

West Valley Parameter Ranges

Fluvial Parameters

Channel erodibility for uniform substrate

Threshold for channel erosion into uniform substrate

For models that do not explicitly account for rock/till layers, we use a range of channel erosion thresholds bounded by those found for rock and till (see below). Critical shear stress = 5 - 130 Pa, and $\omega_c = 0.35$ to 46.

Change in channel erosion threshold with depth

Gran et al. (2013) showed that the D_{50} can increase with increasing incision depth as the channel incises through glacial sediments and terraces. For this model, we will use the lower bound of erosion threshold from jet tests of 10 Pa for the initiation of the model. Once the channel incises to the modern depth of 160 ft, we can use the upper bound of 130 Pa for bedrock incision (see below).

Channel erodibility into rock

Channel erodibility into till

Threshold for channel erodibility into rock

The critical shear stress for bedrock should be at least as large as that of the D_{50} , for till (see below), and possibly larger. To be safe, we suggest using the lower limit of the threshold for till and an upper limit threshold twice that of the upper limit calculated using the D_{50} , approximately 130 Pa. This corresponds to $\omega_c = 0.35$ to 46 for use in the stream power formulation.

Threshold for channel erodibility into till

To estimate the critical shear stress for till, we can use the $D_{50} = 5\text{cm}$ for the field site (Bennet et al) using the equation:

$$\tau_c = \theta_c(\sigma - \rho)gD_{50} \tag{1}$$

Buffington and Montgomery (1999) found a lower limit of the critical Shields stress θ_c to be 0.03, agreeing with other studies (Parker and Klingeman,

1982; Meyer-Peter and Muller, 1984). We use 0.08 as an upper limit, based on experiments in mixed grain size beds with bedforms (Church et al., 1998). Using this range for critical Shields stress, with sediment density $\sigma = 2650$ kg/m³ and $D_{50} = 5$ cm gives a range for critical shear stress of 24 - 64 Pa. On-site field measurements using the Scour Depth method show a range of critical shear stress from 12 to 90 Pa. Therefore, we recommend using a range of 5 to 100 Pa to account for uncertainty in the estimate of D_{50} .

We can convert the critical shear stress to ω_c for use in the stream power model:

$$\omega_c = \tau_c U_{*c} = \tau_c^{3/2} / \rho^{1/2} = 0.031623 \tau_c^{3/2} \quad (2)$$

Using the values reported above, we obtain a range of $\omega_c = 0.35$ to 31.62.

Rock-till contact zone width

Parameter used for numerical stability- fixed at 10 ft.

n

$n = 0.5$ to 3 is a reasonable range of values (Hancock et al., 1987). Recent research has shown that field values are typically $n \geq 1$.

m

Tucker and Whipple (2002) suggest using a range from 0 to 1.

Vs

For a lower limit on settling velocity, we estimate the clear-water settling velocity for very fine quartz sand (1/16 mm) using the equation from Ferguson and Church (2004):

$$w = \frac{RgD^2}{C_1\nu + (0.75C_2gD^3)^{0.5}} \quad (3)$$

where R is the submerged specific gravity of quartz = 1.65, C_1 is a constant = 18, C_2 is a constant = 0.4, ν is the viscosity of water at 20° C = 1×10^{-6} kg/ms, and $D = 1/16$ mm. From this we obtain a lower bound on settling velocity of 0.0033 m/s.

For an upper bound, we use an estimate of 1 m/s for approximately 5cm quartz grains.

H sp star

Characteristic depth of alluvial scour relevant for bedrock incision. The lower limit should be approximately the D_{50} , which is 5cm for the field site (Bennet et al). The upper limit should be approximately the characteristic flood depth, or 1m.

Hillslope Parameters

Hillslope diffusivity

Soil transport decay depth

This parameter is defined in Johnstone and Hilley (2014) as the scaling depth of the velocity profile of soil. In their study they use values of h^* between 0.12 m and 0.33 m (Johnstone and Hilley, 2014). When $h^* \gg$ soil depth, soil moves as plug flow. Given the variable soil thickness at West Valley and the sensitivity of soil flux to this parameter, we recommend using a range between 0.1 and 1 m.

Initial soil thickness

Maximum soil production rate

Various studies have used cosmogenic radionuclides to estimate maximum soil production rates. Here are measured rates (in m/yr) and their associated lithology and field settings:

- 2.68×10^{-4} (Heimsath 2001a)
Oregon Coast Range, in humid-temperate, hilly landscape underlain by relatively uniform, unweathered arkosic sandstone and siltstone.
- 7.7×10^{-5} (Heimsath 1997,1999)
Tennessee Valley in Marin County, California. Underlying bedrock is greywacke.
- 1.43×10^{-4} (Heimsath 2001b)
Southeastern highlands of Australia, characterized by cool climate and heavy rainfall. Underlying bedrock types are Ordovician metasediments and granite.

