Inventory and initiation zone characterization of debris flows on Mount St. Helens, Washington initiated during a major storm event in November, 2006

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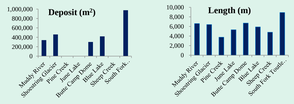
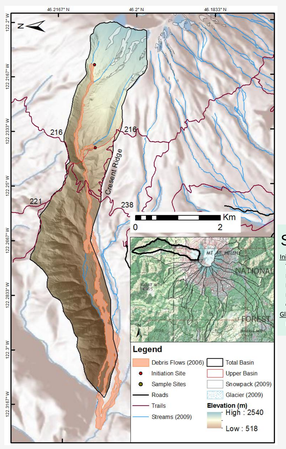
Abstract

The heavy precipitation event of November 3-8, 2006 dropped over 60 cm of rain onto the bare southern slopes of Mount St. Helens and generated debris flows in eight of the sixteen drainages outside the 1980 debris avalanche zone. Debris flows occurred on the upper catchments of the Muddy River, Shoestring Glacier, Pine Creek, June Lake, Butte Camp Dome, Blue Lake, Sheep Creek, and South Fork Toutle River. Debris flows were clustered on the west and south-east sides of the mountain. Of the eight debris flows, three were initiated by landslides, while five were initiated by headward or channel erosion. Six debris flows were initiated in deposits mapped as Holocene volcaniclastic deposits, while two were in 1980 pyroclastics on andesite flows. The largest (~975,000 m^2) and longest (~8,900 m) debris flow was initiated by landslides in the upper South Fork Toutle River Drainage. The average debris flow initiation zone elevation was 1,750 m, with clusters around 1,700 m and 2,000 m elevation. The lower cluster is associated with basins that host modern or historic glaciers, while the upper is possibly associated with recent pyroclastic deposits. Upper drainages with debris flows averaged 41% slopes steeper than 33 degrees, while those without debris flows averaged 34%. The geology of upper basins with debris flows averaged 6% snow and ice cover, 21% consolidated bedrock, and 74% unconsolidated deposits. Geology of basins without debris flows averaged 3% snow and ice cover, 27% bedrock, and 67% unconsolidated deposits. Drainages with debris flows averaged an 89% loss of glacier area between 1998 and 2009, while those without debris flows lost 68%. Further comparing glacier coverage during that period found that only five of ten glaciers still existed in 2009. On average, the glaciers had reduced in area by 67%, decreased in length by 36%, and retreated by an average of 471 m during that period. Basin attributes were measured or calculated in order to construct a predictive debris flow model based on that of Pirot (2010) using multiple logistic regression. The most significant factors were the percentage of slopes steeper than 33 degrees, unconsolidated deposits in the upper basin, and average annual rainfall. These factors predicted the 2006 debris flows with an accuracy of 94% in a debris flow susceptibility map for Mount St. Helens.

Debris Flows

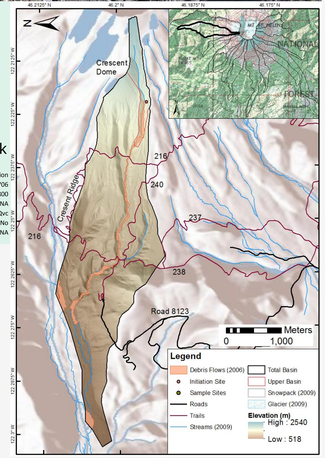
The 8 of 16 drainages that experienced a debris flow in November 2006 are described in detail in the maps and tables below and to the right. Further comparisons are made below and in the basin comparison charts in the central panel.





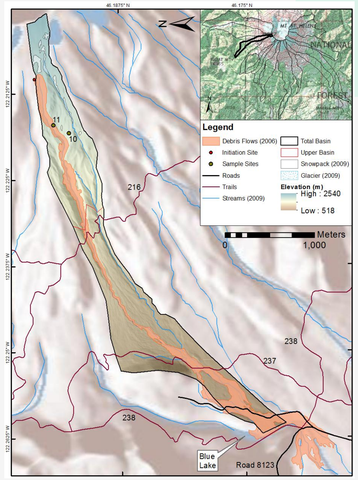
Sheep Creek

Initiation	
Type	Channel Erosion
Elevation (m)	1,706
Length (m)	4,800
Deposit Area (m^2)	NA
Geology	Qva/Qvc
Glacier	No
Direct Connection	NA



