

APPENDIX G: MOVEMENT DATA FROM REFERENCE NAILS ON FRESH LANDSLIDE SCARPS

MEASUREMENT METHOD

Measurements were done in the field by first pounding 10-cm galvanized nails and/or galvanized wires into slide scarps around the margins of the slide such that the nail heads on the scarp and on the soil below the scarp touched. Several nails and/or wires were installed at each site. Wires were used only where it was difficult to seat the nails close enough together to get a measurement. Movement was measured using a plastic scale ruled in tenths and twentieths of an inch. Measurement error on the scale is $\sim \pm 0.05$ in, although the human eye can detect 0.01 inches of displacement between two linear objects. Thus movement less than 0.05 in was detected when heads of nails or heavy gauge wires were displaced, but the exact amount below 0.05 in is unknown. Values for multiple nails were averaged to obtain a representative value of movement. Some data were discarded where nails were obviously disturbed by roadwork, human activity, or instabilities in the soil itself (e.g., nails or wires gradually rotating because of loose soil). Data from the galvanized wires were generally not used because it was very difficult to seat them well enough to prevent shifting of the wires from wind. Figure G1 illustrates a typical site; a 6-in ruler was used for measurements.

DATA

Table G1 lists mean displacements between nail heads from best field data at last field measurement after installation on March 12, 2003. Negative lateral displacements are left lateral; positive lateral displacements are right lateral; positive perpendicular displacements are opening (dilation) perpendicular to the escarpment; positive vertical displacements are downward on the lower block of the scarp. Northing and Easting are in Oregon State Plane North meters [NAD 83] map projection. Strikes and dips of the fresh slide scarp are listed.

Most sites were destroyed by roadwork or other disturbances (burial by talus) after April 2003, at which time monitoring ceased. If no April 11, 2003, data are listed, the site was destroyed before April 2003. See maps in Figures G2–G5 for locations and geology of each site.

DISCUSSION

All movement directions correlate in general with the vector movements measured by re-survey and by inclinometers. Lateral movement is left lateral in all southern slide margins where strike is subparallel to overall

Table G1. Mean displacements between nail heads from best field data at last field measurement after installation on March 12, 2003.

Nail Marker Site	Date	Displacement			Net		Scarp Strike	Scarp Dip	Vector Bearing	Vector Plunge
		Lateral (cm)	Perpendicular (cm)	Vertical (cm)	Horizontal (cm)	Net Slip (cm)				
JC-14	4/11/2003	0.3	0.4	0.9	0.5	1.0	N 80° W	89°-90° S	S 47° W	61° SW
JC-15	4/11/2003	0.6	0.6	0.3	0.9	0.9	N 80° W	89°-90° S	S 55° W	16° SW
JC-17	3/24/2003	-0.1	0.0	0.2	0.1	0.2	N 26° E	89°-90° W	S 26° W	58° SW
JC-18	4/11/2003	0.0	0.5	0.6	0.5	0.8	N 4° E	70°-83° W	N 86° W	51° NW
JC-19	4/11/2003	0.0	0.0	0.0	no data	no data	N 65° E	89°-90° NW	no data	no data
JC-20	4/11/2003	-0.4	0.3	0.1	0.5	0.5	N 60° E	85° N	N 83° W	14° NW
JC-21	3/24/2003	-0.2	0.2	0.0	0.2	0.2	N 6° E	87°-90° W	S 51° W	51° SW
JC-22	3/24/2003	-0.6	0.5	1.0	0.8	1.2	N 40° E	85° NW	S 80° W	51° SW
JC-22b	4/11/2003	-0.1	0.9	1.3	0.9	1.6	N 66° E	85° NW	N 36° W	55° NW
JC-23	4/11/2003	0.0	0.3	0.0	0.3	0.3	N 19° W	89°-90° NW	N 71° W	0° NW
JC-24	4/11/2003	-0.2	0.3	0.7	0.4	0.8	N 2° W	87° NW	S 58° W	62° SW

slide movement direction and right lateral in equivalent areas on the north margin. Measurements at the headscarps show extension and downward displacement but no significant lateral movement.

Site JC-17 had barely discernible movement, much less than movement on the adjacent headscarp to the west, site JC-18. Movement on JC-18 preceded the beginning of movement on the scarp at site JC-17, so it appears that downward displacement at site JC-18 destabilized the area to the east and triggered movement there.

