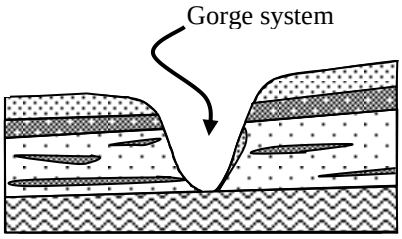
Lower Wishkah WAU
Appendix C

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform #1 – Inner Gorges (>70%) – Very High Hazard



Description of Mass Wasting Unit: Rule-identified inner gorges are steep (>70%) walled canyons or gullies that have been eroded by stream action with evidence of mass wasting along their walls. Inner gorges may be either symmetrical or asymmetrical in profile and are commonly intermittent in lateral extent. They are also occasionally scoured by debris flows during storm events. A 10° (18%) break in slope usually separates the upper margin of an inner gorge feature from the surrounding slope. Also, the scarps of inner gorge slopes revegetate rapidly masking their appearance on aerial photos. Inner gorges have been found in of a wide range of other landforms including deep-seated landslides. Buried wood is often observed in the channels from previous mass wasting events.

Slopes: Generally > 70%
Slope Shape: Convergent to planar
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria and Montesano Formations) and alpine glacial outwash
Elevation: 79 ft to 504 ft
Total Area: 116 acres

Mass Wasting Process: This landform contains primarily shallow undifferentiated landslides, a single debris slide, several small debris flows, and is also found within the bodies of several deep-seated landslides. Recent failures often show exposed soils that lie directly over weathered bedrock. Older failed inner gorges generally accumulate debris in the channel bottom that is usually later masked by the growth of even-aged alder trees.

Forest Practice Sensitivity and Trigger Mechanisms: Root strength decline within and adjacent to inner gorges has been cited as a factor in increasing rates of mass wasting (Krogstad, 1995). Therefore, trees adjacent to an inner gorge feature can have roots extending into the slopes of the inner gorge and provide slope stability. Roads and landings can destabilize slopes by undercutting slopes, over-steepening gradient, or can capture runoff water or shallow groundwater and channel it to point locations. Channeling of water can lead to saturation of the road or landing fill and trigger landslides. Side cast and road (or landing) fill can also over steepen slopes and add weight to the slope leading to mass wasting.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 44 slope failures in a landform covering 116.3 acres. This landform has a Landslide Frequency Rating of 8,049.6 with and without road-related landslides.

Delivery Potential/Criteria: **Very High.** The Landslide Area Rate of Delivery for this landform is 2,250.2 with road and without road-related landslides based on 34 "delivering" landslides totaling 12.3 acres.

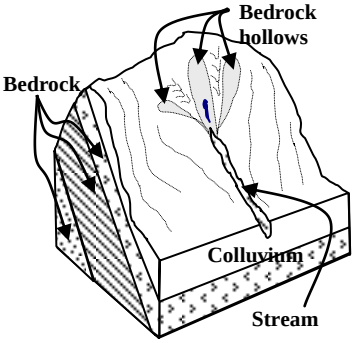
Overall Hazard Potential Rating: **Very High** based on the LHZ Protocol, Table 5.

Confidence: Moderate level of confidence based on good photo coverage but concerns exist due to the number of landslides in this landform, underrepresented DEM accuracy, and limited field verification.

Comments: Computer-generated DEM slope values are much lower than actual slopes verified in field, therefore there may be several rule-identified inner gorges mapped as non-rule-identified inner gorges (Landform #10). The SLPSTB GIS layer representing convergence used for mapping within the Lower Wishkah WAU was also found to underrepresent potentially unstable slopes because of poor DEM accuracy, especially in the upper reaches which could affect the mapping of inner gorges.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform #2 – Bedrock Hollows (>70%) – Very High Hazard



Description of Mass Wasting Unit: Rule-identified bedrock hollows are steep (>70% at the steepest point), shallow spoon-shaped or elongate areas of convergent topography with concave profiles. Bedrock hollows are also called colluvium-filled bedrock hollows, zero-order basins, swales, bedrock depressions, or simply hollows. These features can exist on any steep hillslope and within other landforms. They seldom contain channels but commonly drain directly into inner gorges or other channels down slope. Colluvial debris that accumulates in these steep convergent areas is prone to saturation by precipitation and shallow ground water, making bedrock hollows highly susceptible to slope failures. Over time, bedrock hollows re-vegetate and refill with soil, which can mask their presence on air photos and on the ground.

