III. Raw results of the deep landslide susceptibility analysis for Bull Run Watershed

Susceptible geologic units

In order to determine which geologic units were susceptible to deep landsliding, we first spatially joined the engineering geology and deep landslides to determine the number of landslides occurring in each geologic unit. To perform a one-to-one join, we converted each landslide to a singular point at the landslide's center. We did this because a single landslide polygon may cross several geologic units. We inspected the centralized point of each landslide after the spatial join to confirm that the appropriate geologic unit was selected. We then re-joined these points to the deep landslide polygons in order to attribute each landslide with the correct geologic unit.

Number of landslides occurring in each geologic unit in the Bull Run Watershed

Geologic Unit	Landslide Frequency	Landslide Area/ Geologic Unit Area
Aschoff Buttes cinder cone	1	16.2%
basalt of the Bull Run Watershed	142	9.6%
Columbia River Basalt Group (Wanapum Basalt)	36	8.6%
andesites of Zigzag Mountain and Lolo Pass	23	13.3%
Pliocene lava flows, undivided	1	5.4%
Troutdale Formation	116	24.8%
basaltic andesite of Aschoff Buttes	2	1.1%
Columbia River Basalt Group - (Grande Ronde Basalt)	9	3.8%
andesite of Hiyu Mountain	8	2.6%
Boring Lava	4	0.5%
Rhododendron Formation	151	34.9%

Next, we determined the mean and standard deviation for Landslide Area/Geologic Unit Area.

