APPENDIX E: SLIDE MOVEMENT FROM SURVEYS OF IRON MARKER PINS OCTOBER 24, 2002, AND APRIL 17, 2003

Survey points were established on the ground surface at three east-west sections across the slide (Figure E1). Two sets of readings were taken, one in October 2002 and one in April 2003. Based on readings taken in stable ground (Figures E1 and E2), the survey repeatability error appears to be relatively large, about 11 cm to 15 cm horizontal and 1 to 130 cm vertical (Table E1). Only one point had an error of 130 cm vertical, probably from disturbance of the steel stake or calculation/transcription error; points east of the slide are in recreational use and subject to disturbance. Mean vertical error without this point is 2.9 cm (Table E2).

Differences and vector directions between points are depicted in Table E1 and Figures E3–E8. Arctangents of the vertical over the horizontal movements (Table E2) generally agree with approximate dips of the basal shear zone estimated from inclinometer data, although the large survey errors make any such agreement somewhat fortuitous.

Ground movements within the landslide are generally faster toward the west and the south. Highway damage was largest on the south margin of the slide relative to the north (Figures E9 and E1), confirming the general trend of the resurvey data. Figure E10 documents 18 cm of vertical offset south of the southernmost survey line from December 2002 cumulative slide movement. Movement in the center of the slide at this time was ~5 cm horizontal, based on extensometer data. A much larger movement occurred January 29, 2003, that caused ~24 cm horizontal displacement at the center of the slide and heavy damage to this part of the highway. The damage was repaired before a photo could be taken.

