State of Oregon
Department of Geology and Mineral Industries
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Open File Report

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GEOTECHNICAL INVESTIGATION
JOHNSON CREEK LANDSLIDE
LINCOLN COUNTY, OREGON

Prepared by

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1. INTRODUCTION

This report summarizes the field investigation, data compilation, stability analyses and evaluation of conceptual remedial options for the Johnson Creek Landslide, Lincoln County, Oregon. The slide is less than 0.5 km (¼ mile) south of Otter Rock, Oregon and it impacts U.S. Highway 101, two private structures and local utilities. The site location is shown on Figure 1.

1.1 Purpose and Scope of Work

The primary purpose of this study is to analyze the causative factors of slide movement, and to evaluate the effectiveness and cost of remediation alternatives. The objective is to develop information on Oregon's coastal landslides to benefit the scientific understanding of their movement, and to provide information to the community on the scale and costs of mitigation and remediation. The scope of work for this study consisted of the following work tasks:

- Collect and review available data
- Public meeting to present plan of investigation
- Permitting and utility locates
- Subsurface exploration, installation of geotechnical instrumentation, and instruction of DOGAMI personnel on instrument monitoring
- Laboratory testing
- Data and stability analyses
- Remedial options evaluation
- Technical Report

1.2 Background Information and Previous Investigation

The Oregon Department of Geology and Mineral Industries (DOGAMI) maintains a number of programs aimed at the understanding, safety awareness and economic impacts of Oregon's coastal processes. In collaboration with the Oregon Department of Transportation (ODOT), DOGAMI retained the expertise of Landslide Technology to manage the geotechnical investigation, analyze causative factors, and develop conceptual options to mitigate (slow) or remediate (stop) the landslide movement.

Johnson Creek Landslide has a history of impacting U.S. Highway 101 and two private structures. In the 1970s ODOT performed a series of explorations to investigate the depth of the landslide and evaluate the potential costs of remediation. Six borings with inclinometers were installed between 1972 and 1976. Copies of the logs and inclinometer readings are included in Appendix A. A brief report was prepared by ODOT in 1979 that summarized the results of the investigation and provided discussion of possible remedial options.

Oregon DOT has continued to perform annual maintenance of the roadway through the landslide area. Maintenance efforts are considered typical for coastal highway landslides.

1.3 Acknowledgements

This DOGAMI project was funded through as an ODOT Miscellaneous Contract and Agreement, Project Name: Detailed Geotechnical Analysis of Large Translational Landslides in Seaward-Dipping Sedimentary Rocks. DOGAMI personnel instrumental to this study are George R. Priest, PhD, Coast Section Leader; and Jonathan C. Allan, PhD, Coastal Geomorphologist. Dr. Priest was the overall project manager and performed detailed geologic mapping of the landslide surface features. Dr. Allan monitored instruments and performed data analysis. Committee review included Steve Narkiewicz, Bernie Kleutsch and Matthew Mabey of ODOT, and Dr. Priest, Dr. Allen and Yumei Wang of DOGAMI.

Landslide Technology's team of geotechnical engineers and engineering geologists on this project included: Charles M. Hammond, CEG; Andrew Vessely, CEG, PE; Jonathan Harris, PE; Erica Meyer, EIT; and Darren Beckstrand, GIT. Mr. Hammond was the geotechnical study project manager. Mr. Vessely provided senior oversight and managed the engineering analyses. Mr. Harris managed the instrumentation and data analysis, installed dataloggers and the rain gauge, and assisted with the engineering analyses. Ms. Meyer performed the engineering analyses. Mr. Beckstrand performed the field inspection and assisted with data analysis.

Alan R. Niem, PhD, was retained under separate DOGAMI contract to provide detailed geologic interpretation of stratigraphy and to correlate materials between the borings and surface exposures. Detailed correlation charts were produced, along with detailed interpretations of the landslide cross section.

Oregon DOT loaned GeoKon LC-1 dataloggers and a Slope Indicator inclinometer cable, probe and Datamate to the project.

Geo-Tech Explorations, Inc., of Tualatin, Oregon performed the geotechnical drilling, and installed slope inclinometer casing and vibrating-wire piezometers under the direction of Landslide Technology. Slope Inclinometer Company supplied slope inclinometer casing and vibrating wire piezometers.

Dennison Surveying Inc. of Newport, Oregon was retained under separate DOGAMI contract to survey the landslide topography and to establish permanent survey hubs for long-term monitoring.

2. FIELD INVESTIGATION

The file investigation was performed in two phases, with monitoring of instruments occurring throughout. The first phase consisted of reconnaissance, survey, drilling, sample logging, and installation of inclinometers, rain gauge and erosion pins. The second phase consisted of drilling and installation of vibrating wire pressure transducers (piezometers), and excavation of a test pit. The phased approach allowed the installation of pressure transducers immediately above the basal landslide zone after the inclinometers had measured the depth of sliding.

2.1 Reconnaissance

Reconnaissance of the landslide area was performed by personnel from DOGAMI and Landslide Technology. Surface geology was mapped by DOGAMI. A summary of the geology is discussed in Chapter 4, and DOGAMI's preliminary geologic map is provided in Appendix B. Landslide Technology performed reconnaissance to become familiar with site conditions and topography.

2.2 Topography Survey

Dennison Surveying of Newport, Oregon performed survey of the topography under separate contract. This information was used for surface geology mapping and cross section interpretation, and ground movement direction analysis.

2.3 Exploratory Drilling and Borehole Instrumentation

Drilling. Exploratory drilling program consisted of six borings completed between November 18 and December 5, 2002 (first phase) and January 6 to January 10, 2003 (second phase). Borings completed as part of phase one are designated LT-1 through LT-3 at the locations shown on the Site Plan, Figure 2. Companion borings that were drilled as part of the second phase have a "P" designation.

Geo-Tech Explorations, Inc. of Tualatin, Oregon, performed the exploratory drilling using a track-mounted CME 850 drill rig. A combination of 15-cm ($5^7/_8$-inch) O.D. tricone mud-rotary, casing installation through overburden, and PQ3-wireline diamond core drilling techniques were used to drill the slope inclinometer borings to final depth. Hollow-stem auger techniques were utilized to drill the piezometer borings to final depth. An engineering geologist from our firm was present throughout the field program to coordinate the drilling operations, log and sample the subsurface materials that were encountered, and assist with the installation of instrumentation.

Soil samples in the inclinometer borings (LT-1, LT-2, and LT-3) were obtained at approximately 0.76 or 1.52 meter (2.5- or 5-foot) intervals using a 7.6-cm (3-inch) O.D. split-spoon sample barrel driven by a 63.5-kg (140-lb) auto-trip hammer. The underlying bedrock was sampled by obtaining rock cores using 1.52-meter (5-foot) long, triple barrel coring techniques. The quality of the bedrock was recorded using Rock Quality Designation (RQD) and core recovery indices. Samples were also collected in the piezometer borings in the zones of measured slide movement, using 7.6-cm (3-inch) diameter thin-walled Shelby tubes. In addition, select soil samples were obtained in Boring LT-3P using Standard Penetration Test (SPT) procedures. Drilling methods, sampling depths, total drill hole depths, and descriptions of the soil and rock materials encountered are shown on Summary Boring Logs, Figures 3 through 8.

Instrumentation. Slope inclinometer casings were installed in borings LT-1, LT-2, and LT-3. The inclinometers consist of 3.048-meter (10-foot) lengths of Slope Indicator Company 7.0-cm (2.75-inch) O.D. ABS casings with quick-connect couplings. The annular space between the casings and boring sidewalls was backfilled with cement-bentonite grout, and each inclinometer was capped with a protective surface monument and concrete. Details of the inclinometer installations are included on the Summary Boring Logs, Figures 3 through 8.

Coaxial cable was attached to the downslope exterior of the slope indicator casings. The RG59U coaxial cable is a commonly used for home electronics. The cable can allow the use of Time Domain Reflectometry (TDR) technology for measurement of additional information on slide movement at depth after the casing has been sheared.

Manual boring extensometers were installed within the slope inclinometer casings after the inclinometer probe was unable to pass the shear zone. A schematic of the extensometer is shown in Figure 9. The extensometers allow for continued slide monitoring, although at a reduced accuracy and with no directional information as compared to the inclinometer. The extensometer consists of a braided steel rope anchored with an attached chain in a 10-foot long concrete and sand plug at the bottom of the casing. A 2- to 3-foot section of steel rope extends from the top of the casing with a crimped ferrel attached near the end of the rope. The distance between the top of the casing and the bottom of the ferrel become the gauge length of the extensometer.

Four vibrating wire pressure transducers, manufactured by Slope Indicator Company, were installed in companion borings LT-1P, LT-2P, and LT-3P. In each boring, the pressure transducers were installed within 2 meters (7 feet) above the slide plane. The sand pack around the transducer penetrated the slide plane. Therefore, continued slide movement would not damage the transducers, but can still measure pore-water pressures at the slide zone. An additional pressure transducer was installed 5.1 meter (20 feet) below the slide zone in LT-2P. This transducer lost communication with the datalogger due to slide movement on February 1, 2003. Pore-water pressures are recorded every hour with single channel GEOKON dataloggers provided by ODOT.

Monitoring. Landslide Technology measured initial readings of the inclinometers and piezometers. DOGAMI has performed subsequent instrument monitoring.

Permits. Permission to perform the drilling and instrumentation were acquired from:

- Oregon Department of Transportation (temporary access)
- Oregon Water Resources Department (geotech hole reports, tributary water use)
- Boise Cascade Building Solutions (temporary access)
- Johnson Creek Water Services Company (public water use)

2.4 Precipitation

A rain gauge was installed above the head scarp at the location shown on Figure 1. The rain gauge is a Global Water, Inc., RG200 tipping bucket rain gauge connected to a Global Water model GL400-1-1 pulse type datalogger. The datalogger is programmed to record rainfall amounts every hour.

2.5 Test Pit

An exploratory test pit was performed on March 24, 2003 on the beach near the toe of the bluff. The test pit was logged and documented by DOGAMI personnel. A diagram depicting the subsurface materials encountered in the test pit is included in Appendix C.

2.6 Surface Ground Movement Survey

Permanent hubs and line-of-sight survey were used to monitor surface ground movement. Permanent survey hubs are established along three east-west lines as shown on maps in Appendix D. Vector movements calculated from the survey data are also shown in Appendix D.

A line-of-sight survey was established along U.S. Highway 101 at the location shown in Appendix E. The purpose of this survey line is to obtain measurements of lateral movement between pins and a north-south line that is fixed at points outside of the landslide.

2.7 Erosion

Survey pins were installed into the face of the bluff by DOGAMI to measure the rate of erosion. Thirty-five, 298-mm ($11^7/_8$ inch) long pins were inserted in six profiles up the face of the bluff at the locations shown in Appendix F.

2.8 Sand Movement

Beach sand movement can affect the stability of the Johnson Creek Landslide. Measurements of beach sand levels were obtained using two methods: Light Detection and Ranging Data (LIDAR) and topography survey. Results of the surveys are provided in Appendix G.

