TRASK CONTEXTUAL ANALYSIS II: GEOLOGY/GEOMORPHOLOGY OF THE STUDY CATCHMENTS WITH REFERENCE TO INFLUENCES ON HABITAT REACH CHARACTERISTICS

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CONTENTS

LANDSCAPE CONTROL IN HEADWATER STREAMS

Headwater channels such as the Trask Watershed Study small catchments cannot be studied independently from the hillslopes in which they are embedded (e.g., Sun et al. 1996). Their form and process directly express geomorphic adjustments to the overarching constraints of geology and climate as well as modifications from land use. While downstream rivers mainly reflect fluvial adjustments to upstream inputs, headwater streams, in contrast, respond to a more complicated suite of inputs from direct hillslope impingement to inputs from upstream sources. This document looks landscape influences (mainly geology) and local influences on channel metrics o f the small catchments in the Trask Study area.

TRASK GEOLOGY OVERVIEW

The information on the geology of the Trask (Figure 1) is derived from Wells et al., (1994). The bedrock geology of the study area is a mix of igneous and sedimentary formations dating back 40 to 60 million years. The oldest rocks in the Trask and the Tillamook Basin are the submarine basalts of the Siletz River Volcanics which form deeply incised drainages in the Trask. These volcanic rocks form the oceanic basement of the Oregon Coast Range (citation from Geologic Summary). The Trask study area has a complicated geologic signature making specific statements about the exact character of the formation difficult. However, we can examine whether assumed connections between hillslope and channel morphologic character generally hold true.

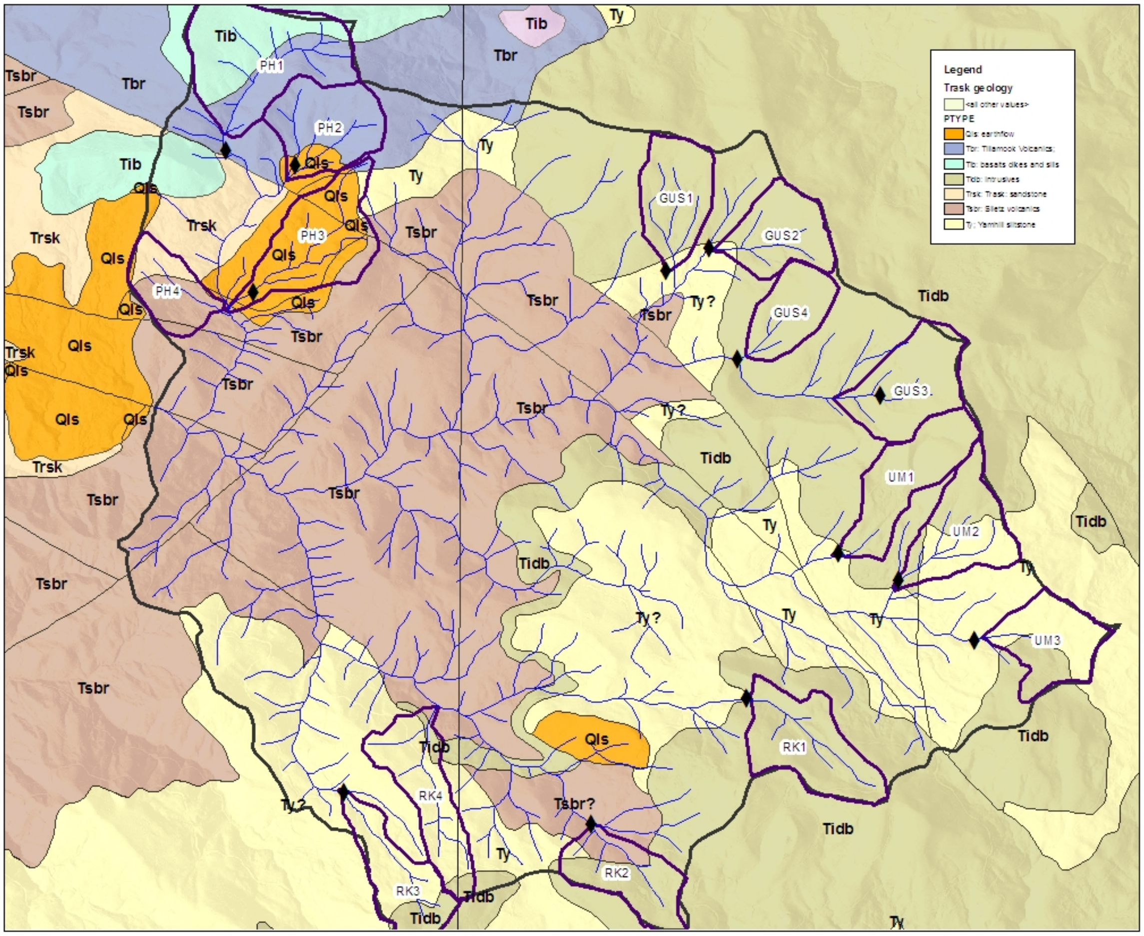
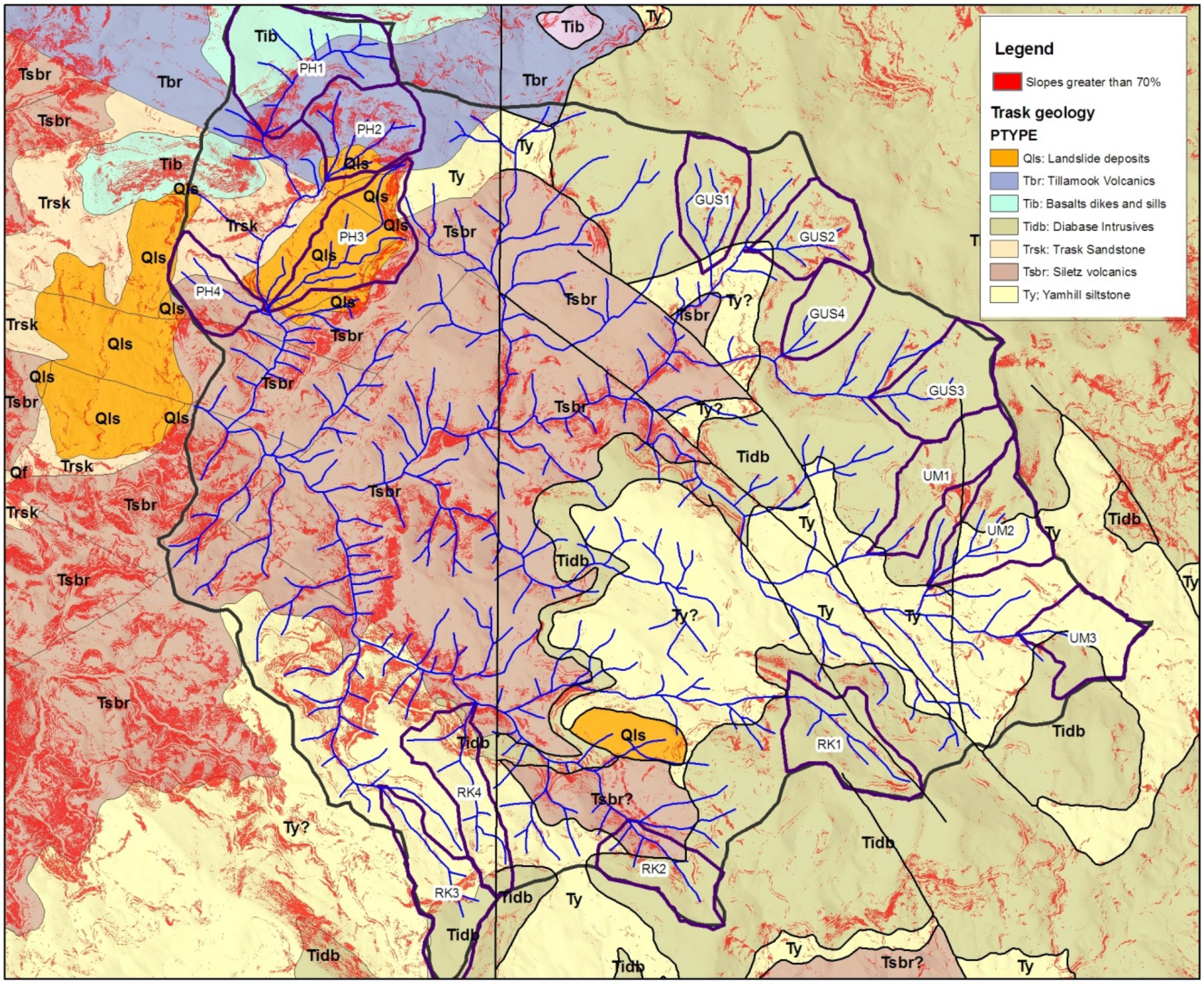