Site JC-19 had no detectable movement during the observation period even though significant movement occurred during the same period at the slide plane (extensometer data) and the slide margins. The site JC-19 slide scarp has ~40 cm of down-to-the-north displacement over a period of ~64 years since the Old Coast Highway was abandoned, so significant movement has occurred in the past. A check of this sheltered site in November of 2004 revealed no movement had occurred to that time, so apparently no significant internal deformation in the landslide is occurring along this northeast-trending slide scarp.

Movement at the extensometer in borehole LT-3 during the March 20–26, 2003, movement event is $\sim 0.5 \pm 0.3$ cm. This is the same amount as the opening (dilation) measured on the fissure at site JC-18 between March 12 and April 11, 2003 (0.5 ± 0.1 cm). We infer that this opening probably coincided with the March 20–26 movement at site LT-3, which lies only 18 m to the northwest of site JC-18.

The nails at the northern margin at U.S. Highway 101 recorded right-lateral movement of $0.3\text{--}0.6 \pm 0.1$ cm (sites JC-14 and JC-15). Nails at the northeast headscarp (site JC-24) recorded 0.3 ± 0.1 cm of dilation perpendicular to the scarp. Nails at the southern margin at the Old Coast Highway (site JC-20) recorded left-lateral movement of -0.4 ± 0.1 cm, while nails in the southernmost margin (sites JC-22 and JC-23) had left-lateral movements of 0 to -0.6 ± 0.1 cm. We conclude

that movement in the northern, central, and southern part of the slide at and east of U.S. Highway 101 was similar during the March 20–26 movement event. This movement was not translated to the northernmost site west of U.S. Highway 101 (site JC-23).

Net horizontal movement at site JC-20 on the southern margin of the slide where it cuts the Old Coast Highway is 0.4 cm left lateral and 0.3 cm perpendicular to the scarp striking $N60^\circ E$. This corresponds to a net horizontal slip of 0.5 cm toward $N83^\circ W$. This is probably a reasonably good estimate of the net horizontal slip vector for this part of the Johnson Creek landslide, as it matches well with net direction of slip estimated independently from horizontal offset of the Old Coast Highway (see discussion in main text). Because most of the slip is subparallel to the slide margin, a narrow graben would be expected. This is one of the narrowest graben at the slide margin.

Net horizontal movement at sites JC-14 and JC-15 is 0.3 to 0.6 cm right lateral and 0.4 to 0.6 cm perpendicular to the scarp striking $N80^\circ W$ on the northern margin of the slide where it cuts the Highway 101. This corresponds to a net horizontal slip of 0.5–0.8 cm toward $S47\text{--}55^\circ W$, $67\text{--}75^\circ$ southwest of the scarp strike. Because a large part of the slip is perpendicular to the slide margin, a significant graben would be expected, and such is the case. The graben at sites JC-14 and JC-15 is 0.8–13 m wide, narrower than the 17–20 m graben at the central headwall, where all movement is perpendicular to the margin, but wider than the 4–6 m graben at the southern margin (site JC-20) where most movement is subparallel to the margin.

SITE PHOTOS

Photos of individual monitoring sites are given in Figures G6–G17.



Figure G1. A typical marker nail site (JC-23); 6-in ruler used for measurements.