Slopes: Generally > 70%
Slope Shape: Convergent to concave-planar
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alpine glacial outwash, and old alluvium.
Elevation: 25 ft to 558 ft
Total Area: 153 acres

Mass Wasting Process: This landform contains numerous shallow undifferentiated landslides, several debris flows and debris slides, and was found within many deep-seated landslides and earthflows. Many bedrock hollows connect to inner gorges and non-rule-identified inner gorges, which can act as conduit during a mass wasting event, allowing for direct delivery to a resource. Bedrock hollows are also generally adjacent to steep gradient hillslopes in the Lower Wishkah WAU.

Forest Practice Sensitivity and Trigger Mechanisms: Root strength decline within and adjacent to inner gorges has been cited as a factor in increasing rates of mass wasting (Krogstad, 1995). Therefore, trees adjacent to an inner gorge can have roots extending into the slopes of bedrock hollow and provide slope stability. Roads and landings can destabilize slopes by undercutting the slope, oversteepening gradient, and can capture runoff water or shallow groundwater and channel it to point locations. Channeling of water can lead to saturation of the road or landing fill and trigger landslides. Side cast and road (or landing) fill can also over steepen slopes and add weight to slopes leading to mass wasting.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 58 slope failures in a landform covering 153 acres. This landform has a Landslide Frequency Rating of 8,065.6 with and without road-related landslides.

Delivery Potential/Criteria: **Very High.** The Landslide Area Rate of Delivery for this landform is 1,265.5 with road-related landslides based on 34 "delivering" landslides totaling 9.1 acres. Without road-related landslides, the landslide area rate of delivery (LAR) is 1,251.6 based on 57 "delivering" landslides totaling 9 acres.

Overall Hazard Potential Rating: **Very High** based on the LHZ Protocol, Table 5.

Confidence: Moderate level of confidence based on good photo coverage but concerns occurred due to the number of landslides in this landform, underrepresented DEM accuracy, and limited field verification.

Comments: Computer-generated DEM slope values are much lower than actual values of slopes measured in the field. Due to slope underrepresentation and limitations of the SLPSTB GIS layer representing convergence used during mapping, bedrock hollows might not have been mapped or are misshapen. Due to mapping constraints, small (<0.5 ac) bedrock hollows were merged into adjacent high hazard landforms such as Steep Gradient Hillslopes or Moderate Gradient Hillslopes.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform # 7 – Active Scarps of Deep-Seated Landslides (>20%) –Very High Hazard

Description of Mass Wasting Unit: This unit consists of previously failed, deep-seated landslide headscarps with slopes 20% and greater. These highly weathered bedrock slopes are located at the apex of deep-seated landslides and contain secondary mass wasting processes.

Slopes: 20% and greater
Slope Shape: Convergent to planar
Material: Glacial outwash and marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alpine glacial outwash, and old alluvium.
Elevation: 50 ft to 574 ft
Total Area: 357 acres

Mass Wasting Process: The landslides within this landform were mostly shallow landslides (90%) with fewer debris slides and debris flows and one smaller deep-seated landslide. High precipitation events increase the likelihood of secondary landslides on the steeper slopes of this landform.

Forest Practice Sensitivity and Triggering Mechanisms: Although most of the deep-seated landslides mapped in this report are stable under present drier climatic conditions, frequent smaller shallow rapid landslides occur on the weakened deep-seated landslide materials. Half of the landslides within this landform were on moderate to steep slopes (41-110%) ground that had poor rooting strength or were road-related. A few landslides have failed at much gentler slope gradients. These failures could possibly be due to weathering of the bedrock and/or the structural characteristics of the area, including faulting and folding of the bedrock. Shallow slope failures within this landform could be triggered by infiltration of water due to prolonged storm events or rainy season as well as improper water management associated with harvest or road building activities.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 111 slope failures in a landform covering 357 acres. This landform has a Landslide Frequency Rating of 6,615.4 with road-related landslides and 6,377 without road-related landslides.

Delivery Potential/Criteria: **High.** The Landslide Area Rate of Delivery for this landform is 613.9 with road-related landslides based on 40 "delivering" landslides totaling 10.3 acres. Without road-related landslides, the LAR is 566.2 based on 39 "delivering" landslides totaling 9.5 acres.

Overall Hazard Potential Rating: **Very High** based on LHZ Protocol, Table 5.

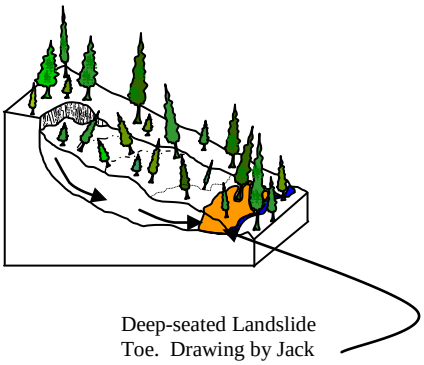
Confidence: Moderate level of confidence based on good photo coverage, underrepresented DEM accuracy, and limited field observations. Confidence level increases for the landform features found in the southern corner of the WAU where almost all deep-seated landslides were field identified.