Fig. 1 Trask general geology. The descriptions of the units are found in Appendix A.

One feature of a particular rock type is its strength, usually called its rock mass strength (RMS) which can influence watershed properties such as hillslope gradient. The in-situ rock mass strength of a particular rock unit is difficult to quantify due to the extreme variability in lithology (i.e., physical characteristics), weathering and alteration processes. Rock variability in the Trask likely is due to a number of factors including material source and compositional heterogeneity, active tectonics, and high erosion rates, which, in turn, dictate the types of discontinuities, or structural gaps, found in rock masses. Based on the Trask rock-unit descriptions, discontinuities include: bedding planes (strike, dip of rock layers), joint surfaces (cracks, fractures), folds, faults, and foliations. Large spatial densities of penetrative discontinuities (i.e., ones that break up granular interlocking contacts) are a key factor in decreasing RMS because they create structural defects and act as conduits for subsurface water flow, and they can lead to the kinds of landslide and rockfall events that influence slope shape (Shaw, 2011, pers. Comm.). Compositional variability also is a key factor in creating non-uniform RMS within any one rock formation or outcrop. Consider, for example, a common geologic unit in the Trask, the Tsbr unit which is one member of the Siletz River Volcanics. This unit has submarine and subaerial basalt breccias (basically rock debris with angular fragments), mudflow breccias, basaltic sandstone and is locally inter-fingered with the overlying sandstone of Trask River. So to assume one property for the entire unit is difficult and must be interpreted with caution.

In general terms diabase (an intrusive) will be stronger (using a uniaxial compressive strength test) than basalt, which in turn is stronger than sandstone and siltstone. The breccias are difficult to assign a strength rating to since they are composed of various materials, but are generally assumed to be weaker. The relative strength of the rock mass interacts with landscape processes to determine rates of weathering and erosion. For example, hillsides composed of a more resistant material would be expected to have steeper slopes since the material is able to resist erosion. The overlay of slope map with the geology map indicates that this is only generally true (Fig. 2). Consider the “weaker” Tillamook Volcanic unit (Tbr) in Pothole C; it appears to have steeper slopes than the intrusive stronger Basalt Dikes and Sills (Tib) unit (Fig. 3), indicating something more than just slope response to assumed RMS. Weathering and failures associated with rock discontinuities might be influencing the presence of less-steep slopes in harder (greater RMS) units. If the diabase, for example, contains a relatively greater density of discontinuities than the basalt, it could have correspondingly lower RMS values. A potential indication of large densities of discontinuities in the diabase could be the large spatial densities of landslides within the Trask basin (Shaw, 2011, pers. comm.; a similar observation was made regarding rockfall and landslide occurrences in diabase units of the neighboring Yamhill drainage). In several cases, however, the assumed in-situ RMS appears to influence slope gradient where the Tsbr (Siletz Volcanics) are steeper than the main body of the Qls (landslide) unit.


Legend
Slopes greater than 70%
Trask geology
PTYPE
Qls: Landslide deposits
Tbr: Tillamook Volcanics
Tib: Basalts dikes and sills
Tidb: Diabase Intrusives
Trsk: Trask Sandstone
Tsbr: Siletz volcanics
Ty; Yamhill siltstone
PH1
PH2
PH3
PH4
GUS1
GUS2
GUS3
GUS4
UM1
UM2
UM3
RK1
RK2
RK3
RK4
Tib
Tbr
Tsbr
Trsk
Qls
Qf
Ty
Ty?
Tidb
Tsbr?

