Burned Area Emergency Response
Hydrologic Response Report

Norse Peak Fire
Mount Baker-Snoqualmie National Forest
and Okanogan-Wenatchee National Forest

October 2017

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Background

The Norse Peak Fire and American Fire (known collectively as the Norse Peak Fire) were among thirteen starts that were ignited by lightning between 10-11 August, 2017, in the vicinity of the William O. Douglas and Norse Peak Wilderness Areas on the Naches Ranger District of the Okanogan-Wenatchee National Forest. Eventually, the small starts became the Norse Peak Fire with an official ignition date of August 11, 2017. When Norse Peak Fire spread north of State Route (SR) 410 and American Fire reached the south-end of SR 410, the two fires became a shared incident. The fires mainly burned wilderness areas that were difficult to access. Therefore, the approach was less suppression oriented.

The fire was eventually divided into North and South Zones to provide for more effective management and safety. The dividing line between the two zones is the Pacific Crest Trail and mirrors the border between the Mount Baker-Snoqualmie and Okanogan-Wenatchee National Forests. The North Zone is in Pierce County, west of the Pacific Crest Trail, and the South Zone is east of the Pacific Crest Trail.

Up to August 28, 2017 fire growth had been moderate until a thermal trough moved over the fire and south winds pushed the fire into the Mount Baker-Snoqualmie National Forest. While the American Fire had grown moderately that day, the fire north of SR 410 nearly doubled in size, growing north and east into the Norse Peak Wilderness. Air attack was the primary suppression tactic. Ground-based efforts were minimized because of the limited access in wilderness, steep terrain, and on-the-ground fire conditions. By the morning of August 30th, the fire had grown over 9,000 acres.

As of October 10, 2017, the Norse Peak Fire had reached approximately 52,056 acres in size and the American Fire had reached 3,853 acres, collectively 55,909 acres. 50% of the fire was mapped as high or moderate soil burn severity (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.

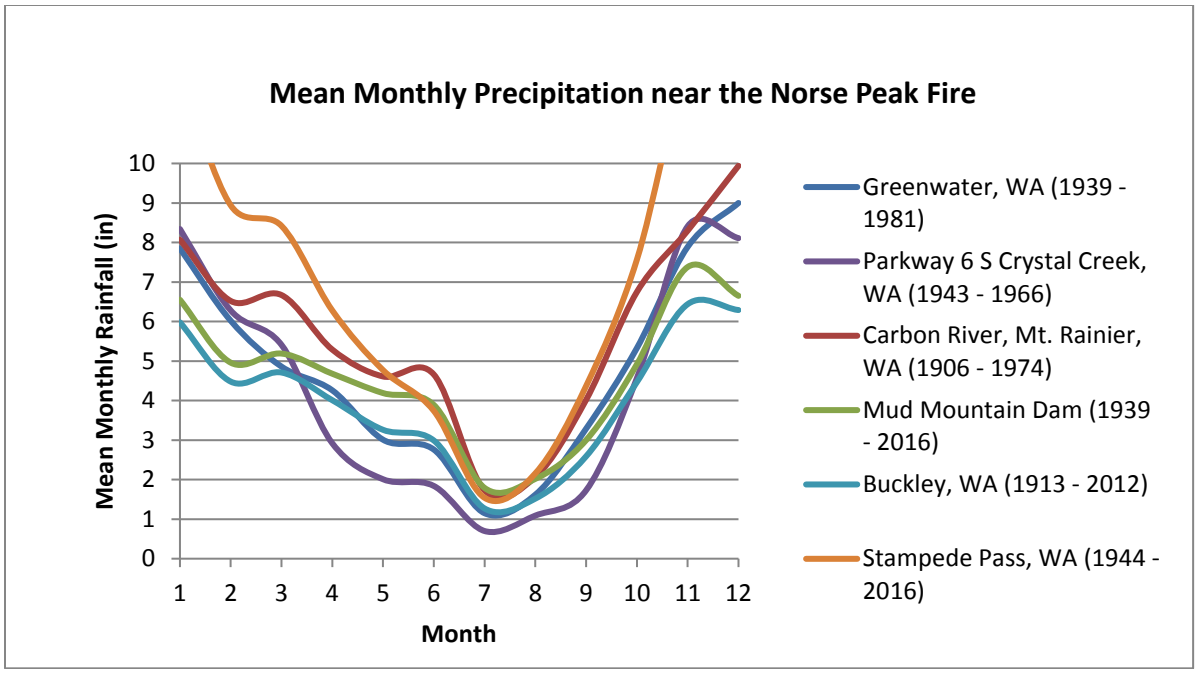

Figure 1. Average monthly precipitation at locations within the burned area perimeter. Source: Western Regional Climate Center

Fire Severity Assessment

The BAER team received a Burned Area Reflectance Classification (BARC) satellite imagery map of the Norse Peak Fire from the Remote Sensing Applications Center (RSAC) in Salt Lake City, Utah. The BAER Team adjusted the preliminary BARC map based on field observations and aerial reconnaissance (see Soils Specialist Report). Resource conditions resulting from the Norse Peak Fire were reviewed by conducting an on-the-ground reconnaissance within the burn area from 6 - 10 October, 2017 (prior to containment) with a focus on at-risk resources and accompanying pour points, as identified by the BAER team.