Comments: Computer-generated DEM's slope values have been shown to be underrepresented by us to 80% based on field verification of Landform #7. Due to quality of air photo copies used in this study, some deep-seated landslide headscarps could not be delineated within the landslide. As a result, some areas that could have been included within this landform were not. Based on the high mass wasting activity seen inside many deep-seated landslide headscarps within this WAU, it is possible that the delivery potential for this specific landform is much higher than observed on the aerial photography.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform Number: #8 –Deep-Seated Landslide Toes (65%)– Very High Hazard

Description of Mass Wasting Unit: This landform consists of rule-identified deep-seated landslide toes. The toe area is usually hummocky, planar or irregular and slopes are between 55% and 85% (based on underrepresented DEM slope values). Mass wasting processes related to failure of deep-seated landslide toes includes shallow surficial mass wasting and/or slumping. The downslope edge of the toe can become oversteepend from stream erosion or from rotation of the landslide mass.



Deep-seated Landslide Toe. Drawing by Jack Powell.

Slopes:	65% and greater
Slope Shape:	Convergent to planar
Material:	Marine sedimentary tuffaceous siltstones and sandstones (mainly Astoria Formation) and alpine glacial outwash
Elevation:	109 ft to 459 ft
Total Area:	11 acres

Forest Practice Sensitivity and Triggering Mechanisms: Downcutting and undercutting by marginal streams and streams that flow across the base of these deep-seated landslide toes has oversteepened and destabilized the feature. These fluvial processes can trigger continued movement of the deep-seated landslide toe and has created several shallow undifferentiated landslides and one debris flow. This landform is sensitive to any forest practice activity that redirects water onto these toes, reduces root strength, undercuts or oversteepens the toes.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 7 slope failures in a landform covering 11 acres. This landform has a Landslide Frequency Rating of 13,180.2 with road- and without road-related landslides.

Delivery Potential/Criteria: **Very High.** The Landslide Area Rate of Delivery for this landform 1,882.9 with road- and without road-related landslides is based on 4 "delivering" landslides totaling 1.0 acres.

Overall Hazard Potential Rating: **Very High** based on LHZ Protocol, Table 5.

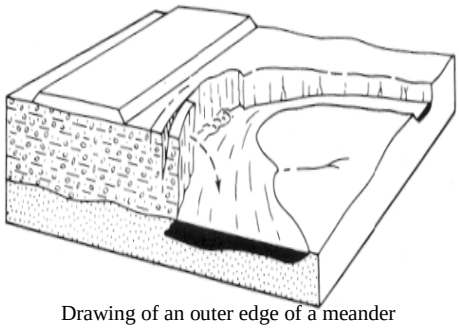
Confidence: Moderate level of confidence based on good photo coverage, underrepresented DEM accuracy, and limited field observations.

Comments: Computer-generated DEM's slope values have been shown to be fairly underrepresented DEM accuracy based on field observation and verification of Landform #7. Due to quality of air photo copies used in this study, some deep-seated landslide toes could not be delineated within the landslide. As a result, some areas that could have been included within this landform were not. Based on the high mass wasting activity per landform area seen inside many deep-seated landslides within this WAU, it is possible that the delivery potential for this specific landform is much higher than observed on the aerial photography.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform #9 – Outside Edges of Meander Bends – Very High Hazard

Description of Mass Wasting Unit: In the northern portion of the WAU, the river and several tributaries have created unstable slopes by undercutting of the outer edges of meander bends along valley walls. These slopes often contain shallow landslides, including shallow undifferentiated, debris flows, and debris slides, and also large deep-seated landslides and earthflows.



Drawing of an outer edge of a meander bend (Forest Practices Board Manual).

Slopes: >11%
Slope Shape: Convergent to Concave-Planar
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alluvium, and alpine glacial outwash.
Elevation: 3 ft to 355 ft
Total Area: 119 acres

Mass Wasting Processes: In the northern half of the Lower Wishkah WAU, the valley constricts a great deal. The constriction of the valley increases the amount of interaction between the river and valley walls. As the river meanders in the north, energy is concentrated in the outside edges of these meander bends. The concentration of this energy causes a positive feedback mechanism between the outer edge of the meander bend and the valley wall in which the meander bend undercuts and oversteepens the valley wall and increases the likelihood of mass wasting events, including shallow undifferentiated landslides, debris flows, debris slides, and even larger, deep-seated landslides.