Mean and standard deviation of landslide frequency per geologic unit

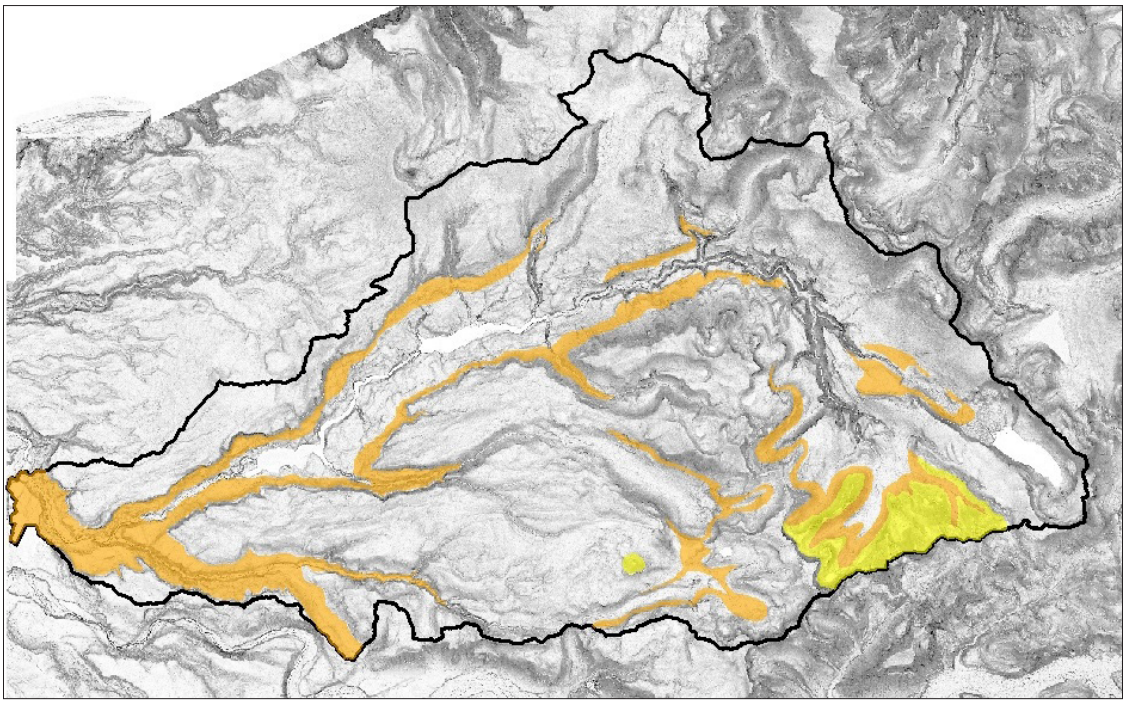
Mean	10.98
Standard Deviation	10.79

We assigned scores ranging from 0 to 2 to each geologic unit. We assigned a score of 0 to any unit with a Landslide Area/Geologic Unit Area less than the mean. We assigned a score of 1 to any unit with Landslide Area/Geologic Unit Area greater than or equal to the mean and less than the mean plus one standard deviation. We assigned a score of 2 to any unit with Landslide Area/Geologic Unit Area greater than or equal to the mean plus 1 standard deviation. Using criteria listed above, we assigned a score of 2 to two geologic units, a score of 1 to two geologic units, and a score of 0 to all other units.

Relative scores assigned to each geologic unit based upon landslide frequency and criteria listed above.

Geologic Unit	Score
cinder cone/small volcano	1
basalt of the Bull Run Watershed	0
Columbia River Basalt (Wanapum and Frenchman Springs Members)	0
andesites of Zigzag Mountain and Lolo Pass	1
Cascade Platform lavas	0
Troutdale Formation	2
basaltic andesite of Aschoff Buttes	0
Columbia River Basalt - (Grande Ronde Member)	0
andesite of Hiyu Mountain - Quaternary andesite	0
Boring Lava	0
Rhododendron Formation	2

Map showing susceptible geologic units with scores of 0 (no color, gray), 1 (yellow), and 2 (orange) in the Bull Run Watershed (thick black line).



Susceptible geologic contacts

In order to determine which contacts were susceptible to deep landsliding, we compared the engineering geology and deep landslide databases. We overlaid landslides on the geology dataset to see how many landslides intersect with the boundary between two geologic units. We performed a query for each possible geologic contact to determine the frequency of landsliding. For example, where the Rhododendron Formation contacts the basalt of the Bull Run Watershed, a total of 122 landslides intersect. We exported all associated landslides for each susceptible geologic contact into new, separate datasets.

We selected for further analysis those geologic units with the highest number of landslides occurring on their contacts and their associated landslides. We did not select any contact with 5 or fewer intersecting landslides.

Geologic contacts with in the Bull Run study area and the number of landslides that intersect each contact.

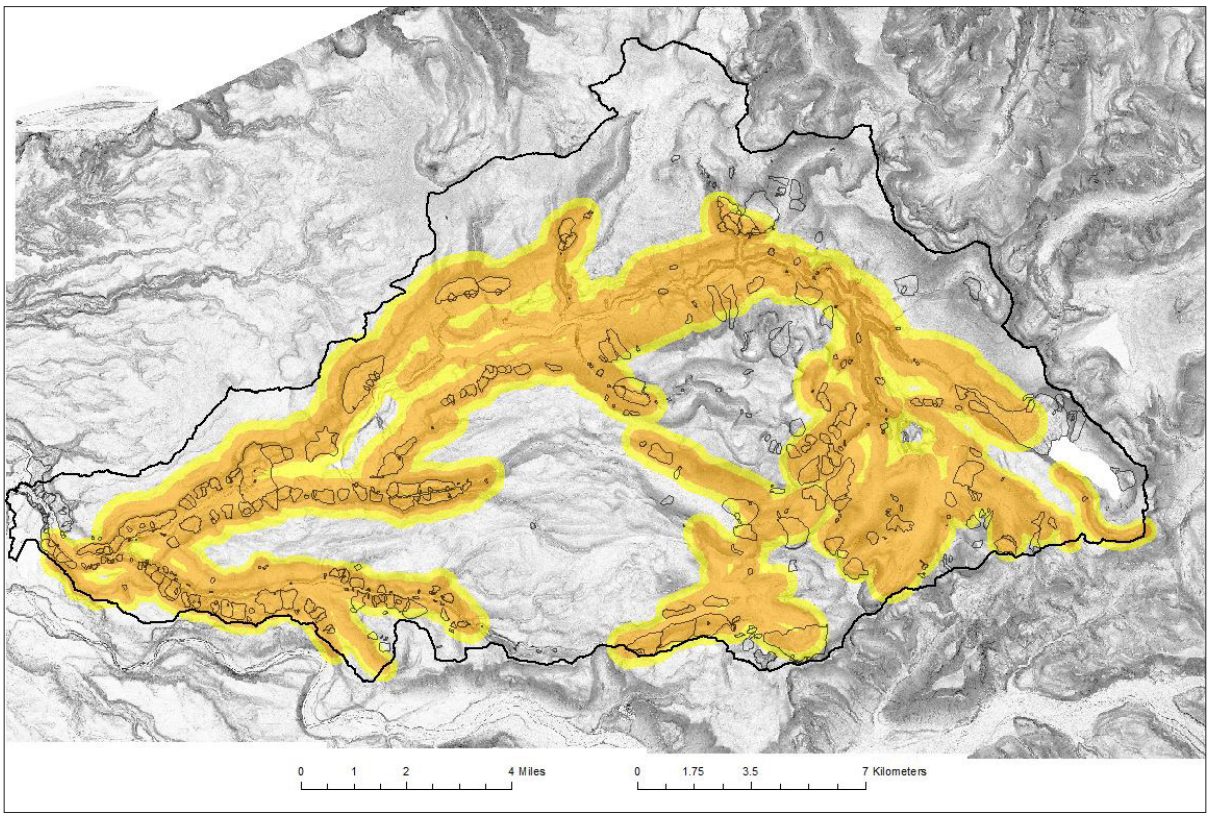
Contact	Landslides
Basalt of Bull Run - Rhododendron	122
Basalt of Bull Run - Troutdale Formation	28
Rhododendron Formation - Toutdale Formation	45
RhododendronFormation - Boring Lavas	14
Rhododendron Formation - Columbia River Basalt (Wanapum and Frenchman Spring Members)	73
Rhododendron Formation - Columbia River Basalt (Grande Ronde Member)	7
Rhododendron Formation - Andesite of Zigzag Mountain and Lolo Pass	13
Columbia River Basalt (Wanapum and Frenchman Spring Members) - Columbia River Basalt (Grande Ronde Member)	18
Cascade Platform Lavas - Andesite of Hiyu Mountain	11

