

## Significant Deep-Seated Landslides in Washington State – 1984 to 2014

Landslide Name	Date	Location	Area	Volume	Comments	Fatalities	Direct Costs (millions in 2014 \$)	References
SR 530 (aka Oso or Hazel)	Mar. 22, 2014	North Fork Stillaguamish River, Snohomish Co.	~262 acres of landslide and debris	Initial estimate 10 million yd <sup>3</sup>	Partially dammed river; 49 homes destroyed and 43 lives lost; flooded 0.55 mi <sup>2</sup> of valley; debris field in area of Steelhead Drive is more than 60 ft deep. Severed SR 530 for nearly 2 months. Total impacted area is ~1 mi <sup>2</sup> .	43	>80*	Geotechnical Extreme Event Reconnaissance, 2014, The 22 March 2014 Oso landslide, Snohomish County, Washington, p. 186. *Source: Washington State Emergency Management Division
Ledgewood–Bonair (Whidbey Island)	Mar. 27, 2013	Island Co.	12 acres; 900 ft wide; 700 ft long	~200,000 yd <sup>3</sup>	Small portion of a larger landslide complex, ~1.5 mi long, ~11,000 years old; 35 homes evacuated when landslide occurred; 20 homes still at risk, either through structural damage or loss of property.	0		Slaughter, Steven; Sarikhan, Isabelle; Polenz, Michael; Walsh, Tim, 2013, Quick report for the Ledgewood–Bonair landslide, Whidbey Island, Island County, Washington: Washington Division of Geology and Earth Resources Quick Report, 7 p. [ <a href="http://www.dnr.wa.gov/Publications/ger_qr_whidbey_island_landslide_2013.pdf">http://www.dnr.wa.gov/Publications/ger_qr_whidbey_island_landslide_2013.pdf</a> ]
Nile Valley (SR 410 MP 108)	Oct. 11, 2009	Yakima Co.	~110 acres	40 million yd <sup>3</sup>	Buried one house, severely damaged four others; blocked Naches River and flooded the valley causing significant flood damage to four additional houses; destroyed a 2,500 ft of SR 410. Direct costs for constructing detour route, re-channelizing river and reconstructing the highway.	0	22	WSDOT, 2010, Nile Valley landslide: geotechnical report, May, p. 380. WSDOT, 2010, SR 410 Nile Valley landslide – reconstruct route, December. Cornforth, D. H., 2010, Landslide review and analyses–Nile landslide, Washington: Landslide Technology, 1 v.
Green River Bridge (SR 169 MP 5)	Nov. 2008	King Co.	200 ft long; 200 ft wide		Landslide reactivation threatened south bridge abutment, resulting in multi-month highway closure. Major structural project required to protect south bridge abutment.	0	≈5–10	WSDOT, 2009, Green River Bridge #169/8 – Pier 1 Landslide: geotechnical documentation for FHWA emergency relief, memorandum, 16 p.
Piper Road–Rock Creek	Feb. 2007	Stevenson, Skamania Co.	11 acres; 1,000 ft long; 550 ft wide		The north side of the Columbia River Gorge is one of the most famous landslide provinces in the world. Wet climate, weak bedrock, steep terrain, and a regional dip of 5–30° toward the gorge create ideal conditions for landslides. Landslide occurred within water-saturated clay layers under permeable conglomerate in Eagle Creek Formation.	0		Washington Division of Geology and Earth Resources, 2007, The Rock Creek landslide near Stevenson: DGER News, v. 4, no. 1, p. 1-2. [ <a href="http://www.dnr.wa.gov/publications/ger_dgernews_2007_v4_no1.pdf">http://www.dnr.wa.gov/publications/ger_dgernews_2007_v4_no1.pdf</a> ]
Rockcrusher Hill (U.S. 101 MP 72.6)	2006	Grays Harbor Co.	1,500 ft long; 400 ft wide	0.5 million yd <sup>3</sup>	Ongoing deformation with acceleration in 2006 resulted in costly temporary repair (that has now failed) and now requires frequent repairs to keep highway open. Threatens severing US 101, which would require ~50-mile-long detour. Estimated \$7 million repair programmed for 2015.		2	WSDOT, 2007, SR 101 MP 72.6 landslide–geotechnical recommendations; 75 p.