Forest Practice Sensitivity and Trigger Mechanisms: Any disturbance of root strength, concentrating or channeling of water, or disturbance of the ground within this landform increases the likelihood of mass wasting. In the Lower Wishkah WAU, the greatest risk to increased instability of this landform is associated with the removal of root strength. This risk increases in the northern portion of the WAU where the valley constricts and slopes above the outside edges of meander bends become steeper. Sediment delivery to the Lower Wishkah River and its main creek tributaries from slope failures within this landform is unavoidable, since mass wasting in meander bends is a natural process. However, forest practices on meander bends, whether they are road building, harvest, etc., increase the instability of this landform.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 57 slope failures in a landform covering 119 acres. This landform has a Landslide Frequency Rating of 10,191.3 with road-related landslides and without road-related landslides.

Delivery Potential/Criteria: **Very High.** The Landslide Area Rate of Delivery for this landform is 2,467.4 with road-related and non-road-related landslides based on 51 "delivering" landslides totaling 13.8 acres.
Overall Hazard Potential Rating: **Very High** based on LHZ Protocol, Table 5.

Confidence: Moderate based on the number of landslides located in this landform, good photo coverage, and minimal field observation due to the location of this landform.

Comments: Outer edges of meander bends are rule-identified in the Forest Practices Rules. The outsides of Meander Bends are more fully described in the Forest Board Manual, Section 16 (p. M16-21). This landform falls entirely within the riparian area of the Lower Wishkah River and its larger tributaries.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform #10 – Non-Rule-Identified Inner Gorges (35-69%) – Very High Hazard

Description of Mass Wasting Unit: This landform has similar characteristics to rule-identified inner gorges but has convergent slopes of 35-69%. The landform is expressed as gentle walled canyons or gullies generally with a 10° (18%) break in slope separating the upper margin of the inner gorge feature from the surrounding slope. The non-rule-identified inner gorges may be either symmetrical or asymmetrical in profile and are commonly intermittent in lateral extent. The inner gorge feature is commonly eroded or scoured by stream action with evidence of mass wasting along the walls. The non-rule-identified inner gorges in this report contained at least one or more landslides within its bounds.

Slopes: 35% to 69% (based on 10 meter DEM data or field verified)
Slope Shape: Convergent to planar
Material: Marine sedimentary tuffaceous siltstones and sandstones (Astoria and Montesano Formations), alluvium, and alpine glacial outwash
Elevation: 27 ft to 495 ft
Total Area: 293 acres

Mass Wasting Process: This landform contains numerous shallow undifferentiated landslides, debris flows, debris slides, and some deep-seated landslides. These features often contain streams.

Forest Practice Sensitivity and Trigger Mechanisms: Root strength decline within and adjacent to these non-rule-identified inner gorges has been cited as a factor in increasing rates of mass wasting (Krogstad, 1995). Therefore, trees adjacent to an inner gorge can have roots extending into the slopes of the inner gorge that provide slope stability. Roads and landings can destabilize slopes by undercutting the slope, oversteepening gradient, and/or can capture runoff water or shallow groundwater and channel it to point locations. Channeling of water can lead to saturation of the road or landing fill and trigger landslides. Side cast and road (or landing) fill can also oversteepen slopes and add weight to the slope leading to mass wasting.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 123 slope failures in a landform covering 293 acres. This landform has a Landslide Frequency Rating of 8,941 with roads and 8,722.9 without road-related landslides.

Delivery Potential/Criteria: **Very High.** The Landslide Area Rate of Delivery is 1,715.5 with road-related landslides for this landform based on 84 "delivering" landslides totaling 23.6 acres and is 1,671.9 without road-related landslides based on 82 "delivering" landslides totaling 23 acres.

Overall Hazard Potential Rating: **Very High** based on the LHZ Protocol, Table 5.

Confidence: Moderate based on the number of landslides located in this landform, good photo coverage, underrepresented DEM accuracy, and limited field observation.

Comments: Computer-generated DEM slope values are much lower than actual slopes verified in the field; therefore, it is possible that several rule-identified inner gorges have been mapped as non-rule-identified inner gorges. The SLPSTB GIS layer representing convergence used for mapping within the Lower Wishkah WAU was also found to be underrepresented, especially in the northern portion, which could affect the mapping of non-rule-identified inner gorges.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform # 11 – Steep Gradient Hillslopes (>65%) - Very High Hazard

Description of Mass Wasting Unit: This landform contains slopes greater than 65% that are convergent to divergent in shape. This landform is often located between mapped rule-identified inner gorges and bedrock hollows. The landslides in this landform were mapped from aerial photographs and, given the inaccuracy of DEM slope determinations, much of this landform may actually contain rule-identified hazard landforms (e.g., inner gorges or bedrock hollows). This is especially true in the northern portion of the WAU where field verification was unfeasible and DEM-derived GIS layers were found to have some inaccuracies.

