Lahar Flow Models

References:

Encyclopedia of Volcanoes: pp 601-616

Scott, KM, 1988, Origins, behavior, and sedimentology of lahars and lahar-runout flows in the Toutle-Cowlitz River system: USGS Prof. Paper 1447A.

Iverson, RM, 1997, The physics of Debris flows, Reviews of Geophysics, **35**:245-296

Model Constraints

- Flows are neither steady nor uniform
- Pore pressure is laterally heterogeneous
- Mobility governed by fluid interiors with lithostatic pore pressures and resistant coarse-grained exteriors
- There is a range from frictional to collisional grain interactions

Flow Resistance

- Bingham model
  - Assumes a rigid plug
- Bagnold model
  - Assumes grain collisions
- Combination model
  - Coulomb friction plus collisional losses

Shear Strength

❶ $k = c + \sigma \tan \phi$

k = shear strength

c = cohesion

σ = normal stress

ϕ = friction angle

❷ $\sigma = (\sigma - P)$

P = pore pressure

Bingham Model

- Describes movement of clay slurries
- A rigid plug is inferred
- Resistance depends on viscosity (μ) and strength (S) of the material

$$\tau_b = S + \mu \, du/dt$$

Bagnold Model

- Assumes that grain collisions are important
- Resisting stress in granular flow is given by:

$$\tau_b = \nu \rho_s d^2 (du/dt)^2$$

ν is the solids fraction

d is the particle diameter

ρ_s is the density of solid particles

$d^2 (du/dt)^2$ is proportional to the granular temperature

Combination Model

- Both Coulomb friction and collisional losses
- Movement in a viscous fluid

$$\tau_f = \nu (\rho_s g h - P) \tan(\varphi)$$

tan (φ) is the friction coefficient
P is the fluid pressure

- If $P = \rho_s g h$ the flow is liquefied
- At the flow perimeter $P = \rho_f g h$
- In the flow interior, $P = 0.8 \rho_s g h$

Flow Components

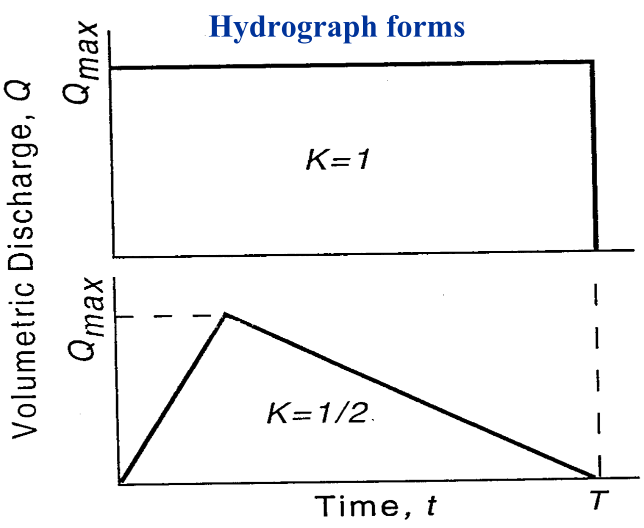
- Fluid phase
  - Frictionless mixture water and fine particles
  - Responsible for cohesive strength
- Granular phase
  - Coarser particles
  - Determines frictional strength

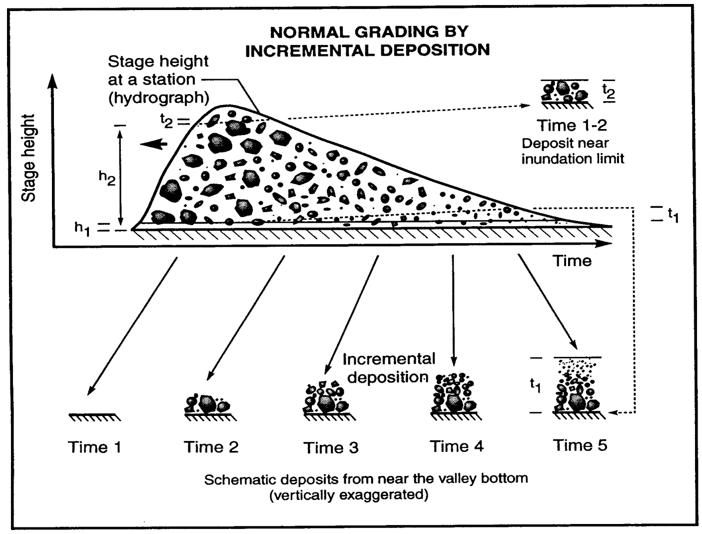
Flow Transformations

- Debris avalanches
- Debris flows flows
- Hyperconcentrated flows
- Stream flows