South Toutle

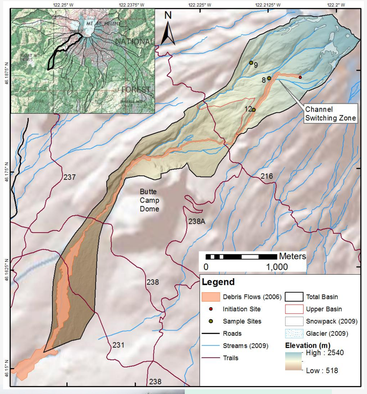
Initiation	
Type	Landslide
Elevation (m)	1,695
Length (m)	8,900
Deposit Area (m^2)	975,000
Geology	Qvc
Glacier	No
Direct Connection	NA



Blue Lake

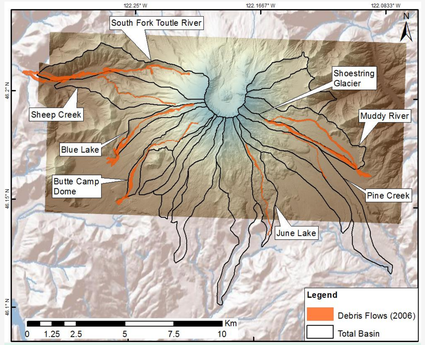
Initiation	
Type	Landslide
Elevation (m)	2,124
Length (m)	5,900
Deposit Area (m^2)	420,000
Geology	Qvc
Glacier	No
Direct Connection	NA

View of the Blue Lake Debris Flow deposit covering about 350 meters of Road 8123 and all of the Blue Lake trailhead parking area by deposits of up to three meters thick (USDA-FS, 2007).



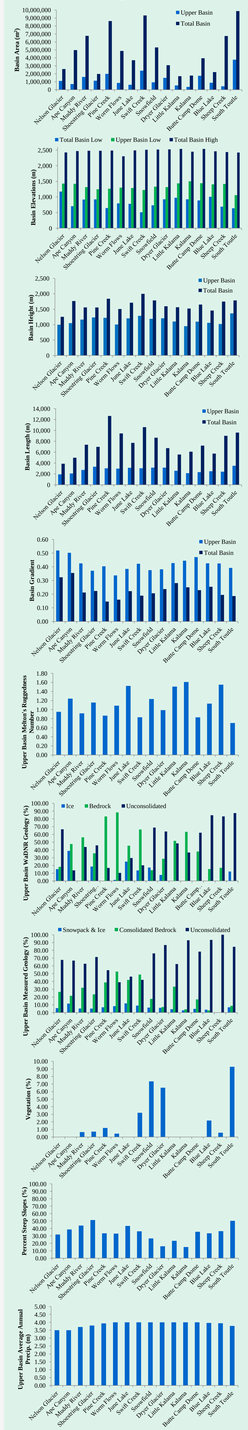
Butte Camp Dome

Initiation	
Type	Channel Erosion
Elevation (m)	1,986
Length (m)	6,700
Deposit Area (m^2)	300,000
Geology	Qvc
Glacier	No
Direct Connection	NA



Debris flow inventory map showing defined drainage outlines and 2006 event flow paths. The largest and longest debris flow occurred in the South Fork Toutle Drainage in the western quadrant. The depositional area comprised about 975,000 m^2 and a total length of 8,900 m. The next largest debris flow deposit, at 420,000 m^2, was from the June Lake drainage. The smallest of 300,000 m^2 occurred in the Butte Camp Dome drainage.

Basin Comparisons



Muddy River/Shoestring Glacier

Courtesy of David Anderson

Lahar plain, 1986

8/2005

8/2011

Shoestring Glacier

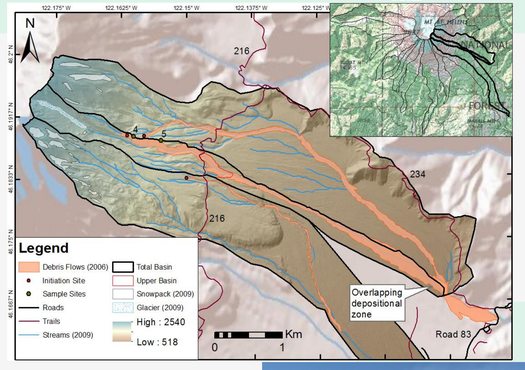
Initiation	
Type	Channel Erosion
Elevation (m)	1,706
Length (m)	6,400
Deposit Area (m^2)	460,000
Geology	Qvc
Glacier	Yes
Direct Connection	No