Slopes: 65% and greater
Slope Shape: Convergent to Divergent
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alpine glacial outwash, alluvium, and old alluvium.
Elevation: 29 ft to 462 ft
Total Area: 223 acres

Mass Wasting Processes: Oversteepening of slopes, soil saturation, and/or loss of root strength in this landform has triggered shallow undifferentiated landslides but also debris slides, debris flows, and some deep-seated landslides.

Forest Practice Sensitivity and Trigger Mechanisms: Timber harvest on these steep slopes may result in the loss of root strength, which is a main factor of slope instability. The loss of root strength, changes in slope gradient, and changes in hydrology caused by timber harvesting can also increase mass wasting. Also, road construction and/or landing construction can aid in increasing slope instability by destabilizing slopes through undercutting the slope, oversteepening gradient, and/or can capture runoff water or shallow groundwater and channel it to point locations. Channeling or ponding of water can lead to saturation of the road or landing fill and trigger landslides.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 53 slope failures in a landform covering 223 acres. This landform has a Landslide Frequency Rating of 5,054.5 with roads and 4,482.3 without road-related landslides.

Delivery Potential/Criteria: **High.** The Landslide Area Rate of Delivery is 696.2 with road-related landslides for this landform is based on 29 "delivering" landslides totaling 7.3 acres. Without road-related landslides the LAR is 410.1 based on 23 "delivering" landslides totaling 4.3 acres.

Overall Hazard Potential Rating: **Very High** based on the LHZ Protocol, Table 5.

Confidence: Moderate level of confidence based on the number of landslides in this landform, good photo coverage, and limited field verification due to access issues.

Comments: The majority of this landform is based on slope gradients drawn from computer-generated SLPSTB representing convergence and slope percent GIS layers which have been identified in the field as being underrepresented. Rule-identified features such as inner gorges, toes of deep-seated landslides and bedrock hollows may have been included in this landform due to mapping constraints.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform # 12 – Moderate Gradient Hillslopes (41 to 64%) – Very High Hazard

Description of Mass Wasting Unit: This landform includes slopes found throughout the WAU and is frequently adjacent to inner gorges and bedrock hollows. These slopes vary in shape (the majority being planar) and have gradients between 41% and 64%. This landform includes head scarps of relict or dormant deep-seated landslides as well as other landslide processes that were not previously mapped.

Slopes: 41 to 64%
Slope Shape: Convergent to divergent
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alpine glacial outwash and drift, alluvium, and old alluvium.
Elevation: 5 ft to 554 ft
Total Area: 2,542 acres

Mass Wasting Process: Shallow undifferentiated landslides, debris slides, debris flows, deep-seated landslides, and large earthflows occur within this map unit. The majority of landslides in this landform occurred in submature timber stands, many along the edges of younger harvest units.

Forest Practice Sensitivity and Trigger Mechanisms: Timber harvest on slopes between 41% and 65% may result in the loss of root strength, which is a main factor of slope instability. The loss of root strength, changes in slope gradient, and changes in hydrology caused by timber harvesting, such as increased infiltration, can also increase the possibility of mass wasting. Also, road construction and/or landing construction can also aid in increasing slope instability. Roads and landings can also destabilize slopes by undercutting the slope, over steepening gradient, and/or can capture runoff water or shallow groundwater and channel it to point locations. Channeling and ponding of water can lead to saturation of the road or landing fill and trigger landslides.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 333 slope failures in a landform covering 2,541.7 acres. This landform has a Landslide Frequency Rating of 2,787.5 with road-related landslides and 2,728.9 without road-related landslides.

Delivery Potential/Criteria: **High.** The Landslide Area Rate of Delivery for this landform is 344.9 based on 174 "delivering" landslides totaling 41.2 acres with roads-related landslides. Without road-related landslides, the LAR is 339.9 based on 171 "delivering" landslides totaling 40.6 acres.

Overall Hazard Potential Rating: **Very High** based on the LHZ Protocol, Table 5.

Confidence: Moderate level of confidence based on good photo coverage, underrepresented DEM accuracy, and limited field observations.