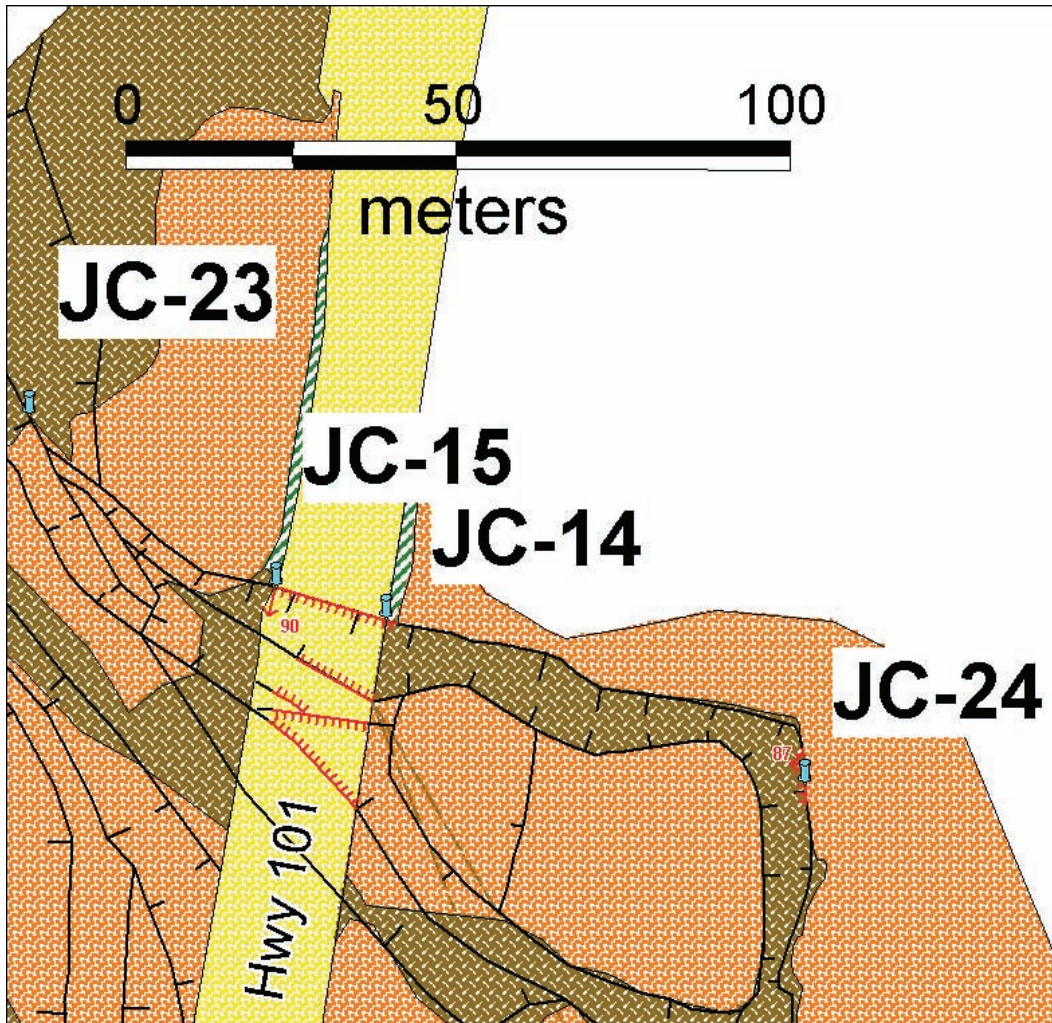


Figure G3. Marker nail locations in north part of slide. Orange unit is Pleistocene marine terrace sand; green striped unit is Astoria Formation; brown unit is colluvium; yellow unit is highway fill. Small red arrow indicates direction of dip of recently active slide scarp (red line with teeth in direction of scarp inclination); red number is dip in degrees.