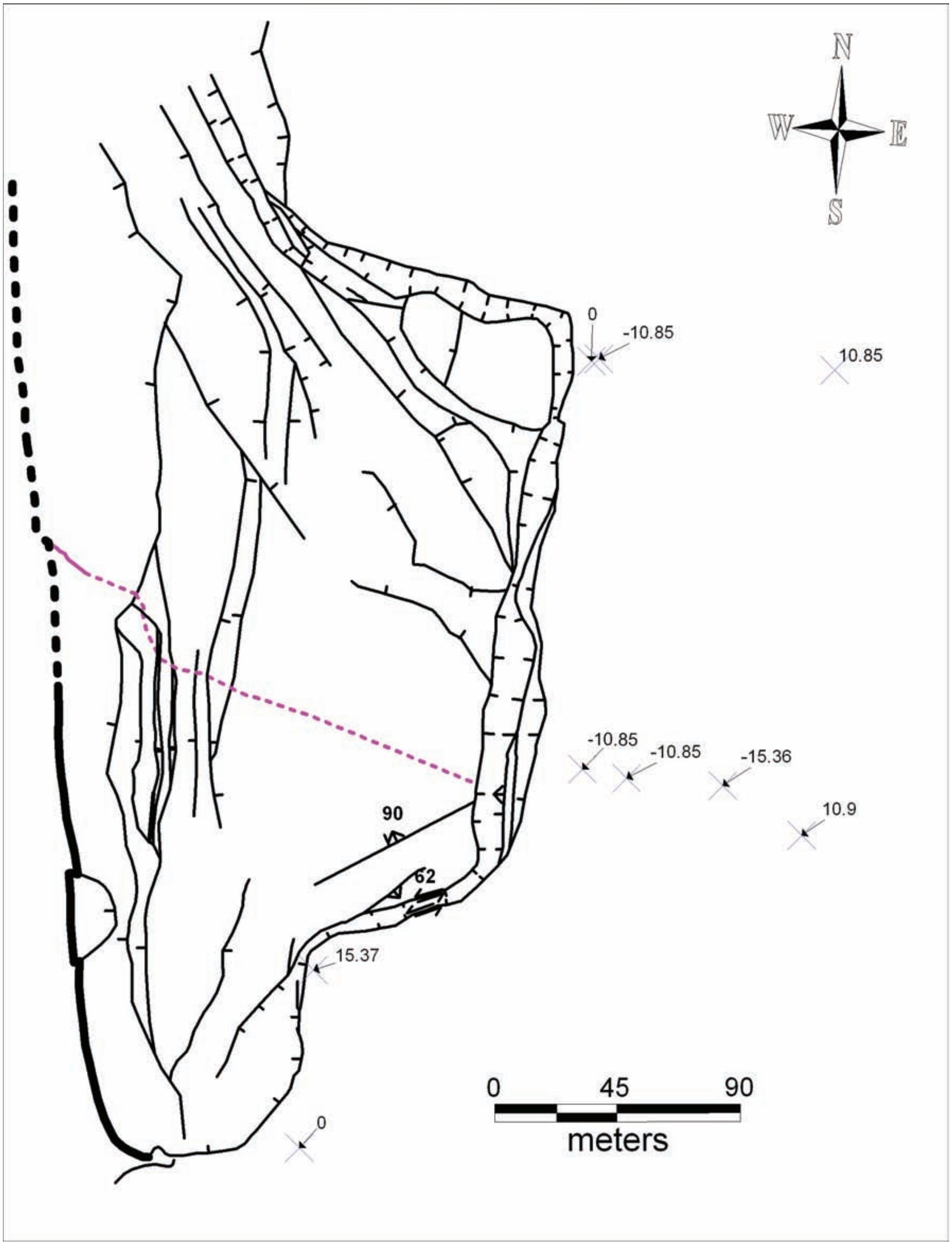

Figure E1. Horizontal error in centimeters for relocation of survey points on stable ground outside the landslide. See Figure 2 of the main text for explanation of slide block boundaries (black and purple lines).

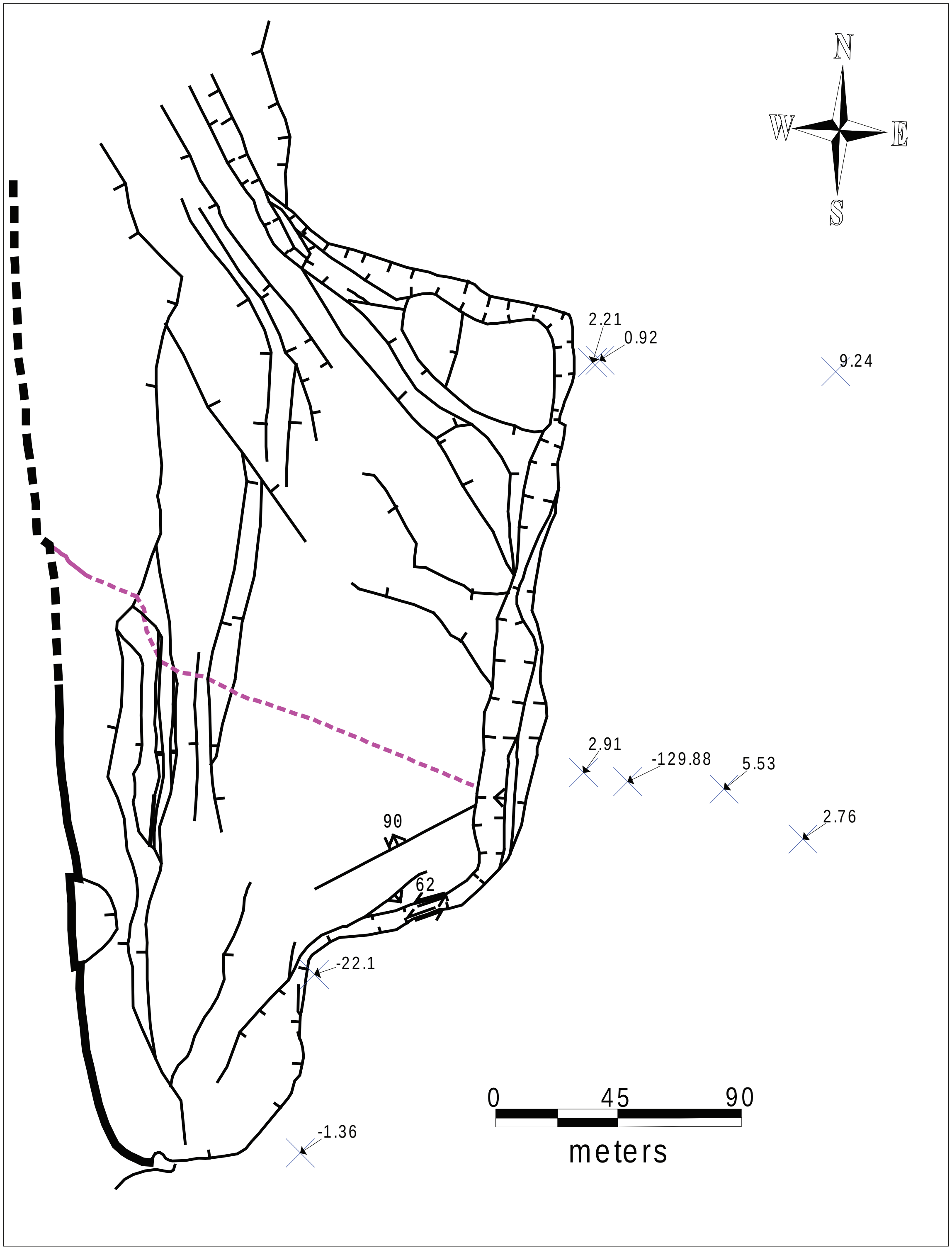

Figure E2. Vertical error in centimeters for relocation of survey points on stable ground outside the landslide

Table E1. Re-survey of steel stake markers at the headwall for error analysis.