Design Flow Runoff Response

Wildfires result in increased runoff and sediment yield commensurate with burn severity. Burn Area Emergency Rehabilitation (BAER) teams use burn severity to estimate runoff and sediment increase resulting from fire. These increases are calculated as adjusted design flow and sediment potential (See Soils Specialist Report). Adjusted design flow is the flow increase expected to occur as a result of decreased infiltration and interception following a wildfire. Together these values are utilized to provide estimates of flooding and sedimentation potential and to evaluate the values at risk identified by the BAER team.

Runoff Response

Post-fire flow is calculated using the same regression relationships as pre-fire flow. However, post-fire runoff response is estimated by assuming an increased runoff commensurate with burn

severity. The Norse Peak Fire is expected to respond to an average annual rainfall event differently for lands with soil burn severity of low, moderate, and high. Assumptions of post-fire increases for the fire are listed on Table 1. Differences were evident for soil hydrophobicity between the west- and east- side of the fire, separated by county line (King/Pierce for west side and Yakama/Kittitas for east side). The west side of the fire was found to be have more naturally occurring hydrophobic soils

	Times Increase	
Burn Severity	West side	East side
Unburn/ Very Low	1	1
Low	1.5	1.25
Mod	3	2
High	4	3

Table 1. Post-fire increases

Flood discharges were determined from USGS flow records. A total of 7 gage stations provided points for discharge.

Gage Station	**Watershed Area (mi^2)**	**Discharge Values at Associated Return Intervals from Gage Records (Cubic Feet per Second)**					
		Q 1.5	**2.0 Year**	**5.0 Year**	**10 Year**	**25 Year**	**50 Year**
12488500 American River	78.90	1266.00	1629	2449	3027.00	3802.00	4395.00
12097500 Greenwater	73.50	1083.00	1535	2748	3724.00	5140.00	6339.00
12105000 SMAY Creek	8.56	354.00	476	774	1000.00	1312.00	1563.00
12103500 Snow Creek	11.50	666.00	897	1462	1888.00	2477.00	2958.00
12097000 White River at Greenwater	216.00	3678.00	4909	7870	10093.00	13122.00	15560.00
12105710 NF Green River	16.70	800.00	1059	1675	2128.00	2742.00	3236.00
12480500 Teanaway River	200.00	2405.00	3007	4075	4301.00	4330.00	-

Table 2. USGS gage data used for the Norse Peak Fire

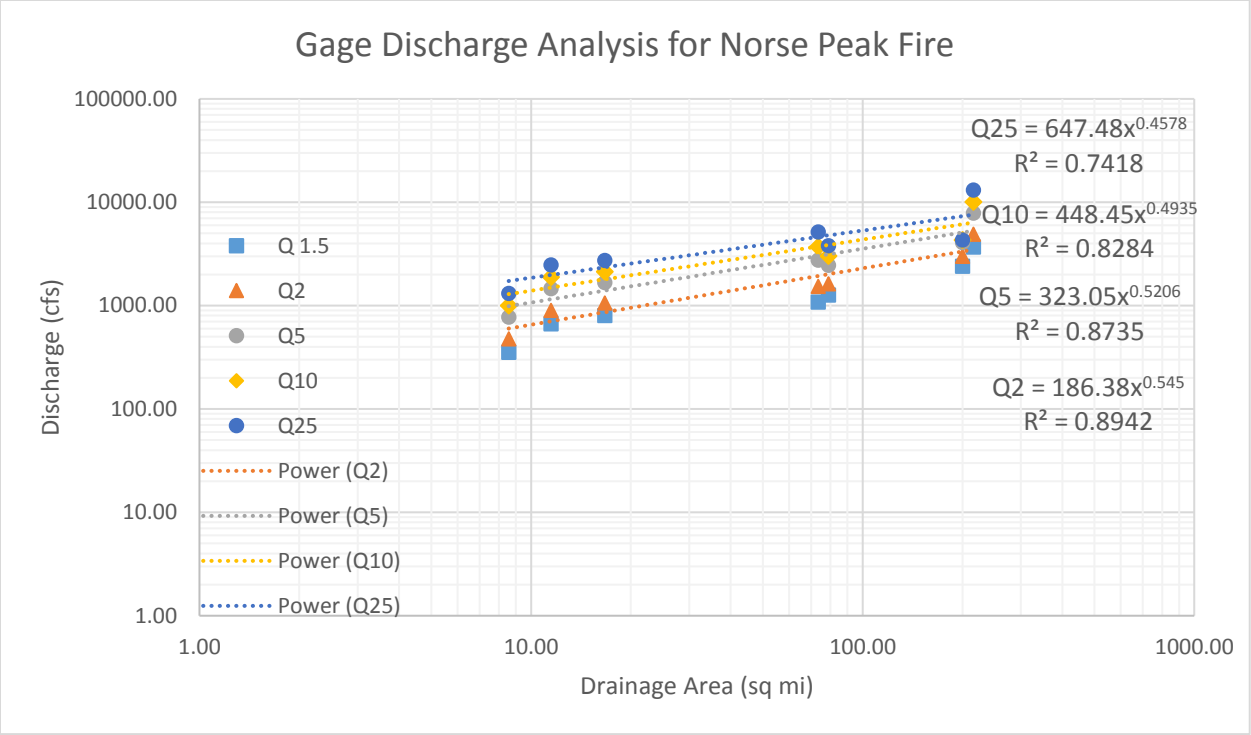

Figure 2. Return intervals for gages in proximity to Norse Peak Fire.