3. LABORATORY TESTING

Laboratory testing was performed to determine soil index properties for correlation with engineering parameters and to aid with classification. All testing was performed at the Landslide Technology soil laboratory in Portland, Oregon. Tests were performed on selected samples collected during field explorations to verify field classifications and determine the following properties:

- Soil Classification
- Natural Moisture Content
- In-Place Density
- Residual Shear Strength

3.1 Soil Classification

Soil and rock core samples obtained from the field exploration program were visually re-examined in the laboratory to confirm field classifications using ASTM D 2488. Together with the results of additional laboratory testing, final soil descriptions were prepared in general accordance with ASTM D 2487. Soil classifications and descriptions are presented on the Summary Boring Logs, Figures 2 through 7.

3.2 Natural Moisture Content

Moisture contents were determined on all samples retrieved from the field explorations in general accordance with ASTM D 2216. The results of moisture content tests are shown on the Summary Boring Logs.

3.3 In-Place Density

In-place density tests were performed on selected core samples obtained during field explorations. The tests were performed in general accordance with ASTM D 2937. The results of in-place density tests are summarized below.

Table 3-1: Summary of In-Place Density Testing

Boring No.	Sample No.	Depth meters (feet)	Soil Description	Moist Unit Weight kN/m^3 (pcf)	Moisture Content	Dry Unit Weight kN/m^3 (pcf)
LT-1	R-4	10.5 -10.8 (34.4-35.4)	SOFT (R2), gray, silty, fine SANDSTONE	21.3 (135.5)	21%	17.5 (111.8)
LT-2	R-10	18.8 -19.0 (61.7-62.3)	VERY SOFT (R1), gray, fine silty SANDSTONE	21.5 (137.1)	18%	18.3 (116.5)

3.4 Residual Shear Strength

Residual shear strength tests were performed on shear zone material obtained from a drill core sample. The specimen was obtained in boring LT-2 at a depth of 18.1 meters (59 feet). The zone of slide movement measured in inclinometer LT-2 is between depths of 17.4 to 18.6 meters (57 to 61 feet). The tested soil is soft, slightly clayey, sandy silt: no sand or gravel sized fragments were in the sample.

The specimen was remolded by hand and placed into the ring-shear apparatus. The ring shear specimen is 0.20 inches thick and has a surface area of 6.2 square inches. Once the sample is placed in the ring shear apparatus it consolidates in a water bath for each load increment prior to shearing. The sample was tested at 490, 245 and 123 KPa (5.1, 2.6 and 1.3 tsf) confining pressure to simulate the range of in-situ effective confining stress along the shear zone. In-situ confining pressures at the shear zone within LT-1, LT-2 and LT-3 were estimated to be 380, 290 and 120 KPa (4.0, 3.0 and 1.3 tsf), respectively, using groundwater levels obtained from the newly installed vibrating wire piezometers. Following consolidation of the samples, shearing was commenced at a rate of 0.024 degrees per minute until reaching residual strength. The test was repeated for each of the three loads detailed above. A plot of the raw test data is included in Appendix H, Ring Shear Test Plot. Residual shear strength tests resulted in an effective residual phi angle of 13.1 degrees, with no cohesion. Results are shown graphically on Figure 10.

4. GEOLOGY AND SURFACE CONDITIONS

Dr. Alan Niem and DOGAMI have provided detailed interpretations, maps and cross sections of the geology for this project. As summarized below, this information and the interpretation of surface features provide insight to the geologic and structural control of the landslide. This information was used in the interpretation of data for geotechnical analysis.

4.1 Site Geology

Johnson Creek Landslide is within the Miocene Astoria Formation, and is comprised of siltstone, fine sandstone, mudstone and tuffaceous claystone. This geologic formation is widespread on the Oregon Coast, with mapped exposures from Astoria to south of Newport. Numerous landslides occur within this formation.

Johnson Creek Landslide occurs on a nearly flat-lying Pleistocene terrace above a 17-meter (56-foot) bluff at the beach. The terrace is comprised of 3 to 6 meters (10 to 20 feet) of sand overlying a basal cobble layer. The terrace deposits overlie a 1- to 2-meter (3- to 6-foot) layer of decomposed Astoria Formation, which in turn, overlies visually fresh bedrock of the Astoria Formation. Within the landslide these formation materials are displaced, fractured and sheared (i.e., slide debris).

The structural dip of the Astoria Formation at the site has been measured in nearby exposures at 15 to 20 degrees to the west. The coastline and bluff faces about 5 degrees south of west. A generally northwest-trending strike-slip fault zone has been mapped by Alan Niem in the sea cliffs at Otter Rock, about 1 km northwest of Johnson Creek Landslide, and it has been postulated that this fault or a similar fault zone extends through the landslide where it would have faulted and displaced the Astoria Formation.

4.2 Geotechnical Interpretation of Surface Features

Johnson Creek Landslide is approximately 200 meters (660 feet) long (east-west) and 400 meters (1300 feet) wide (north-south) and is bounded by steep-sided ravines at Johnson Creek to the south and a local creek to the north. Surface features within the slide area include: the headscarp, graben, the slide toe at the base of the shoreline bluff, the bluff, sumps in the bluff, and elongate ridges and depressions. Most of these features are outlined on the Site Plan, Figure 2.

Headscarp. The headscarp is up to 10 meters (33 feet) high around the east limit of the landslide. The headscarp has two generalized appearances: steep to the north and relatively gentle to the south. The northern scarp exposes terrace sand in an oversteepend scarp face, while the southern scarp is mostly covered with colluvium and vegetation. Considering the time that is necessary for erosion and development of colluvium, the difference in the condition along the scarp suggests that the northern area is a more youthful feature, while the southern portion of the scarp is older.

East of the headscarp the surface elevation varies from 33 to 40 meters (108 to 131 feet). Within the landslide the surface elevation rises from about 22 meters (72 feet) in the south to 34 meters (112 feet) in the north. The difference in elevation within the slide is interpreted to be due to older and more significant amounts of displacement in the southern portion of the slide.

Graben. The graben of this landslide changes from south to north. To the south the graben is very subtle with a 10-meter (33-foot) scarp to the east and an irregular 1 to 2-meter (3- to 7-foot) back or reverse-facing scarp to the west. In this area the graben varies from about 10 to 20 meters (33 to 66 feet) wide. To the north the graben is well defined with prominent 10-meter (33-foot) headscarp and reserve scarp, and is 5 to 10 meters (16 to 33 feet) wide.

Toe. The toe of the landslide is at the base of the shoreline bluff. At the south where Johnson Creek flows onto the beach, in-place bedrock is exposed in the creek ravine. North of the creek, in-place bedrock is not visible and a gouge zone of soft clayey sandy silt is exposed along the upper portions of the beach. The test pit encountered about 2 meters (7 feet) of gouge above in-place Astoria Formation (Appendix C).

Bluff. Exposures of landslide debris in the bluff include bedding that is tilted, fractured and sheared. Bedding that is relatively intact tends to dip between 15 and 45 degrees to the east. This “back-rotation” is likely due to upward movement of slide blocks and local slumping of the oversteepend bluff. If the basal slide zone of a translational slide rises to the surface at its toe, a passive wedge is formed where material can rotate relative to the main slide mass. Local slumps can also result in back-rotation of slide blocks. Westward movement of the main slide mass oversteepens the bluff, which can locally slump over the low strength gouge.

Central Area. Elongate ridges and depressions characterize the ground surface within the central area of the landslide. These features are visible in the relatively flat terrace, but due to the high amount of natural surface activity in this coastal environment, they are often relatively subtle and covered with dense vegetation. Shown on the Figure 2, these features appear to occur in two regions: along the bluff and in the northeast. Very long and narrow features characterize the ground surface along the bluff. These features are interpreted to be high angle tensional features that occur due to stress relief parallel to the bluff, possibly along pre-existing tectonic faults or joints and fractures within the bedrock.

Northwest-trending ridges and depressions characterize the northeast portion of the landslide. In additional, a relatively intact slide block appears isolated in the northeast corner of the landslide. The northeast features are likely influenced by: stress relief southward into the older slide area, westward movement along the tilted bedding, and pre-existing northwest-trending tectonic fractures.

4.3 Surface Water and Groundwater

Surface water on the Johnson Creek Landslide locally ponds in the landslide graben. Creeks to the north and south appear to flow around the slide area. Prominent wetland features are not readily evident, probably due to the high permeability of the terrace deposits and fractured landslide debris. However, apparent wetland plants occur in scattered areas, which indicates that locally perched groundwater levels may occur within the surface terrace deposits overlying lower permeable Astoria Formation.

5. GEOTECHNICAL DATA

Geotechnical data collected for this investigation included subsurface materials, groundwater levels, precipitation, bluff erosion and movement of beach sand. Relevant impacts to landslide stability are summarized in the following paragraphs.

5.1 Subsurface Materials/Conditions

Exploratory borings encountered materials that are separated into three geotechnical engineering units identified as terrace sand overlying a thin layer of decomposed Astoria Formation, fractured Astoria Formation slide debris, and in-place bedrock of the Astoria Formation. Detailed descriptions of the subsurface materials are included on the Summary Boring Logs, Figures 3 through 8.

Terrace sand and decomposed Astoria Formation was encountered to depths of 5.0 to 6.9 meters (16.4 to 22.6 feet). This material consists of loose to medium dense, silty sand overlying 1 to 2 meters (3 to 6 feet) of medium stiff, silty clay.

Astoria Formation slide debris consists generally of moderately to high fractured sandstone, siltstone and mudstone. This fractured rock is typically very soft rock (R1) with lesser soft rock (R2). In-place Astoria Formation is typically a soft rock (R2). Due to drill and sample specifications for the drilling investigation, Standard Penetration Tests (SPT) were not taken in the dill holes, except to isolate the base of the terrace sand in Boring LT-3P.

Slickensides and apparent gouge zones were also encountered in both the slide debris and the in-place rock underlying the landslide. Slickenside orientations were typically near vertical. Vertical slickensides were also encountered on fracture surfaces in the in-place rock, which suggests that other tectonic-induced strain (faults) may be present in the slide area.

Gouge material encountered in the borings is classified as very soft, slightly clayey to clayey, sandy silt. Brecciated siltstone and sandstone was commonly encountered in the slide debris, and was not encountered in the in-place rock. Slickensides were often encountered in the brecciated material.

5.2 Landslide Movements

Landslide movements were measured at the shear zone with inclinometers and extensometers, and on the ground surface with survey hubs.

Shear Zone Monitoring. Landslide movements have been detected in all three of the inclinometer casings. Inclinometer deflection plots are shown in Figures 11, 12 and

13, respectively. Shear movements are detected at depths of 26.5, 18.6 and 7.0 meters (87, 61 and 23 feet) below ground surface for LT-1, LT-2 and LT-3, respectively.

Initial readings were taken on the three casings on December 5, and November 25 and 27, 2002, respectively. Shear movement was first detected in the casings on December 16, 2002. By December 26, inclinometers LT-1 and LT-2 could not be read due to the probe not being able to pass the distorted casing at the slide zone. They were converted to fixed borehole extensometers at that time. By the first week of January 2003, LT-3 was no longer readable and was also converted to an extensometer. Extensometer movement is shown in Figure 14. Movement continues to be recorded with the extensometers in each of the casings. It should be noted that ground movements obtained from the inclinometer system have a high precision (0.25-mm, 0.01-inch) compared to that of the extensometer (3-mm, 1/8-inch).