We determined the mean and standard deviation of the associated landslides for each susceptible geologic contact. We performed statistical analysis on each landslide dataset to determine the mean landslide width and standard deviation. We created two buffers around each susceptible geologic contact using the mean landslide width distance and the mean + 1 standard deviation. We assigned the mean buffer a value of 2 and the mean + 1 standard deviation a value of 1.

Contact	Mean Landslide Width (ft)	Standard Deviation	Mean + 1 Standard Deviation
Basalt of Bull Run - Rhododendron	1028	814	1842
Basalt of Bull Run - Troutdale Formation	837	570	1470
Rhododendron Formation - Toutdale Formation	743	562	1352
RhododendronFormation - Boring Lavas	1581	967	2548
Rhododendron Formation - Columbia River Basalt (Wanapum and Frenchman Spring Members)	1153	959	2112
Rhododendron Formation - Columbia River Basalt (Grande Ronde Member)	1175	353	1528
Rhododendron Formation - Andesite of Zigzag Mountain and Lolo Pass	1146	604	1750
Columbia River Basalt (Wanapum and Frenchman Spring Members) - Columbia River Basalt (Grande Ronde Member)	832	1251	2083
Cascade Platform Lavas - Andesite of Hiyu Mountain	700	511	1211

We then merged all geologic contact buffers into one file to be used in the final moderate susceptibility mapping.

Map showing susceptible geologic contacts with scores of 0 (no color, gray), 1(yellow), and 2 (orange) in the Bull Run Watershed (thick black line). Landslides are outlined in black.