Hydrograph

- Flow characteristics vs. time
- Stage height (m)
- Discharge
  - Q (m^3/s)
  - Area under the curve is total volume
- Maximum discharge
- Duration





Geometric Considerations

- Source
  - Size and shape
  - volume
- Deposit
  - Cross sectional area
  - Planimetric area

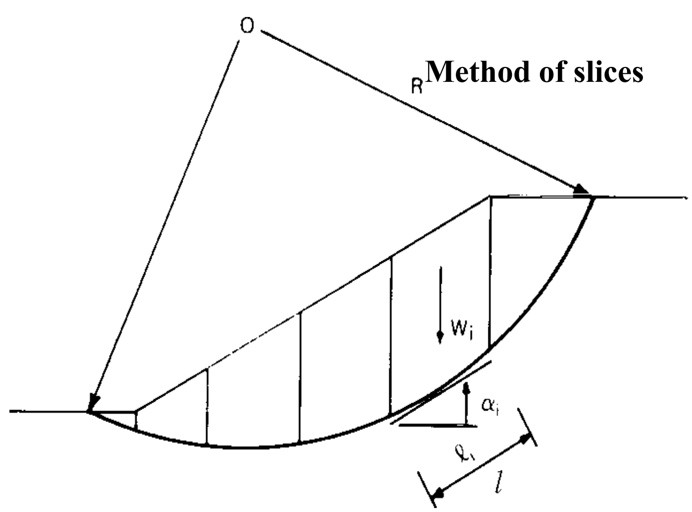
Source Characteristics

- General failure body
- Saucer shaped geometry
- Terzaghi (1931) slip surface
- Volume approximation
  - cone formula
  - volume ~ $1/3\ \pi\ r^2h\ \sim\ A\ h/3$

Method of Slices

$$F = (\Sigma S_{ui} l)/(\Sigma W_i \sin \alpha_I)$$

S_u = undrained shear strength
l = length of arc
W = weight of slice
α = slope angle of slice



LAHARZ Model

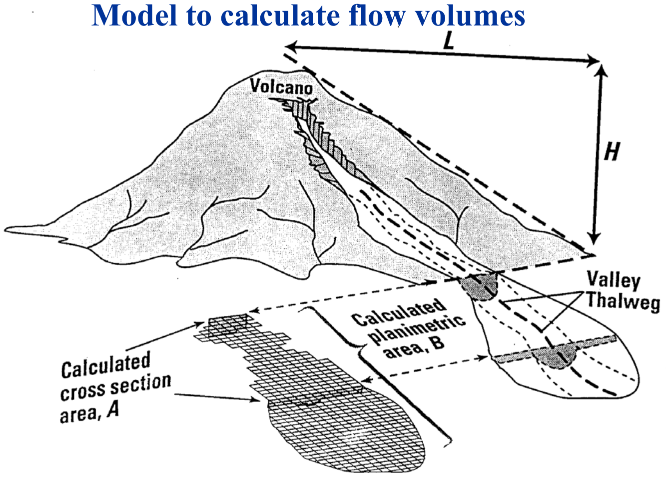
Reference:

Iverson, Richard M., Schilling, Steven P., Vallance, James W., 1998, Objective delineation of lahar-inundation hazard zones, Geological Society of America Bulletin, 110 (8), p. 972-984.

Deposit Geometry

- Cross sectional area (A_{sec})
  - Stream profile
  - Top of deposit/flow
- Planimetric area (A_{sur})
  - Outline of deposit
- Cumulative volume calculation