Inclinometers LT-1, LT-2 and LT-3 measured shear zone movement vectors in the directions 273, 258 and 247 degrees azimuth, respectively. Based on analysis of inclinometer data, apparent shear movement near the base of inclinometer LT-2 is likely due to systematic error and is not related to actual shear movement.

Previous Shear Zone Monitoring. Inclinometer plots from six borings installed in Johnson Creek Landslide in the 1970s, along with accompanying borings logs, are included in Appendix A. This data provides additional information; however, there are a number of variables to consider. The vertical and horizontal datum in not included, and the measurement point for the “slope meter tubes” is unknown. The plots for three of the borings (76-2, 76-3 and 76-4) have similar appearances, which can be attributed to the depth of movement deeper than the casing. Therefore, the actual depth of movement in these borings is unknown. The plot for the boring 76-1 appears reasonable; however, there is a high degree of uncertainty in the actual depth compared to the current data (± 5 feet).

Ground Surface Monitoring. Survey points were established on the ground surface at three east-west sections across the slide (Appendix D). Two sets of readings have been taken in October 2002 and April 2003. Based on readings taken upslope of the main slide graben, the survey repeatability error appears to be relatively large, about 0.03 to 0.09 m (average 0.07 m). However, even with this limitation, general trends emerge that are helpful to understand the overall differences in ground movement across the slide area. In summary, the ground movements within the boundaries of the landslide are faster to the south and to the west, as follows:

Corrected Average Vector Movement (meters)	
North Survey Hubs	0.00
Middle Survey Hubs	0.17
South Survey Hubs	0.32
West of Highway 101	0.24
East of Highway 101	0.03

Vector movement azimuths are included in Appendix D. The middle and southern survey lines show similar direction of ground surface movement in the main part of the slide mass (away from the shoreline bluff) compared to that measured at the shear zone – west-southwest in the upper and eastern area of the slide, and west in the lower and western area of the slide.

A line-of-sight survey was established along the road and two sets of readings have been taken in January and February 2003 (Appendix E). This data also shows that the southern area of the slide has moved faster than the northern area. Additional ground surface monitoring will provide more information that is useful in the evaluation of this landslide.

5.3 Groundwater and Precipitation

Groundwater levels within the landslide were measured with vibrating-wire piezometers installed at the slide zone in Borings LT-1P, LT-2P and LT-3P, and in bedrock in Boring LT-2P. Groundwater level elevations at each piezometer are shown on Figure 15.

Rainfall intensity in mm per hour is also shown on Figure 15. The rainfall data was affected by wind gusts until a shield was installed on January 7, 2003. Prior to this date occasional false tipping occurred, usually no more than one tip per hour. Each tip equals 0.25 mm (0.01 inches) of rainfall.

The shallowest piezometer LT-3P responds quickly to rainfall events of varying intensity and duration. Piezometers LT-1P and LT-2P show less sensitivity with depth and respond to events of larger intensity and duration.

The deep piezometer, LT-2P Bedrock, has a lower piezometric level than that at the slide zone (LT-2P). Based on the limited data, it appears that groundwater levels in the slide mass are primarily influenced by surface water, with less influence from a deeper groundwater source.

Data Correlation. Correlations between rainfall and ground movement were evaluated. Ground movement, groundwater level above the slide zone and precipitation are summarized in Figure 16. Three separate slide movement events were recorded as follows:

- Event 1: December 13 to 16, 2003
- Event 2: January 27 to February 3, 2003
- Event 3: March 20 to 24, 2003

Correlation was observed between piezometric level and slide movement during Events 2 and 3. As part of this correlation, at LT-2 in the central area of the landslide, a minimum level of approximately 10 meters (33 feet) of head above the slide plane was reached before triggering ground movement (Figure 16).

Correlation was also noted between ground movement and antecedent rainfall and intensity. Various rainfall duration periods were evaluated, and it was found that slide movement occurs after a minimum of 55 to 60 mm (2.2 to 2.4 inches) of rainfall has been measured at the site in the previous 24-hour period (Figure 17). Several other events occurred with less rainfall over the same time period with no observable movement.

5.4 Erosion and Beach Sand Movement

Bluff erosion data was collected using survey pins (Appendix F). Erosion was measured between December 9, 2002 and April 10, 2003. Measurements indicate the sandstone and siltstone erode at different rates. The average rate of erosion for sandstone was 0.10 meters (0.3 feet) per month, which is about five times faster than the rate for siltstone at 0.02 meters (0.07 feet) per month. Erosion at some of the monitoring pins resulted in the loss of the pin.

Landslide movement can affect the rate of erosion. Movement would increase the likelihood of mass wasting with the loss of blocks or slivers of slide debris during storm events. This may account for some of the lost monitoring pins.

Annual cyclic beach sand movement was measured with Lidar and survey techniques (Appendix G). About 1.5 to 2 meters (5 to 7 feet) of sand moved off the beach between September 2002 and April 2003. At the toe of the slide about 1 meter of sand moved out during the same time period.

No correlations between erosion or beach sand movement and the ground movement measured with inclinometers and survey hubs was recognized during the study of this landslide.

5.5 Interpreted Landslide Cross Section

A cross section of Johnson Creek Landslide is shown in Figure 18. The landslide is relatively shallow near its head, deepens toward the west, and then thins as the basal slide zone rises toward the surface. A deep landslide graben does not occur in the head of the main slide mass (i.e., it has a small driving wedge). Instead, the graben appears to be a remnant as the slide has moved laterally and downslope away from the headscarp.

Johnson Creek Landslide is a complex, translational slide. Slide geometry and movement appears to be controlled by bedding or layers in the Astoria Formation. The Astoria Formation is tilted about 17 degrees to the west, and the upper area of the slide is moving to the west-southwest while the lower area is moving in the down dip direction (west). The change in movement direction and the apparent age difference across the slide, older to the south and younger to the north, are likely related to variables in the slide geometry, and causative factors such as bluff erosion.

6. LANDSLIDE STABILITY EVALUATION

A slope stability evaluation of the landslide was performed using available information, including: (i) borehole data; (ii) depth of sliding and groundwater data from instrumentation; (iii) geologic reconnaissance of the site; and (iv) topographic map. The results of the stability analysis were used in evaluating potential slide treatment options, which are discussed in Chapter 7 – Remediation Option Analysis.

6.1 Back Analysis

The stability analyses were performed on Cross-Section A-A', Figure 18. This section was selected because it is near parallel to the direction of slide movement and passes through the three sets of instrumented borings. Analyses were performed using Spencer's Method in the computer program XSTABL. Soil parameters used for this study are discussed in more detail in the following sections.

The analyses were performed by back-calculating the required strength (angle of shearing resistance, ϕ') along the shear zone for incipient failure conditions (i.e., for a factor of safety equal to 1.0). The improvements to the factor of safety (FS) were then checked for various treatment options using the back-calculated ϕ_r'.

Shear Zone. The location of the shear zone is estimated based on the known depth of movement in inclinometers LT-1, LT-2 and LT-3, the location of cracks observed upslope from the instrumentation, interpreted topography, and observations from the test pit at the slide toe. The analyzed slip surface is shown in Figure 18.

Groundwater Levels. Groundwater levels used in the back analysis stability evaluation are based on piezometer measurements when a threshold level of 10.0 meters (32.8 feet) of head on the slide plane was reached in LT-2P. The depth of the groundwater measured below the ground surface at this time for LT-1P, LT-2P and LT-3P was 19.2 meters (Elev. 5.4 m), 8.6 meters (Elev. 15.7 m) and 0.7 meters (Elev. 23.3 m), respectively. This groundwater level was kept constant throughout the back analysis and is shown in Figure 18.

Material Parameters. Strength and density parameters of the soil and rock used in the analyses were estimated based on moisture content, material classification, and our experience with similar materials. Residual ring shear testing of the Astoria Formation material found in the shear zone resulted in an effective residual friction angle of $\phi'_r = 13.1$ degrees. The strength and density parameters of the soil and rock used in the analysis are summarized in Table 7.1.

Table 6.1 - Summary of Material Strength and Density Parameters

Material	Unit Weight kN/m^3 (pcf)	Cohesion Intercept, c' Pa (psf)	Angle of Shearing Resistance, ϕ' (degrees)
Terrace Sand & Decomposed Astoria Formation	18.1 (115)	0	32
Astoria Formation	21.2 (135)	0	6.5*
Rockfill	18.1 (115)	0	42

*Back calculated value from the geologic cross-section shown in Figure 18.

Analysis Results. The back-calculated residual strength (ϕ_r') value for the slip surface analyzed in Cross Section A-A' was determined to be 6.5 degrees. This single digit value is comparable with similar slides in the Astoria Formation and other large translational landslides in tuffaceous sediments and decomposed volcanic rocks, all of which have been investigated Landslide Technology. The difference between the back analyzed ϕ' value and the value obtained from the ring shear testing (13.1 degrees) may be attributed to the fact that the sample tested may not be representative of the entire failure surface. The back-calculated ϕ_r' value is an average value for the model.

6.2 Sensitivity Analysis

A parametric investigation was performed to evaluate the sensitivity of landslide stability to the following parameters: precipitation, groundwater levels, erosion and beach sand level. Specific parameters were varied as discussed in the following sections.

Precipitation and Groundwater. An evaluation of the sensitivity of slide movement to precipitation and groundwater level was performed. As discussed in Section 5.3, a rainfall event which measures 55- to 60-mm of rainfall in a 24-hour period is likely to trigger landslide movement. Peak rainfall events cause groundwater to rise above threshold levels, further destabilizing the landslide. With the available piezometer data, groundwater levels for a "severe storm" were modeled by raising the highest measured levels in piezometers LT-1P, LT-2P and LT-3P by 1.5 meters (but not above the ground surface). Groundwater levels used for the theoretical "severe storm" analysis are elevation 9.0 meters, 19.0 meters and 24.1 meters at piezometer locations LT-1P, LT-2P and LT-3P, respectively. The results indicate that a rise in groundwater level of 1.5 meters above the back-analyzed level would decrease the FS of the slide mass by seven percent.

During the winter months groundwater levels appear to stay at reasonably stable levels, except during moderate to severe rainfall events. These "normal winter" levels were measured at average elevations of 5.0 meters, 14.6 meters and 21.4 meters in piezometers LT-1P, LT-2P and LT-3P, respectively. By varying only the groundwater level in the slide the results of the analysis indicate that decreasing the groundwater level to the theoretical "normal winter" results in an increase in the FS of the slide on the order of two percent higher than the back analysis.

Erosion and Beach Sand Movement. To evaluate the effect of ocean surf on the stability of the slide, both erosion of the cliff face at the toe of the slide and the seasonal deposition and removal of sand due to surf action were analyzed.