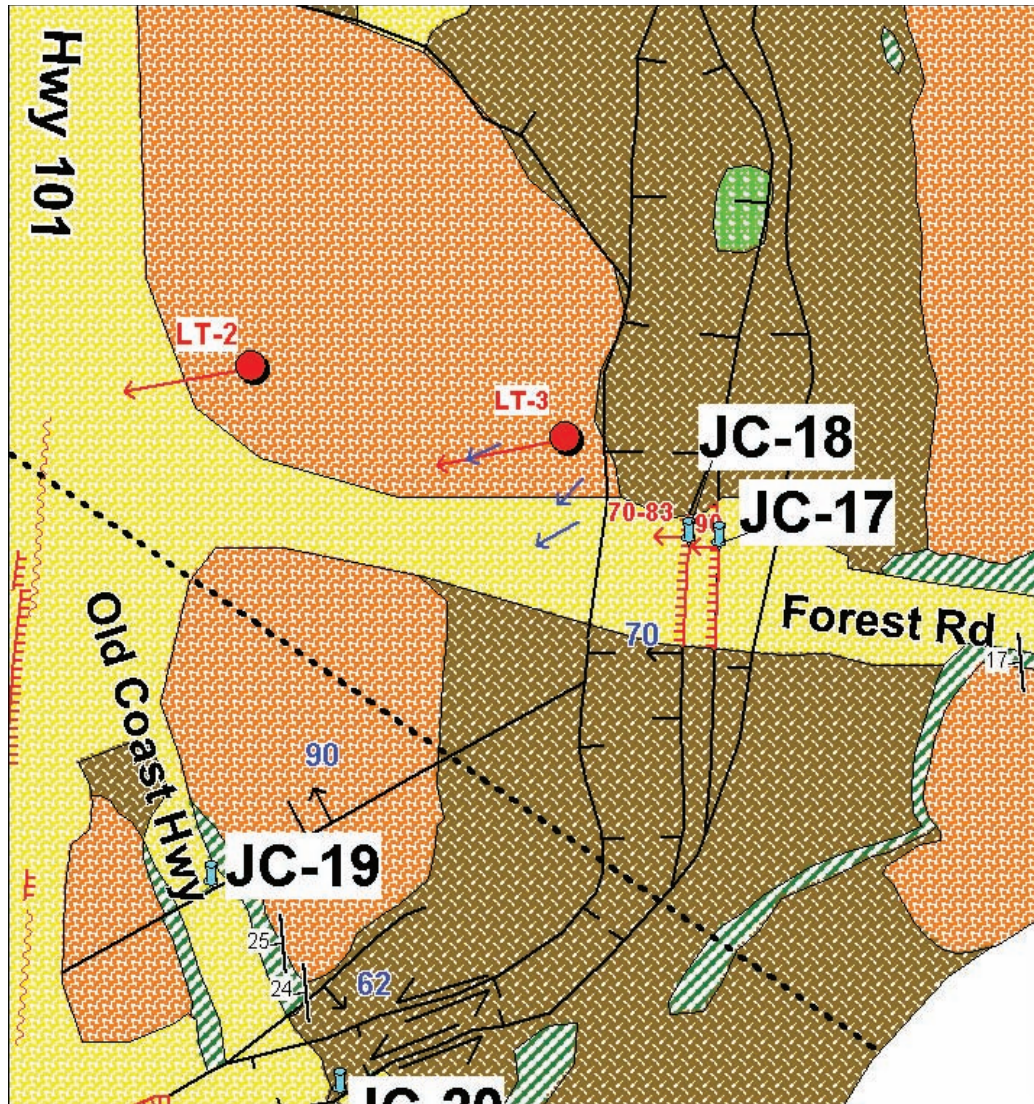


Figure G4. Marker nail locations in the central part of the slide. Red circles with arrows are inclinometer locations with movement vectors from inclinometer data; other symbols as in figures above; bright green unit is sag pond deposit in headwall graben. Symbols as above; dashed line indicating a tectonic fault is from Priest and others (2006) and does not reflect interpretation in this paper that this structure is an internal slide block boundary.