Model to calculate flow volumes

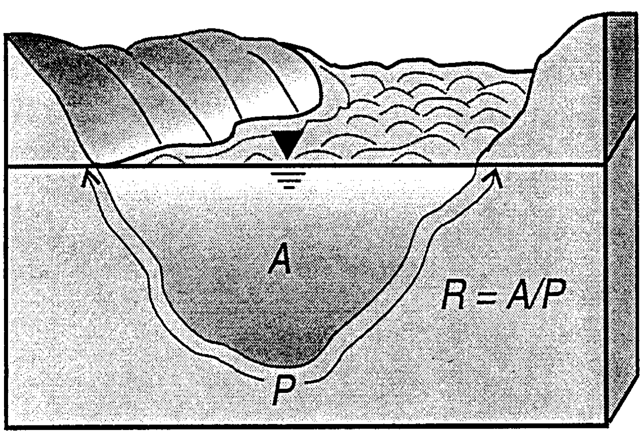


Calculation of Areas

- Model of Iverson et al. (1998)
- Sectional Area

  $A = 0.05\ V^{2/3}$
- Planimetric Area

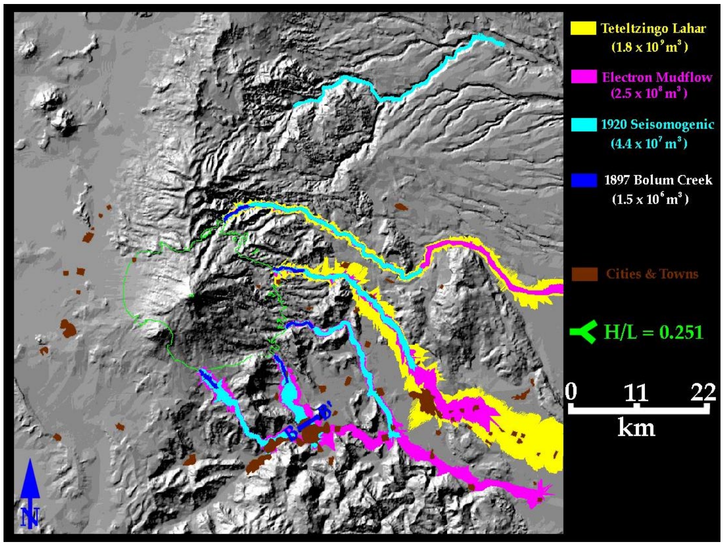
  $B = 200\ V^{2/3}$
- Volumes are incrementally deposited



Hydraulic radius (R) = Wetted perimeter * Area

Pico de Orizaba

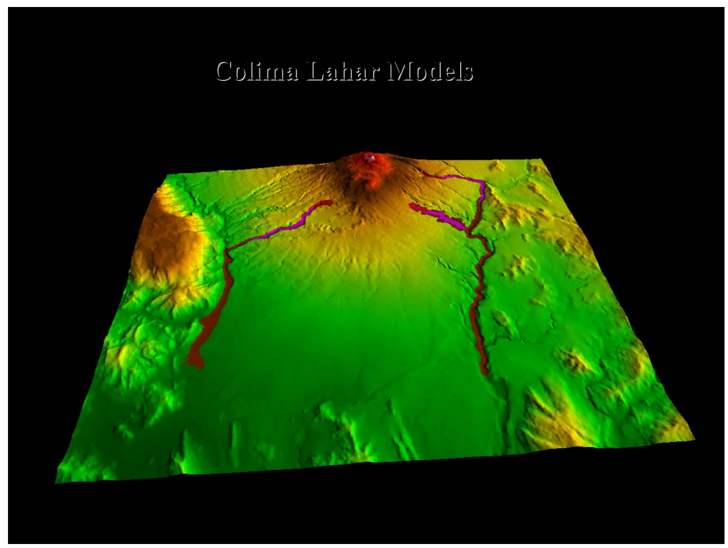
- Many large debris flows have occurred in the past
- Several orders of magnitude modeled with LAHARZ
- This is the basis of a debris-flow hazards map of the volcano