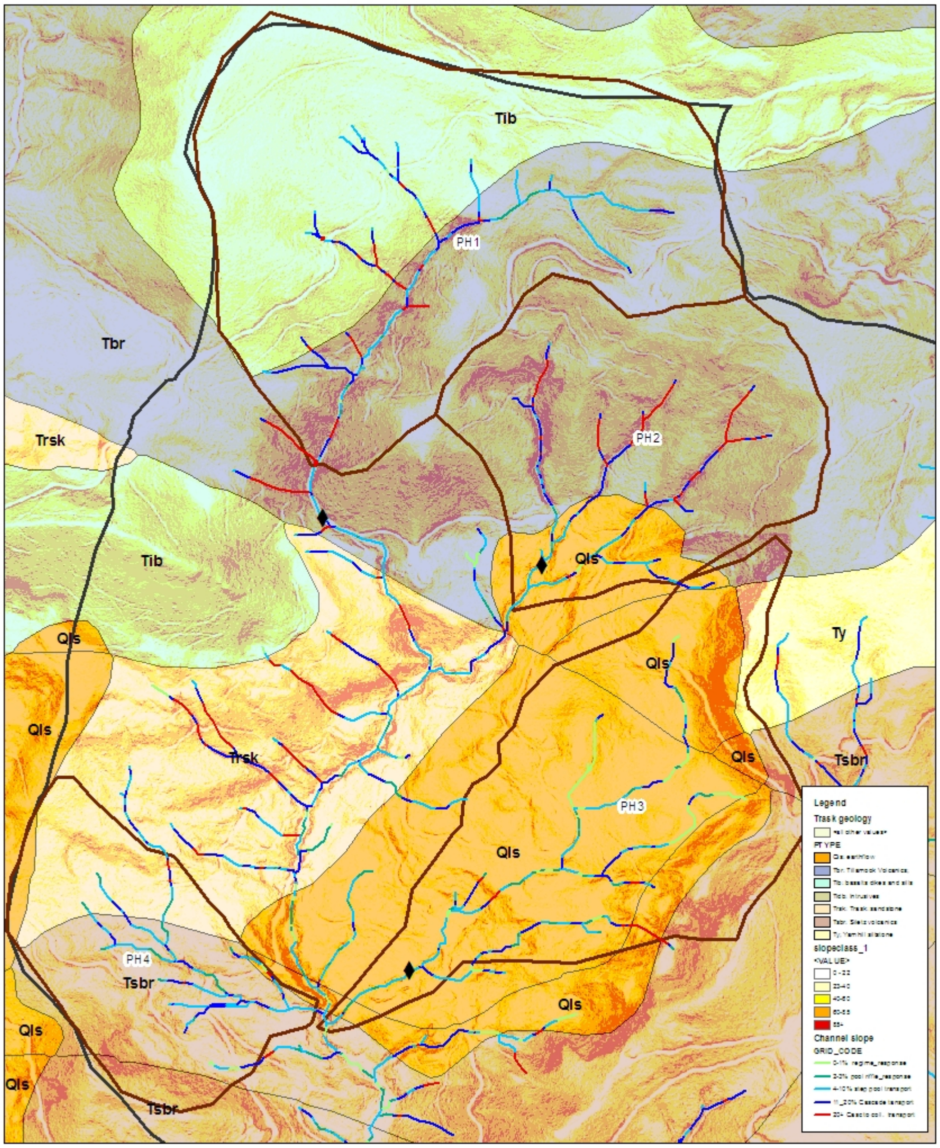


Fig. 3 Geology of Pothole Creek with slope classes. Red indicates the steepest slopes. The slope breaks for the stream channels are described in Appendix B. The green and light blue channel slopes are less steep while the dark blue and red are steeper.

RELATIONSHIP BETWEEN CATCHMENTS AND CHANNELS

Watershed resistance to weathering and erosion can influence channel metrics such as channel incision, slope, median bed particle diameter (D50) and channel architecture in mountain streams (Golden and Springer, 2006; Wohl, 2000; Whipple, 2004). These resulting channel characteristics can in turn influence habitat parameters for aquatic ecosystems. In the Trask Watershed Study area there is variability in channel metrics including a key habitat metric; substrate size (Fig. 4). The following section examines the interaction of catchment and channel metrics such as D50.

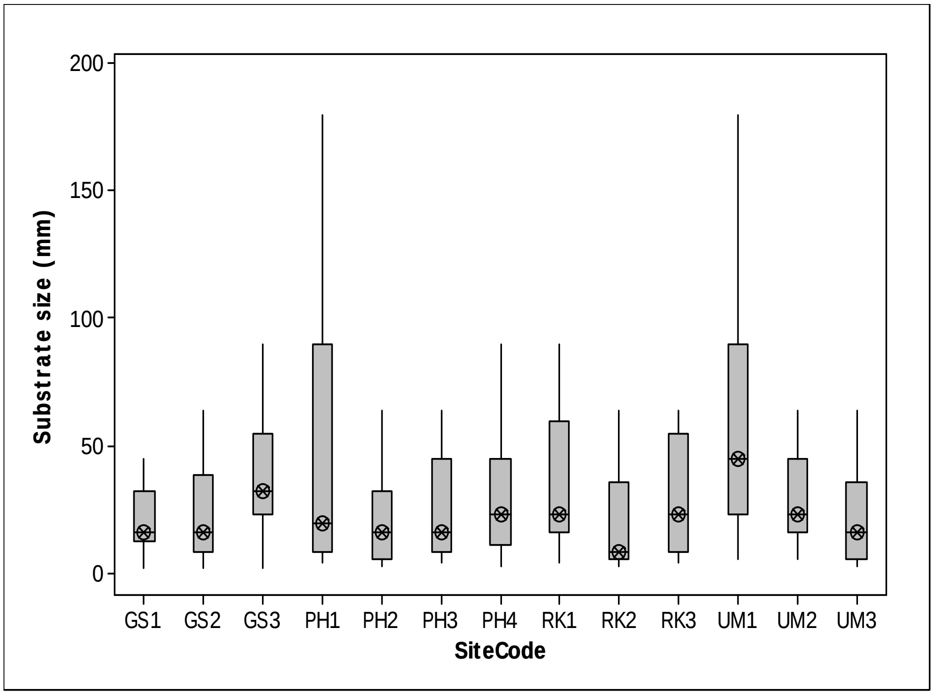


Fig 4. Particle size distributions for habitat reach substrate data (data from L. Ashkenas)