Distance (m) East of Headscarp	Horizontal Error (cm)	Vertical Error (cm)	Area
3.2	0.0	2.2	northeast headwall
6.0	10.9	0.9	northeast headwall
93.0	10.9	9.2	northeast headwall
3.6	0.0	0.3	central headwall
4.4	0.0	1.1	central headwall
21.0	10.9	2.9	central headwall
37.5	10.9	129.9*	central headwall
72.8	15.4	5.5	central headwall
101.6	10.9	2.8	central headwall
18.5	0.0	1.4	southeast headwall
Mean	7.0	15.6	all headwall sites
Standard deviation	6.1	40.2	all headwall sites
Mean without 129.9-cm vertical error	6.5	2.9	all headwall sites but one
Standard deviation without 129.9-cm vertical error	6.4	2.8	all headwall sites but one
Mean without 129.9-cm vertical error plus 1 standard deviation	13	6	all headwall sites but one

All horizontal and vertical values should be zero at these selected points outside of the landslide.
*The vertical error of 129.9 cm is probably a local anomaly caused by tampering with the steel stake.

Table E2. Slide movement between October 2002 and April 2003 from re-survey of steel stakes.

Site	Horizontal (cm West)	Vertical (cm) (–) = Down to the West	Estimated Slide Dip from Resurvey (Arctangent of Vertical/Horizontal)	Estimated Slide Dip from Boreholes + Outcrops (–) = East
North survey hubs	< ± 13	< ± 6	—	—
Middle survey hubs near LT-3 borehole (east of Highway 101)	20 ± 13	– 8 ± 6	22° ± 33°	21–23°
Middle survey hubs near LT-1 borehole (west of Highway 101)	22 ± 13	– 6 ± 6	15° ± 33°	~10.5°
Middle survey hubs on back-tilted block at top of sea cliff	24 ± 13	– 6 ± 6	14° ± 33°	~ – 10°
South survey hubs east of Highway 101	15 ± 13	– 22 ± 6	56° ± 33°	no data
South survey hubs west of Highway 101	33 ± 13	– 9 ± 6	15° ± 33°	no data
South survey hubs on back-tilted block at top of sea cliff	131 ± 13	– 70 ± 6	28° ± 33°	no data

Error estimates are from Table E1 using the mean error (without the 129.9-cm outlier) plus one standard deviation. Slide dips are estimated from geologic cross sections between drill holes and surface outcrop of the slide plane. Middle survey hubs are at the same latitude as the LT-1, LT-2, and LT-3 boreholes; no hubs were near the LT-2 borehole.