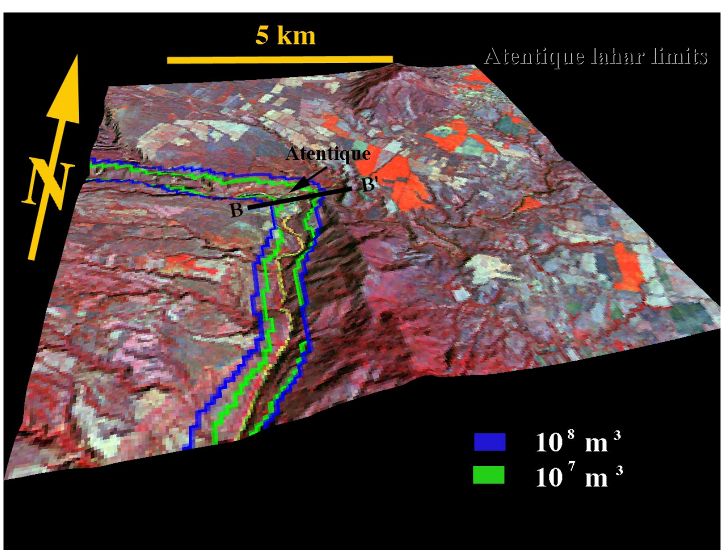


Volcan Colima

- Most active volcano in Mexico
- Large volcanic debris avalanches and lahars occurred in the past
- Recurrence interval is about 2000 years for large events
- Recurrence interval for small lahars is about 100 years

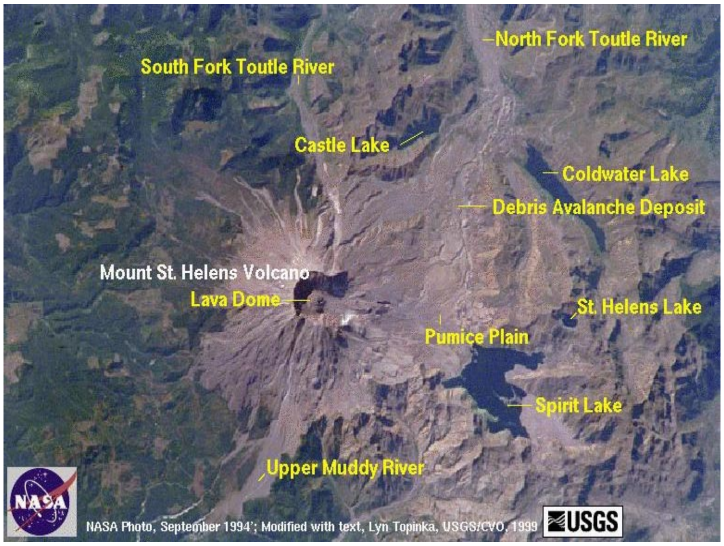
Colima Lahar, Barranca La Lumbre, 1 June 2000

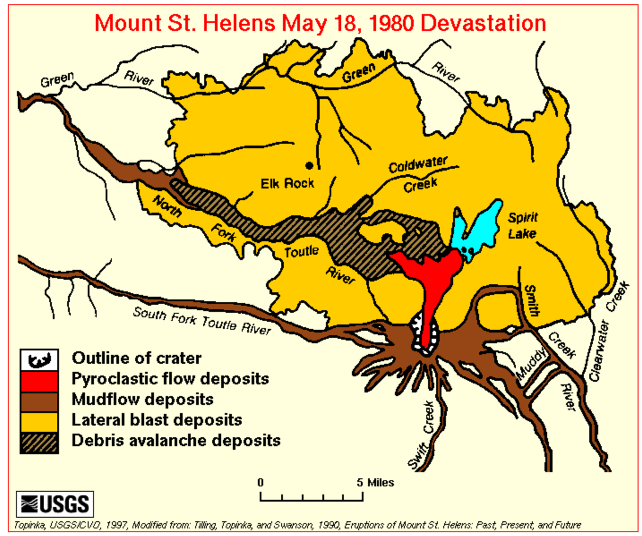




Mount St. Helens Mudflows

- Followed major drainages
- Several types represented
- Present a large geologic hazard


North Fork Toutle River
South Fork Toutle River
Castle Lake
Coldwater Lake
Debris Avalanche Deposit
Mount St. Helens Volcano
Lava Dome
St. Helens Lake
Pumice Plain
Spirit Lake
Upper Muddy River
NASA Photo, September 1994'; Modified with text, Lyn Topinka, USGS/CVO, 1999


Mount St. Helens May 18, 1980 Devastation
Green River
Green River
Elk Rock
Coldwater Creek
Spirit Lake
North Fork Toutle River
South Fork Toutle River
Smith Creek
Clearwater Creek
Muddy River
Swift Creek
Outline of crater
Pyroclastic flow deposits
Mudflow deposits
Lateral blast deposits
Debris avalanche deposits
0
5 Miles
Topinka, USGS/CVO, 1997, Modified from: Tilling, Topinka, and Swanson, 1990, Eruptions of Mount St. Helens: Past, Present, and Future