While it is attractive to group basins by lithology and assume similar sediment patterns and processes; this may not be possible for areas with multiple geologic strata (Golden and Springer 2006). For example, the intrusive geologies (more resistant) of the Trask have two reaches with larger D50 particles also have the lowest D50 as well (Fig. 5). Further, the earthflow, sedimentary and volcanic geologies all appear to have similar sized particles, which would not be expected based simply on inferences about geologic strength. For the Trask, it may not be possible to directly infer channel metrics from mapped geologic formation due to the complexity of the area. However, the geology and its inferred rock mass strength may be able to inform other catchment characteristics. The relationship between an index of composite strength for a catchment (area weighted average of relative strength of unit) and various catchment and stream characteristics is shown in Fig 6. As this figure indicates there is little association between catchment slope and an index of composite strength, which is surprising since composite strength and stream slope were correlated with an adj. r-square of 17.8% (although the p-value was 0.066) and channel slope and catchment slope were highly correlated with an adj. r-square of 80.7. The composite strength was best correlated to stream density (based on Lidar-derived streams with some judgment) with an adj. r-square of 30.34 and a p-value of 0.019. There was no relationship between the catchment composite strength and the median particle size diameter of the habitat reach.

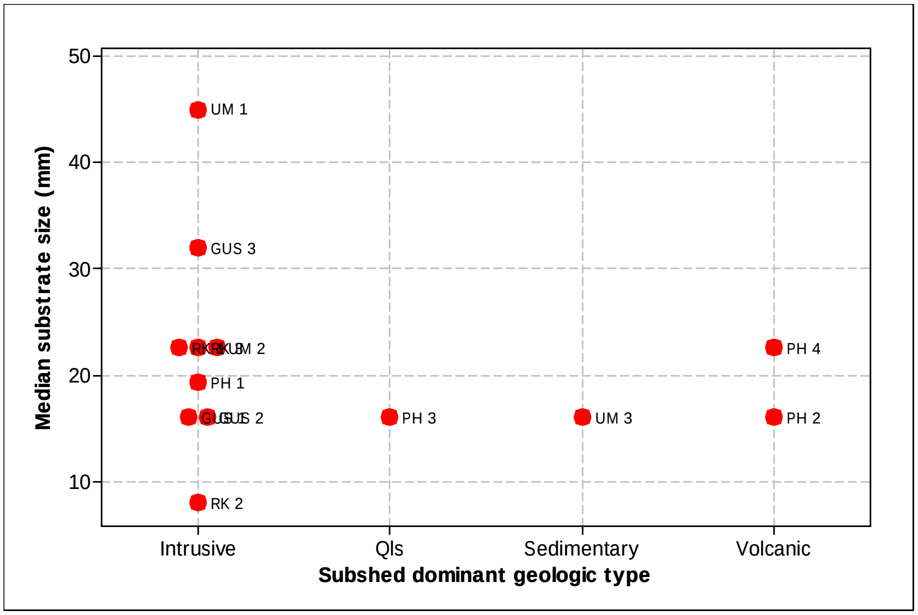


Fig. 5 Median particle size diameter for the habitat reach and catchment geologic type.

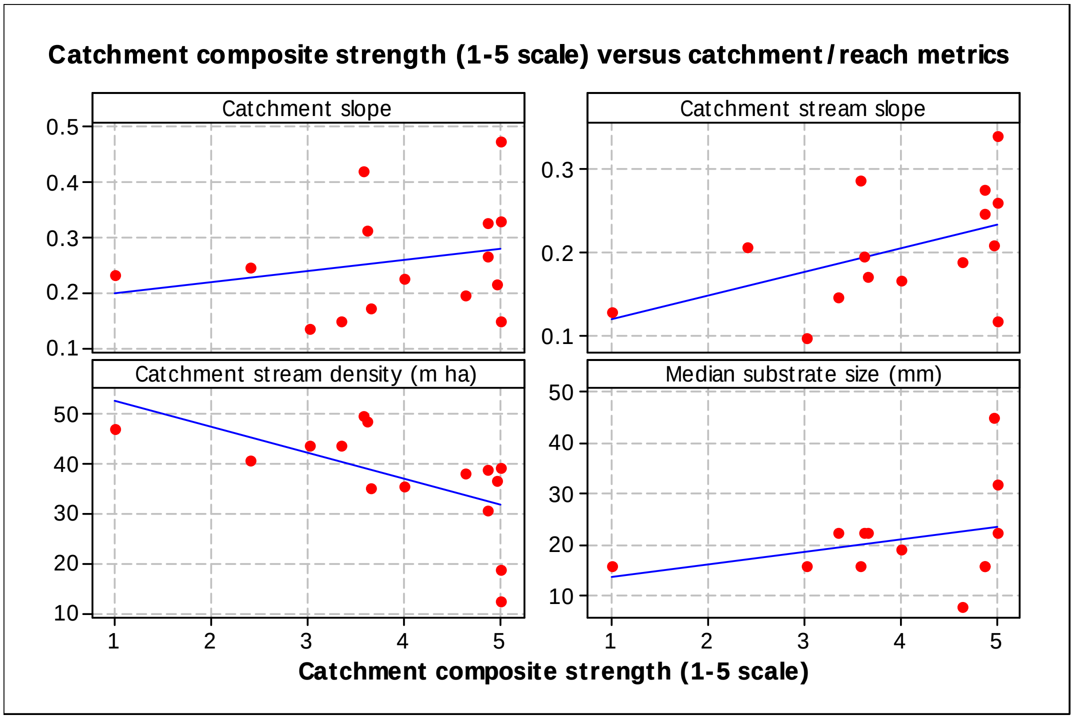


Fig. 6 Catchment stream slope versus the relative strength of the mapped geology for the catchment. Composite relative strength based on area weighted average.