Watershed areas of 8.56 to 216 square miles associated with gage station locations were plotted on a log-log plot against discharges to yield equations associated with the various return intervals. The 2-year flood return interval was used for this BAER analysis because it has a 50% chance of occurring on any given year. The 2-year regression equation for discharge is as follows:

$$Q_2 = 186.38*(\text{Drainage Area}^{0.545})$$

Drainage area was determined through pour points of interest taken on the ground within the burned area. Locations of pour points are shown in Appendix A. The points were brought into Streamstats (https://streamstats.usgs.gov/ss/) through which the drainage areas above the pour points were determined. Results of the increased discharge from the fire to these pour points can be seen in Figures 3 and 4.

Pour point watersheds are related to specific values at risk that have the potential to be adversely affected by post-fire flow. Pour points include risk to road culverts, private structures, and natural resources.

Summary of Watershed Response

Eight 6th Field watersheds overlap with the fire perimeter; percent burned of these watersheds range from 2%-50%. Those watershed that burned at a higher percentage (Crow Creek, Lower American River, Upper American River, Upper Greenwater River, and Silver Creek/White River) have the most "values at risk" identified that may be affected from post-fire flow (Table 3). The following systems are expected to have the greatest change in flow and raise the most concern due to proximity to cabins, campgrounds, roads, etc: Greenwater River, Minnehaha

Creek, Deep Creek, Goat Creek, Union Creek, Kettle Creek, American River and Crow Creek (Table 4). Changes in flow responses are assumed due to the loss of vegetation and increased soil hydrophobicity as a result of the fire (Ice et. al. 2004).

The responses are expected to be most evident during initial and larger storm events immediately after the fire. Thereafter, responses are expected to become less evident as vegetation is reestablished, providing ground cover, increasing surface roughness, and stabilizing and improving the infiltration capacity of the soils. The estimated vegetative recovery for watersheds affected by the fires are expected to be approximately 3 years, primarily due to the favorable growing conditions. Flood potential will decrease as vegetation reestablishes, providing ground cover, increasing surface roughness, and stabilizing and improving the infiltration capacity of the soils. Time for recovery of elevated peak flows to base flow will likely take longer than the vegetative recovery period in this region (USDA 1999).

HUC 6th Watershed	Total Acres	Q2 Burned	Q2 Unburned	Q5 Unburn	Q10 Unburn
Crow Creek	26122.5	2454.95	1407.03	2227.77	2796.80
Lower American River	20754.1	1989.36	1241.23	1976.32	2496.63
Lower Bumping River	29426.4	1762.73	1501.39	2370.27	2966.10
Lower Greenwater River	32640.3	1876.94	1588.65	2501.69	3121.78
Silver Creek/White River	32599.4	2348.05	1587.56	2500.05	3119.85
Upper American River	30186.8	2360.82	1522.41	2401.96	3003.68
Upper Greenwater River	16081.2	1937.38	1080.13	1730.54	2201.32
Upper Little Naches River	28927.4	1961.89	1487.46	2349.25	2941.17