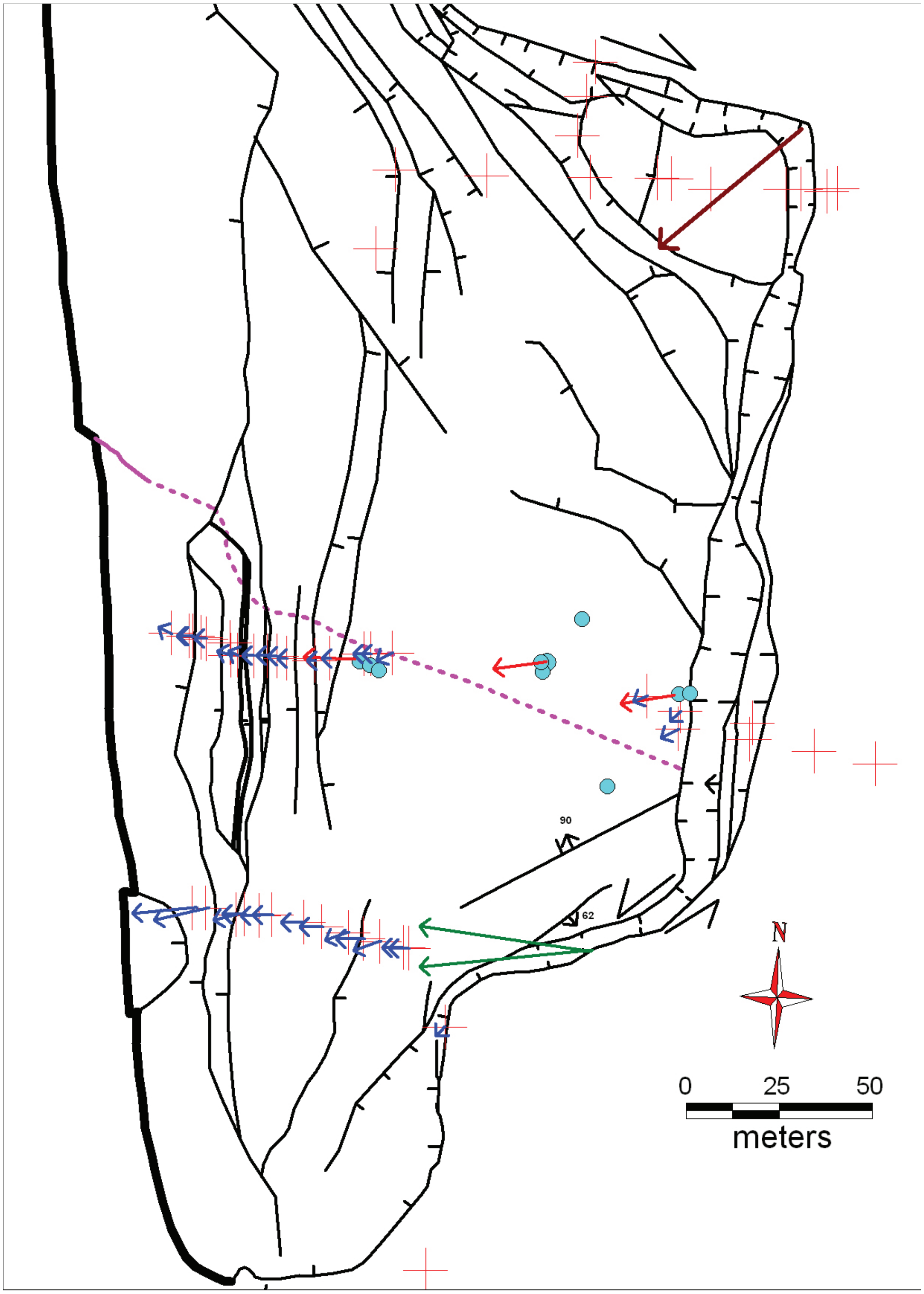

Figure E3. Qualitative vectors drawn in direction of slide movement for steel stakes surveyed October 24, 2002, and April 17, 2003 (blue arrows) and for inclinometer data (red arrows) collected between December 11 and December 31, 2002. Relative lengths of arrows correspond roughly to relative amounts of movement. Red crosses without arrows are points where slide movement between surveys was less than the error in the measurement. Blue dots are boreholes. Boreholes with red arrows are inclinometer holes with direction of movement from inclinometer surveys. Green arrows illustrate possible movement direction from offset of the Old Coast Highway; brown arrow illustrates general movement direction inferred from scarp trends and offset of marker nails in the northeastern part of the slide. See Figure 2 of the main text for explanation of slide block boundaries (black and purple lines).