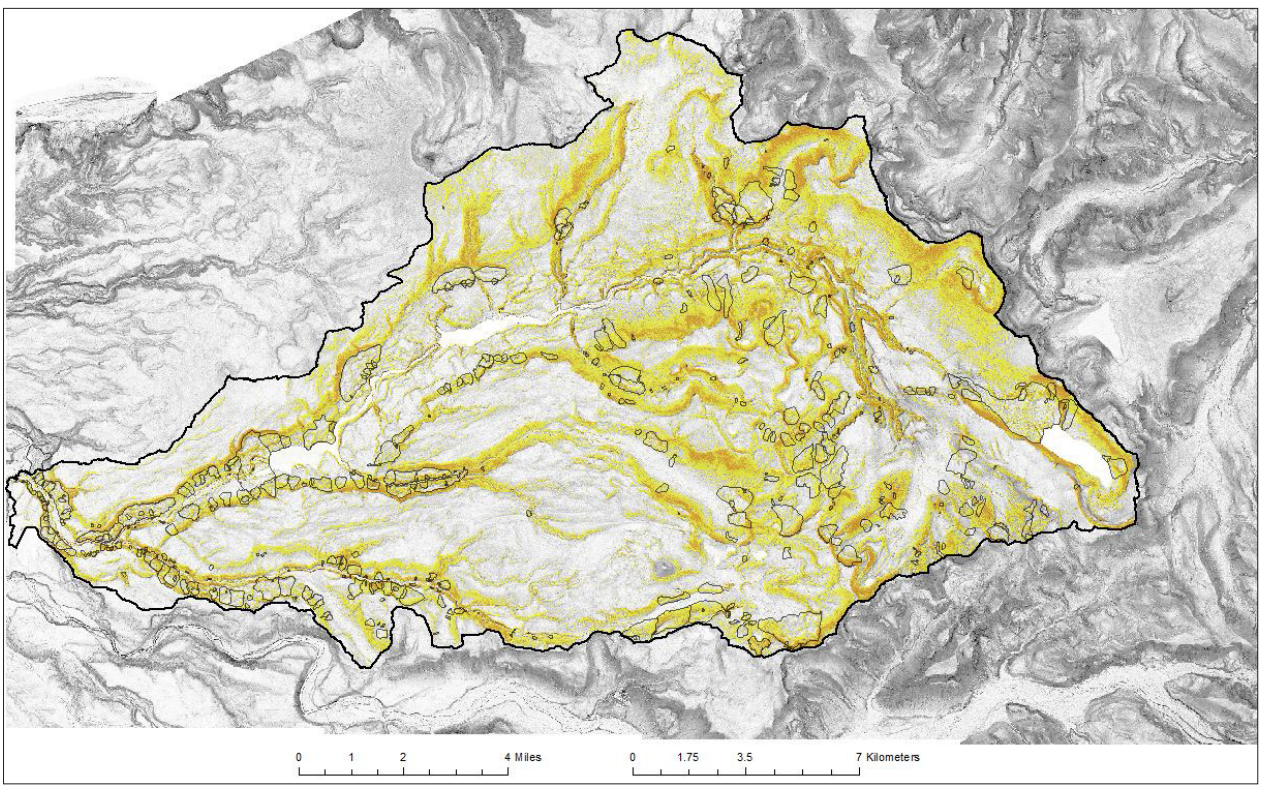


Susceptible slopes

The deep landslide polygons used in this analysis are the same polygons that were joined with the engineering geology in the Susceptible Geologic Units section. We ran summary statistics on the deep landslides polygons to determine the slope mean and standard deviation. The output of summary statistics produces a table. We then joined this table to the engineering geology so that each engineering geology unit would have an associated mean landslide slope. In addition to the mean landslide slope, we added a new field to each geologic unit. Within this new field, we calculated the mean minus two times the standard deviation.

We then performed queries with the slope raster based on the mean and the mean minus two times the standard deviation fields. Anywhere where the slope raster equaled the slope mean of a particular geologic unit, we assigned the cell a value of 2. Anywhere where the slope raster was less than the slope mean and greater than the mean minus two times the standard deviation of a particular geologic unit, we assigned the cell a value of 1.

Map showing susceptible slopes with scores of 0 (no color, gray), 1 (yellow), and 2 (orange) in the Bull Run Watershed (thick black line). Landslides are outlined in black.

