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Bedrock Control on Slope Gradients in the Luckiamute Watershed, Central Coast Range, Oregon: Implications for Sediment Transport and Storage

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The Luckiamute River watershed drains 815 sq km along the east flank of the Coast Range in west-central Oregon. Active mountain building and extreme precipitation patterns result in a dynamic geomorphic system characterized by seasonal flooding and slope failure. Style of surficial process and landform associations are controlled by topographic position, underlying bedrock geology, and resistance to erosion.

Bedrock map units are grouped into four lithospatial domains, these include the Siletz River Volcanics Domain (south), the Tyee Domain (west-southwest), the Yamhill-Intrusive Domain (north-northwest), and the Valley Fill-Spencer Domain (east). The Siletz River Domain comprises 19% of the watershed and is mainly seafloor basalt. The Tyee Domain (29% of total area) is underlain by arkosic sandstone lithofacies with local mafic intrusives. The Yamhill-Intrusive Domain occupies 23% of the watershed and is characterized by outcrop of marine siltstone and mafic intrusives. The Valley Fill-Spencer Domain (29%) is underlain by a patchwork of marine sandstones and Quaternary alluvium. Hillslope landforms and colluvial processes dominate the Siletz River, Tyee, and Yamhill domains, whereas fluvial landforms and alluvial processes are characteristic of the Valley Fill Domain.

GIS-based analyses of USGS 10-meter DEMs elucidate associations between lithospatial domains and slope gradients. Average gradients for the Valley Fill, Siletz, Yamhill, and Tyee domains are 3.2 (n = 2290702 10-m cells), 12.7 (n = 1510287 10-m cells), 11.9 (n = 1926899 10-m cells), and 14.5 (n = 2409140 10-m cells) degrees, respectively. The Tyee Domain is associated with significantly steeper slopes on average compared to the other three domains. In addition, greater than 14% of the Tyee Domain area has slopes greater than 25 degrees, compared to less than 1% for the Valley Fill Domain, and less than 8% for the Siletz and Yamhill domains. Results of the slope analyses are consistent with debris-flow hazard models released by the Oregon Department of Forestry, suggesting that hillslopes in the Tyee Domain are most prone to slope failure (percent of domain area in hazard zone: Tyee = 38.1, Siletz = 30.2, Yamhill = 24.6, and Valley Fill = 0.7). Morphometric analysis of valley widths at 500 m increments shows that drainage across the Tyee Domain covers a much wider swath of valley floor (average valley width = 274 m) compared to a similar-sized drainage area in the Yamhill Domain (average valley width = 109 m). These data suggest that bedrock lithology exerts a strong control on hillslope morphology, style of hillslope process, and valley erosion dynamics in headwater portions of the Luckiamute.

The interplay between hillslope transport mechanisms, delivery rates, and channel hydraulics control the volume of sediment exported or stored within a mountainous watershed. The comparatively steep, debris-flow-prone slopes and wide valley bottoms in the Tyee Domain indicate a potential for hillslope transport rates to be greater than the ability of the channel system to export sediment. Analytical results presented herein provide a preliminary dataset upon which to build a field-based sediment-storage budget for the Luckiamute watershed. The working hypothesis is that the Tyee Domain has a significantly greater volume of valley-bottom sediment in storage compared to the other upland domains (Siletz, Yamhill). The model implies that spatial variation of bedrock lithology is a primary factor controlling slope gradients, hillslope delivery rates, and the resulting sediment-transport efficiency of the channel system.