Comments: The majority of this landform is based on slope gradients drawn from computer-generated SLPSTB representing convergence and slope percent GIS layers which have been identified in the field as being underrepresented. Rule-identified features such as inner gorges, toes of deep-seated landslides and bedrock hollows may have been included in this landform due to mapping constraints.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform #14 - Floodplain and Flats (0-10%) - Low Hazard

Description of Mass Wasting Unit: This map unit includes all valley and stream bottoms, flat terraces, major stream flood plains, wetlands, and large flat upland areas with gradients between 0 % and 10%. These areas generally have low landslide potential and as a result are not likely to deliver sediment to a stream, impact public safety or impact a public resource. In areas where creeks diverge from the main river, narrow flats have been mapped as low gradient hillslopes for ease of mapping.

Slopes: 0% and 10%
Slope Shape: All slope shapes are found within this landform.
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alpine glacial outwash and drift, and alluvium.
Elevation: 0 ft to 793 ft
Total Area: 12,530 acres

Mass Wasting Process: Shallow undifferentiated landslides make up the majority of the mass wasting processes that occurred in this landform. However, several debris slides, deep-seated landslides and one debris flow were mapped within this landform. Mass wasting on these naturally stable slopes is unlikely but possible due to improper routing of surface waters and the unstable nature of several formations, like glacial till and the marine sediments.

Forest Practice Sensitivity and Trigger Mechanisms: Many of the landslides in this landform have occurred adjacent to the Lower Wishkah River and its larger tributary creeks. This suggests that fluvial processes, such as undercutting of slopes or greater saturation of the land within the landform could initiate landslides in this naturally stable landform. Roads also play a small role in triggering landslides within this landform. Roads and landings can also destabilize slopes by undercutting the slope, over steepening gradient, and/or can capture runoff water or shallow groundwater and channel it to point locations. Channeling and ponding of water can lead to saturation of the road or landing fill and trigger landslides.

Mass Wasting Potential: **Low** for roads and timber harvest based on 19 slope failures in a landform covering 12,529.5 acres. This landform has a Landslide Frequency Rating of 32.3 with road-related landslides and 27.2 without road-related landslides.

Delivery Potential/Criteria: **Low**. The Landslide Area Rate of Delivery for this landform is 3.7 based on 13 “delivering” landslides totaling 2.2 acres with road-related landslides. Without road-related landslides the LAR is 2.7 based on 10 “delivering” landslides totaling 1.6 acres.

Overall Hazard Potential Rating: **Low** based on the LHZ Protocol, Table 4.

Confidence: Moderate level of confidence based on good photo coverage, underrepresented DEM accuracy DEM data, and limited field observations

Comments: This landform was mapped using DEM slope percent GIS layer and may contain areas of steeper slopes due to the underrepresentation of slopes in the available DEM data. Some areas may have been included within this landform that have slopes greater than 10% but these areas do not have a likelihood of slope failure. Typically, one would not find landslides within this landform, but due to its presence near the Wishkah River and its tributaries and forest roads, several landslides were found within this landform.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform #15 - Ridge Tops and Noses (0-10%) – Low Hazard

Description of Mass Wasting Unit: This landform includes all ridge tops and noses of ridges with all slope forms and gradients between 0 % and 10% that exhibit a low landslide potential, and/or are not likely to deliver sediment to a stream, impact public safety or impact a public resource.

Slopes: 0% and 10%
Slope Shape: All slope shapes are found within this landform.
Material: Mainly alpine glacial outwash and drift due to the capping position of these geologic units but some marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alluvium, and old alluvium are present.
Elevation: 119 ft to 610 ft
Total Area: 375 acres

Mass Wasting Process: No landslides have been located within with this landform.

Forest Practice Sensitivity and Trigger Mechanisms: Poor forest management practices on this landform could cause mass wasting on slopes below ridge tops and noses.

Mass Wasting Potential: **Low** for road construction and timber harvest based on no slope failure identified in a landform covering 375 acres. This landform has a Landslide Frequency Rating of zero with road- and without road-related landslides.

Delivery Potential/Criteria: **Low**. The Landslide Area Rate of Delivery for this unit is zero. No delivering mass wasting features were noted within this landform.

Overall Hazard Potential Rating: **Low** based on the LHZ Protocol, Table 5.

Confidence: Moderate level of confidence based on good photo coverage, underrepresented DEM accuracy, and limited field observations.

Comments: This landform was mapped using DEM slope percent GIS layer and may contain areas of steeper slope due to the inaccuracy of the available DEM data. Some areas may have been included within this landform that have slopes greater than 10%, but these areas do not have a likelihood of slope failure.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform # 16 - Low Gradient Hillslopes (11-40%) – Low Hazard

Description of Mass Wasting Unit: This map unit includes all slope shapes and gradients between 11% and 40% that are not likely to deliver sediment to a stream, impact public safety, or impact a public resource. In areas where creeks diverge from the main river, narrow flats have been mapped as low gradient hillslopes for ease of mapping.