Table 3. HUC 6th Watershed Data for Possible Storm Events

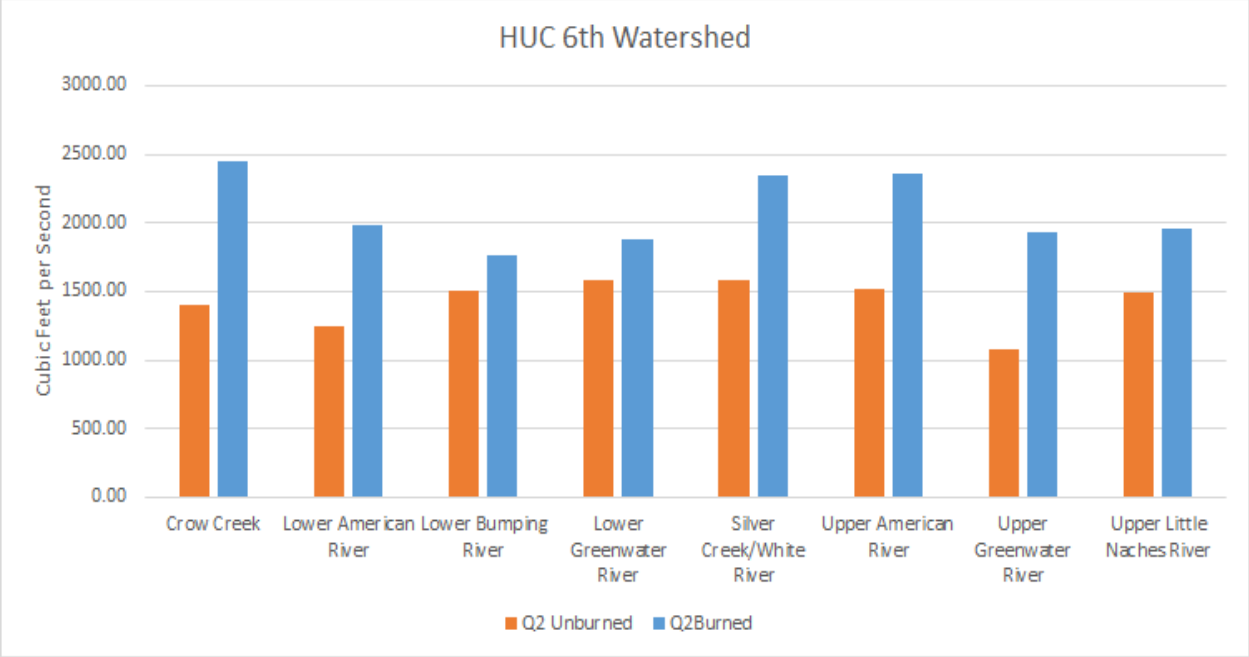

Figure 3. HUC 6th Watershed Flow Increase Table.

Initial erosion of surface soil during the first large storm events will reduce slope roughness by filling depressions above rocks, logs, and remaining vegetation. The ability of the burned slopes to detain water and sediment will be reduced accordingly. This will result in the potential for increased floods and will increase the distance that eroded materials are transported. However, several factors favor a quick recovery in terms of normal hydrologic response of some hillslopes. The existence of fine roots in the 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 (See Soils Specialist Report). The major concern for vegetative recovery and, in turn, hydrologic recovery is in the high severity burn areas.

Pour Point	Acres	Unburn Q2	Burned Q2	Unburned Q5	Unburned Q10	Unburned Q25
28 Mile Creek	4672	550.69	794.67	909.32	1196.09	1608.63
American River Hells Crossing	44748.8	1886.72	4417.89	2948.28	3647.75	4525.69
Camp Fife	320	127.74	219.11	225.19	318.53	471.43
Crow Creek Campground	26022.4	1404.09	3948.24	2223.32	2791.50	3531.04
Deep Cr	2054.4	351.92	1231.60	592.87	797.40	1104.34
Goat Creek Crossing	2835.2	419.46	1803.82	701.11	934.79	1279.82
Greenwater Acclimation Pond	22656	1301.99	4772.26	2068.62	2607.04	3314.06
Minnehaha Creek	1440	289.96	536.33	492.74	669.14	938.55
Pleasant Valley Campground	4051.2	509.52	1209.65	844.27	1114.83	1506.99
Ski Chalet	32	36.42	61.24	67.91	102.25	164.29
Ski Chalet#2	64	53.14	164.85	97.42	143.95	225.65
Strawberry Creek	979.2	234.99	484.32	403.11	553.17	786.64
Union Creek/Hwy 410	7372.8	706.14	2230.83	1153.09	1498.10	1982.25

Table 4. Pour Point Data for Possible Storm Events

A	Estimated Vegetative Recovery Period	3 Years
B	Design Chance of Success	80%
C	Equivalent Design Recurrence Interval	5 years
D	Design Storm Duration	24 hours
E	Design Storm Magnitude	4.5 in
F	Design Flow	42.97 cfs/mi^2
G	Estimated Reduction in Infiltration	35%
H	Adjusted Design Flow	119.4 cfs/mi^2

