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Open-File Report O–01–02

The Nisqually, Washington, Earthquake of February 28, 2001. Summary Report

2001

This summary report provides a quick overview of the Nisqually earthquake and our reconnaissance efforts. It has not been subjected to the Agency's standard review process.

Cover photo

Damage induced by lateral spread along Sunset Lake in Tumwater.

The Nisqually, Washington, Earthquake of February 28, 2001. Summary Report

By
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INTRODUCTION

On February 28, 2001, at 10:54 a.m., a magnitude (M) 6.8 earthquake shook the Pacific Northwest. Its epicenter was in the vicinity of Nisqually, Washington. This intraplate event occurred within the subducting Juan de Fuca plate along the Cascadia margin which stretches from northern California to British Columbia, Canada. Although the damage was less than observed in most large urban earthquakes, serious damage was found in Olympia, Seattle, Tacoma, and elsewhere.

The Nisqually earthquake has important implications for future Oregon quakes and is of concern for scientists, engineers, emergency managers, and many others. As a lead technical agency, the Department of Geology and Mineral Industries (DOGAMI) took initiative to coordinate field efforts. In response to the quake, DOGAMI formed an Oregon Investigation Field Team (hereafter "the Team") whose members visited the immediately affected area to investigate the earthquake. To better serve Oregon's public safety needs, we sought to expand our technical understanding of seismic ground response, attenuation, amplification, building and lifeline seismic behavior, and secondary hazards (landslides and liquefaction). We also sought to learn from the Nisqually emergency response, post-earthquake investigation coordination, the establishment of the Earthquake Engineering Research Institute data clearing house, and our Washington counterpart's support of state government and media needs.

This summary report includes basic information on the earthquake, the Team's field observations, a short discussion of the Nisqually earthquake and an outline of the Team's thoughts on Oregon's earthquake preparedness needs. The Team's efforts focused on gathering field data and acting as a source for technical information to the media and public. What the Team gathered represents short-lived, fragile, and perishable geologic and engineering evidence. This includes information on landslides, liquefaction, lateral spreading, and settling, as well as building and lifeline damage. The Team worked closely with others in the Puget Sound Region to augment ongoing efforts.

EARTHQUAKE PROFILE

- 10:54 a.m. Pacific Standard Time
- Magnitude 6.8
- 15–20 seconds of strong shaking (felt shaking was longer)
- Location: 17.6 km (10.9 mi) NE of Olympia and 57.5 km (35.7 mi) SW of Seattle. Very close to the location of the M 7.1 earthquake of 1949
- Intraplate event
- Possible aftershocks
  (e.g., 1/13/01 El Salvador M 7.6 intraplate earthquake was followed by the 2/13/01 M 6.6 crustal earthquake and 2/28/01 M 5.4 intraplate quake; see discussion)
- No tsunami threat
- Depth 52 km (32.3 mi)
  Large cone of shaking and felt area because of depth
  High attenuation of ground shaking because of depth (i.e., low shaking levels)
  Dominated by lower frequency waves (higher frequency waves are filtered out)
  Felt area: Portland OR; Vancouver, B.C.; Salt Lake City, UT
- PGA around Seattle up to 0.2 g in limited areas (and recorded up to 0.3 g)
- PGA around Tacoma lower (0.06 g measured)
- Estimated costs: $2 billion (State HAZUS estimate) to $3.9 billion (FEMA HAZUS estimate)
- About 400 injuries
- No fatalities directly associated with earthquake. One reported fatal heart attack.

DAMAGE OBSERVATIONS

The Team's reconnaissance included surveys in Olympia, Seattle, Tumwater, Burien, Maplewood, Tacoma, and Nisqually. Investigations were conducted March 2, 3, and 4. Damage types observed included structural, nonstructural, contents, lifelines, landslides, liquefaction, lateral spreading, sand boils, and settling.

Infrastructure damage observed included bridges, roads, unreinforced masonry buildings (URMs), concrete frames, tilt-ups, mobile homes, RVs, parapets, facings, and windows. In places, liquefaction, lateral spreading, settling, and landslides significantly contributed to the earthquake-related damage.

Listed below are sites of observed damage arranged under the categories of buildings, lifelines, landslides, and liquefaction. Eighteen photographs are included at the end of this report to highlight some of the more prominent damage locations.

