fire for the purposes of this report.

The majority of the geology within the Norse Peak Fire formed 5 to 23 million years ago (mya). Much of the lithology consists of volcanic material: lava flows, volcanic necks and sills, and ash layers. These areas are dominated by the Fifes Peak Formation (Tabor et al., 2006). A smaller portion of the fire contains Oligocene (23 to 33 mya) volcanic rocks dominated by the Ohanapecosh Formation (Fiske et al., 1963). Additional geology in the area consists of volcanic rocks of Huckleberry Mountain (Frizzell and others, 1984), tuffaceous rocks (Swanson, 1978), and sandstone (Swanson, 1978). A smaller portion of the fire area consists of nonglacial Quaternary alluvium and landslide deposits. Lava flows and volcanic necks form resistant features and outcrops, as they are generally fine-grained and competent, whereas pyroclastics have little resistance to weathering and tend to form unstable soils. During the late Pleistocene, the area was carved by glacial activity, resulting in glacial troughs. These troughs form the primary drainage network within the fire. These troughs tend to have steep sidewalls that taper to gently-sloped valley floors. The steep slopes tend to have a high percentage of rock outcrop that is unaffected by the fire and tend to produce rock soil cover, which protects the soil from erosion. The gentle slopes of the valley bottoms tend to accumulate eroded soil, reducing sediment delivery to channels.

Soils within the fire area are dominated by volcanic colluvium, generally ashy sandy loam and ashy loamy sand from Mount Rainier eruptions. The soils on the steeper slopes tend to be shallow and less productive, whereas the valley bottoms to mid slopes tend to be deeper and very productive. The volcanic ash in the soils also contributes to high soil productivity, though this ashy component can be easily transported by wind and water due to its low particle density. Because productive soils produce high biomass forests, high surface fuel concentrations were predominant in the forested portions of the fire, particularly on middle and lower slopes. Where the forests burned with high fire intensity, the soils predictably were burned with high severity. Soil surveys maintained by the Natural Resources Conservation Services (NRCS) web soil survey provided soil properties necessary for analysis. The fire area is covered by the following soil surveys: Snoqualmie Pass Area (NRCS, 1992); and Wenatchee National Forest, Naches Area (NRCS, 2009).

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The dominant soils within the burn area are shown in Table 2. Over 80% of the dominant soils are in Soil Group B. Soils in this group have moderately low runoff potential when thoroughly wet; water transmission through the soil is unimpeded.

Table 2. Dominant soil map units within the Norse Peak Fire.

MUSYM	Map Unit Name	Map Unit Texture, Top Layer	Acres in Burn	Percent of Burn	Hydrologic Soil Group
128	Typic Vitricryands, 45 to 90 percent slopes	Ashy loamy sand	16,370	31.4%	B
134	Typic Vitricryands-Rubble land-Rock Outcrop complex, 20 to 60 percent slopes	Ashy loamy sand	6,024	11.6%	B

152	Nimue loamy sand, 30 to 65 percent slopes	Ashy loamy sand	5,396	10.4%	B
155	Nimue loamy sand, tuff substratum, 30 to 65 percent slopes	Ashy loamy sand	9,874	19.0%	B
156	Nimue-Rock outcrop complex, 30 to 90 percent slopes	Ashy loamy sand	5,131	9.9%	B
221	Rock outcrop-Haywire complex, 45 to 90 percent slopes	Ashy sandy loam	4,485	8.6%	C
	Total		***47,280***	***90.9%***	

Depths, organic content, and hydrophobicity of soils are influenced by vegetation and climate. Lower-elevation forest (1,700 feet to 2,700 feet elevation) is dominated by western hemlock, Douglas fir, and western red-cedar. Mid-elevation forest extends from 2,700 feet upward to 4,000 to 6,000 feet elevation depending on aspect, and contains Pacific silver fir, western hemlock, Douglas fir, western white pine, noble fir, and pockets of Alaska yellow cedar. Above about 4,500 feet, high elevation forest is characterized by subalpine fir, mountain hemlock, and Alaska yellow cedar. Mid-elevation slopes on the east side include lodgepole pine, Engelmann spruce, and whitebark pine; lower slopes are dominated by ponderosa pine, Douglas fir, western larch, and lodgepole pine. North-facing slopes and valley floors have denser vegetation, and soils are thicker and finer with greater organic content. South-facing slopes tend to have shallower, rockier soils with sparser vegetation and less undergrowth. Species do not show significant aspect-driven differences, but younger stands tend to have more substantial undergrowth. The tree species, particularly the hemlock, are sensitive to fire. It is not clear what the vegetative response to the fire will be, though it is likely a strong shrub response will occur beginning in the spring of 2018. Because the stands in most moderate and high severity areas were dense and the trees were not completely consumed, branch breakage and tree fall will rapidly add soil cover and surface roughness once snow begins to add a load to the standing dead trees. This will reduce sediment transport to stream channels during snow melt.