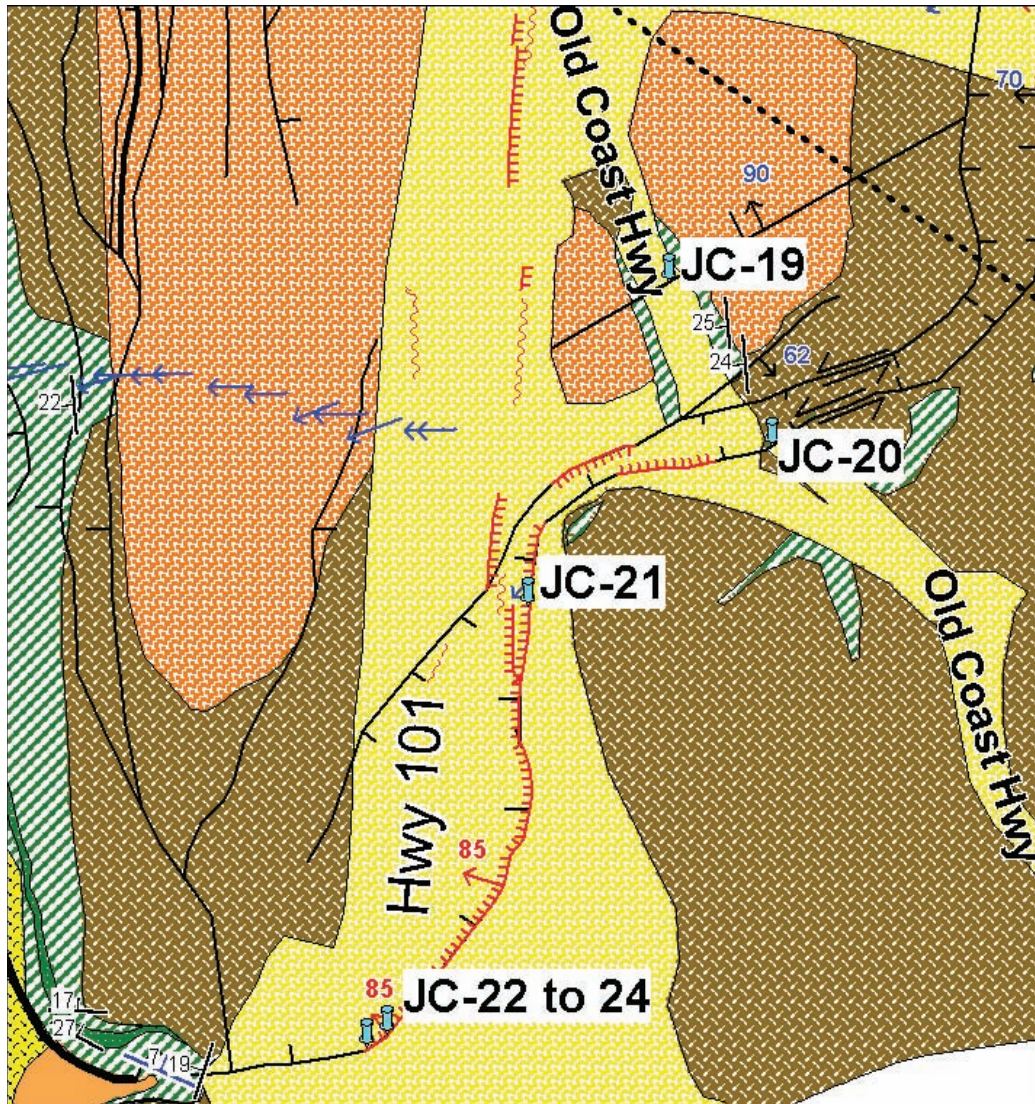


Figure G5. Marker nail locations in southern part of landslide; symbols as in figures above. Dark green unit is sandstone marker bed in Astoria Formation at the toe of the slide.



Figure G6. Marker nail site JC-17 with displaced steel survey marker at headscarp, looking east.
This stake was not used in the resurvey.



Figure G7. Marker nail site JC-17 showing nail locations next to forest road, looking east southeast.
The scarp is in gravel fill from the forest road.



Figure G8. Marker nail site JC-18, looking southeast. The scarp is in gravel fill from the forest road. Exposed portions of the two vertical nails on the right are ~1.2 cm long. Note that fresh gravel dumped on the road has disturbed the nails on the right, so that measurement was not used.



Figure G9. Marker nail site JC-19 looking south. Yellow field book is ~19 cm long. Note that all nail heads are still touching in this April 2003 photograph, so no significant movement occurred. Scarp is in relatively fresh Astoria Formation siltstone and sandstone with a thin covering of gravel from the Old Coast Highway.



Figure G10. Marker nail site JC-20 looking south. Yellow field book is ~19 cm long. Scarp cuts Old Coast Highway. The scarp is in weathered Astoria Formation colluvium below the Old Coast Highway and some gravel fill from the adjacent private driveway.



Figure G11. Marker nail site JC-20 looking south. Yellow field book is ~19 cm long.



Figure G12. Marker nail site JC-21 looking southeast. Yellow field book is ~19 cm long. The scarp is in gravel fill from the Highway 101.



Figure G13. Marker nail sites JC-22 (near red highway cone at top of highway embankment) to JC-24 (to the right of the yellow field book) looking northeast parallel to the strike of the fresh headscarp (red orange fill of excavated Astoria Formation). Yellow field book is ~19 cm long. The near-vertical portion of scarp is ~1.2 m high.



Figure G14. Marker nail site JC-22 looking southeast on west side of U.S. Highway 101. Scarp is asphalt and gravel.



Figure G15. Marker nail site JC-23 with both wires and nails, looking south southeast. Scarp is in red orange fill of excavated Astoria Formation overlain by gravel and asphalt. Near vertical portion of scarp is ~1.2 m high.



Figure G16. Marker nail site JC-23 on north margin of the landslide looking east southeast. Yellow field book is ~19 cm long.



Figure G17. Marker nail site JC-24 looking southeast. This is the northeast headwall of the landslide. The tan unit in the near vertical escarpment is Pleistocene marine terrace sand. Talus lies along the base of the slope.