Hazel	2006	North Fork Stillaguamish River, Snohomish Co.	1,000 ft long; 1,000 ft wide	2 million yd <sup>3</sup>	Partially dammed river; log revetment constructed to reduce river erosion of landslide toe.	0		Stillaguamish Tribe Natural Resources Department, 2006, Oso slide and North Fork Stillaguamish River avulsion February [ <a href="http://www.stillaguamish.nsn.us/steelhead%20haven%20slide.htm">http://www.stillaguamish.nsn.us/steelhead%20haven%20slide.htm</a> ]
Montesano (SR107 MP 4.7)	Dec. 2005	Grays Harbor Co.	300 ft long; 300 ft wide	100,000 yd <sup>3</sup>	Initiated from recent clearcut on previously mapped deep-seated landslide. Severed highway and toed out in Chehalis River. Retaining wall required to stabilize landslide and reopen the highway.	0	≈5	Landslide Technology, 2006, geotechnical report prepared for WSDOT.

Bogachiel (U.S. 101 MP 184)	2004	Jefferson Co.	700 ft long; 2,800 ft wide	1–2 million yd <sup>3</sup>	Ongoing deformation within large landslide complex, with failure surface greater than 100 ft deep beneath highway and toeing out in river. Localized acceleration in 2004 resulted in costly repairs for 200-ft-wide section. Movement persists and threatening previous repairs. Evidence for prehistoric catastrophic failures. Threatens severing US 101 with no detour route and no viable mitigation.	0	8	WSDOT, 2007, Bogachiel landslide– geologic assessment and mitigation alternatives, 49 p.
Afternoon Creek (SR 20 MP 121.5)	Nov. 9, 2003	Whatcom Co.	500 ft long; 800 ft wide	1 million yd <sup>3</sup>	Rainfall-induced rock slide inundated creek and rockfall debris covered portion of the highway and severely damaged bridge. Cut off access to Diablo residents and upstream Seattle City Light dams. Protection embankment constructed to contain future rockfalls.	0	≈10–15	URS and Wyllie & Norrish, 2004, geotechnical reports prepared for WSDOT
Carlyon Beach	Feb. 6, 1999	Thurston Co.	45 acres; 3,000 ft wide; 900 ft long		Forty one homes and properties were damaged or destroyed. Numerous streets were damaged in Carlyon Beach along with subsurface utilities and overhead power lines. Scarps within the landslide were up to 15 ft in height. Headscarp threatens Hunter Point Road.	0		GeoEngineers, Inc., 1999, Report—Phase II geotechnical study, Carlyon Beach/Hunter Point landslide, Thurston County, Washington: GeoEngineers, Inc. [under contract to] Thurston County Development Services, 1 v.
Jorstad Creek (U.S. 101 MP 322)	Feb. 1999	Mason Co.	500 ft long; 1,000 ft wide	1 million yd <sup>3</sup>	Resulted in long duration closure of US 101 with very long detour route. Extensive drainage network required to stabilize slope.	0	≈3	Golder, 1999, Geotechnical report—landslide on U.S. 101 MP 326 Lilliwaup, Washington, prepared for WSDOT.
Lilliwaup U.S. 101 MP 326)	Feb. 1999	Mason Co.	500 ft long; 1,800 ft wide	1.5 million yd <sup>3</sup>	Resulted in long duration closure of US 101 with very long detour route. Extensive drainage and retaining wall required to stabilize slope.	0	≈5–10	Golder, 1999, Geotechnical report—landslide on U.S. 101 MP 322, prepared for WSDOT.
Ross Point Complex (SR 166 MP 0.5 to 2.0)	Feb. 1999	Kitsap Co.	300 ft long; 5,000 ft wide		Reactivated landslide complex beginning in 1992 and episodically active through 1999 on approximately mile-long bench above SR 166, resulting in numerous short and long-term closures involving injury accident. Drainage, grading, and rock buttresses required to stabilize landslides.	0	≈15	WSDOT reports and memos
Allyn Curves (SR 3)	Dec. 1998	Mason Co.	2,000 ft long; 1,300 ft wide		Episodically active for decades followed by severe deformation and retrogression in 1997–8 and 1998–99, resulted in 5 month highway closure. Realignment in 1993 and stabilization in 1999 costs totaled around \$5 million.	0	≈10–15	WSDOT report and memos
Aldercrest–Banyon	Feb. 1998; Oct. 1998	Cowlitz Co.	3,000 ft long; 1,500 <sup>+</sup> ft wide		Second costliest landslide disaster in U.S. history involving homes after the Portuguese Bend landslide in southern California; affected 138 homes.	0	110	Wegmann, K. W., compiler, 2004, Geologic field trip to the Aldercrest–Banyon landslide and Mount St. Helens, Washington, Part 1—Stevenson to Castle Rock: Washington Division of Geology and Earth Resources, 24 p. [ <a href="http://www.dnr.wa.gov/publications/ger_misc_field_trip_stevenson_castle_rock.pdf">http://www.dnr.wa.gov/publications/ger_misc_field_trip_stevenson_castle_rock.pdf</a> ]

Woodway (Rosary Heights)	Jan. 15, 1997	Snohomish Co.	disrupted a 30,000 m <sup>2</sup> bluff area	100,000 m <sup>3</sup>	Pushed five cars of a passing freight train into Puget Sound	0		Arndt, B. P., 1999, Determination of the conditions necessary for slope failure of a deep-seated landslide at Woodway, Washington: Colorado School of Mines Master of Engineering thesis, 216 p.