To evaluate the sensitivity of the slide to erosion of the bluff at the beach, stability analyses were performed and compared to the back-analysis results. The models were developed by offsetting the entire face of the bluff (up to an approximate elevation of 14.6 meters) 0.3 meters (1 foot), 1.5 meters (5 feet), and 3.0 meters (10 feet) to the east, respectively. To isolate the effect of the erosion, the geometry of the shear zone at the toe remained unchanged from the back analysis. To keep the groundwater conditions constant through the analyses, groundwater levels for the 3.0-meter erosion study were used. The only difference between this groundwater level and that used in the back analysis is a slight lowering of the water level west of LT-1P due to a change in the inflection point of the groundwater surface at the beach as a result of the changing location of the cliff face.

An additional study was performed to isolate and evaluate the effect of seasonal deposition and removal of sand from the beach relative to the stability of the slide. The model for this analysis consisted of adding approximately one meter of sand to the beach area, which isolated the effect of the sand by limiting variations to the model (i.e., the failure surface). For this analysis the groundwater level remained unchanged from the back analysis model. The geometry of the shear zone was modified only by extending the toe outward to the new ground surface.

Summary of Sensitivity Analysis. A parametric study has been performed to evaluate the sensitivity of the slide to three major parameters: (1) precipitation and groundwater, (2) erosion, and (3) the seasonal deposition and removal of sand on the beach. The back analysis model was used as the reference, and for each parameter incremental changes were made to determine the resulting percent change in FS. A summary of the analyses is provided in the table below.

Table 6.2 – Summary of Sensitivity Analyses

Parameter	Change in FS From Back-Analysis (- Decrease / + Increase)
Groundwater	
"Normal" 2003 winter level	+2.0 %
"Severe Storm"	-7.2 %
Erosion of Cliff Face	
0.5 meters (1 foot) of Erosion	- 0.8 %
1.5 meters (5 feet) of Erosion	- 3.6 %
3.0 meters (10 feet) of Erosion	- 6.8 %
Seasonal Deposition/Removal of Sand	
1.0 meter (3 feet) Removal	- 0.3 %
1.0 meter (3 feet) Deposition	+ 0.3 %

7. CONCEPTUAL REMEDIATION OPTIONS

Several remedial options have been evaluated to increase landslide stability and minimize ground movement affecting the roadway. These options include (i) unloading near the headscarp, (ii) toe buttress, (iii) horizontal drains, (iv) tied-back shear pile wall, and (v) maintenance. Each option was designed to improve the factor of safety by at least 10 percent (FS=1.10) during the "severe storm" event.

A brief discussion of each option is presented, along with advantages and disadvantages. The cost estimate for each option is based on general and specialized construction costs, plus a 25 percent contingency to provide for the uncertainties of conceptual level design. The cost estimates do not include costs for environmental issues (e.g. permitting), final design, preparation of plans and specifications, contractor procurement, or construction control.

The northern and southern limits were estimated based on topographic interpretations and headscarp cracks observed in the highway and along the approximate northern and southern limits of the slide area (Figure 1). For the purpose of estimating costs of the treatment options, the slide is assumed to be 360 meters (1180 feet) wide along the beach.

7.1 Option 1 - Unload Upper Slide

This option entails unloading the head of the slide by excavating material east of the highway, and installing two French drains along the east side of the excavation. The excavation would extend approximately 160 meters (525 feet) north from the access road crossing the headscarp. The approximate limits of the excavation are shown on Figure 19. The elevation of the excavation floor would be approximately 18 meters (59 feet) (Figure 20).

French drains would minimize ponding during and after construction. A connector drain would be constructed to tie the two drains together at the southern end of the excavation, and a drainline would outlet into the drainage swale south of the slide and east of the highway, as shown on Figure 19.

This option provides a theoretical improvement in the factor of safety of 20 percent using back-analyzed groundwater levels, and a 12 percent improvement using the "severe storm" event.

<u>Advantages</u>:

- Relatively low construction cost
- No environmental impact to the beach area

- Good access for construction
- Simple construction techniques
- Minor long-term maintenance required
- Highway alignment not affected

Disadvantages:

- Provides no protection against continued toe erosion, which could eventually reactivate slide movement even with unloading implemented
- Short-term environmental impacts
- Requires disposal of excavated material
- Relocation of utilities
- Potential ponding in the excavation area

Conceptual Construction Cost: $0.9 million

7.2 Option 2 - Toe Buttress

This option would involve building a buttress on the beach along the toe of the slide as shown in Figures 19 and 20. The buttress would consist of rockfill with a key extending approximately 2 meters (6 feet) below the beach, and riprap facing for erosion protection. The buttress would be 11 meters high (36 feet), extend approximately 8 meters (26 feet) onto the beach from the bluff, and have a 1V:1.5H slope face with the level top extending approximately 2 meters (6 feet) out from the existing slope face.

Construction would consist of excavating the key trench in sections, placing a geotextile fabric and then rockfill materials in lifts. The construction of the key trench would occur in 15-meter (50-foot) sections to prevent slide instability during construction. Once the length of key was fully constructed, rockfill and riprap would be placed in lifts along the length of the slide to the finished height.

This option provides a theoretical improvement in the factor of safety of 19 percent using back-analyzed groundwater levels, and a 12 percent improvement using the “severe storm” event.

Advantages:

- High degree of confidence in stability improvement
- Relatively low construction cost
- Limits rate of bluff erosion
- Simple construction techniques

- Minimal long-term maintenance required
- Highway alignment not affected

Disadvantages:

- High environmental impact (construction on beach)
- Limited access to site

Conceptual Construction Cost: $1.1 million

7.3 Option 3 - Horizontal Drains

This option would consist of installing horizontal drains through the slide mass from the toe of the slope (Figures 19 and 21). The drains would consist of slotted PVC pipe installed laterally into the slope face with a specialized drill rig. The horizontal drains would attempt to reduce the groundwater level during normal conditions and prevent the buildup of groundwater pressure during extreme rainstorm events.

Based on the stability analyses, improvement in the FS from horizontal drains is about 1% during the "severe storm" event. Also, the rotational failures at the toe of the larger slide are likely to shear the horizontal drains rendering them less effective or inoperable, which could also worsen the stability of the rotational failures.

Other options would be necessary to provide additional stability to the overall slide, such as a toe buttress. A riprap toe buttress could minimize erosion of the bluff and could provide stability to the rotational toe failures.

Based on the 1% improvement in FS during the "severe storm" and the potential for rotational failures at the slide toe, this option is not recommended for the Johnson Creek Landslide. Nevertheless, to provide comparison to other options, a conceptual design might include two drain arrays as shown in Figure 19. The cost estimate includes a total of 36 horizontal drains in two arrays for a total constructed length of 4270 meters (14,000 feet).

Advantages:

- Relatively low construction cost
- Simple construction techniques
- Highway alignment not affected
- Low long-term environmental impact
- Minor long-term maintenance

Disadvantages

- Stability improvement is low
- Limited design life of the drains with erosion and slide movement
- Limited access to site

Conceptual Construction Cost: $0.5 million

7.4 Option 4 – Tied-Back Shear Pile Wall

This option consists of constructing a row of large diameter, heavily reinforced concrete piles with tieback anchors to resist slide movement, installed just west of the highway as shown in Figures 19 and 21. Conceptual design consists of a 342-meter-long (1122-foot) wall of 1.4-meter (4 feet) diameter and 36 meter (120 feet) deep piles with a spacing of 3.0 meters (10 feet). A continuous, structural capping beam would be constructed at the top of the shear piles. Two rows of tiebacks would be installed through the capping beam (Figure 21). The tiebacks would decrease pile deflection and movements, and would result in less passive contact pressures in the sandstone below the shear zone. The wall and anchors could be covered and the site restored to a natural condition. This conceptual design provides a factor of safety of 1.3 during the "severe storm" event.

Advantages:

- High degree of confidence in stability improvement
- Low environmental impact (no construction on beach)
- Minimal long-term maintenance
- Highway alignment not affected

Disadvantages:

- Expensive
- Specialized construction technique
- Construction could impact highway traffic
- Lower slide area may continue to move due to continued bluff erosion

Conceptual Construction Cost: $11 to 14 million

7.5 Option 5 – Road Maintenance

This option would consist of continued maintenance of the road. This option requires that the slide area continue to be inspected on a weekly basis and a daily basis during large storm events, and then quickly repaired when significant movements occur. ODOT records indicate that yearly costs for maintenance have been approximately $15,000 per year prior to the late 1970s, and $20,000 per year more recently.

Advantages:

- Inexpensive
- Low environmental impact

Disadvantages

- No effective stabilization
- Landslide will continue to move
- Continued risk to property and life safety
- Requires continual inspection and emergency repair as necessary

Cost: $20,000 a year for basic maintenance (~$400,000 for 20 years)

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The geotechnical investigation described herein provides an understanding of the mechanics of the landslide and the relationship during the study period between ground movement, groundwater fluctuations, precipitation, bluff erosion and beach sand movement. Johnson Creek Landslide is a complex translational slide. It is marginally stable and moves when groundwater levels rise to a threshold that is often reached during winter storms. Precipitation amounts of 55 to 60-mm over a 24-hour period appear to trigger movement. Compared to groundwater fluctuation, typical rates of erosion and beach sand movement that were measured during the study period have marginal impacts on the stability of Johnson Creek Landslide.

Remediation options that were evaluated for Johnson Creek Landslide include unloading, buttressing, draining, a tied-back shear pile wall, and maintenance. A summary of the construction options is provided in the following table:

	Remediation Option				
	1 Unload	2 Buttress	3 Horizontal Drains	4 Tied-Back Shear Pile Wall	5 Maintain
Effectiveness	Moderate	High	Low	High	Low
Constructibility	Good	Good	Moderate	Difficult	n.a.
Engineering	Simple	Moderate	Moderate	Difficult	Simple
Environmental Long-Term Impact	Low	High	Low	Low	Low
Maintenance Long-Term	Low	Low	Moderate	Low	High
Construction Costs ($ Million)	0.9	1.1	0.5	11-14	0.4 (20 yrs)

Unloading, buttressing and a tied-back shear pile wall are effective methods to remediate this landslide. Considering the large size of this landslide, unloading and buttressing are relatively low cost options. With stabilization and cost consideration, buttressing would be a preferential option; however, it has a significant environmental impact. A shear pile wall is extremely expensive primarily due to the depth of sliding. Draining groundwater from the landslide through horizontal drains would be ineffective. Groundwater levels within the slide mass are relatively low, and high groundwater levels following precipitation events rapidly drop or naturally drain from the fractured slide mass. Based on the conceptual costs for the construction of these remediation options, annual maintenance becomes a reasonable option.

8.2 Recommendations

The Phase 1 investigation has developed a preliminary understanding of what causes the slide to move, and a better understanding of slide geometry, subsurface materials properties, and groundwater conditions. Basic concepts to stabilize the slide have been reviewed and conceptual estimates of the cost have been developed. Phase 1 has also raised a number of other questions that, if answered, could help to futher understand the landslide. Some of these unknowns are:

a) Depth and geometry of the slide to the north and south of the central cross-section. Could the slide be treated as two separate slides?

b) Differences in the influence of bluff erosion from one area of the slide to another.

c) The influence of a possible tectonic fault or fracture system cutting through the slide area.

d) Dip direction of bedding beneath the landslide.

e) Hydrogeology of the slide debris.