The climate in the fire area follows a strong east-west gradient with drier conditions on the east end of the fire, and a strong elevational gradient. The fire area tends to receive much of its precipitation as snow. Erosional events will likely occur during fall rainstorms and spring rain on snow events. Data from the nearest climate stations are shown in Table 3.

Table 3. Precipitation Data from climate stations near the Norse Peak Fire.

Station	Distance from Fire (miles)	Direction from Fire	Annual Precipitation (inches)	No. of Wet Days per Year
Cedar Lake	12	West	102.07	193
Packwood	30	South	51.21	129
Ellensburg	30	East	8.69	69

(Estimates derived using the Rock:Clime tool; Elliot et al., 1991). Heaviest precipitation comes from November through March. Higher elevations are also prone to rain-on-snow events. Small debris flows and avalanches are common events at higher elevations.

Climate, pre-fire soil texture, amount and depth of litter cover, soil moisture, and soil organic matter as well as the temperature and residence time of fire all affect the degree of soil modification and resulting soil hydrophobicity

(DeBano 2000a; Doerr and others 2000). Well-drained, coarse-grained soils are more prone to fire-induced water repellency than are fine-grained soils. Areas with denser undergrowth or thicker duff tend to experience longer fire residence times and greater soil heating. However, although water repellency typically increases due to fire heating, forest soils may have a degree of natural hydrophobicity, typically under canopies of true fir (*Abies* spp.) and in fine-grained ashy soils (Robichaud and Hungerford 2000; Doerr and others 2000). Our water drop tests in unburned forest patches demonstrated a degree of hydrophobicity in the upper few cm, particularly below stands of fir.

In general, areas with more rainfall, finer-textured soils, steep slopes, and high burn severity will be most susceptible to erosion. Soils with a significant rock surface cover will be less susceptible, as rock protects the soil surface and slows surface runoff. Scree slopes will also slow surface runoff and entrain sediment being transported from above. Many areas that burned with moderate severity are already developing a thick cover of needle cast, which will help protect the soil against erosion. Areas that burned with low severity generally maintained sufficient surface cover to slow sheet erosion and promote infiltration. However, upslope contributions from steeper, more severely burned areas may influence erosional processes in low-severity areas; while downstream low and unburned soil and ground cover will help trap sediment produced by upslope burned slopes.

B. Burned Area Reconnaissance/Methodology

Landscape analysis was primarily accomplished with 10 meter digital elevation models using GIS. The majority of the Norse Peak is not accessible due to steep slopes, and downed and hazard trees. Even pre-fire, road access was minimal since much of the moderate and high SBS is in the Norse Peak Wilderness. A large majority of field observations of the deep interior of the burn area came from flight reconnaissance. Field reconnaissance was limited to areas of the fire close to roads and one hike along a portion of the PCT. BAER team members accessed the fire area using Highway 410 and FSRs 70, 71, and 72 on the Mt. Baker-Snoqualmie NF; and FSRs 18 and 19 on the Okanogan-Wenatchee NF.

Precipitation events preceded the arrival of the BAER team and occurred during field reconnaissance. Portions of the burned area experienced snowfall. SBS determinations had to take account of snow cover and canopy cover, while field observations had to account for natural background hydrophobicity.

SOIL BURN SEVERITY: Photos in Appendix C show soils with different burn severities. The SBS map was developed using satellite imagery provided by the Forest Service Geospatial and Technology Center (GTAC) and verified with on-the-ground observations and aerial reconnaissance. More than a dozen SBS field observations were made, covering all three burn severity classes, using procedures developed by Parsons et al. (2010). Information about soil structure alteration, root burn, and water repellency were collected along with soil characteristics. Many of the slopes throughout the fire area are steep and sparsely vegetated with areas of scree or rock outcrops. These outcrops and scree areas have been classified as unburned/very low severity. A more detailed explanation of the SBS production process is provided in Appendix D.