Maple Hill	Feb. 1996	Skamania Co.	≤1,200 ft across		Severely damaged four homes and rendered them uninhabitable; Loop Road inundated with debris flow generated at the toe of the falling mass; Stewart and View Roads also severely damaged, along with utilities; minor movements began Nov. 1995.	0		Biever, M. P.; Peterson, G. L.; Squier, L. R., 1999, Geotechnical investigation—Maple Hill landslide: Squier Associates, Inc., 1 v.
Morrill Gravel Pit slope failure (U.S. 97A MP 201)	May 19, 1995	Chelan Co.	500 ft long; 1,100 ft wide		Catastrophic mine slope failure killed two people, including young boy, and inundated US 97A.	2	1	Mine Safety and Health Administration, 1995, Investigation of massive slope failure portable crusher no 2, 48 p.
Peters Road (U.S. 12 MP 114)	Nov. 22, 1994	Lewis Co.	2,000 ft long; 500 ft wide	300-500,000 yd <sup>3</sup>	Catastrophic debris avalanche buried US 12 in 70,000 yds <sup>3</sup> of debris, effectively isolating the communities of Randle and Packwood from I-5. Major retrogression in 1995. Temporary detour route constructed around landslide runout in 1994; permanent realignment constructed in 1996.	0	≈10–15	Golder, 1995, Geotechnical study—Peters landslide, SR 12, MP 114, prepared for WSDOT, 146 p.
Satus Pass (U.S. 97 MP 28.3)	1992	Yakama Nation	1,000 ft long; 700 ft wide	1.5 million yd <sup>3</sup>	Ongoing movement since highway embankment constructed on very large landslide in 1960. Highway was realigned off of the landslide in the late 1990s.	0	≈5	WSDOT, 1993, Satus Pass settlement correction—geotechnical report, 20 p.
KM Mountain	Feb. 10, 1990	Wahkiakum Co.	1,100 ft long; ~800 ft wide	1.5–2 million yd <sup>3</sup>	Destroyed 700 ft of SR 4; several mile-long, single-lane detour route required for many months. Stabilization required major regrading and large rock buttress.	0	≈5	Lowell, S. M., 1990, K M Mountain landslide: Washington Geologic Newsletter, v. 18, no. 4, p. 3-7. [ <a href="http://www.dnr.wa.gov/publications/ger_washington_geology_1990_v18_no4.pdf">http://www.dnr.wa.gov/publications/ger_washington_geology_1990_v18_no4.pdf</a> ]
SR 112 MP 36	Feb. 1990	Clallam Co.	1,500 ft long; 500 ft wide		Destroyed approximately 500 ft of highway and toed out in the Straits, resulting in 8 month closure. Highway realigned off of active portion.	0	≈5	WSDOT, 1990 report and memos
Jim Creek (SR112 MP 32)	November 1990	Clallam Co.	300 ft long; 300 ft wide		Destroyed approximately 300 ft of highway and toed out in creek, resulting in 2-month-long highway closure with a very long detour.	0	≈5	WSDOT and Golder reports and memos prepared for WSDOT
Hazel	1988	North Fork Stillaguamish River, Snohomish Co.			Partially dammed river	0		Miller, D. J.; Sias, J. C., 1998, Deciphering large landslides—linking hydrological, groundwater and slope stability models through GIS: Hydrological Processes, v. 12, no. 6, p. 923-941.