Median particle size of the habitat reach was compared to the slope, catchment area, and index of stream power and an index of unit stream power to determine whether these driving forces could explain the median substrate size (Fig. 7). Stream power provides an index of the transport capacity of a channel and is the product of discharge, slope and the specific weight of water (Bagnold, 1966, 1977 in

Knighton 1984). In estimating stream power, discharge becomes very important since the ability of a stream to transport bedload and suspended load increases markedly with increasing discharge (Leopold et al. 1964 as cited in Bull1979). Indices of stream power are often used in place of actual values and take the form Ω=AS where Ω is stream power and A is area and S is slope. Unit stream power is stream power divided by bankfull width (W). In the Trask we had wetted width, but not bankfull and so had to assume they were close.

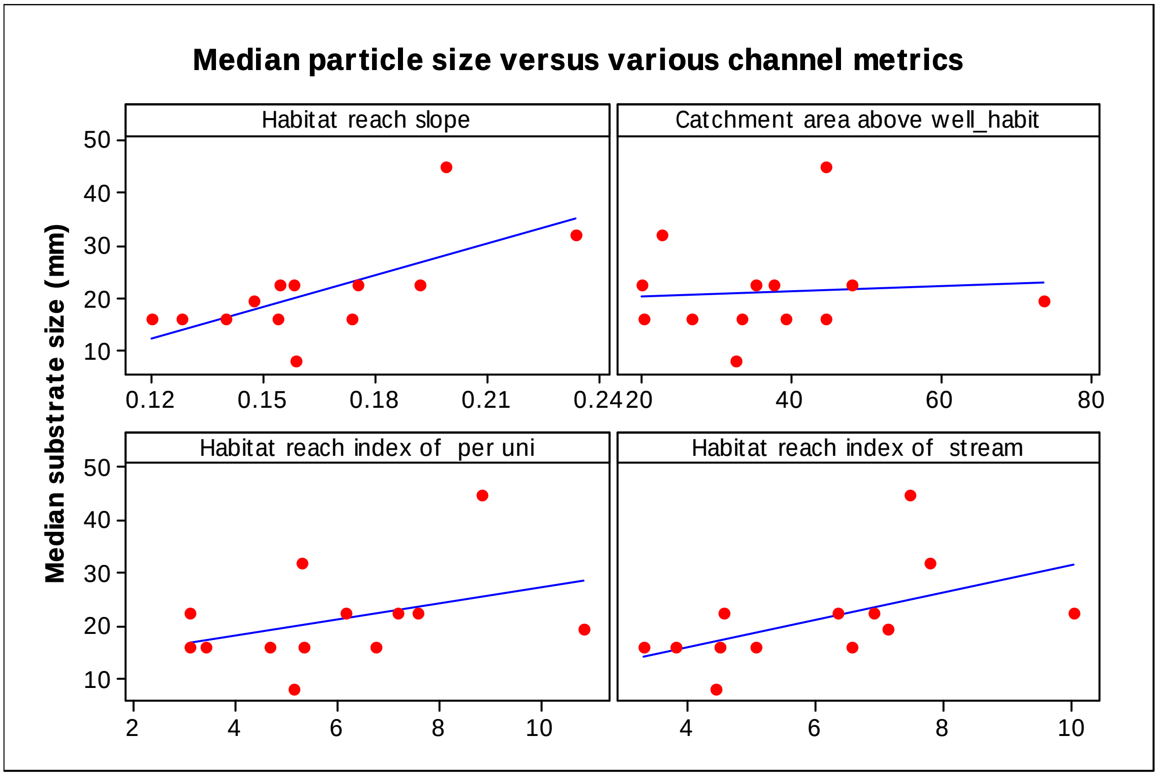


Fig. 7 Median substrate size (D50) for the habitat reaches compared to various local and catchment metrics.

The slope and area of habitat reaches were combined and then divided by channel width to get an index of stream power and an index of per unit area stream power. Interestingly, the variable that explained the most variation in habitat reach D50 was the slope of the habitat reach (adj. r-square 39.5; p-value 0.013) while drainage area did not explain any of the variation, which is similar to Golden and Springer (2006) who found that drainage area did not explain D50 for their small streams. The indices stream power and unit stream power explained 22.7 and 7.0 percent, respectively of the variation in D50. While stream power may be more influential for fluvially dominated reaches, its influence on small headwater streams with significant hillslope influence may be less. Thus, for headwater streams, which generally have low discharge, stream power can be low relative to substrate resistance (Merritts and Vincent 1989) and may not adequately explain channel metrics for streams with significant hilllslope interaction.

DISCUSSION

Using coarse scale catchment characteristics to infer channel metrics for specific reaches may not be possible in the Trask due to its complicated geology. However, some catchment characteristics appear to relate to mapped geology. The stream density appeared to correlate to the lithology. Median particle size for the habitat reaches was most strongly correlated t o the slope of the reach. This section will need work.

REFERENCES

Golden, L. A. and G.S. Springer. 2006. Channel geometry, median grain size, and stream power in small mountain streams. Geomorphology 78 (2006) 64-76.

Merritts, D.J., and Vincent, K.R. 1989. Geomorphic response of coastal streams to low, intermediate, and high rates of uplift, Mendocino junction region, northern California. Geol. Soc. of Am. Bull. 109: 1373-1388

Sun et al

Wells,

Whipple, 2004

Wohl, E. 2000. Mountain Rivers. Water Res. Monograph 14. Am. Geophys. Union. Wash., DC. 320 pp.

APPENDIX A: DESCRIPTION OF TRASK GEOLOGIC UNITS

Surface Deposits

Qls Landslide deposits (Holocene and Pleistocene)--Poorly sorted angularto subrounded bedrock clasts in weathered muddy matrix, forming hummocky topography with closed depressions and poor drainage; also includes coherent bedrock glide blocks and colluvial aprons of angular cobbles and boulders at the base of steep slopes.