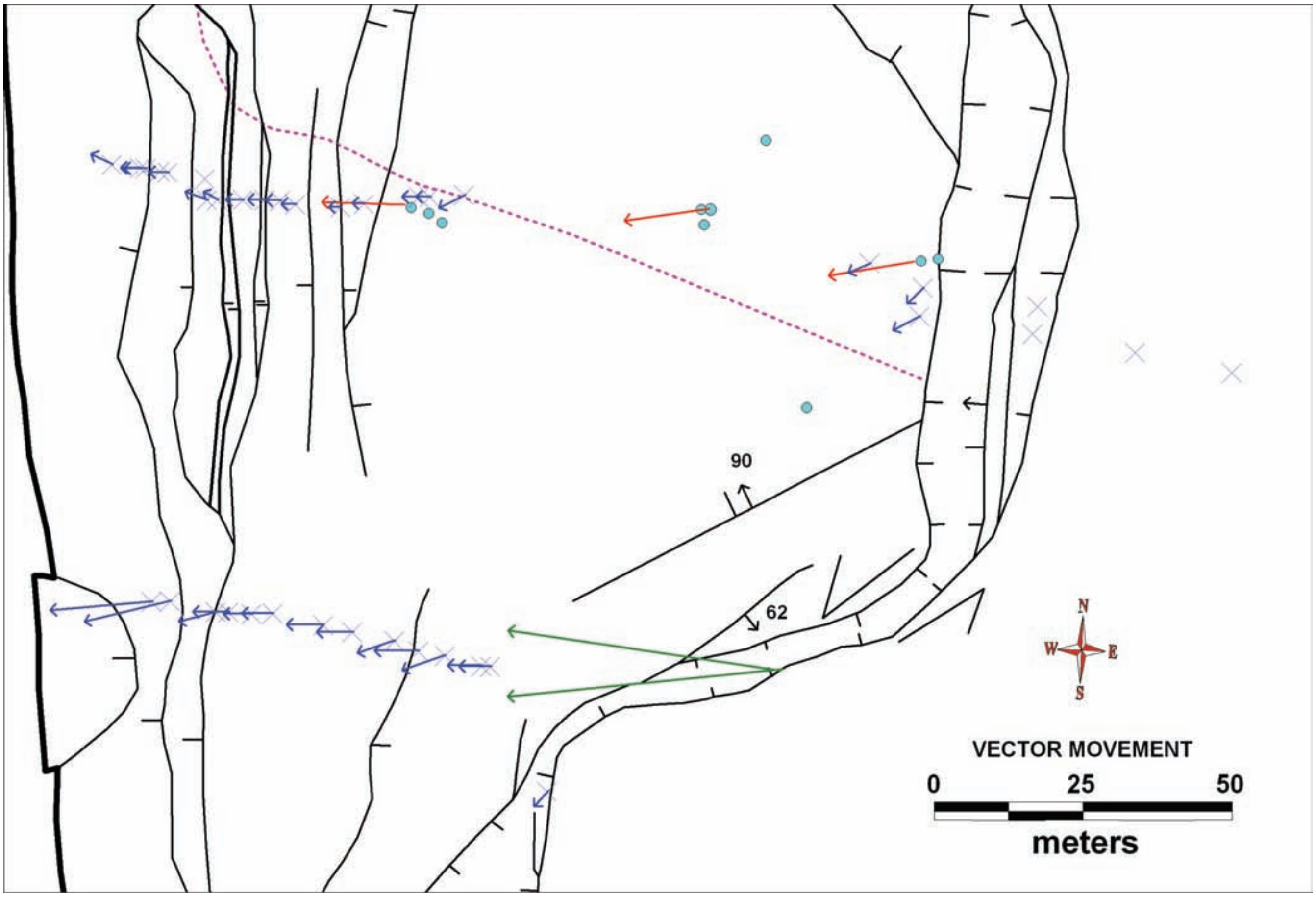

Figure E4. Detailed view of vector directions of slide movement in the southern part of the Johnson Creek landslide. Arrow length is qualitatively drawn to correlate with amount of horizontal movement; symbols as in Figure E3.