Prosser (I-82 MP 92)	1986–1987	Benton Co.			Interstate construction remobilized several very large, prehistoric landslide complexes. Stabilization required alignment revisions, buttresses and grading.	0	≈10–15	WSDOT reports and memos Jamsgard, J. 2013, I-82 Prosser landslide investigation, Benton City, WA technical report, University of Washington master's report, 103 p.

Swift Creek	ongoing	Whatcom			Active, slow-moving landslide deposits more than 100,000 yds <sup>3</sup> of asbestos-laden sediment annually into Swift Creek, raising considerable public health concern and threatening localized flooding of the Nooksack River.	0		McKenzie-Johnson, A. S., 2004, Kinematics of Swift Creek landslide, northwest Washington, Western Washington University master's thesis.
Van Zandt Dike	ongoing	Whatcom			Active landslide	0		Brunengo, M. J., 2001, The Van Zandt Dike landslide, Northwest Geological Society field trip guide, 25 p.
<b>TOTALS</b>						<b>45</b>	<b>≈\$300</b>	

## Widespread Shallow Landslide and Debris Flow Events in Washington State – 1984 to 2014

Time Period	Areas Affected	Description	Fatalities	References
January 2009	western Washington, including Lewis, Skagit, Whatcom, Kittitas, Clark, and Cowlitz Counties	A typical atmospheric river (Pineapple Express) storm rolled through the state, bringing with it warm rains that rapidly melted lowland snow. The Washington Geological Survey reported that the storm caused more than 1,500 landslides greater than 5,000 ft <sup>2</sup> in size. More than 500 landslides were recorded in eastern Lewis County. Approximately 300 to 500 landslides occurred in Skagit and Whatcom Counties.		Sarikhan, I. Y.; Contreras, T. A., 2009, Landslide field trip to Morton, Glenoma, and Randle, Lewis County, Washington: Washington Division of Geology and Earth Resources Open File Report 2009-1, 13 p. [ <a href="http://www.dnr.wa.gov/publications/ger_ofr2009-1_landslide_field_trip.pdf">http://www.dnr.wa.gov/publications/ger_ofr2009-1_landslide_field_trip.pdf</a> ]
December 2007	western Washington, including Mason, Jefferson, Lewis, and Thurston Counties	The storm event of December 1–3, 2007 caused thousands of landslides and major flooding. The storm brought snow, warm rain, and hurricane force winds across much of western Washington. Landslides blocked or damaged roads, isolating communities in the height of the storm and delaying emergency response. A massive debris avalanche and numerous smaller landslides blocked SR 6. SR 8 was blocked by landslides near Onalaska. Highway 101 was blocked north of the Skokomish River. Nearly 20 in. of rain was recorded within a 48-hour period in the headwaters of the Chehalis River. This caused more than 1,600 landslides in the Chehalis headwater basin alone, clogging flood waters with debris. I-5 was flooded with as much as 10 ft of water.		Sarikhan, I. Y.; Stanton, K. D.; Contreras, T. A.; Polenz, Michael; Powell, Jack; Walsh, T. J.; Logan, R. L., 2008, Landslide reconnaissance following the storm event of December 1-3, 2007, in western Washington: Washington Division of Geology and Earth Resources Open File Report 2008-5, 16 p. [ <a href="http://www.dnr.wa.gov/publications/ger_ofr2008-5_dec2007_landslides.pdf">http://www.dnr.wa.gov/publications/ger_ofr2008-5_dec2007_landslides.pdf</a> ]
December 2006	western Washington	A strong storm known as the Hanukkah Eve Storm of 2006 brought hurricane force wind gusts and heavy rains to western Washington. The storm initiated a small number of landslides around western Washington.		
January to February 2006	entire state	Prolonged heavy rainfall from December 2005 into January 2006 caused numerous landslides throughout the state. More than 13 in. of rain fell between December 19 and January 14. Slides, slumps, or settlement closed lanes of I-5, US 101, SR's 4, 9, 14, 107, 105, 112, 116, 166, 302, and 530 for various periods. On February 3, the Governor signed emergency proclamation requesting federal funds for all 39 counties.		Information from news reports and the Washington Department of Transportation
October 2003	entire state, including Skagit, Okanogan, Clallam, Jefferson, Mason, Snohomish, Pierce Counties	Heavy rainfall caused severe flooding and landslides in 15 counties. Landslides or ground failure caused temporary closures on nine state highways. Landslides closed SR 20 between Skagit and Okanogan Counties, a landslide closed SR 112 in Clallam County, debris flows also blocked US 101 in Jefferson and Mason Counties, US 2 in Snohomish County, and SR 410 in Pierce County.		