Table 5. Hydrologic Design Factors

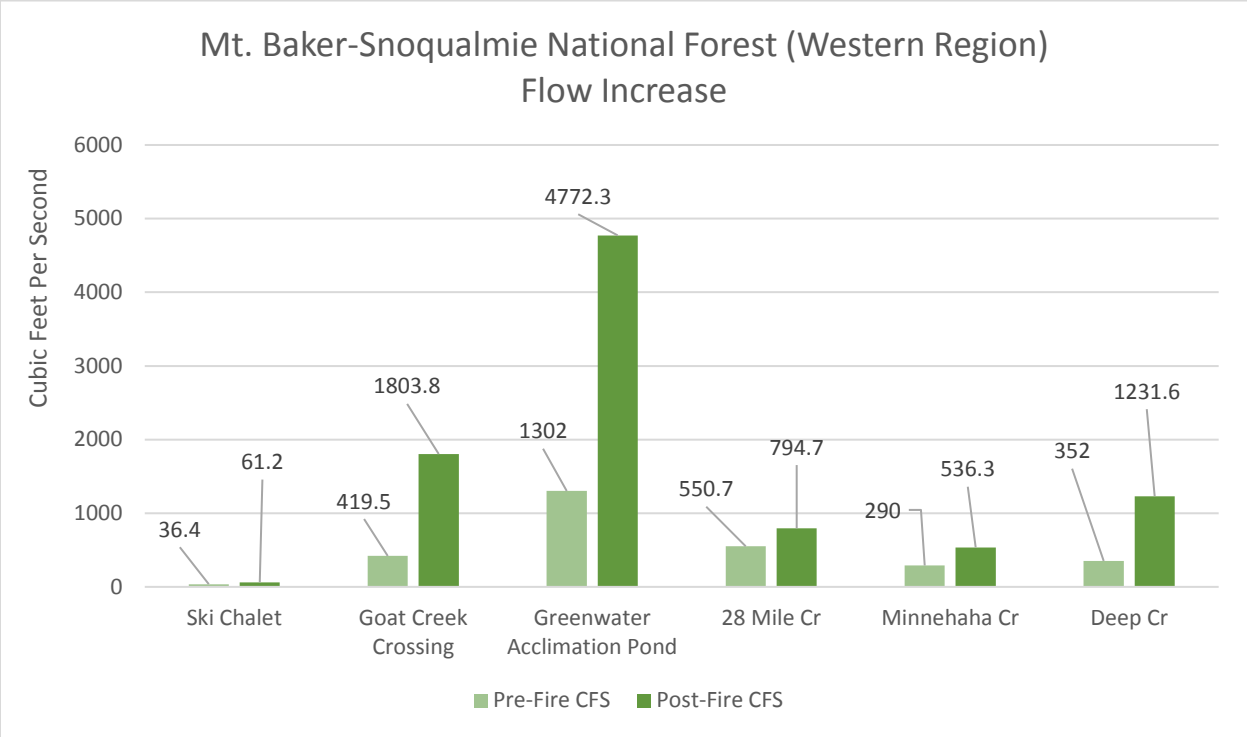

Figure 4. Mt. Baker-Snoqualmie National Forest, Pre and Post Fire Flow Rates

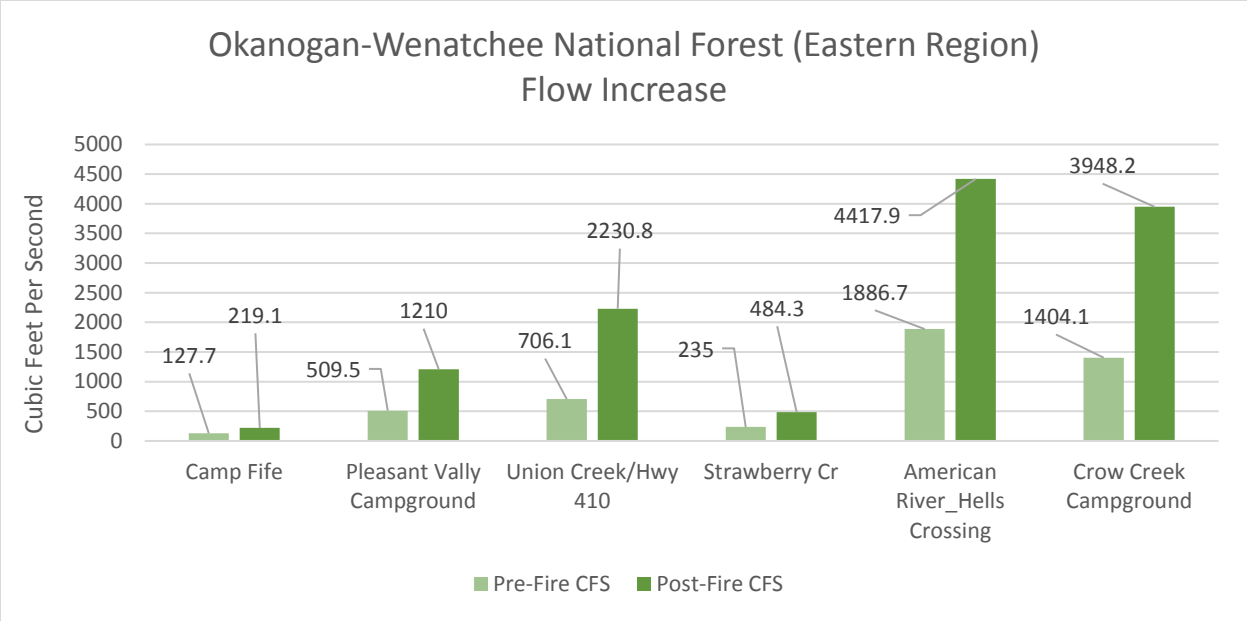

Figure 5. Okanogan-Wenatchee National Forest, Pre and Post Fire Flow Rates

Emergency Determination- Implications of post-fire runoff

The objective of this analysis is to predict post-fire runoff with the goal of mitigating risk to life, property, and natural and cultural resources. After identifying potential Values at Risk (VAR), the magnitude of this risk was systematically evaluated. The risk matrix shown in Table 6 was utilized to identify values in need of mitigation efforts.

The probability of damage or loss within one to three years is classified into four categories: unlikely occurrence (<10%); possible occurrence (>10% to <50%); likely occurrence (>50% to <90%); and very likely or nearly certain occurrence (>90%). This information is combined with an assessment of the magnitude of the consequences. These are classified as major, with implications for loss of life or injury to humans, substantial property damage, irreversible damage to critical natural or cultural resources; moderate, indicating injury or illness to humans, moderate property damage, damage to critical natural or cultural resources resulting in considerable or long term effects; or minor, with property damage limited in economic value and/or to few investments, damage to natural or cultural resources resulting in minimal, recoverable or localized effects.

Values Determined to be at Risk

The BAER team analyzed many different types of values or resources at risk. Values include infrastructure (roads, trails, etc.), buildings, cultural resources, and human life. Pour points were developed with these values in mind. Understanding increased flow risks in relation to these values helps determine what risks may be present.