EROSION DETERMINATION:
Generally, erosion will be highest in areas of moderate to severe soil burn severity (SBS) and slopes greater than 25%, excluding rock outcrops. These areas tend to be concentrated at higher elevations, on north-facing slopes, or on interior valley floors within designated wilderness. Field reconnaissance showed that most areas identified on the SBS map as having moderate soil burn severity already had significant surface cover reestablishing from needle fall (approaching 100% in many area). Additionally, many soil areas have surface rock cover that shields the soil from raindrop impact and entrains/slows surface runoff, allowing it to infiltrate into the soil.

Erosion modeling was performed using GeoWEPP (Miller *et al.,* 2016), based on a 5-year storm event. Erosion rates for pre- and post-fire modeling are based primarily on soil texture, rock fragments, climate, soil burn severity, slope, and vegetation communities. This modeling routes erosion, which is helpful in identifying areas of erosion as well as areas of deposition.

C. Findings of the On-The-Ground Survey

1. Resource Condition Resulting from the Fire

Tables 4 and 5 show the final overall breakdown of SBS within the fire perimeter. Appendix A provides a map of the distribution of SBS. Approximately 50% of the fire's 52,056 acres was mapped as high or moderate SBS, and 50% was mapped as low SBS or unburned. The nature of the fire resulted in a mosaic soil burn severity pattern, with the interior having the highest soil burn severity.

Based on our limited field reconnaissance, we determined that about 60% of the moderate and high SBS acres actually had elevated levels of hydrophobicity; as a result, combined moderate and high SBS was estimated at 15,850 acres (32% of the fire area). Additionally, about 20% of the low severity acres were water-repellent (changes beyond background levels).

Moderate and high soil severities were spread throughout upper portions of the drainages of Little Naches River, Crow Creek, American River, Bumping River, Union Creek, Silver Creek, Goat Creek, White River, and Greenwater River. Moderate and high soil burn severity areas exhibited high soil water repellency (5 minutes or more for infiltration). Low and unburned areas have some natural background soil water repellency. Much of the area mapped at moderate burn severity has significant needle cast, which will likely lessen erosion on those slopes. Additionally, throughout much of the burn there are downed trees, which will lessen the potential for erosion. It appears that SBS is correlated to a degree with duff thickness, soil depth, and soil texture. South-facing slopes tended to have less understory vegetation, less duff, and thinner and rockier soils. These south-facing slopes tended to burn at low to moderate intensity, while deeper soils with less surface rock cover burned with higher intensity.

Table 4. Breakdown of Soil Burn Severity within the Norse Peak Fire.

Overall Soil Burn Severity Acres				
Unburned/V. Low	Low	Moderate	High	**Total**
16,457	12,010	18,801	8,651	**55,920**
29%	21%	34%	15%	**100%**

Table 5. Soil Burn Severity Breakdown by Watershed, Within Fire Perimeter

6th Field Watersheds	% Low	% Mod	% High	% M + H
Little Naches River	10%	26%	48%	74%
Crow Creek	19%	52%	17%	69%
Upper American River	22%	41%	10%	51%
Lower American River	43%	27%	3%	30%
Lower Bumping Creek	31%	34%	0%	34%
Silver Creek-White River	7%	66%	11%	77%
Upper Greenwater River	10%	29%	26%	71%
Lower Greenwater River	16%	14%	0%	14%
Total	**21%**	**34%**	**15%**	**49%**

Areas with high SBS generally lack needle cover because crowns were fully consumed. These high SBS areas where steeper slopes and finer-textured, low-rock content soils are present are the most susceptible to erosion. Due to the current presence of snow on the ground, it is expected that erosion rates on high SBS areas and related deposition downslope will be substantially lower until spring, at which time erosion and deposition rates may peak as precipitation events add to snowmelt runoff. The area's generally wet climate and mosaic nature of the fire will speed soil recovery.

Slopes and channels below areas with higher erosion rates also appear to be areas with the highest debris flow hazards, as shown in Slaughter and Contreras (2017). The amount of material moved in a debris flow and resulting hazard are much greater than those resulting from surface erosion.