Intrusive Rocks

Tib Basalt dikes and sills (late middle Eocene)--Aphyric to abundantly plagioclase, augite, and olivine-phyric basalt dikes and sills, mostly as north-northwest to west-northwest-trending swarms cutting subaerial Tillamook flows and all older units. Dikes are compositionally and petrographically similar to Tillamook flows and represent feeder vents for the Tillamook Volcanics. Dikes are up to 10 m wide and 5 km long; some composite dikes have multiple episodes of intrusion ranging in composition from basalt to dacite.

Tidb Diabase (middle Eocene)--Aphyric to plagioclase-phyric, amygdaloidal diabase with smectite clays and zeolite vesicle fillings; locally pillowform with radial columnar joints, more commonly tabular bodies with well developed columnar joints and a layered appearance; sills are cut by the regional dike swarm that fed Tillamook Volcanics but intrude strata as young as Yamhill Formation, suggesting a minimum age of about 43 Ma; unit may include some basalt and diabase correlative with the Tillamook Volcanics.

Sedimentary Rocks

Ty: Yamhill Formation (upper middle Eocene)--Massive to thin bedded, laminated, dark gray siltstone commonly containing thin tuff beds, thin arkosic sandstone beds, calcareous concretions, fish scales and carbonaceous plant fragments; locally contains interbeds of paper-thin laminated, black, kerogen-rich "oil shale" near the top of the section where it is interbedded with submarine basalt lapilli breccias of the Tillamook Volcanics.

Trsk: Sandstone of Trask River (lower Eocene)--Thin bedded, plane laminated, fine grained, dark gray indurated turbidite sandstone and siltstone; locally concretionary and cut by carbonate veins and fracture fillings; exhibits large scale soft sediment folding as well as postlithification deformation; thickness is variable, up to 800m; apparently it is deposited on a surface of high relief on the Siletz River Volcanics; unit contains nannoplankton.

Volcanic

Tsbr: Basalt lapilli breccia unit - Siletz River Volcanics (lower Eocene) Basalt lapilli breccia unit--Submarine and subaerial basalt lapilli breccia, pillow breccia, mudflow breccia, and basaltic sandstone and conglomerate; beds are massive to thick bedded; clasts commonly are plagioclase and pyroxene-phyric with greenish-brown smectitic clay alteration and zeolite and calcite veins and amygdules; locally oxidized red, with subaerial bombs and cinders; unit locally interfingers with overlying Sandstone of Trask River.

Tbr: Submarine basalt tuff and breccia - Tillamook Volcanics (upper middle Eocene): Submarine pillow basalt flows, filled lava tubes, and interbedded flow breccias; augite and plagioclase-phyric in upper part, commonly amygdaloidal,with zeolite and smectite vesicle fillings and slicken-sided shear surfaces containing clay, calcite, zeolite, quartz, and pyrite; sedimentary interbeds contain foraminifera referrable to lower Ulatisian or Penutian stages (W. W. Rau, written communication, 1970) and nannoplankton referrable to CP zones 11 and 9b (David Bukry, written communication, 1988) Potassium-Argon ages of 57.1±1.5 Ma and 54.8±1.0 Ma were determined from pillow basalt in the Trask River and an age of 52.9±1.0 Ma was determined from pillow basalt in the Nestucca River (Duncan, 1982).