- 1×10^{-3} (Heimsath 2012)
San Gabriel Mountains in California.
- 7×10^{-6} (Small 1997)
Alpine environments across the western US. Lithologies represented are granite and gneiss.

Based on these studies, we recommend using a range of 1×10^{-6} to 1×10^{-3} m/yr.

Soil production decay depth

Studies have shown the soil production decay depth to be approximately 0.5 m in a number of sites around the world (Pelletier 2009, Heimsath 1997, 1999, 2001a,b). Because weathering rate is fairly sensitive to this parameter, we recommend using a range of 0.2-1 m.

Critical slope The critical slope for nonlinear sediment flux has been estimated in a number of studies:

- 1.4 (Roering 1999) Oregon Coast Range
- 1.25 (Ganti 2012) Oregon Coast Range
- 1.2 (Roering 2007) Oregon Coast Range and Gabilan Mesa
- 0.6 (Roering 2001) Physical experiments with a pile of loose sand

Based on these studies, we recommend using a range for critical slope between 1 and 1.4.

Hydrologic Parameters

Hydraulic conductivity

We use a range of hydraulic conductivities found for glacial till from a number of field studies:

- 10^{-6} to 10^{-2} mm/s (Mohanty et al., 1994)
- 10^{-4} mm/s (Strobel 1993)
- 5×10^{-4} to 5×10^{-2} (Ronayne 2012)

We use a range of 10^{-6} to 10^{-2} mm/s.

Recharge Rate

To calculate the saturation area scale, we need to know the recharge rate. We use a range from field and numerical modeling studies of recharge rates through glacial till:

- 0.035 to 0.051 m/yr (Daniels, 1991)
- 0.04 to 0.19 m/yr (Bauer 1997)
- 0.69 m/yr (Masterson, 2007)

Based on these studies, we use a range between 0.03 m/yr and 1 m/yr.

Saturation area scale

Saturation area scale will be dynamically calculated from saturated conductivity, soil thickness, cell size and recharge rate (see value ranges for conductivity and recharge rate above):

$$A_{sat} = \frac{KH(dx)}{R} \quad (4)$$

Infiltration capacity

Measured on site (Report 2) to be between $5 * 10^{-1}$ and $8.52 * 10^2$ mm/hr.

Mean annual precipitation

The mean annual rainfall between 1981 and 2016 is 43.6 inches/yr. The range of total yearly rainfall from this time period has a minimum of 32.11 inches and a maximum of 56.07 inches per year. To account for extremes beyond the range of observations, we use a yearly total rainfall range of 20 - 60 inches.

Fraction of precipitation days

We use meteorological data from a weather station near West Valley, in Franklinville (weather station ID GHCND:USC00303025: see data downloaded from NOAA). While closer weather stations exist, they do not have the yearly precipitation data needed for these parameters. Data from 1981-2016 report total yearly and monthly rainfall, as well as number of days of rainfall above a threshold. The data show that the most rainfall occurs on

days with 0.5 to 1 inch of rainfall; we chose to use the number of these days as a measure of storm duration. The mean number of days with rainfall between 0.5 and 1 inch during the recorded history is 25. Therefore, the fraction of precipitation days is $\frac{25}{365}$.

Mean storm duration Assuming for model simplicity that each storm lasts 1 day, then the storm duration parameters are as follows:

$$\text{Mean storm duration} = 1 \text{ day}; \quad (5)$$

Mean interstorm duration

$$\text{Mean Interstorm duration} = \frac{365}{\text{number storm days}} = \frac{365}{25} = 14.6 \text{ days} \quad (6)$$

Mean storm depth

While we use a fixed storm and interstorm duration, we need to test a range of storm depth values. The range of total yearly rainfall from the meteorological data has a minimum of 32.11 inches and a maximum of 56.07 inches per year. To account for extremes beyond the range of observations, we use a yearly total rainfall range of 20 - 70 inches. To turn this into storm duration, we divide this total rainfall by the number of storm days in a year:

$$\text{mean storm depth} = \frac{\text{total rainfall}}{\text{number of storm days}} = 0.8 - 2.8 \text{ inches/storm} \quad (7)$$

Just to be safe we can round this to 0.5 - 3 inches/storm.

Rainfall intensity

Rainfall intensity will be calculated from mean annual precipitation and the fraction of precipitation days:

$$I = \frac{MAP}{f} \quad (8)$$

where I is intensity, MAP is mean annual precipitation, and f is the fraction of precipitation days.

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