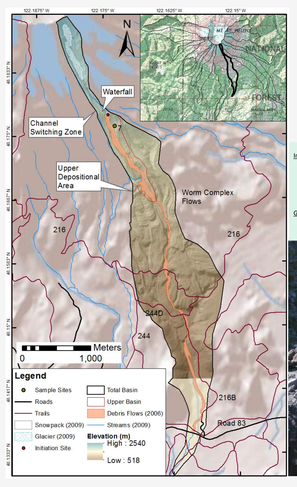
Muddy River

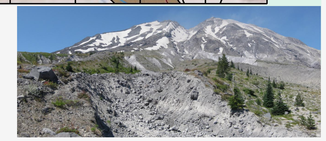
Initiation	
Type	Channel Erosion
Elevation (m)	1,706
Length (m)	6,600
Deposit Area (m^2)	340,000
Geology	Qvc
Glacier	No
Direct Connection	NA

Pine Creek

Initiation	
Type	Channel Erosion
Elevation (m)	1,403
Length (m)	3,760
Deposit Area (m^2)	NA
Geology	Qvc
Glacier	No
Direct Connection	NA



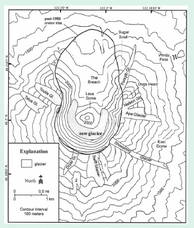


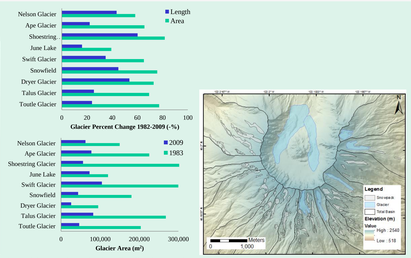


June Lake

Initiation	
Type	Landslide
Elevation (m)	1,706
Length (m)	5,300
Deposit Area (m^2)	
Geology	Qva/Qvc
Glacier	Yes
Direct Connection	Yes

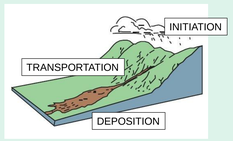
Glacial Change





Mount St. Helens edifice with post-May 18, 1980 eruption glacier distribution and extents (left map). Redrawn from Brugman and Post (1981). On The right are glacier extents and distributions as they existed as of 2009. The glaciers remaining are Nelson, Ape, Shoestring, June (#1), and Swift. The diagrams show the decrease in glacier area and length between 1982 and 2009.

Background



Debris flows

- Channelized flow path
- Initiated by a glacial outburst, landslide, erosion, or dam failure
- Transports debris at ~25 mph
- Bulks up during transport with addition of soil, rock, organic debris
- Creates a lobate debris fan

Location

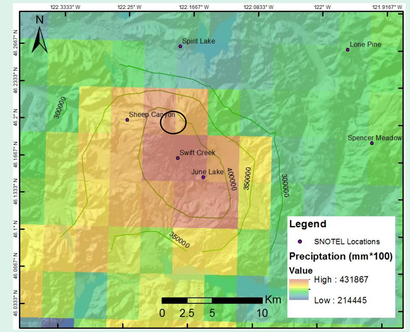
- Southwestern WA state
- 50 miles (80 km) northeast of Portland

Geology

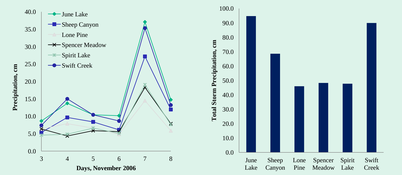
- Composite volcano
- ~300,000 years old
- Largely constructed during the past 3,000 years
- Eruptive phases: fallout tephra and pyroclastic events then a long hiatus
- Three primary river systems drain the volcano: Lewis River, North and South Toutle Rivers, Kalama River

Initiation event

- Extreme rain event (pineapple express) on Nov. 6-9, 2006
- Over 3x normal daily rainfall within a 24 hour period
- Initiated debris flows on all central Cascade volcanoes: Rainier (northern-most) to Jefferson (southern-most)



Map showing the gridded PRISM average annual precipitation data for 2006 in hundredths of millimeters and as contours. Locations of nearby SNOTEL sites are also shown. The highest average rainfall values for this area are 430 cm. Crater is denoted by black circle.



Graph of rainfall measurements during the period of November 3-8 at the SNOTEL sites June Lake (1,049 m), Sheep Canyon (1,216 m), Lone Pine (1,198 m), Spenser Meadow (1,036 m), Spirt Lake (1,072 m), and Swift Creek (1,353 m). June Lake and Swift Creek (see map), experienced the greatest rainfall accumulation (USDA-NRCS, 2007).

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