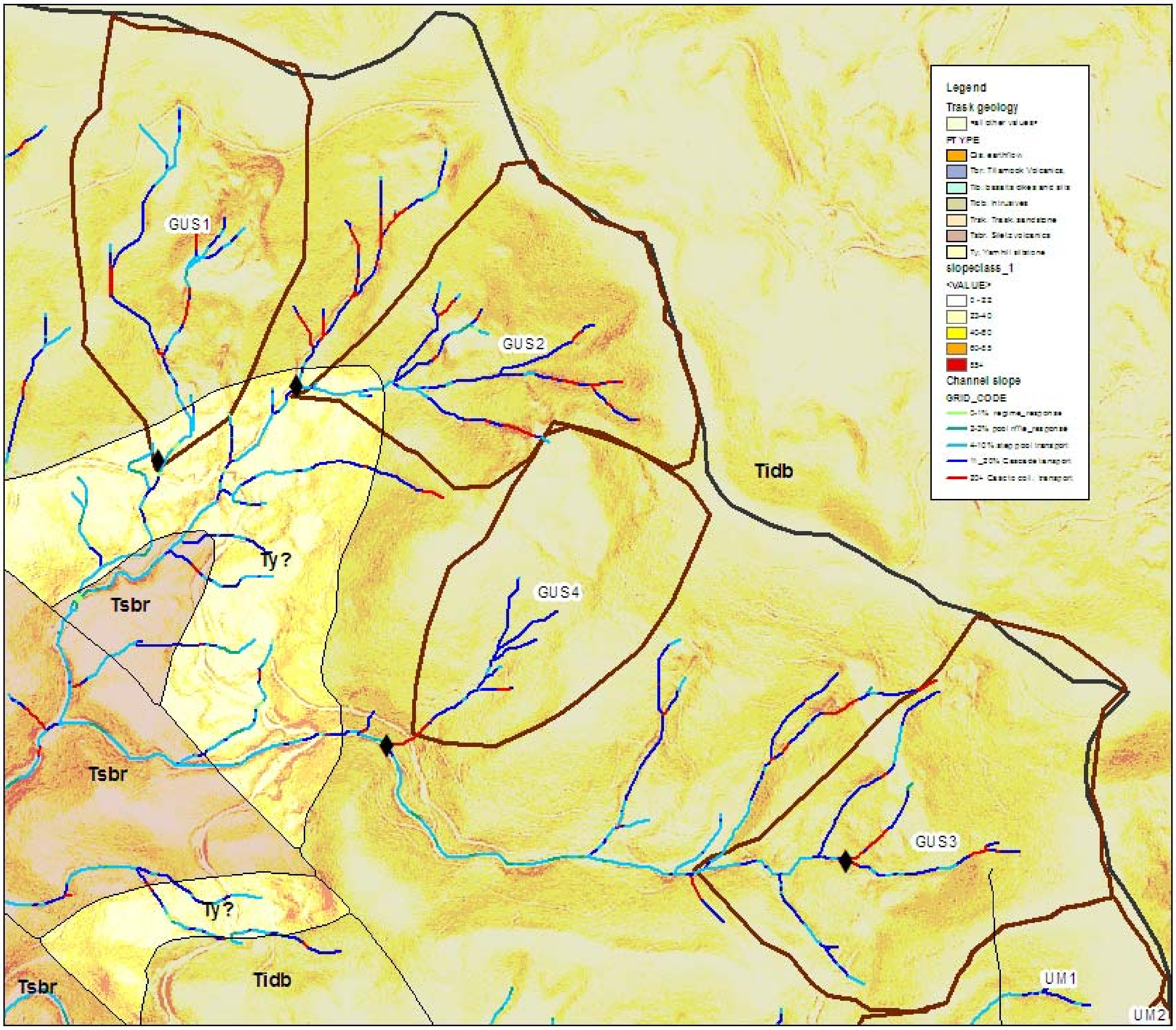
APPENDIX B DETAILS ON CATCHMENTS

Watershed	Dominant geology of habitat reach	Habitat reach geologic type	Catchment dominant geology (unit with >50% by area)	Subshed Geology type
GUS 1	Ty	Sedimentary	Tidb	Intrusive
GUS 2	Ty	Sedimentary	Tidb	Intrusive
GUS 3	Tidb	Intrusive	Tidb	Intrusive
GUS 4	Tidb	Intrusive	Tidb	Intrusive
PH 1	Tbr	Volcanic	Tib	Intrusive basalt
PH 2	Qls	Landslide deposit	Tbr	Volcanic
PH 3	Qls	Landslide deposit	Qls	Landslide deposit
PH 4	Tsbr	Volcanic	Tsbr	Volcanic
RK 1	Tidb	Intrusive	Tidb	Intrusive
RK 2	Tsbr	Volcanic	Tidb	Intrusive
RK 3	Ty	Sedimentary	Ty	Sedimentary
RK 4	Tsbr	Volcanic	Ty	Sedimentary
UM 1	Ty	Sedimentary	Tidb	Intrusive
UM 2	Tidb	Intrusive	Tidb	Intrusive
UM 3	Ty	Sedimentary	Ty	Sedimentary

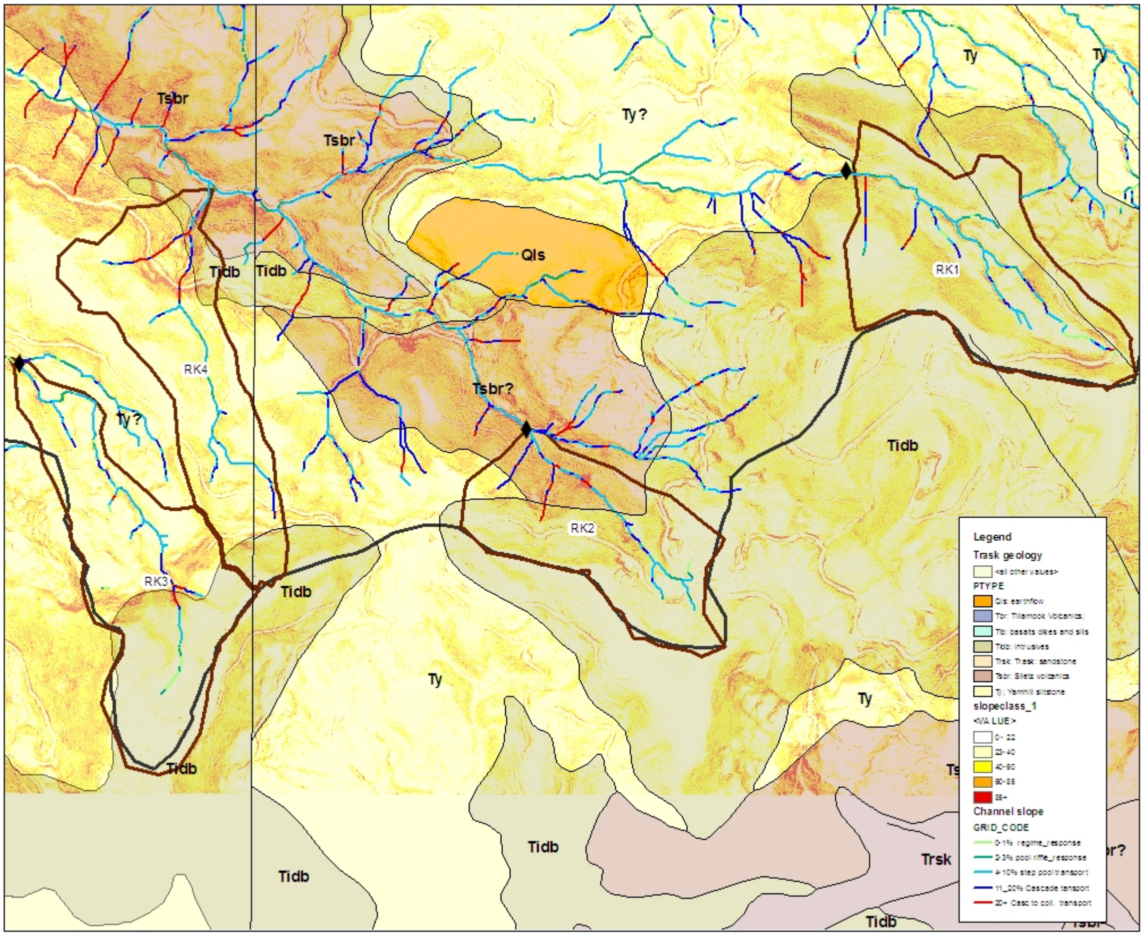
APPENDIX B. STREAM GRADIENT MAP

A channel gradient map was derived using the LiDAR DEM (David Hockman-Wert) and then classified based on Montgomery and Buffington (1993). The green lines represent low gradient reaches (<1% slope) termed "regime" to pool-riffle. Regime means that they have many mobile bed forms. These low gradient reaches would are considered response reaches since they tend to be areas of accumulation of sediment or wood. The darker green channels are the pool riffle channels to plane bed channels, their gradients range from over 1% to 3%; these are also response reaches. The teal lines represent 4-10% step-pool to cascade reaches, which tend to transport sediment rather than accumulate as much as the lower gradient reaches. The dark blue lines are 11-20% cascade to colluvial reaches that are both transport and sources areas of sediment from mass wasting events. Red lines are channels or hollows steeper than 20%, which are also sources reaches.