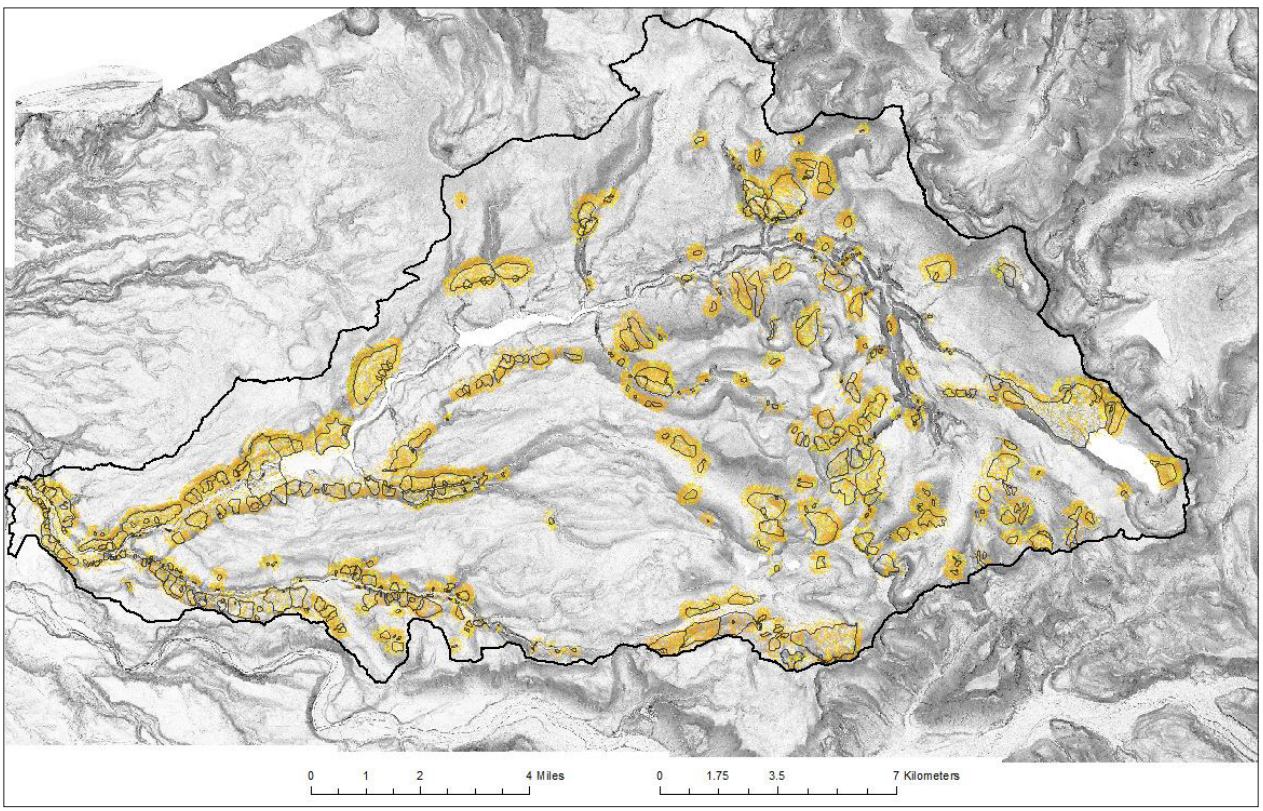


Preferred direction of movement

We converted the landslide polygons to a raster by using attributed landslide direction. We then converted the raster to points. We created an interpolated raster surface from these points using an inverse distance weighted (IDW) method with a maximum distance set to the mean landslide width (660 ft).

We then performed queries with the aspect raster and the interpolated IDW raster. Anywhere where the aspect raster was less than or equal to the IDW raster plus 22.5 and where the aspect raster was greater than or equal to the IDW raster minus 22.5, we assigned a value of 2. Anywhere where the aspect raster was less than or equal to the IDW raster plus 45 and where the aspect raster was greater than or equal to the IDW raster minus 45, we assigned a value of 1.

Map showing preferred direction of movement with scores of 0 (no color, gray), 1 (yellow), and 2 (orange) in the Bull Run Watershed (thick black line). Landslides are outlined in black.



Combined moderate factors score

We then added the final geologic unit, geologic contacts, slopes, and preferred direction rasters together to create a combined moderate factor score. These rasters have values of 0, 1, and 2, so the final raster has values ranging from 0 to 8. A score of zero mean that none of the factors were present; a score of 8 means that all four factors were present, each with a score of 2.

Map showing combined moderate factor scores ranging from 0 to 8 in the Bull Run Watershed (thick black line). Landslides are outlined in black.