Nisqually Earthquake – February 28, 2001	western Washington, including Tacoma, Renton, Olympia, Burien, and Tumwater	The magnitude 6.8 earthquake produced a number of significant, widely scattered landslides resulting in at least \$34.3 million in losses. Salmon Beach suffered a 1,300 yd <sup>3</sup> landslide that demolished two homes. Cedar River had two landslides, one of which was an estimated 50,000 yd <sup>3</sup> . The parkway on Capitol Lake experienced significant damage from ground failure. Five homes in Burien sustained structural damage when underlying fill formed a landslide.		Highland, L. M., 2003, An account of preliminary landslide damage and losses resulting from the February 28, 2001, Nisqually, Washington, earthquake: U.S. Geological Survey Open-File Report 03-211, 48 p. [ <a href="http://pubs.usgs.gov/of/2003/ofr-03-211/ofr-03-211.pdf">http://pubs.usgs.gov/of/2003/ofr-03-211/ofr-03-211.pdf</a> ]

September 17, 1997	Clallam Co.	Debris flow-avalanche kills one in Port Angeles tavern situated below steep slope. Weather was not especially wet preceding the event (0.5 in. of rain).	1	
December 1996 to January 1997	western Washington, primarily the bluffs of Puget Sound, Lake Washington, Lake Union, Portage Bay, West Seattle, Magnolia Bluff, and along the I-5 corridor	December precipitation was 191% of normal, triggering hundreds of landslides and debris flows on steep bluffs and ravines. At least four people were killed by these events, and millions of dollars of damage were caused. A landslide on January 15 derailed five cars of a freight train midway between Seattle and Everett. Twenty to 30 landslides occurred in Pierce County, including one that cut phone service to homes on Salmon Beach. In Whatcom and Clark Counties, two interstate natural gas lines were ruptured due to landslides, causing explosions, fires, and evacuations.	4	Gerstel, W. J.; Brunengo, M. J.; Lingley, W. S., Jr.; Logan, R. L.; Shipman, Hugh; Walsh, T. J., 1997, Puget Sound bluffs—The where, why, and when of landslides following the holiday 1996/97 storms: Washington Geology, v. 25, no. 1, p. 17-31. [ <a href="http://www.dnr.wa.gov/publications/ger_washington_geology_1997_v25_no1.pdf">http://www.dnr.wa.gov/publications/ger_washington_geology_1997_v25_no1.pdf</a> ] Baum, R. L.; Chleborad, A. F.; Schuster, R. L., 1998, Landslides triggered by the winter 1996-97 storms in the Puget Lowland, Washington: U.S. Geological Survey Open-File Report 98-239, 16 p., 1 plate. [ <a href="http://pubs.usgs.gov/of/1998/ofr-98-239/">http://pubs.usgs.gov/of/1998/ofr-98-239/</a> ]
February 1996	entire state, including Walla Walla, Seattle, and Pierce, Thurston, Lewis, Clark, and Skamania Counties	Near-record snowfall in January followed by warm, heavy rain caused massive flooding and landslides. Landslides damaged or destroyed nearly 8,000 homes and closed traffic along major highways (including I-5, SR 4, and SR 503) for several days. Damages totaled at least \$800 million. The highest concentration of landslides occurred near Walla Walla. Seattle had more than 40 landslides during the winter, about two-thirds of which were related to the storm. Lewis County had the largest landslide, with an estimated 1.5 million yd <sup>3</sup> of debris.		U.S. Federal Emergency Management Agency, 1996, Interagency Hazard Mitigation Team report, including progress report on early implementation strategies—State of Washington, winter storms of 1995-1996; FEMA-DR-1079, declared January 3, 1996; FEMA-DR-1100-WA, declared February 9, 1996: U.S. Federal Emergency Management Agency, 88 p. Harp, E. L.; Chleborad, A. F.; Schuster, R. L.; Cannon, S. H.; Reid, M. E.; Wilson, R. C., 1998, Landslides and landslide hazards in Washington State due to February 5-9, 1996 storm: U.S. Geological Survey Administrative Report, 1 v. [ <a href="http://www.preventionweb.net/files/1585_Washhrp.pdf">http://www.preventionweb.net/files/1585_Washhrp.pdf</a> ]
November 2, 1985	Skagit Co.	Marblemount debris flow	4	
<b>TOTAL</b>			<b>9</b>	