2. Consequences of the Fire on Values at Risk

A fraction of the tons per acre predicted in the erosion models will actually make it to a stream. This is shown in the sediment in tons per acre analysis. Much of the lower portions of the slopes are unburned and will act to catch debris before it enters the stream or reaches any locations considered to be values at risk. Goat Creek and Union Creek are exceptions, where most of the valley bottom burned with high soil burn severity.

A stormflow discharge model was prepared to determine post-burn discharge at specified pour points (simulated watershed outlets) at or near values at risk determined via interdisciplinary review. The discharge per pour point, in cubic feet per second (cfs), for a 5-year rain event is shown in Table 6.

Table 6. Post-Fire Stormflow Discharge at Specified Pour Points for a 5-year Storm.

Pour Point	Area (mile^2)	Pre-Fire Flow (cfs)	Post-Fire Flow (cfs)	Times Increase
Twenty-Eight Mile Creek outlet	7.30	550.69	794.67	1.44
Lower Greenwater River at fish acclimation pond	35.40	1301.99	4772.26	3.67
Crow Creek at Long Meadow Campground	40.66	1404.09	3948.24	2.51
Unnamed Stream at Camp Fife	0.50	127.74	219.11	1.72
Strawberry Creek near Fife Boy Scout Camp	1.53	234.99	484.32	2.06
Pleasant Valley Campground	6.33	509.52	1209.65	2.37
American River at Hells Crossing	69.92	1886.72	4417.89	2.34
Union Creek Trailhead at SH 410	11.52	706.14	2230.83	3.16
Recreation residences below FSR 7176-410 / Ski Chalet	0.05	36.42	61.24	1.68
Goat Creek at FSR 7176	4.43	419.46	1803.82	4.30
Deep Creek at SH 410	3.21	351.92	1231.60	3.50
Minnehaha Creek at SH 410	2.25	289.96	536.33	1.85

A 5-year interval erosion event was modeled for the post-fire environment using GeoWEPP (Miller, et al.). The estimated pre-fire erosion was effectively zero across the fire area. The presence of a continuous and thick litter layer, forest vegetation root masses, and significant surface rock content generally precludes significant erosion from occurring on non-disturbed surfaces. The average and total erosion rates for the pour points in Table 5 are shown below in Table 7.

Table 7. Post-Fire Soil Erosion Rates for a Five-Year Storm.

Hydrologic Pour Point	Average Tons/Acre Pre-Fire	Average Tons/Acre Post-Fire
Camp Fife	0.1	0.85
Union Creek at SR 410	0.1	4.98
Ski Chalet	0.01	0.01
Pleasant Valley CG	0.1	2.17
Goat Creek at FSR 7176	0.1	5.03
Crow Creek CG	0.1	2.21
Greenwater River	0.1	2.66
28 Mile Creek outlet	0.1	0.21
Deep Creek at SR 410	0.1	2.62
Strawberry Creek	0.1	1.89
Minnehaha Creek at SR 410	0.1	0.63

Erosion during the first large storm events will reduce slope roughness by filling depressions above rocks and logs, and the ability of burned slopes to retain water and sediment will be reduced accordingly. This will result in increased flood potential, erosion, and distance that eroded materials are transported. However, several factors favor a quick recovery of soil function and normal hydrologic response on hillslopes. The existence of fine roots in low and moderate severity burn areas just below the surface will likely aid plant recovery, and suggests there still might be a seed source for natural vegetation recovery. Needle-cast is already forming a protective layer atop areas of low and moderate burn severity. The major concern for soil recovery and related vegetative and hydrologic recovery is in high severity burn areas. The estimated vegetative recovery for watersheds affected by the fires is expected to be approximately 3 years, primarily due to the area's favorable growing conditions, and soil recovery should also be comparatively rapid.

III. Emergency Determination

SOIL PRODUCTIVITY: As shown in Table 6, post-fire erosion rates are expected to range from 1 to 5 tons/acre, with highest rates on steep slopes with fine-textured soils that have a low surface rock cover. In addition, western hemlock and cedar forest communities are poorly adapted to fire. Even light ground fires may damage shallow roots and increase susceptibility to fungal infection. Soil destabilization may be an ongoing process due to progressive tree mortality and tip; however, soil recovery is expected to be fairly rapid within the burn area. Additionally, limited access, steep slopes, and the majority of the fire being in wilderness all pose major limitations to potential treatments.