Slopes: 11% and 40%
Slope Shape: Convergent to planar divergent.
Material: Marine sedimentary tuffaceous siltstones and sandstones (Lincoln Creek, Astoria, and Montesano Formations), alpine glacial outwash and drift, alluvium, and old alluvium.
Elevation: 18 ft to 803 ft
Total Area: 13,804 acres

Mass Wasting Process: Shallow undifferentiated landslides are the main mass wasting process followed by deep-seated landslides. Also occurring within this landform are a few debris slides, debris flows, and large earthflows. These landslides often occur after storm events and are commonly associated with the weak nature of the bedrock, specifically in areas where there are larger structural controls (faulting and folding) which determines the geologic units that are expressed at the surface, such as in the south, where the Lincoln Creek Formation crops out at the surface. Also, landslides occurring within deep-seated landslides where the headscarp and/or toe could not be delineated represent 31% of the smaller, shallow landslides mapped in this landform. This suggests previous, deep-seated landslide events could aid in the shallow mass wasting found in this landform. The majority of landslides in this landform occurred in submature harvest stands and many along the edge of younger harvest units.

Forest Practice Sensitivity and Trigger Mechanisms: Timber harvest on slopes between 11% and 40% may result in the loss of root strength, which is a main factor of slope instability. The loss of root strength and changes in hydrology caused by timber harvesting can also increase the possibility of mass wasting. Also, road construction and/or landing construction can aid in increasing slope instability. Roads and landings can destabilize slopes by undercutting the slope, oversteepening gradient, and/or can capture runoff water or shallow groundwater and channel it to point locations. Channeling and ponding of water can lead to saturation of the road or landing fill and trigger landslides.

Mass Wasting Potential: **High** for roads and timber harvest based on 160 slope failures in a landform covering 13,803.6 acres. This landform has a Landslide Frequency Rating of 246.6 with road- and 179 without road-related landslides.

Delivery Potential/Criteria: **Low.** The Landslide Area Rate of Delivery for this landform is 30.4 based on 79 “delivering” landslides totaling 19.7 acres with road-related landslides. Without road-related landslides the LAR is 27.3 based on 74 “delivering” landslides totaling 17.7 acres.

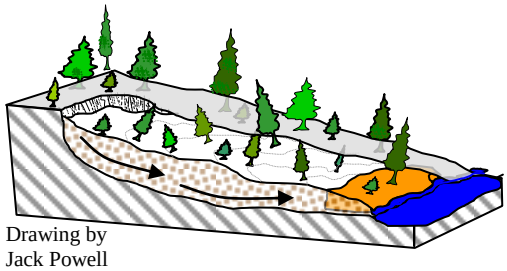
Overall Hazard Potential Rating: **Low** for the entire unit based on the LHZ Protocol, Table 5.

Confidence: Moderate level of confidence based on good photo coverage, underrepresented DEM accuracy DEM data, and limited field observations.

Comments: The majority of this landform is based on slope gradients drawn from computer-generated convergence and slope percent GIS layers which have been identified in the field as being underrepresented .

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform # 17 - Dormant Distinct Low Gradient Earthflows (11-85%) – High Hazard


Drawing by
Jack Powell

Description of Mass Wasting Unit: This map unit is found throughout the WAU and is composed of low-angle earthflows that are generally dormant distinct in activity. Slopes range from 11% up to 85% at the headscarps. This specific landform was created by the analyst based on the number of smaller, delivering landslides found within the bounds of these earthflows. In the field, the low-angle earthflows show deranged internal drainage, with much of the surface water pooling over the entire feature allowing for the establishment of hydrophilic plant species. Also noted in the field were areas within the feature where bedrock cropped out at the surface suggesting these earthflows are composed mainly of the soil and disaggregated bedrock that mantles the lithified bedrock. Based on the appearance of these earthflows in the field, it can be surmised these events generally move along the dip-slope of the underlying bedrock. Most of the large earthflow events had bedrock composed of the Astoria Formation suggesting this specific geologic formation is prone to large mass wasting events regardless of slope gradient.

Slopes: 11% and 85%
Slope Shape: Convergent to planar
Material: Mainly marine sedimentary tuffaceous siltstones and sandstones, specifically the Astoria Formation, and few events in glacial outwash.
Elevation: 36 ft to 602 ft
Total Area: 497 acres

Mass Wasting Process: The landform is dominated by large earthflows and deep-seated landslides as discussed above. Smaller landslides within the landform consist mainly of shallow undifferentiated landslides but also several debris flows and debris slides.