Probability of Damage or Loss	Magnitude of Consequences		
	Major	Moderate	Minor
	Risk		
Very Likely	Very High	Very High	Low
Likely	Very High	High	Low
Possible	High	Intermediate	Low
Unlikely	Intermediate	Low	Very Low

Table 6. Risk Assessment Matrix.

Recreational Residences

Residence	Possibility for Damage	Magnitude of Consequence	Risk	Notes and Recommendations
Halfway Flat Rec Residences	Possible	Minor	Low	Some increase in flow. Flooding possible in low lying areas, but effects would be minor in damage. Recommend notifying cabin owners they may be inconvenienced from flooding.
Indian Flat Rec Residences	Possible	Minor	Low	Some increase in flow. Flooding possible in low lying areas, but effects would be minor in damage. Recommend notifying cabin owners they may be inconvenienced from flooding.
American River Summer Homes	Possible	Minor	Low	Some increase in flow. Flooding possible in low lying areas, but effects would be minor in damage. Recommend notifying cabin owners they may be inconvenienced from flooding.
Sleepy Hollow Summer Homes	Possible	Minor	Low	Some increase in flow. Flooding possible in low lying areas, but effects would be minor in damage. Recommend notifying cabin owners they may be inconvenienced from flooding.
Idle Hour Summer Homes	None	None	Very Low	High above burn; outside burn area
Pleasant Valley Rec Residences	Possible	Minor	Low	Some increase in flow. Flooding possible in low lying areas, but effects would be minor in damage. Recommend notifying cabin owners they may be inconvenienced from flooding.
The Dalles Rec Residences	Possible	Minor	Low	Some increase in flow. Flooding possible in low lying areas, but effects would be minor in damage. Recommend notifying cabin owners they may be inconvenienced from flooding.

Crystal Mountain Ski Clubs	Likely	Moderate	High	Expected increases in flow not large, but avalanche or debris flow danger pose greater risk. Recommended to notify these cabin owners there is a risk to their property.
Goat Creek	Likely	Major	Very High	Flows in Goat Creek are expected to increase to a 30-year flood event during large storms with post-fire conditions. Four cabins are in imminent danger of flooding due to their proximity to the stream (within floodplain); [redacted]. These should not be occupied during winter and spring storms. The other cabins are higher on the banks but may still experience nuisance flooding and should be notified.
Alta Crystal Lodge	Possible	Moderate	Intermediate	Lodge is set back from creek fairly high.
Silver Springs	Unlikely	Minor	Very Low	No immediate risk.

Table 7. Recreation Residence Evaluation Table.

Roads

Roads	**Possibility for Damage**	**Magnitude of Consequence**	**Risk**	**Notes and Recommendations**
Goat Creek Crossing FS Road 7176	Possible	Moderate	Intermediate	Pipe is undersized. Flows expected to increase to equate to a 30-year flood event. Two cabins sit directly below this crossing in the floodplain; these are at imminent danger if crossing fails. Recommended to storm patrol this crossing, pull crossing, or heavily armor it.
FS Road 7150 next to Minnehaha Creek	Likely	Moderate	High	Road has pre-fire maintenance issues. Fire may expected to exacerbate maintenance condition. Flows with post-fire conditions are expected to increase to a 6-year flood event.
FS Road 7190410-Bullion Basin Road(Gold Hill Road)	Likely	Moderate	High	Road has experienced problems in past due to steep landscape above. Flows are not expected to have a significant increase, but avalanche danger and debris flow potential pose a greater risk. Recommended to storm patrol and close road.
Hell's Crossing at HWY 410	Likely	Moderate	High	Expected flows with post-fire conditions up to 25-year flood event. Since bridge has moderate capacity to pass flow,

				water may back up or top over bridge. Streambanks downstream of this crossing shows sign of erosion; It is recommended to install barriers to deflect water from further eroding the banks or plant riparian vegetation to stabilize the bank. DOT should be notified to patrol this area during/after storms.
7031- Lower Greenwater River watershed	Likely	Moderate	High	Part of this road is situated within the flood-prone area of Greenwater River. The watershed is expected to have flows increase up to a 30-year flood event, given post-fire conditions. Impacts to road is likely.

Table 8. Roads Evaluation Table.

Other Recreation Facilities

Facility	**Possibility for Damage**	**Magnitude of Consequence**	**Risk**	**Notes and Recommendations**
Halfway Flat Campground	Unlikely	Minor	Very Low	No immediate risk.
Hells Crossing Campground	Unlikely	Minor	Very Low	No immediate risk.
Cougar Flat	Unlikely	Minor	Very Low	No immediate risk.
Pleasant Valley Campground	Likely	Moderate	High	Pleasant Valley Campground sits directly adjacent to American River and across the mouth of Kettle Creek. Flows are expected to increase to a 10-year flood event for Kettle Creek, given post-fire conditions. This may cause flooding to the campground during winter and spring storm events. It is recommended to install barriers to deflect water from damaging infrastructure [redacted]. Streambank armoring would also be useful to protect fish habitat.
Lodgepole Campground	Unlikely	Minor	Very Low	No immediate risk.
The Dalles Campground	Unlikely	Minor	Very Low	No immediate risk.
The Dalles Picnic Area	Likely	Moderate	High	Flows in Minnehaha Creek are expected to increase to a 6-year flood event during large storms, post fire conditions. Since this Picnic area is below road 410 and adjacent to Minnehaha Creek, flooding is expected with potential minor damage to infrastructure.