Probability of Damage: Possible
Magnitude of Consequences: Minor
RISK: Low

SOIL EROSION AND DEPOSITION: In moderate and high SBS areas with steeper slopes, there are short-term localized risks of soil erosion and debris flows, and associated risk of deposition of sediment and debris downslope and downstream. Some locations, in particular Goat Creek at the FSR 7176 crossing and two of the Crystal Mountain Ski Chalets, have elevated sediment or debris deposition potential due to a combination of upslope topography, geology, and soil severity. However, vegetation recovery is expected to be fairly rapid within the burn area, and significant buffers of unburned vegetation may protect these locations from sediment and debris impacts.

Probability of Damage: Likely
Magnitude of Consequences: Moderate to high
RISK: Variable; generally moderate, locally high

IV. Treatments to Mitigate the Emergency

As noted in Slaughter and Contreras (2017), with regard to modeling of debris flow hazards, the area identified as having the highest concern is the Boy Scouts of America Camp Fife. Camp administrators should be notified and are encouraged to seek appropriate professional consulting. Other areas of concern were Deep Creek (SR 410 MP 55.5), Alta Crystal Resort, Goat Creek communities, four buildings at Crystal Mountain Resort, and Cabins near Union Creek. Tenants have already been notified along Goat Creek and elsewhere. As stated above, due to the large vegetated buffer distance between moderate or severe SBS and any structures, in debris flow most or all of the sediment may settle out prior to reaching these structures.

Other recommended treatments are generally to be applied in spring and summer 2018. Much of the interior area of the fire area is already covered with snow and experiencing winter conditions. Application of treatments will still be viable in spring and summer of the first post-fire year since snow cover will protect most of the slopes from erosion over the winter and spring runoff is expected to be dominated by snowmelt, which is more gradual and thus less erosive than storm runoff.

ROAD AND TRAIL TREATMENT EFFECTS ON SOILS: Proposed BAER treatments on roads and trails will mitigate some risks to soils by preventing the concentration of flows onto adjacent soil areas that can perpetuate erosion problems on greater portions of the landscape and degrade soil quality.

A. Treatment Types

To protect soil productivity of fine-textured soils that burned with moderate to high severity along treatable slopes (25% to 50% slopes), mulching was considered as a potential treatment.

B. Treatment Objective

The objective of these treatments would be stabilization of soils in place to prevent erosion, loss of soil productivity, and soil deposition downslope.

C. Treatment Description

The soils team identified potential treatment areas by first selecting areas of high burn severity (most areas of moderate burn severity are already starting to recover due to needle cast, and would not benefit from treatments). These areas were further refined by selecting slopes between 25 and 50 percent (slopes over 25 percent will be most susceptible to erosion and transport, and slopes over 50 percent are too steep for mulching treatments to be effective; fallers cannot safely work on slopes over 50%). Finally, rocky slopes were excluded from consideration because mulching is not an effective treatment for these areas. Lastly, remaining areas that passed this screening process were examined for feasibility of treatment and probability of success.

Due to existing snow cover on the majority of high-severity slopes, the relatively minor area of treatable land, the mosaic nature of the fire burn severity, and the fact that the large majority of the treatable acres are within designated wilderness, no soil treatments are proposed. The only exception to this would be very localized treatments applied to protect vulnerable cultural, fisheries, or recreational resource sites. Locations where debris flows may cause damage to life or property are receiving warnings or closures in lieu of soil treatments. These are discussed in more detail in reports for other resources.

D. Treatment Cost

As no soil treatments are proposed, there are no associated costs.