Along with continued monitoring of the Phase 1 instrumentation and survey hubs, a Phase 2 study is recommended. Phase 2 would have the overall objective to establish the preferred method of slide mitigation/remediation. This phase of study would develop a complete physical model of the geometric variability in the subsurface materials and conditions of the slide, as uncovered in Phase 1, and would establish an acceptable goal for Factor of Safety in the design of the mitigation/remediation.

Primary tasks for Phase 2 would include:

1. Meeting with owners and agencies to set goals for design and mitigation/ remediation.

2. New exploration and instrumentation to fine-tune the understanding of the geometry and relationship of the different areas within the slide, and to continue monitoring causative factors.
3. Preliminary biological and wildlife assessments.
4. Initiating the permit processes to establish acceptable environmental and site impacts.
5. Construction resource assessment.
6. Preliminary design review meetings to select the method(s) of mitigation/ remediation.
7. Engineering analyses.
8. Preliminary Design Report with cost estimate.

We understand that monitoring of the landslide activity will continue over the next three to four years. With this in mind, the following geotechnical recommendations are provided:

- Continue monitoring extensometers and line-of-sight survey immediately before and after significant rain events, on a weekly basis during the wet fall to spring months, and monthly during the drier season.
- Add additional survey points to the line-of-sight survey, distributed across the width of the slide.
- Collect TDR measurements on the coaxial cables.
- Replace the bluff erosion monitoring pins with 4-foot iron rods driven to full depth.
- Upload and check dataloggers on a monthly basis.
- Replace the batteries in the piezometers and rain gauge dataloggers on an annual basis.
- Perform a geotechnical engineering review of monitoring data on an annual basis, with recommendations for monitoring and instrument maintenance.

Limitations in the Use and Interpretation of This Geotechnical Report

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Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross-sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report; nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.

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1460\F01 MWT

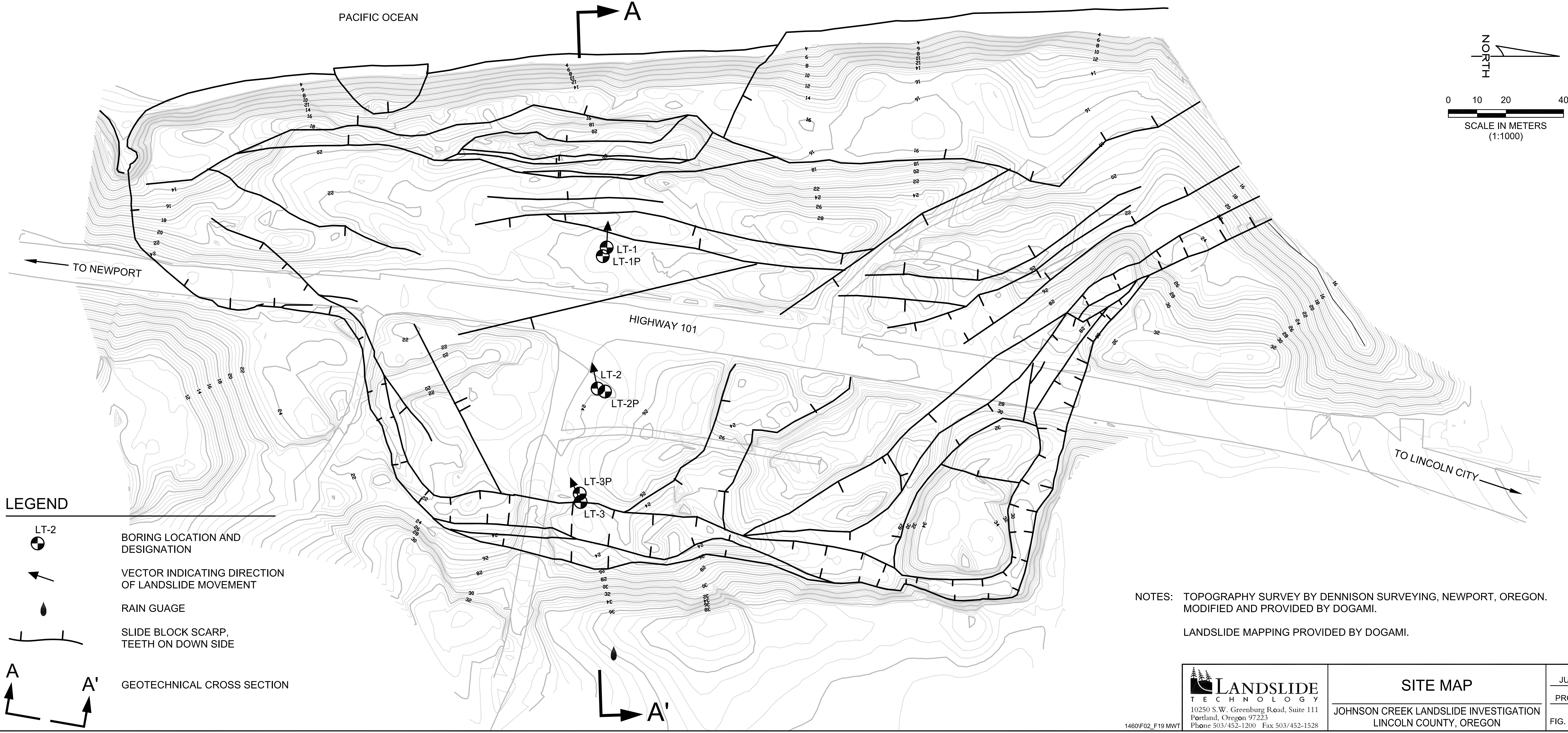
SITE LOCATION MAP

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 1



NOTES: TOPOGRAPHY SURVEY BY DENNISON SURVEYING, NEWPORT, OREGON. MODIFIED AND PROVIDED BY DOGAMI.

LANDSLIDE MAPPING PROVIDED BY DOGAMI.

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1460\F02_F19 MWT

SITE MAP

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

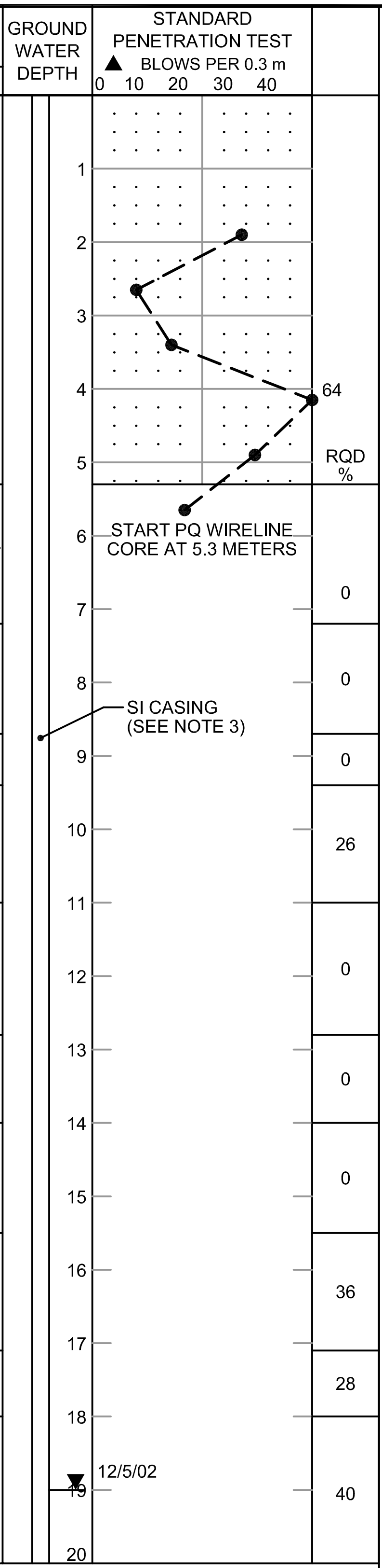
PROJ. 1460

FIG. 2

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION
		SURFACE ELEV. (m) 24.6
		LOOSE to MEDIUM DENSE, red-brown, slightly silty, fine to medium SAND; minor iron-oxide stratification and induration, trace organics, about 0.5 m lens of soft, gray and orange, sandy clayey silt at about 2 m (TERRACE SAND)
20.9	3.7	MEDIUM STIFF to STIFF, orange and gray, slightly sandy, clayey SILT to silty CLAY; trace organics, very soft/very loose zone encountered at 4.5 meters (DECOMPOSED ASTORIA FORMATION) ...increase in sand content: 5.2 meters
18.8	5.8	VERY SOFT (R1), gray, moderately weathered, silty FINE SANDSTONE, highly to very highly jointed, two predominant joint sets at about 20-30° and about 50-70° with occasional joints at higher and lower angles, iron-oxide weathering on most joint surfaces, slightly fossiliferous, slightly micaceous (ASTORIA FORMATION) ...brecciated siltstone in a slightly clayey silt matrix associated with possible slickensides: 12.5 meters ...becoming slightly weathered to fresh, no iron-oxide staining: 13 meters
9.1	15.5	SOFT (R2), gray, slightly weathered to fresh, slightly silty FINE to MEDIUM SANDSTONE, moderately to highly jointed, predominantly jointed at 50-70°, fossiliferous, micaceous (ASTORIA FORMATION) ...0.2 meter thick brecciated zone:16.1 meters
5.5	19.1	SOFT (R2), gray, slightly weathered to fresh, silty FINE SANDSTONE, moderately jointed with very highly jointed zones, predominantly at 60-80°, slightly fossiliferous, micaceous (ASTORIA FORMATION) ...SOFT, very highly fractured, with angular fragments in clayey matrix with associated slickensides (80-90° rake) at 20.0 to 20.8 meters

SAMPLES NO.	**
1	8
2	14
3	9
4	10
5	0
6	24

RUN NO.	CORE RECV. %	RQD %
R-1	27	0
R-2	36	0
R-3	40	0
R-4	92	26
R-5	62	0
R-6	55	0
R-7	72	0
R-8	86	36
R-9	80	28
R-10	100	40



LEGEND

- ▨ 0.051 m S.P.T. SAMPLE
- * SAMPLE NOT RECOVERED
- ** BLOW COUNT PER 0.6 m
- 0.076 m SAMPLE
- 0.076 m THIN WALL SAMPLE
- U P PITCHER SAMPLE
- IMPERVIOUS SEAL
- ▼ WATER LEVEL
- ■ PIEZOMETER TIP
- LIQUID LIMIT / NATURAL WATER CONTENT / PLASTIC LIMIT
- ● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. 7.0 CENTIMETER O.D. SLOPE INDICATOR (SI) CASING. ANNULUS BACKFILLED WITH CEMENT BENTONITE GROUT (5.5 TO 33.8 METERS), 10-20 SAND (2.7 TO 5.5 METERS), AND HYDRATED BENTONITE CHIPS (0 TO 2.7 METERS). LOCKING ABOVE-GROUND MONUMENT INSTALLED.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 11/27/02 FINISH: 12/5/02
DRILLING TECHNIQUE: 0 to 6.4 m, Mud rotary;
6.4 to 35.8 m, PQ Wireline coring

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SUMMARY BORING LOG
LT-1 (1 OF 2)