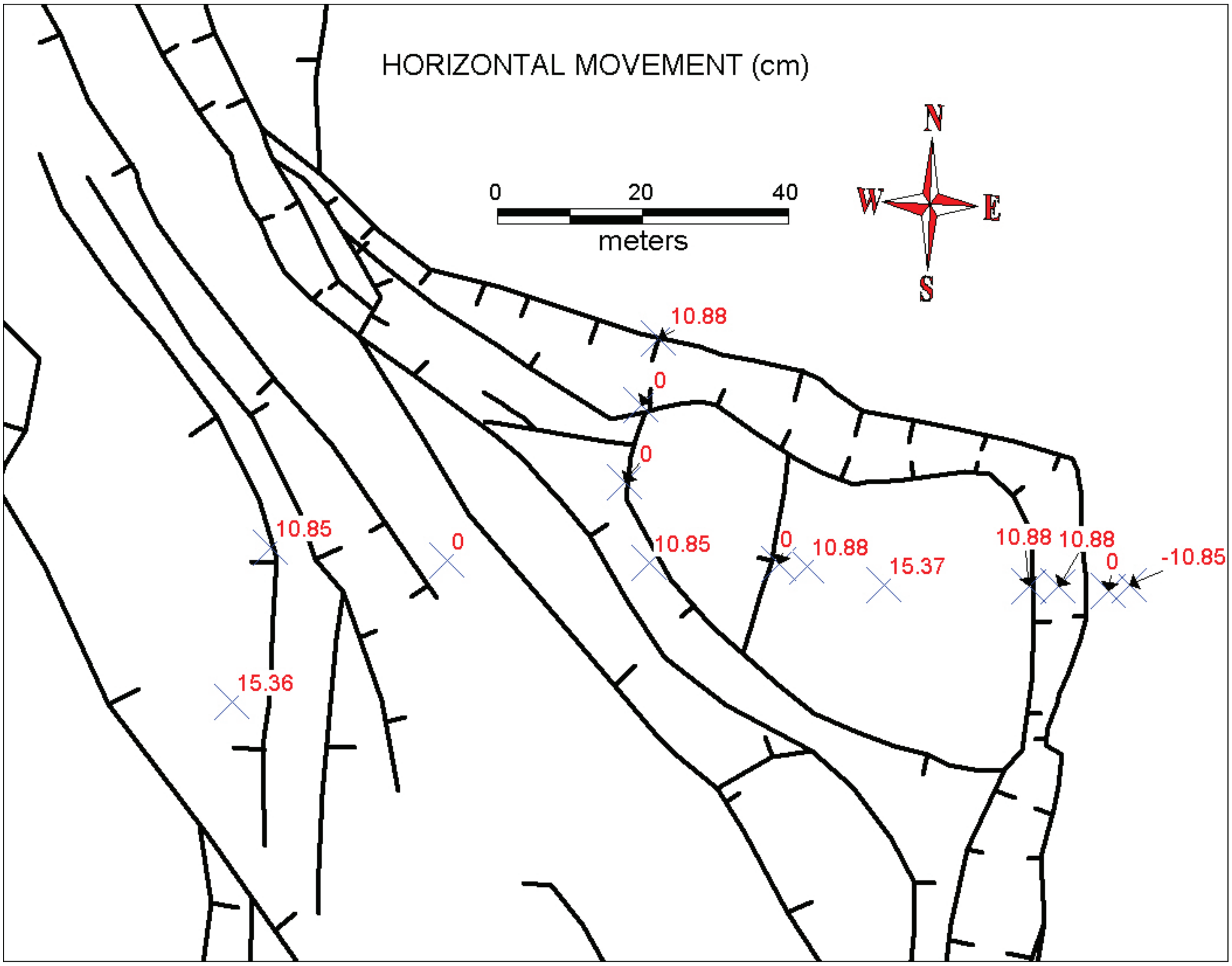

Figure E5. Horizontal movement (cm; negative is east) at steel stakes (blue crosses) in northern part of landslide between October 24, 2002, and April 17, 2003. Note that most movement is equal to or less than the survey error of ±10.85 cm (except for one anomalous negative value at the headwall of the slide). Note that one control point east of the figure area was left off for to enlarge scale. Data for this point are listed in Table E2.