Forest Practice Sensitivity and Trigger Mechanisms: The loss of root strength, changes in slope gradient, and changes in hydrology resulting from timber harvesting and road or landing construction have the potential to initiate slope failure. This is especially true for this landform where material mantling bedrock on dip-slopes tends to be fairly thin and mass wasting events seem to occur frequently. Removal of trees also allows for more infiltration of rainwater into the material mantling bedrock in this landform. Increased infiltration of water increases the weight of the overlying mass and may help to initiate smaller landslide in this landform and could also reactivate movement of the deep-seated landslide mass.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 31 slope failures in a landform covering 497 acres. This landform has a Landslide Frequency Rating of 1,328.2 with road- and without road-related landslides.

Delivery Potential/Criteria: **High.** The Landslide Area Rate of Delivery for this landform is 231.4 based on 20 "delivering" landslides totaling 5.4 acres with road- and without road-related landslides.

Overall Hazard Potential Rating: **Very High** for the entire unit based on the LHZ Protocol, Table 5.

Confidence: High level of confidence based on good photo coverage and field observations.

Comments: The majority of this landform is based on air photo identification and field verification and thus identification and subsequent mapping of these features is based on a fairly high confidence level. Due to canopy cover, it is possible that not all low-angle earthflows have been identified. Because of this landform's ability to deliver, caution should be taken when harvesting earthflows in the Lower Wishkah WAU.

Form A-2 Descriptions of Landforms for the Lower Wishkah WAU

Landform # 18 - Active Deep-Seated Landslides (20-85%) – High Hazard

Description of Mass Wasting Unit: This map unit is based on field verified, actively moving deep-seated landslides and one earthflow. The landform has slopes that range from 20% to 85% and is located on planar to divergent slopes. The area in which these active deep-seated landslides occur has been affected by structural folding.

The deep-seated landslides that are associated with this landform are located in and around the Fern Hill Cemetery. The largest deep-seated landslide was first identified in1962 air photos and has increased in size every subsequent flight line that was analyzed in this study. Portions of these landslides have been harvested over the past 50 years. These harvests have been observed on air photos to be associated with the initiation of smaller mass wasting events over the entire surface of the landslide, especially on the headscarp of the deep-seated slide. Smaller landslides found on the northern boundary of the cemetery were reported by workers, who were present on the day of field verification, to have grown in size every year for the past decade. These deep-seated landslides deliver to two creeks that drain directly into the Wishkah River.

The active earthflow is reported to have begun movement 11 years ago and is associated with a larger deep-seated feature first identified on the 1981 air photo set. The earthflow was reportedly initiated after a clear-cut of second growth fir and was stated to increase speed of movement after large storm events, such as the storm event that took place in December of 2007. The active portion of the deep-seated earthflow is on a 16% slope and delivers directly to residential property (see figure 7A of report).

Slopes:	20% and 85%
Slope Shape:	Concave to planar
Material:	The landslides found in an around the cemetery are associated with the Montesano Formation and the earthflow is associated with the Astoria formation.
Elevation:	25 ft to 434 ft
Total Area:	84 acres

Mass Wasting Process: Deep-seated landslides are the primary form of mass wasting in this landform. However, shallow undifferentiated landslides, debris slides, and debris flows also occur within these active deep-seated landslides on varying slope shapes and fail at gradients between 11 to 40%.

Forest Practice Sensitivity and Trigger Mechanisms: Timber harvesting is clearly a contributor to the mass wasting related to this landform. The loss of root strength, changes in slope gradient, and changes in hydrology resulting from timber harvesting has been shown to initiate slope failure. Roads may increase instability of the slopes in and around the cemetery by adding weight to slopes and capturing runoff water or shallow groundwater and channeling it to point locations, which infiltrates the scarps of these deep-seated landslides. Another probable cause for the mass wasting in the cemetery is the continued saturation of the ground by the sprinkler system over the entire year.

Mass Wasting Potential: **Very High** for roads and timber harvest based on 15 slope failures in a landform covering 84 acres. This landform has a Landslide Frequency Rating of 3,785.9 with road- and without road-related landslides.

Delivery Potential/Criteria: **High.** The Landslide Area Rate of Delivery for this landform is 252.4 based on 5 "delivering" landslides totaling 1 acre with road- and without road-related landslides.

Overall Hazard Potential Rating: **Very High** for the entire unit based on the LHZ Protocol, Table 5.

Confidence: High level of confidence based on good photo coverage and field observation and verification.

Comments: This landform is based solely on field verification and thus identification and subsequent mapping of these features is based on a high confidence level. Because not all deep-seated landslides were visited in the field, it is possible that some active deep-seated landslides were not mapped in this landform.