Union Creek Trailhead	Likely	Moderate	High	Trailhead situated next to Union Creek. Due to the large area burned in the Union Creek watershed, flows are expected to increase to a 30-year flood event. This may cause damage to property in the trailhead during storm events. It is recommended to install barriers to deflect water from damaging infrastructure or temporarily removing these infrastructures (footbridges, picnic tables, etc).
Crow Creek Campground	Likely	Minor	Low	Hydrologic model shows increase for flows at this location. This area may get flooded. Post-fire flows are expected to reach up to a 30-year flood event. It is recommended to install barriers to deflect water from damaging infrastructure [redacted]. Streambank armoring would also be useful to protect fish habitat.

Table 9. Recreation Facilities Evaluation Table.

General and standard treatments to roads and trails (such as stormproofing stabilization, and storm patrols) will be helpful in anticipation of elevated hydrologic responses from the burned areas. There are also two 303(d) listed system within or immediately outside the fire area; Upper Naches (temperature) and Upper White River (sediment, temperature, and pH). Since most post-wildfire effects are natural and impractical to mitigate from a land management standpoint, an increase in identified pollutants may occur. However, implementation of identified treatments to roads and trails will help.

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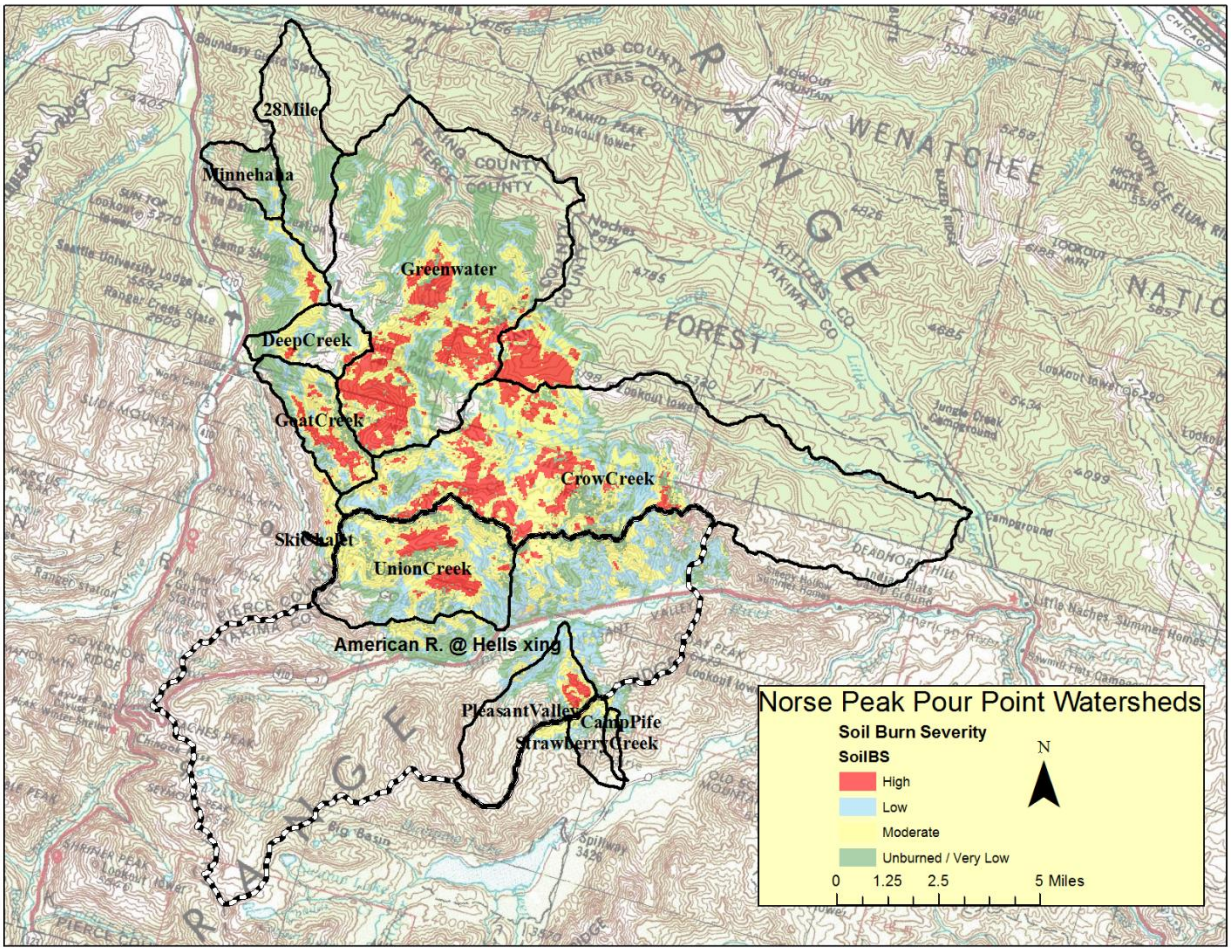
List of Appendices:

Appendix A- Pour Point Watershed Map



Appendix B: HUC 6 Watersheds/ Pour-Point Affected by the Norse Peak Fire (Percent of watersheds burned are reported in parentheses.)