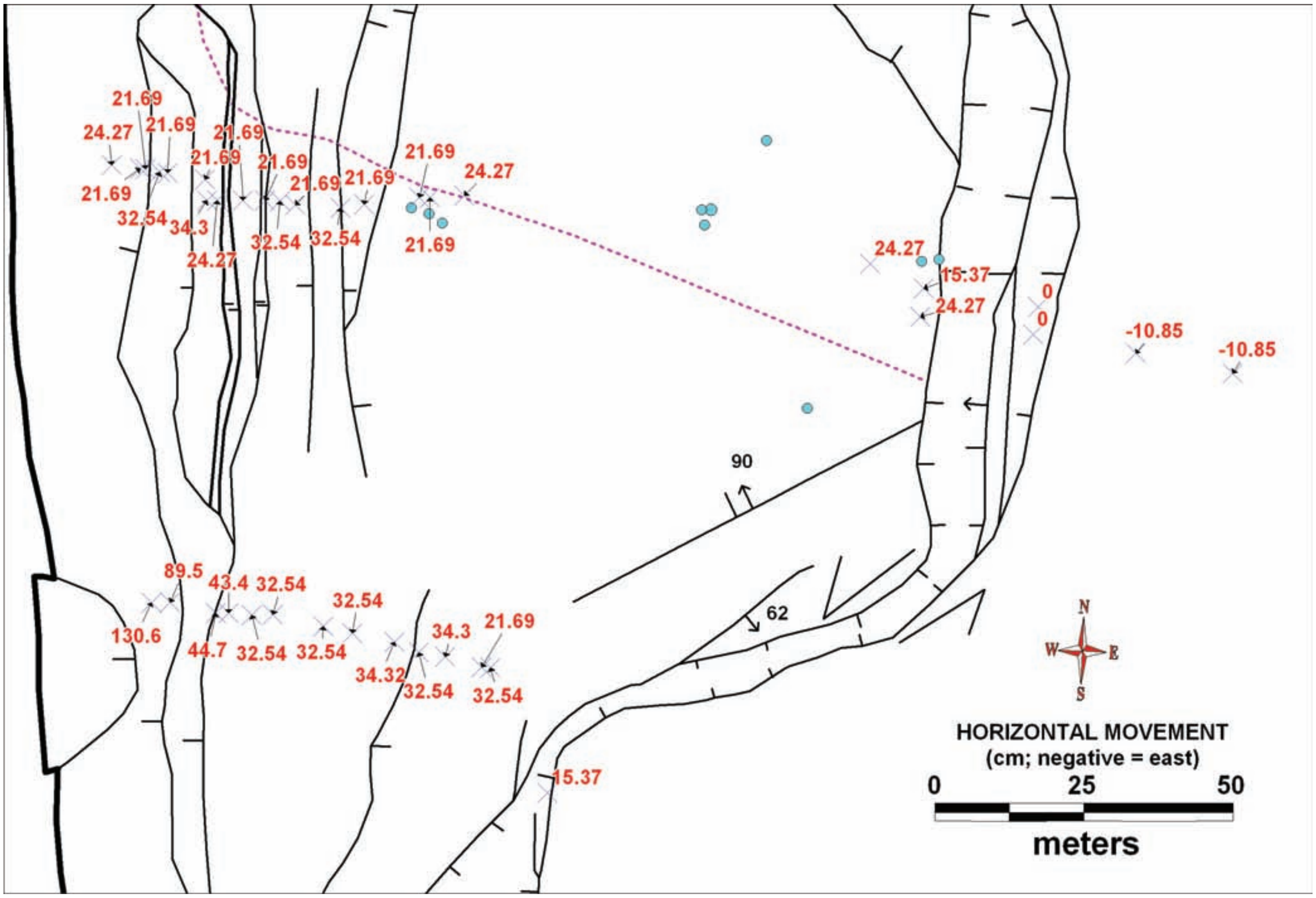

Figure E6. Horizontal movement (cm; negative is east) at steel stakes (Xs) in the southern part of the landslide. Boreholes for this project are blue dots. Movement east of the headwall of –10.85 cm (eastward movement) is survey error, so this is the approximate error of the data.

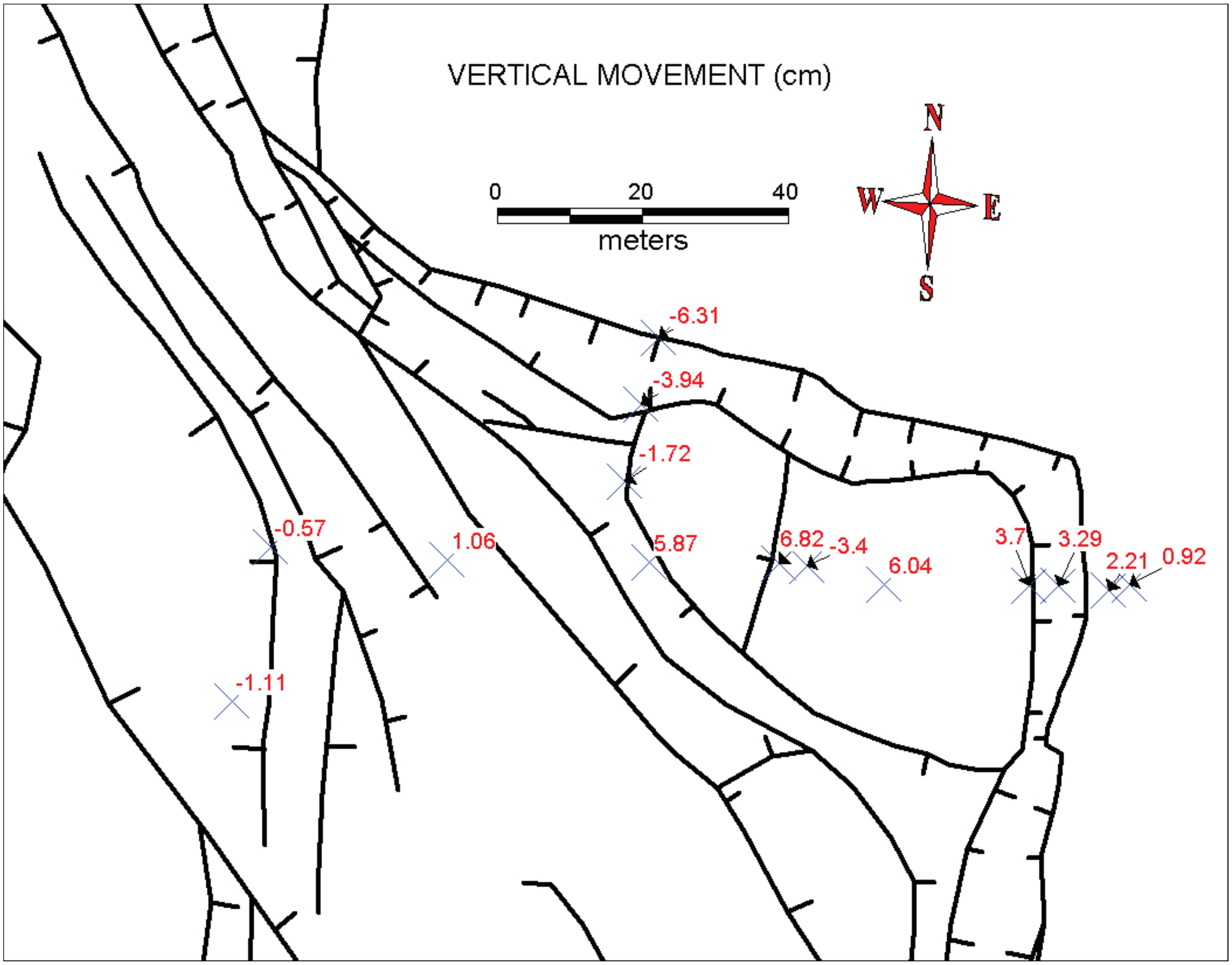

Figure E7. Vertical movement in the northeastern part of the landslide (negative is down).