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
PROJ. 1460
FIG. 3

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.6	RUN NO.	CORE RECV. %	GROUND WATER DEPTH	STANDARD PENETRATION TEST ▲ BLOWS PER 0.3 m 0 10 20 30 40	RQD %
		(continued from previous page) ...possible bedding dipping at about 16°: 21.3 meters	R-11	74		21	32
3.0	21.6	VERY SOFT (R1) to SOFT (R2), gray, slightly weathered to fresh, fine sandy SILTSTONE, highly to very highly jointed, two predominant joint sets at 60-80° and 25-45°, occasional slickensides with 80-90° rakes and brecciated, clay filled zones, trace fossiliferous (ASTORIA FORMATION) ...grades to a clayey SILTSTONE: 23.0 to 26.2 meters	R-12	100		22	0
			R-13	100		23 24	61
			R-14	93		25 26	55
		...grades to a fine sandy SILTSTONE, becomes moderately jointed: 26.2 meters	R-15	86		27	84
			R-16	100	SI CASING (SEE NOTE 3)	28	100
-4.1	28.7	SOFT (R2), gray, slightly weathered to fresh, silty FINE SANDSTONE, moderately to slightly jointed, two predominant joint sets at 70-80° and 10-20°, fossiliferous, micaceous, faint bedding about 20° (ASTORIA FORMATION)	R-17	93		29 30	87
			R-18	100		31 32	100
-7.7	32.3	SOFT (R2), gray, slightly weathered to fresh, clayey SILTSTONE (ASTORIA FORMATION)	R-19	66		33	13
-9.2	33.8	Bottom of boring: 33.8 meters				34	

LEGEND

▨ 0.051 m S.P.T. SAMPLE

* SAMPLE NOT RECOVERED

** BLOW COUNT PER 0.6 m

0.076 m SAMPLE

U 0.076 m THIN WALL SAMPLE

P PITCHER SAMPLE

IMPERVIOUS SEAL

▼ WATER LEVEL

■ PIEZOMETER TIP

LIQUID LIMIT

NATURAL WATER CONTENT

PLASTIC LIMIT

● WATER CONTENT IN PERCENT

NOTES

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3. 7.0 CENTIMETER O.D. SLOPE INDICATOR (SI) CASING. ANNULUS BACKFILLED WITH CEMENT BENTONITE GROUT (5.5 TO 33.8 METERS), 10-20 SAND (2.7 TO 5.5 METERS), AND HYDRATED BENTONITE CHIPS (0 TO 2.7 METERS). LOCKING ABOVE-GROUND MONUMENT INSTALLED.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 11/27/02 FINISH: 12/5/02
DRILLING TECHNIQUE: 0 to 6.4 m, Mud rotary;
6.4 to 35.8 m, PQ Wireline coring

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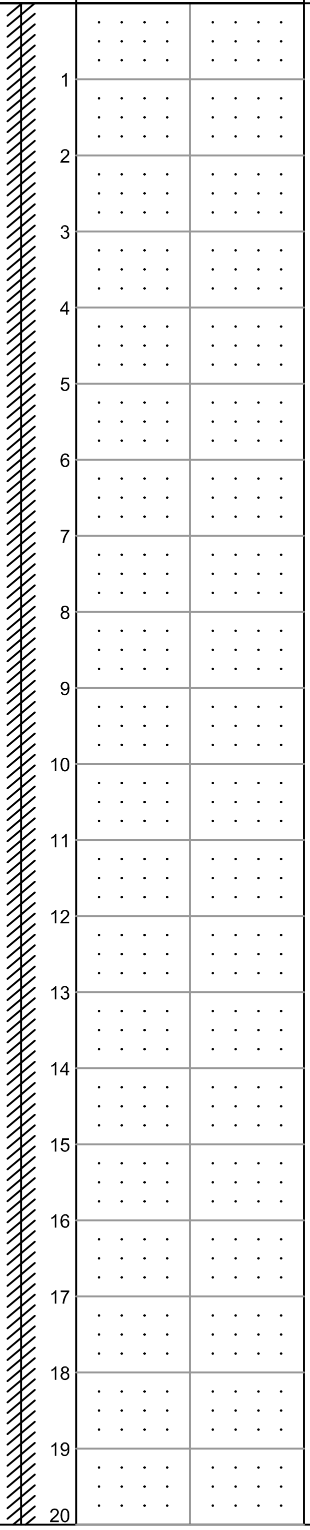
SUMMARY BORING LOG
LT-1 (2 OF 2)

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
PROJ. 1460
FIG. 3

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.7	SAMPLES NO.		SAMPLES **	GROUND WATER DEPTH	STANDARD PENETRATION TEST ▲ BLOWS PER 0.3 m 0 10 20 30 40	
		Quick drill boring, see SUMMARY BORING LOG LT-1 for subsurface information.						



LEGEND

▨	0.051 m S.P.T. SAMPLE
*	SAMPLE NOT RECOVERED
**	BLOW COUNT PER 0.6 m
▯	0.076 m SAMPLE
U	0.076 m THIN WALL SAMPLE
P	PITCHER SAMPLE
▨	IMPERVIOUS SEAL
▼	WATER LEVEL
■	PIEZOMETER TIP
├─●─┤	LIQUID LIMIT NATURAL WATER CONTENT PLASTIC LIMIT
●	WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. VIBRATING WIRE PIEZOMETERS, SLOPE INDICATOR COMPANY, MODEL 52611020, 350 kPa RANGE, S/N 75300, TIP AT 24.8 METERS. LOCKING ABOVE GROUND MONUMENT INSTALLED.
4. 10-20 SILICA SAND SURROUND MATERIAL, BENTONITE CHIP SEAL.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 1/9/03 FINISH: 1/10/03
DRILLING TECHNIQUE: 0 to 10.7 m, Hollow Stem Auger, 0.20 m O.D.; 10.7 to 26.8 m, Mud Rotary with 0.10 m Tricone bit

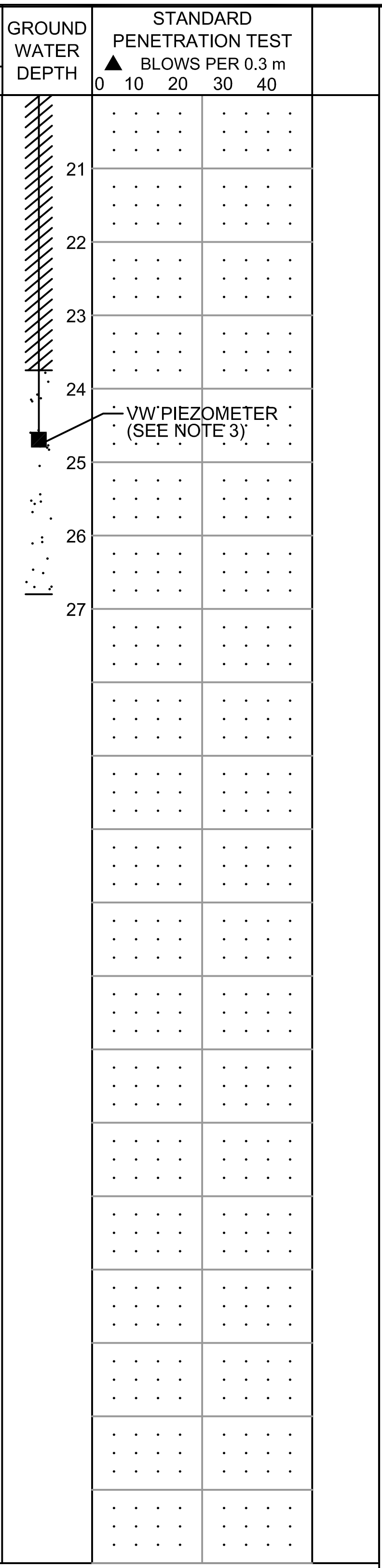
LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223

SUMMARY BORING LOG
LT-1P (1 OF 2)

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
PROJ. 1460
FIG. 4

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.7	SAMPLES NO.		SAMPLES **
		(continued from previous page)	1	⌶	U
-2.1	26.8	Bottom of boring: 26.8 meters			



LEGEND

- ▨ 0.051 m S.P.T. SAMPLE
- * SAMPLE NOT RECOVERED
- ** BLOW COUNT PER 0.6 m
- ⌶ 0.076 m SAMPLE
- U 0.076 m THIN WALL SAMPLE
- P PITCHER SAMPLE
- ▨ IMPERVIOUS SEAL
- ▼ WATER LEVEL
- ■ PIEZOMETER TIP
- ├─●─┤ LIQUID LIMIT / NATURAL WATER CONTENT / PLASTIC LIMIT
- ● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. VIBRATING WIRE PIEZOMETERS, SLOPE INDICATOR COMPANY, MODEL 52611020, 350 kPa RANGE, S/N 75300, TIP AT 24.8 METERS. LOCKING ABOVE GROUND MONUMENT INSTALLED.
4. 10-20 SILICA SAND SURROUND MATERIAL, BENTONITE CHIP SEAL.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 1/9/03 FINISH: 1/10/03
DRILLING TECHNIQUE: 0 to 10.7 m, Hollow Stem Auger, 0.20 m O.D.; 10.7 to 26.8 m, Mud Rotary with 0.10 m Tricone bit

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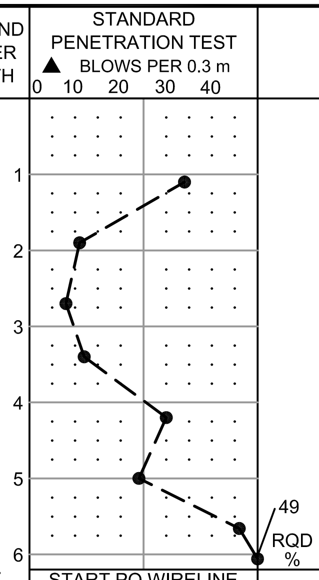
SUMMARY BORING LOG
LT-1P (2 OF 2)

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
PROJ. 1460
FIG. 4

SURFACE ELEV. (m) 24.2

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION	SAMPLES NO.	SAMPLES **	GROUND WATER DEPTH	RQD %
		MEDIUM DENSE, brown, clayey silty, fine to coarse SAND; trace organics (TERRACE SOIL)	1	23		
22.8	1.4	MEDIUM DENSE, brown, slightly silty, fine to medium SAND; minor iron-oxide stratification and induration (TERRACE SAND)	2	29		
			3	32		
			4	24		
			5	24		
			6	43		
18.7	5.5	STIFF to VERY STIFF, orange and gray, highly weathered sandy, silty CLAY grading to slightly clayey, silty SAND (DECOMPOSED ASTORIA FORMATION)	7	42		
			8	23		
			RUN NO.	CORE RECV. %		RQD %
			R-1	85		70
17.3	6.9	VERY SOFT (R1) to SOFT (R2), gray, highly to moderately weathered, silty fine SANDSTONE to slightly silty, fine to medium SANDSTONE, moderately to highly jointed, two predominant joint sets at about 70-80° and 40-50°, iron-oxide weathering most joint surfaces, slightly fossiliferous, slightly micaceous (ASTORIA FORMATION)	R-2	96		52
			R-3	98		12
		...layer of VERY SOFT (R1), light gray, CLAYSTONE/SILTSTONE, tuffaceous: 9.0 to 9.5 meters ...becoming slightly weathered to fresh, no iron-oxide staining: 9.5 meters	R-4	84		28
			R-5	100	▼ 11/21/02	73
		...15-30 cm layers of interbedded siltstone and claystone with bedding about 20°: 12.2 to 12.8 meters	R-6	100		42
			R-7	90		90
9.0	15.2	VERY SOFT (R1), gray, slightly weathered to fresh, fine sandy SILTSTONE, slightly to moderately jointed, trace fossiliferous (ASTORIA FORMATION)	R-8	100		67
			R-9	51		11
		...slickensides: 18.1 meters				
			R-10	100		52
		...slight increase in grain size: 19.8 to 22.8 meters	R-11	100		100