V. References

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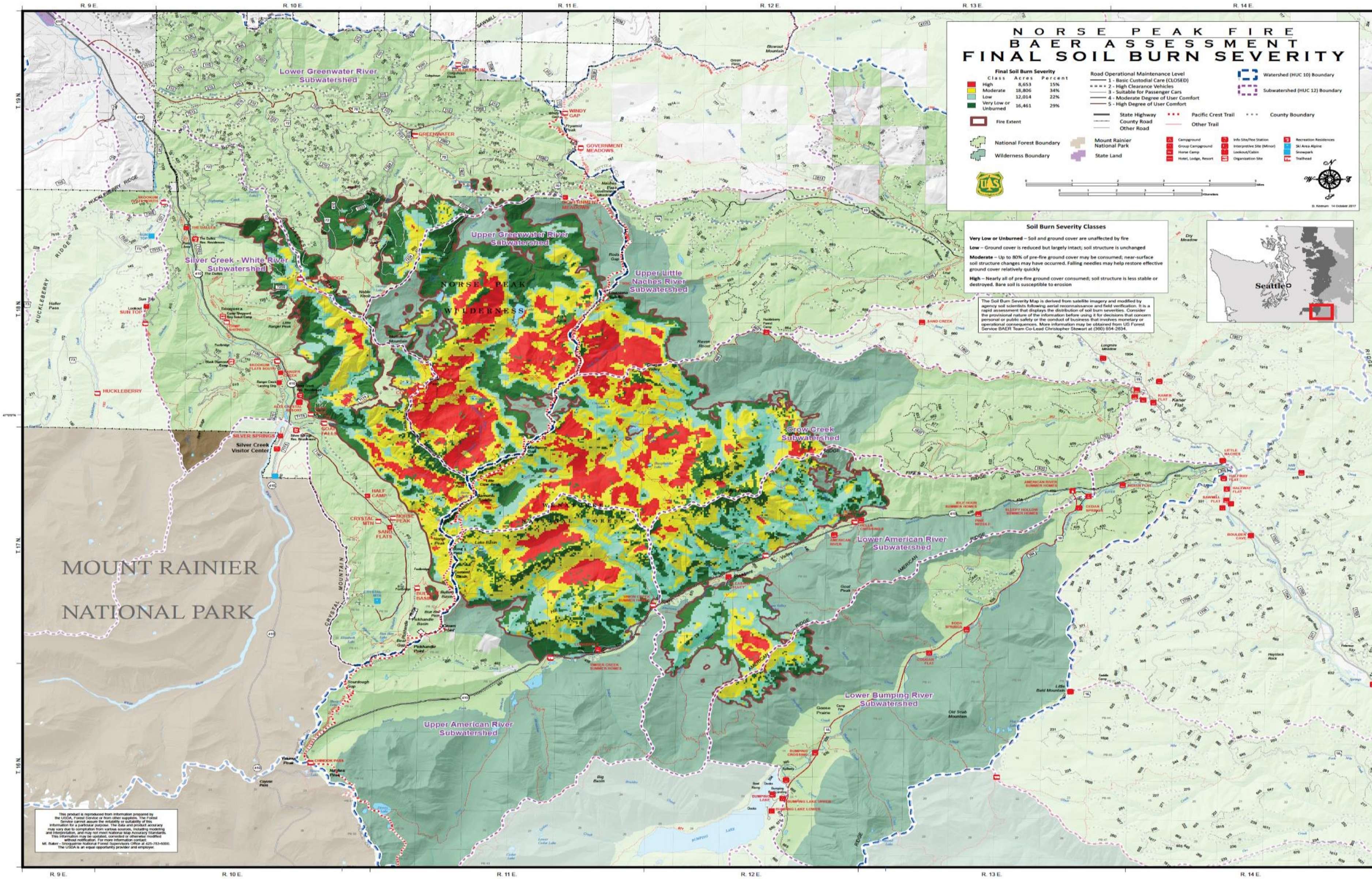
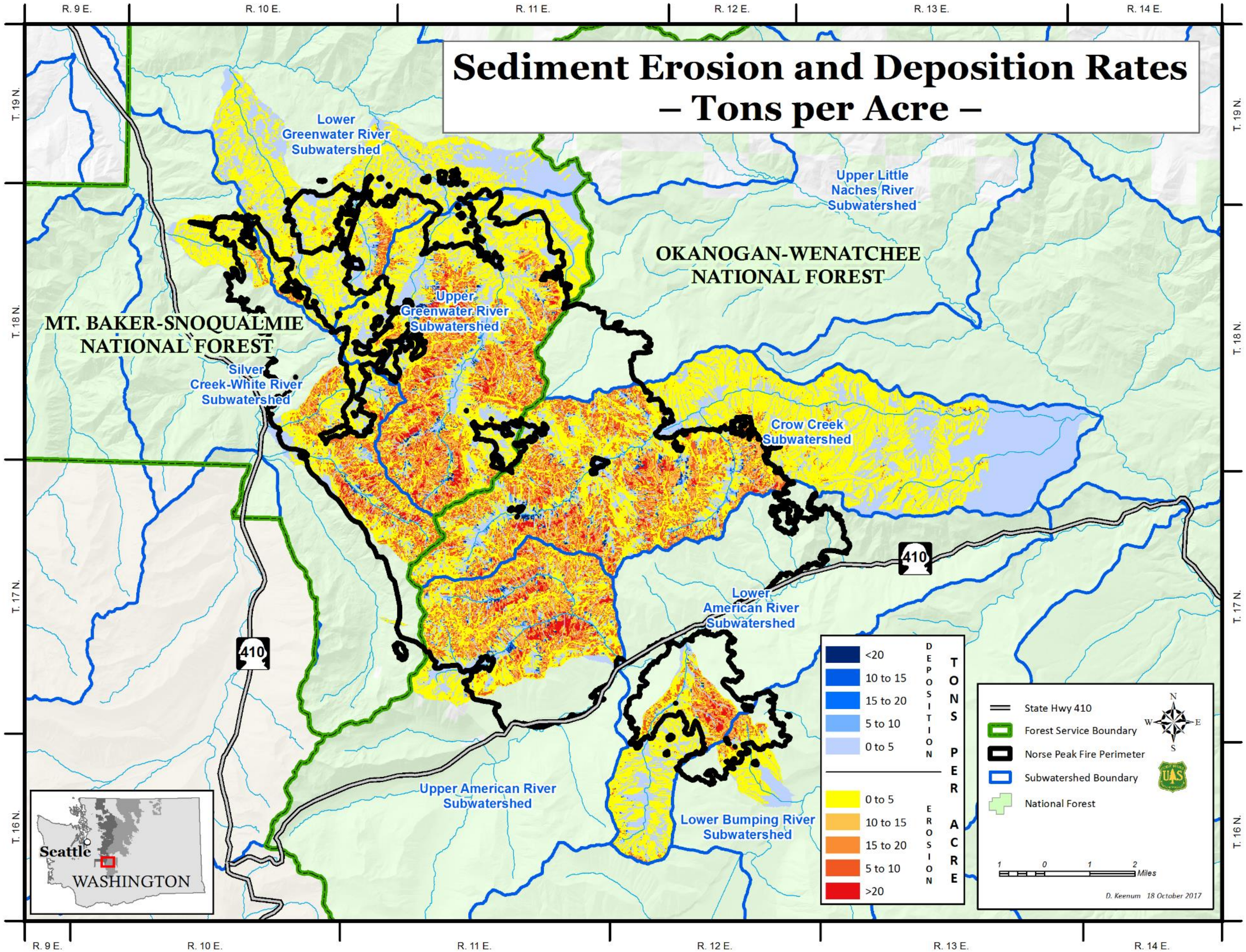
VI. Appendices List:

A – Soil Burn Severity
B – Erosion Rate Map
C – Photos
E – Soil Burn Severity Methodology

APPENDIX A – Soil Burn Severity Map

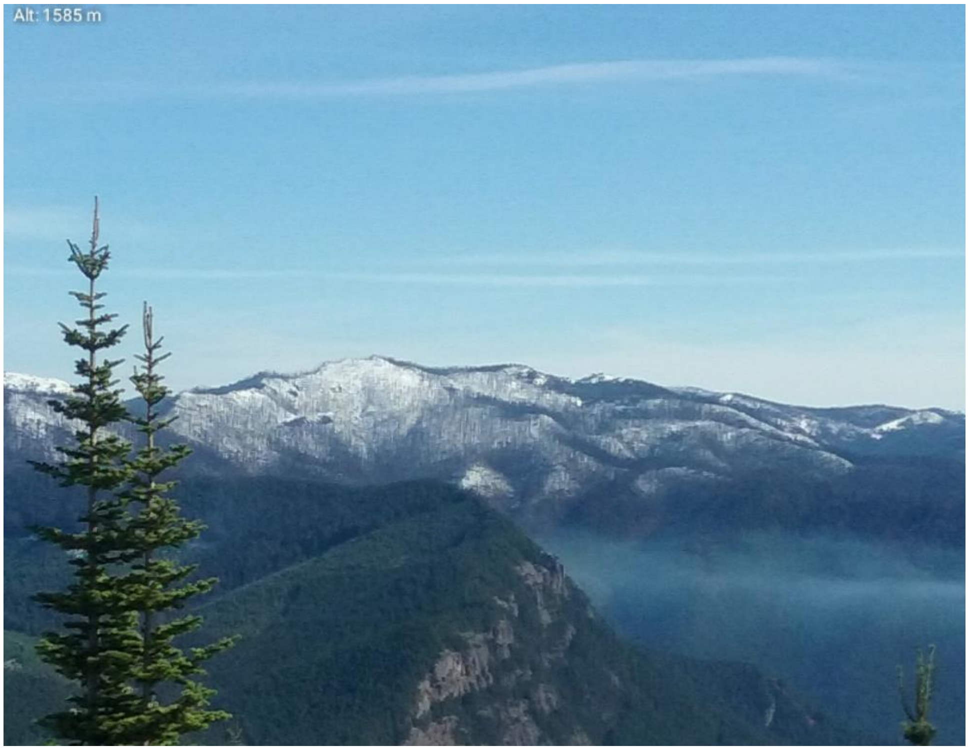


APPENDIX B – Erosion Rate Map



Appendix C - Photos

Soil Erosion and Loss
Snow Covered Soils



Soil Burn Severity

Low

Low soil burn severity sites generally retain substantial unburned vegetation, some of it still alive. Duff and fine roots are still present, though may be singed. Soil generally allows fairly rapid infiltration, and soil aggregate stability is still present.

Moderate

With moderate soil burn severity, most of the pre-fire ground cover (litter and ground fuels) may be consumed, but generally not all of it. Fine roots (~0.1 inch in diameter) may be scorched, but are rarely completely consumed. Soil is generally blackened, with gray patches. Recruitment of effective ground cover is likely to be rapid due to needle-cast from scorched trees. Canopy needles provide an overall brown color to vegetation. Soil structure is generally unchanged, though soil has become moderately hydrophobic, allowing increased runoff.

High

An example of high soil burn severity, showing rilling due to concentrated runoff coming off the Pacific Crest Trail. Soils in this category have lost all or nearly all pre-fire ground cover and surface organic matter (litter, duff, and fine roots), and larger trees and roots are typically charred or completely consumed. Bare soil and ash are exposed and susceptible to erosion, and aggregate structure may be less stable. Soil is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed.

Landscape and Burn Characteristics

APPENDIX D: Soil Burn Severity Mapping Process

Satellite Image Analysis

The satellite image analysis began with a Burned Area Reflectance Classification (BARC) delivered by the Forest Service Geospatial Technology and Applications Center (GTAC). Remote sensing specialists from GTAC analyzed a Landsat 8 image representing pre-fire conditions (acquired 2016-09-13) and a Landsat 7 image representing post-fire conditions (acquired 2017-09-28). The pre-fire and post-fire images were used to create a differenced Normalized Burn Ratio (dNBR) image, which attempts to portray the variation of burn severity within a fire. The severity rating is based on a composite of the severity to the understory (grass, shrub layers), midstory trees, and overstory trees. The BARC is a generalization of the raw, continuous dNBR dataset, simplified for ease of use by non-remote sensing specialists on BAER teams. In addition, GTAC delivered a secondary BARC created from a pre-fire and post-fire subset of Advanced Wide Field Sensor (AWiFS) satellite imagery captured 2016-09-28 and 2017-09-30, respectively. Severity maps generated from AWiFS imagery sacrifice spectral and spatial resolution when compared to Landsat, so this was used as a secondary, fill-in dataset for areas without Landsat observation.

Aerial Reconnaissance, Ground Observations, and BARC Modifications by BAER Team Soil Scientists

The BAER team soil scientists flew over the fire on October 5. Photos from the flight were georeferenced and used, alongside an ArcGlobe project with soil and BARC maps, to verify extents of different burn severities and to make adjustments to the reflectance bands used for each severity class. Field notes, soil data, and photos collected during field reconnaissance were used to further verify the BARC map and document existing soil condition, recovery, and sensitivities within each severity class. Once final adjustments were made to the LandSat and AWiFS images, areas missing data in the LandSat image were replaced with AWiFS data to create a composite image. Hand edits were made by digitizing areas in the composite image that needed adjustment (e.g., rock outcrops), and the composite image was updated with the hand edits to complete a final soil burn severity layer.