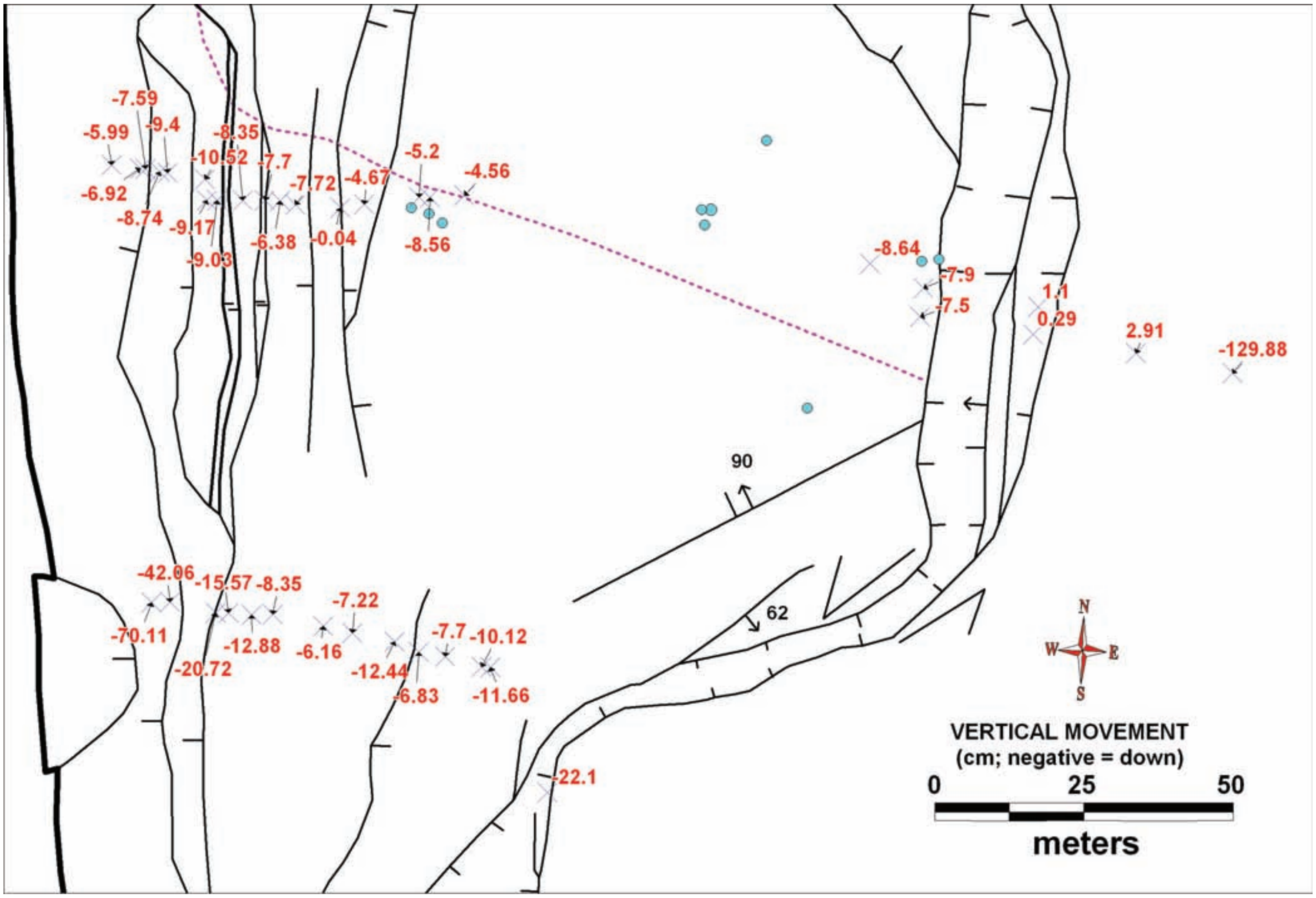

Figure E8. Vertical movement (cm; negative = down) at steel stakes (Xs) in southern part of landslide. Movement east of the headwall of +2.91 to +5.51 cm (upward) is survey error, so this is the approximate error of the data. One survey stake east of the headwall has an error of –129.88 cm, but this is probably a local anomaly caused by tampering with the steel stake.

Figure E9. (top) Damage to Highway 101 on the south margin of the Johnson Creek landslide immediately after a slide movement in January 2003. (bottom) Maximum vertical offset is 17.8 cm down to the northwest; fissures are as wide as 5 cm. This part of the slide is south of the resurvey lines and confirms the general trend of increasing offset to the south. Roger Hart is in the background.

Figure E10. Damage to the north slide margin from the same movement as in Figure E9. Note that offset is only 1-2 cm vertical.