LEGEND

▨ 0.051 m S.P.T. SAMPLE

* SAMPLE NOT RECOVERED

** BLOW COUNT PER 0.6 m

0.076 m SAMPLE

U 0.076 m THIN WALL SAMPLE

P PITCHER SAMPLE

IMPERVIOUS SEAL

▼ WATER LEVEL

■ PIEZOMETER TIP

LIQUID LIMIT

NATURAL WATER CONTENT

PLASTIC LIMIT

● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. 7.0 CENTIMETER O.D. SLOPE INDICATOR (SI) CASING. ANNULUS BACKFILLED WITH CEMENT BENTONITE GROUT (ABOUT 2.5 TO 34.7 METERS), 10-20 SAND (0 TO ABOUT 2.5 METERS). 20-CENTIMETER FLUSH MONUMENT INSTALLED.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 11/18/02 FINISH: 12/22/02
DRILLING TECHNIQUE: 0 to 6.2 m, Mud rotary; 6.2 to 34.7 m, PQ Wireline coring

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SUMMARY BORING LOG
LT-2 (1 OF 2)

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

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FIG. 5

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.2	RUN NO.	CORE RECV. %	GROUND WATER DEPTH	STANDARD PENETRATION TEST ▲ BLOWS PER 0.3 m 0 10 20 30 40	RQD %
		(continued from previous page)	R-12	96		21	96
		...bedding dipping 15-20°: 21.5 meters	R-13	100		22	100
0.7	23.5	VERY SOFT (R1), gray, slightly weathered to fresh, clayey SILTSTONE, moderately to highly jointed, predominantly at 45 to 65°, trace fossiliferous, trace micaceous (ASTORIA FORMATION) ...occasional slickensides with 80-90° rake: 24.7 to 29.0 meters	R-14	70		23 24	54
			R-15	24		25	0
			R-16	100			100
			R-17	67		26	67
			R-18	80		27	80
			R-19	100		28 SI CASING (SEE NOTE 3) 29	100
			R-20	100		30	100
			R-21	100		31	100
-7.5	31.7	SOFT (R2), gray, slightly weathered to fresh, silty fine SANDSTONE, slightly fractured to massive, fossiliferous, micaceous (ASTORIA FORMATION)	R-22	58		32 33	58
		...SOFT (R2) to MEDIUM HARD (R3), light gray, CLAYSTONE, tuffaceous: 33.8 to 34.4 meters	R-23	100		34	100
-10.5	34.7	Bottom of boring: 34.7 meters				35	

LEGEND

▨	0.051 m S.P.T. SAMPLE
*	SAMPLE NOT RECOVERED
**	BLOW COUNT PER 0.6 m
▯	0.076 m SAMPLE
U	0.076 m THIN WALL SAMPLE
P	PITCHER SAMPLE
▨	IMPERVIOUS SEAL
▼	WATER LEVEL
■	PIEZOMETER TIP
├─●─┤	LIQUID LIMIT NATURAL WATER CONTENT PLASTIC LIMIT
●	WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. 7.0 CENTIMETER O.D. SLOPE INDICATOR (SI) CASING. ANNULUS BACKFILLED WITH CEMENT BENTONITE GROUT (ABOUT 2.5 TO 34.7 METERS), 10-20 SAND (0 TO ABOUT 2.5 METERS). 20-CENTIMETER FLUSH MONUMENT INSTALLED.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 11/18/02 FINISH: 12/22/02
DRILLING TECHNIQUE: 0 to 6.2 m, Mud rotary; 6.2 to 34.7 m, PQ Wireline coring

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SUMMARY BORING LOG
LT-2 (2 OF 2)

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
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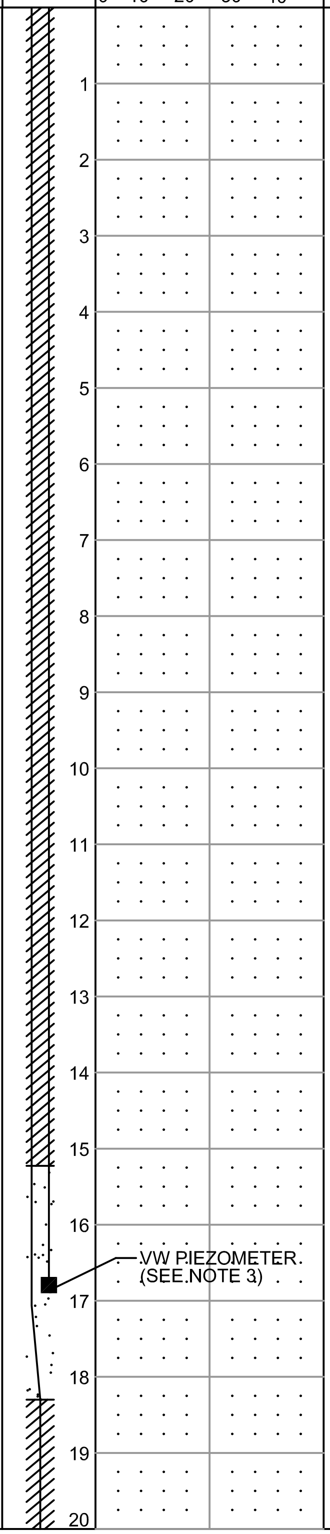
FIG. 5

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.5	SAMPLES NO.		SAMPLES **	GROUND WATER DEPTH	STANDARD PENETRATION TEST ▲ BLOWS PER 0.3 m 0 10 20 30 40
		Quick drill boring, see SUMMARY BORING LOG LT-2 for subsurface information.					
			1 2		U U		



LEGEND

- 0.051 m S.P.T. SAMPLE
- * SAMPLE NOT RECOVERED
- ** BLOW COUNT PER 0.6 m
- 0.076 m SAMPLE
- U 0.076 m THIN WALL SAMPLE
- P PITCHER SAMPLE
- IMPERVIOUS SEAL
- ▼ WATER LEVEL
- ■ PIEZOMETER TIP
- LIQUID LIMIT, NATURAL WATER CONTENT, PLASTIC LIMIT
- ● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. VIBRATING WIRE PIEZOMETERS, SLOPE INDICATOR COMPANY, MODEL 52611020, 350 kPa RANGE, S/N 75265 TIP AT 16.7 METERS; S/N 75266 TIP AT 24.7 METERS. LOCKING ABOVE GROUND MONUMENT INSTALLED.
4. 10-20 SILICA SAND SURROUND MATERIAL, BENTONITE CHIP SEAL.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 1/7/03 FINISH: 1/9/03
DRILLING TECHNIQUE: 0 to 6.1 m, Hollow Stem Auger, 0.20 m O.D.; 6.1 to 25.0 m, Mud Rotary with 0.10 m Tricone bit

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SUMMARY BORING LOG
LT-2P (1 OF 2)
JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
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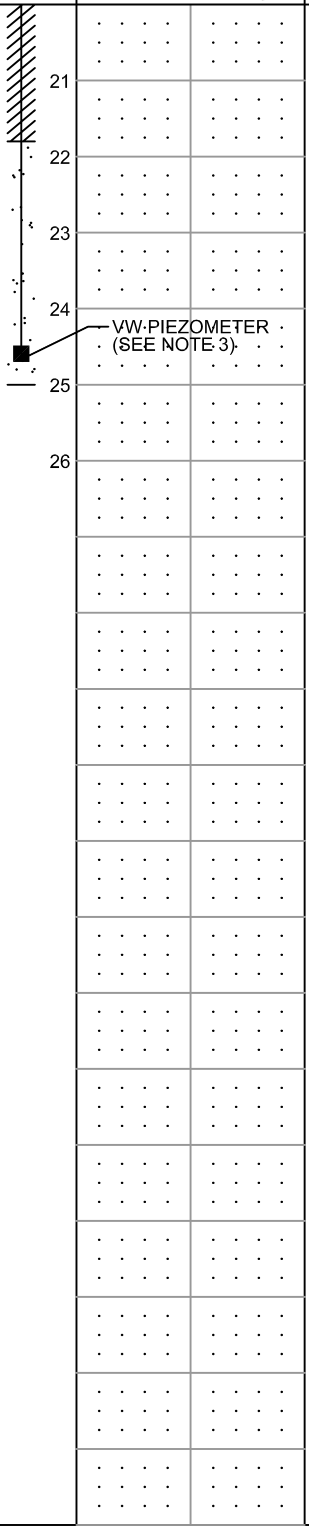
FIG. 6

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.5	SAMPLES NO.	SAMPLES **	GROUND WATER DEPTH	STANDARD PENETRATION TEST ▲ BLOWS PER 0.3 m 0 10 20 30 40
		(continued from previous page)				
-0.5	25.0	Bottom of boring: 25.0 meters				



LEGEND

- ▨ 0.051 m S.P.T. SAMPLE
- * SAMPLE NOT RECOVERED
- ** BLOW COUNT PER 0.6 m
- 0.076 m SAMPLE
- U 0.076 m THIN WALL SAMPLE
- P PITCHER SAMPLE
- IMPERVIOUS SEAL
- ▼ WATER LEVEL
- ■ PIEZOMETER TIP
- LIQUID LIMIT / NATURAL WATER CONTENT / PLASTIC LIMIT
- ● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. VIBRATING WIRE PIEZOMETERS, SLOPE INDICATOR COMPANY, MODEL 52611020, 350 kPa RANGE, S/N 75265 TIP AT 16.7 METERS; S/N 75266 TIP AT 24.7 METERS. LOCKING ABOVE GROUND MONUMENT INSTALLED.
4. 10-20 SILICA SAND SURROUND MATERIAL, BENTONITE CHIP SEAL.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 1/7/03 FINISH: 1/9/03
DRILLING TECHNIQUE: 0 to 6.1 m, Hollow Stem Auger, 0.20 m O.D.; 6.1 to 25.0 m, Mud Rotary with 0.10 m Tricone bit