Buildings

- Seattle Pioneer Place, numerous structures,
  Fenix
- Seattle industrial area, numerous structures
  Seattle Chocolate
  Starbucks HQ
- Olympia, Capitol and nearby structures
- Olympia downtown, numerous structures, including
  Ramada Hotel, Olympia
  Old Olympian Hotel apartments
- Nisqually, mobile home park

Lifelines

- SeaTac Airport (control tower windows and minor terminal damage)
- Boeing Field (runway, extensive liquefaction and settling up to 9 inches)
- Harbor Island Port Terminals (water-pipe breaks, liquefaction, lateral spreading, settling)
- Alaskan Way Viaduct (structural, tie rods, corbels, vertical cracks in columns)
- Spokane Viaduct (minor damage)
- Seattle terminal area (water-pipe breaks, liquefaction, lateral spreading up to 500 ft)

Landslides

- Salmon Beach Landslide near Point Defiance in Tacoma (minor breakage of electrical and sewer lines, staircase; home and trees down)
- Two Cedar River mudslides and flooding in Maplewood (near Renton)
- West Seattle on 36th, affecting 10 homes, 1 home yellow-tagged
- Burien, 8 red-tagged homes
- Highway 101 NW of Olympia

Liquefaction

- Seattle waterfront (Ferry terminals and cracks in pier)
- Olympia, Capitol Lake (liquefaction and lateral spreading)
- Seattle, Harbor Island (ferry terminal, ports, marina)(liquefaction, lateral spreading, settling)
- Trosper, Sunset Lake Mobile Home Park in Tumwater (home slid off foundation, liquefaction, lateral spreading, numerous sand boils)

DISCUSSION

Damage was observed in structures and areas that, for the most part, could be predicted to be vulnerable. These include old buildings (such as URMs), old lifelines (such as the Fourth Avenue bridge in Olympia), areas of poor soil conditions (such as at Harbor Island and Sunset Lake), and steep slopes (Salmon Beach, Burien).

The level of damage for the M 6.8 Nisqually quake was considerably lower than would be expected for a shallower, crustal M 6.8 quake. Two key factors help to explain the lower levels of overall damage. First, the Nisqually quake, with a focus of 52 km, is considered to be a deep earthquake. As the seismic waves propagate up toward the ground surface, they attenuate with greater distance. Because of this depth factor, the ground-shaking levels were dampened and produced less damage than a shallower earthquake would induce. Second, the 2000/2001 rainfall season has been unusually dry. If the region had experienced average precipitation, the slopes would have been more saturated and vulnerable to landsliding. Significantly more landslide and liquefaction failures would be expected if the event occurred during wet slope conditions. For example, the M 7.6 intraplate earthquake of January 13, 2001, in El Salvador had a reported 491 landslides.

The City of Seattle has been a FEMA Project Impact community for three years. Because of regional coordination and public education efforts associated with Project Impact, Seattle's level of preparation and awareness was heightened. Consequently, the emergency response efforts were more efficient. Note, however, that only limited seismic structural improvements were performed as part of Project Impact; consequently, Project Impact did not significantly lower the structural damage.

Past intraplate earthquakes in the Juan de Fuca plate, including those of 1949 (M 7.1), 1965 (M 6.5), and 1999 (M 5.9), produced either no felt aftershocks or only small aftershocks. However, it is possible that large aftershocks may occur. This is illustrated by the El Salvador sequence. The M 7.6 El Salvador intraplate earthquake of January 13, 2001, was followed by two large events. These shocks, the M 6.6 crustal quake on February 13 and the M 5.4 intraplate quake on February 28, were possibly triggered by the earlier earthquake.

OREGON NEEDS

- Detailed studies and analyses on damages
- Studies on faults and data development targeting geohazards (good hazard information guides cost-effective mitigation)
- Studies on infrastructure (roads, bridges, ports, airports, etc.) vulnerability in communities
- Inventory and risk assessment of state-owned facilities
- Actions to provide improved public safety (e.g., brace parapets on URMs)
- Develop regional preparedness and improve public awareness
- Inventory, assess, and retrofit critical and important facilities (e.g., schools, hospitals, fire stations)

TEAM MEMBERS

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Photo 1. Collapsed hollow-clay tile wall at URM building located along Utah Ave. S in South Seattle.

Photo 2. Close-up of a car crushed by the failed wall – the same building on Utah Ave. S in Seattle.

Photo 3. Failed concrete lintel above window bank not attached to girders in a URM building located near the intersection of S Forest St. and Utah Ave. S, Seattle.

Photo 4. Damaged building located near the intersection of First Ave. S and S Dearborn St. in Seattle.

Photo 5. Building damage near the intersection of Second Ave. S and S Jackson St. – the Fenix Underground in Pioneer Square, Seattle.

Photo 6. Building damage near the intersection of Third Ave. S and S Jackson St. – near Pioneer Square, Seattle.

Photo 7. Cracking of the ornamental balusters at the Capitol building in Olympia (Photo by Mike Salsbury of The Olympian*).*

Photo 8. Damage at the Fourth Ave. Bridge in Olympia.