Pour-Point	Total Acres	Unburned Acres	Low Acres	Moderate Acres	High Acres	Total Burned Acres
Ski Chalet	32	29.6 (92.5%)	1.4 (4.4%)	0.98 (3.1%)	0	2.38 (7.4%)
Goat Creek Crossing	2,835.2	931.2 (32.8%)	372.9 (13.2%)	1,060.2 (37.4%)	471 (16.6%)	1904.1 (67.2%)
Greenwater Acclimation Pond	22,656	13,824.5 (61%)	1,658.4 (7.3%)	3,940.4 (17.4%)	0	5598.8 (24.7%)
Twenty-eight Mile Creek	4,672	4,507.2 (96.5%)	108.9 (2.3%)	55.9 (1.2%)	0	164.8 (3.5%)
Minnehaha Creek	1,440	1,060.8 (73.7%)	136.4 (9.5%)	72.3 (5%)	81.1 (5.6%)	289.8 (20.1%)
Deep Creek	2,054.4	989 (48.1%)	371.9 (18.1%)	611.7 (29.8%)	81.1 (3.9%)	1064.7 (51.8%)
Camp Fife	320	272 (85%)	22.3 (7%)	25.9 (8.1%)	0	48.2 (15.1%)
Pleasant Valley Campground	4,051.2	2,935.3 (72.5%)	544.6 (13.4%)	383 (9.5%)	188.3 (4.6%)	1115.9 (27.5%)
Union Creek/HWY 410	7,372.8	2,123 (28.8%)	1,440.2 (19.5%)	2,967.1 (40.2%)	843.9 (11.4%)	5251.2 (71.2%)
Strawberry Creek	979.2	710.4 (72.5%)	116.2 (11.9%)	149.8 (15.3%)	2.3 (.2%)	268.3 (27.4%)
American River at Hells Crossing	44,748.8	37,305.1 (83.4%)	5,451.8 (12.2%)	5,570.8 (12.4%)	1,092.4 (2.4%)	12115 (27.1%)
Crow Creek Campground	26,022.4	15,409 (59%)	2,570.8 (9.9%)	5,454.1 (21%)	2,588.8 (9.9%)	10613.7 (40.8%)

HUC 6th Watershed	Total Acres	Unburned Acres	Low Acres	Moderate Acres	High Acres	Acreage Outside Fire Perimeter
Crow Creek	26,122.5	1,891.6 (7.2%)	2,570.9 (9.8%)	5,452.6 (20.9%)	2,588.2 (9.9%)	13,619.2 (52.1%)
Lower American River	20,754.1	2,190.9 (10.6%)	3,841.9 (18.5%)	2,165.7 (10.4%)	248.8 (1.2%)	12,306.8 (59.3%)
Lower Bumping River	29,426.4	386.4 (1.3%)	346.3 (1.2%)	376.5 (1.3%)	2.3 (.007%)	28,314.9 (96.2%)
Lower Greenwater River	32,640.3	2,078.9 (6.4%)	454.9 (1.4%)	403.8 (1.2%)	3.9 (.01%)	29,698.8 (91%)
Silver Creek/White River	32,599.4	2,872.6 (8.8%)	1,417.6 (4.3%)	2,817.8 (8.6%)	661 (2%)	24,830.5 (76.2%)
Upper American River	30,186.8	2,242.3 (7.4%)	1,859.1 (6.2%)	3,438 (11.4%)	843.9 (2.8%)	21,803.5 (72.2%)
Upper Greenwater River	16,081.2	4,429.9 (27.5%)	1,300.4 (8.1%)	3,570.8 (22.2%)	3,223.7 (20%)	3,556.3 (22.1%)
Upper Little Naches River	28,927.4	364.4 (1.3%)	219.3 (.8%)	576.1 (2%)	1,079.4 (3.7%)	26,688.3 (92.3%)

Appendix C: Pre-Fire and Post- Fire discharge with Times and Percent Increase

Pour-Point Watersheds	Pre-Fire Discharge (cfs)	Post-Fire Discharge (cfs)	Times Increase	Percent Increase
Ski Chalet	36.420	61.243	1.7	68%
Goat Creek Crossing	419.459	1,803.816	4.3	330%
Greenwater Acclimation Pond	1,301.985	4,772.262	3.7	266%
Twenty-eight Mile Creek Acclimation Pond	550.694	794.666	1.4	36%
Minnehaha Creek	127.743	219.105	1.9	71%
Deep Creek	351.920	1,231.603	3.5	249%
Camp Fife	127.743	219.105	1.7	71%
Pleasant Valley Campground/Kettle Creek	509.524	1,209.648	2.3	137%
Union Creek/410 HWY	706.140	2,230.828	3.1	215%
Strawberry Creek	234.994	484.322	2.1	106%
American River at Hells Crossing	1,886.718	4,417.890	2.3	134%
Crow Creek Campground	1,404.092	3,948.237	2.8	181%