APPENDIX C. GEOLOGIC MAP OF THE CATCHMENTS WITH LIDAR-BASED SLOPES INDICATED.



Gus


Tsbr
Tsbr
Ty?
Ty
Ty
Qls
Tidb
Tidb
RK1
RK4
Tsbr?
Ty?
Tidb
RK2
RK3
Tidb
Ty
Ty
Tidb
Tidb
Tidb
Tidb
Trsk
Tidb
Legend
Trask geology
<all other values>
PTYPE
Qls: earthflow
Tbr: Tillamook Volcanics;
Tb: basalts dikes and sills
Tidb: intrusives
Trsk: Trask: sandstone
Tsbr: Siletz volcanics
Ty: Yamhill siltstone
slopeclass_1
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0 - 22
23 - 40
40 - 60
60 - 85
85+
Channel slope
GRID_CODE
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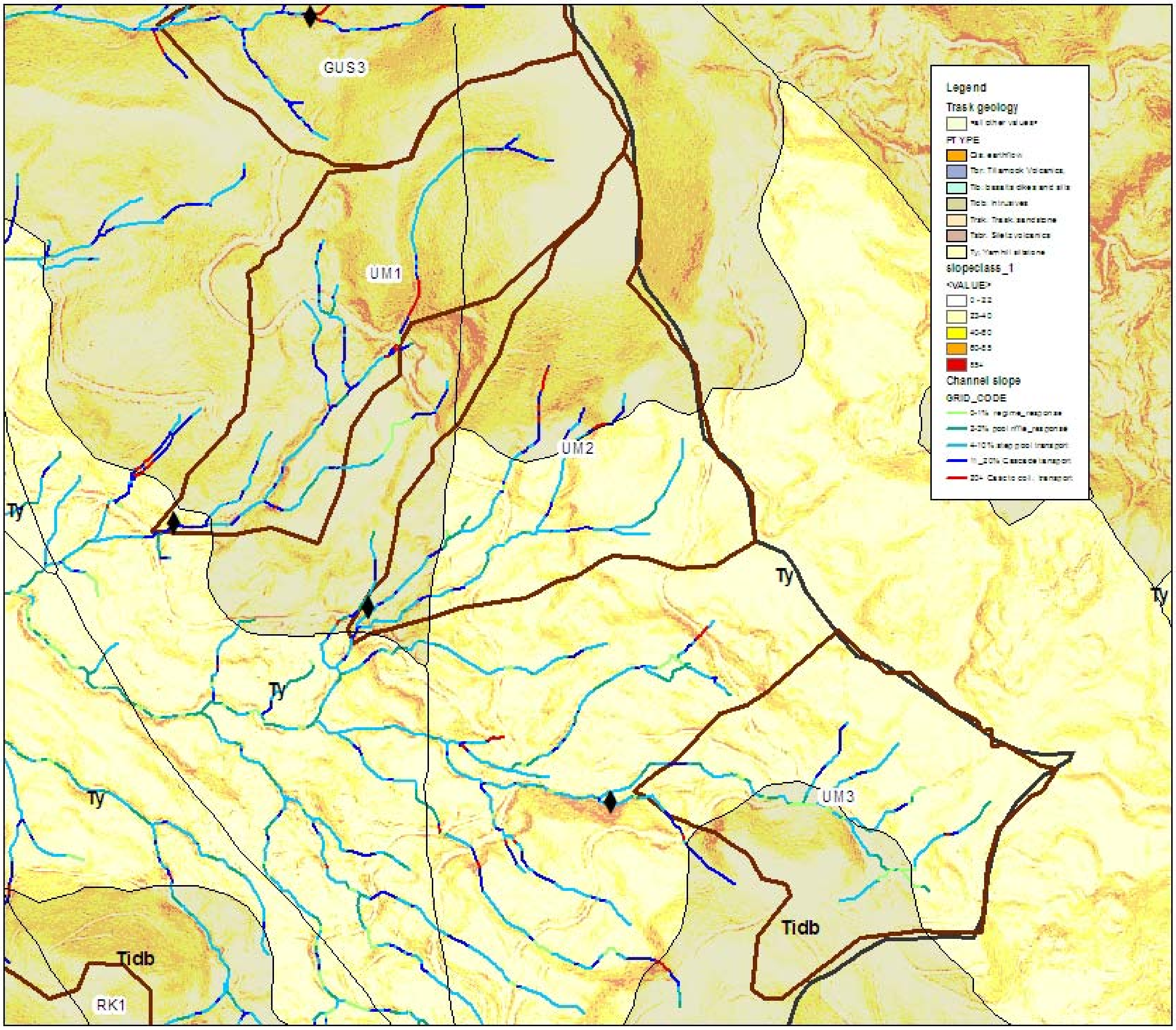
2-3% pool riffle_response
4-10% step pool transport
11_20% Cascade tansport
20+ Casc to coll. transport


GUS3
UM1
UM2
UM3
Ty
Ty
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Ty
Tidb
Tidb
RK1
Legend
Trask geology
<all other values>
PTYPE
Qls: earthflow
Tor: Tillamook Volcanics
Tib: basalts dikes and sills
Tidb: intrusives
Trsk: Trask sandstone
Tsbr: Siletz volcanics
Ty: Yamhill siltstone
slopeclass_1
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20-40
40-60
60-85
85+
Channel slope
GRID_CODE
0-1% regime_response
2-3% pool riffle_response
4-10% step pool transport
11_20% Cascade transport
20+ Cascade coll. transport