Photo 9. Sand boils from crack along utility trench in the Port of Seattle Terminal 30 – Seattle skyline in background.

Photo 10. Sand boil along railroad tracks paralleling E Marginal Way in Seattle – Terminal 30 in the background.

Photo 11. Looking upslope at the lower portion of the Salmon Beach landslide – S of Point Defiance Park in Tacoma.

Photo 12. This home's collapse was caused by the Salmon Beach landslide – four houses were substantially affected as of 3-2-01.

Photo 13. Houses damaged by slope movement in Burien – eight houses were red-tagged as of 3-2-01.

Photo 14. View along scarp of Highway 101 slide NW of Olympia.

Photo 15. Debris-flow damage in Maplewood near Renton.

Photo 16. Debris-flow damage in Maplewood near Renton.

Photo 17. Damage at the Vandorssen residence in Maplewood from a debris flow that struck the back of the building seconds after the onset of shaking.

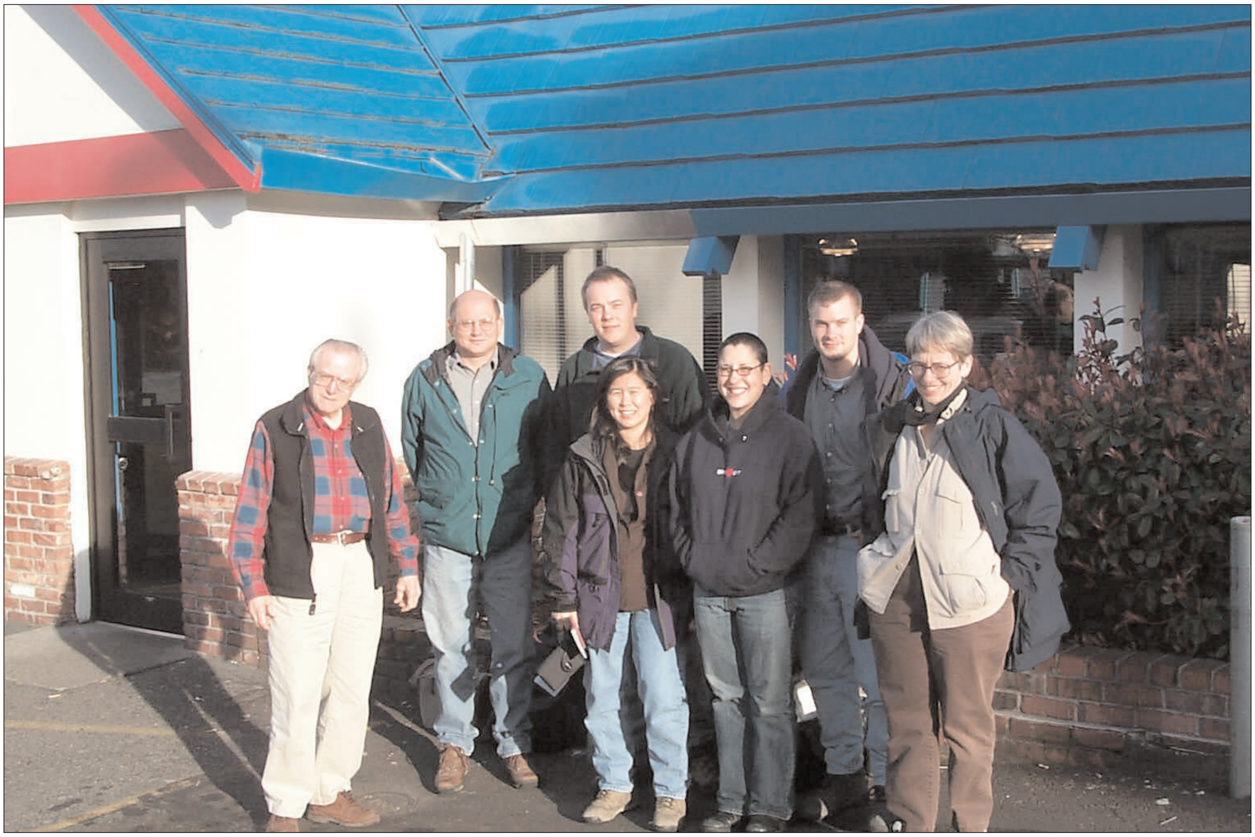

Photo 18. Oregon reconnaissance group photo. From left to right: William Elliott (Elliott Consulting, LLC), Mark Darienzo (Oregon Emergency Management), Greg Graham (DOGAMI), Yumei Wang (DOGAMI), Tova Peltz (GRI), R. Jon Hofmeister (DOGAMI), and Carol Hasenberg (Portland State University).