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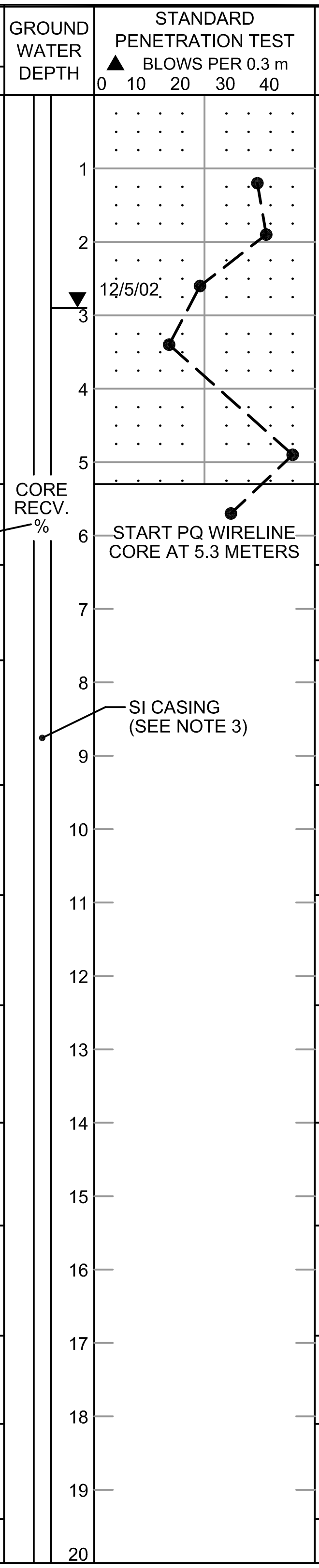
SUMMARY BORING LOG
LT-2P (2 OF 2)
JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

JUN 2003
PROJ. 1460
FIG. 6

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION	SAMPLES NO.	**	RQD %
		SURFACE ELEV. (m) 24.0			
		LOOSE, brown, clayey, silty, fine SAND; high organic content, rootlets, wood (FILL)	1	4	
22.7	1.3	LOOSE, brown to orange, slightly silty, fine to medium SAND; occasional coarse sand and gravel-sized siltstone fragments, minor iron-oxide stratification and induration (TERRACE SAND)	2	4	
			3	3	
			4	6	
		...increase in fines: 4.5 meters	5	9	
19.0	5.0	VERY SOFT (R1) to SOFT (R2), gray, moderately to highly weathered, sandy SILTSTONE; moderately to highly jointed, trace iron-oxide staining, trace fossiliferous (ASTORIA FORMATION)	6	20	
		RUN NO.	R-1	26	0
		...becoming slightly weathered to fresh, no iron-oxide staining: 6.4 meters	R-2	100	67
			R-3	98	94
15.0	9.0	SOFT (R2), gray, slightly weathered to fresh, silty fine SANDSTONE; moderately jointed, predominantly 50-70°, slickensides at 11.3 meters, fossiliferous, micaceous (ASTORIA FORMATION)	R-4	94	90
			R-5	100	100
11.6	12.4	VERY SOFT (R1) to SOFT (R2), gray, fresh, slightly sandy SILTSTONE; moderately to highly jointed, occasional slickensides with 80-90° rake, brecciated at 14.5 meters (ASTORIA FORMATION)	R-6	94	94
			R-7	100	98
7.8	16.2	SOFT (R2), gray, slightly weathered to fresh, silty fine SANDSTONE, moderately to highly jointed, predominantly at 60-70°, occasional slickensides with 80-90° rake, bedding about 15-17°, fossiliferous, micaceous (ASTORIA FORMATION)	R-8	92	70
			R-9	98	98
			R-10	100	100
		...becomes slightly fractured to massive: 19.4 meters	R-11	100	100



LEGEND

▨ 0.051 m S.P.T. SAMPLE

* SAMPLE NOT RECOVERED

** BLOW COUNT PER 0.6 m

0.076 m SAMPLE

U 0.076 m THIN WALL SAMPLE

P PITCHER SAMPLE

IMPERVIOUS SEAL

▼ WATER LEVEL

■ PIEZOMETER TIP

LIQUID LIMIT

NATURAL WATER CONTENT

PLASTIC LIMIT

● WATER CONTENT IN PERCENT

NOTES

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2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. 7.0 CENTIMETER O.D. SLOPE INDICATOR (SI) CASING. ANNULUS BACKFILLED WITH CEMENT BENTONITE GROUT (3.8 TO 28.7 METERS) AND 10-20 SAND (0 TO 3.8 METERS). 20-CENTIMETER FLUSH MONUMENT INSTALLED.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 11/22/02 FINISH: 11/27/02
DRILLING TECHNIQUE: 0 to 5.3 m, Mud rotary; 5.3 to 28.7 m, PQ Wireline coring

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SUMMARY BORING LOG
LT-3 (1 OF 2)

JOHNSON CREEK LANDSLIDE
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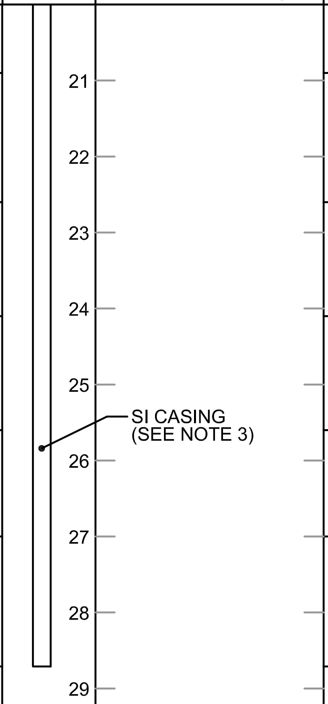
FIG. 7

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.0	RUN NO.	CORE RECV. %	RQD %
		(continued from previous page) ...increase in grain size to fine to medium sandstone: 20.7 to 21.0 meters	R-11 (con't)		
		...layer of SOFT (R2), light gray, CLAYSTONE to SILTSTONE, tuffaceous, bedding at 17-20°: 21.8 to 22.6 meters	R-12	92	85
		...increase in grain size to fine to medium sandstone: 22.9 to 23.8 meters	R-13	100	100
		...layer of SOFT (R2), light gray, CLAYSTONE to SILTSTONE, tuffaceous: 24.2 to 24.5 meters	R-14	86	86
		...layer of SOFT (R2), light gray, CLAYSTONE to SILTSTONE, tuffaceous, faint laminations: 26.5 to 26.8 meters	R-15	100	100
		...increase in grain size to fine to medium sandstone: 27.0 to 28.7 meters	R-16	93	87
-4.7	28.7	Bottom of boring: 28.7 meters			

GROUND WATER DEPTH

STANDARD PENETRATION TEST

▲ BLOWS PER 0.3 m



LEGEND

- ▨ 0.051 m S.P.T. SAMPLE
- * SAMPLE NOT RECOVERED
- ** BLOW COUNT PER 0.6 m
- 0.076 m SAMPLE
- U 0.076 m THIN WALL SAMPLE
- P PITCHER SAMPLE
- IMPERVIOUS SEAL
- ▼ WATER LEVEL
- ■ PIEZOMETER TIP
- LIQUID LIMIT
- NATURAL WATER CONTENT
- PLASTIC LIMIT
- ● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. 7.0 CENTIMETER O.D. SLOPE INDICATOR (SI) CASING. ANNULUS BACKFILLED WITH CEMENT BENTONITE GROUT (3.8 TO 28.7 METERS) AND 10-20 SAND (0 TO 3.8 METERS). 20-CENTIMETER FLUSH MONUMENT INSTALLED.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 11/22/02 FINISH: 11/27/02
DRILLING TECHNIQUE: 0 to 5.3 m, Mud rotary;
5.3 to 28.7 m, PQ Wireline coring

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SUMMARY BORING LOG LT-3 (2 OF 2)

JOHNSON CREEK LANDSLIDE
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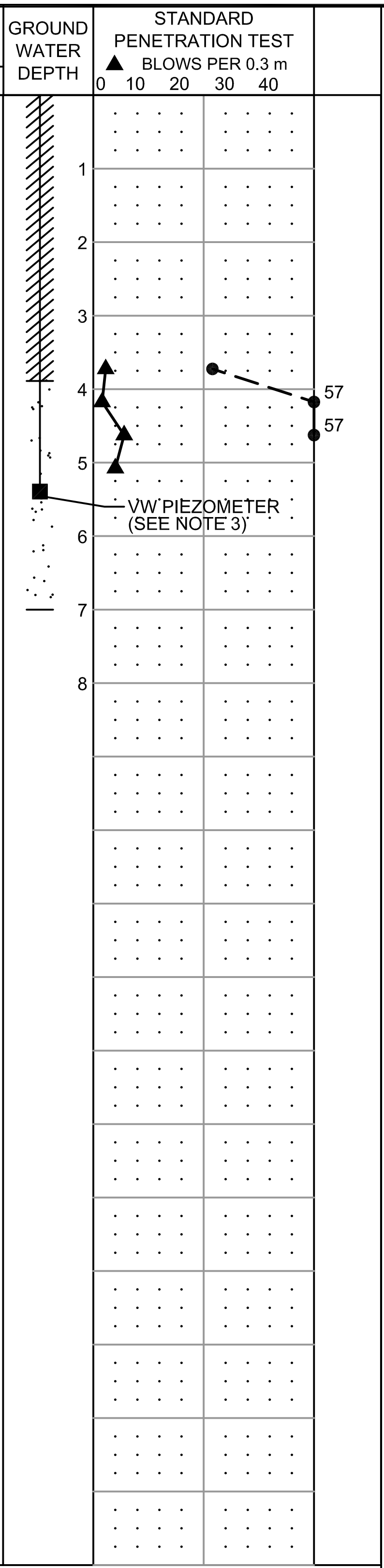
FIG. 7

ELEV.	DEPTH IN METERS	MATERIAL DESCRIPTION SURFACE ELEV. (m) 24.3	SAMPLES NO.	SAMPLES **
		Quick drill boring, SPT samples taken to define terrace sand thickness only, see SUMMARY BORING LOG LT-3 for material descriptions.		
			1 ▨	3
20.2	4.1	...TERRACE SAND unit thickness: 4.1 meters	2 ▨	2
			3 ▨	7
			4 ▨	5*
			5	U
			6	U
17.3	7.0	Bottom of boring: 7.0 meters		



LEGEND

▨ 0.051 m S.P.T. SAMPLE

* SAMPLE NOT RECOVERED

** BLOW COUNT PER 0.6 m

0.076 m SAMPLE

U 0.076 m THIN WALL SAMPLE

P PITCHER SAMPLE

IMPERVIOUS SEAL

▼ WATER LEVEL

■ PIEZOMETER TIP

LIQUID LIMIT

NATURAL WATER CONTENT

PLASTIC LIMIT

● WATER CONTENT IN PERCENT

NOTES

1. MATERIAL DESCRIPTIONS AND INTERFACES ARE INTERPRETIVE AND ACTUAL CHANGES MAY BE GRADUAL.
2. WATER LEVEL IS FOR DATE SHOWN AND MAY VARY WITH TIME OF YEAR.
3. VIBRATING WIRE PIEZOMETER, SLOPE INDICATOR COMPANY, MODEL 52611020, 350 kPa RANGE, S/N 75264, TIP AT 5.5 METERS. LOCKING ABOVE GROUND MONUMENT INSTALLED.
4. 10-20 SILICA SAND SURROUND MATERIAL, BENTONITE CHIP SEAL.

1460\BORINGS MWT

DRILLER: GEO-TECH EXPLORATIONS
DATE START: 1/6/03 FINISH: 1/7/03
DRILLING TECHNIQUE: Hollow Stem Auger, 0.20 m O.D.

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SUMMARY BORING LOG
LT-3P

JOHNSON CREEK LANDSLIDE
NEWPORT, OREGON

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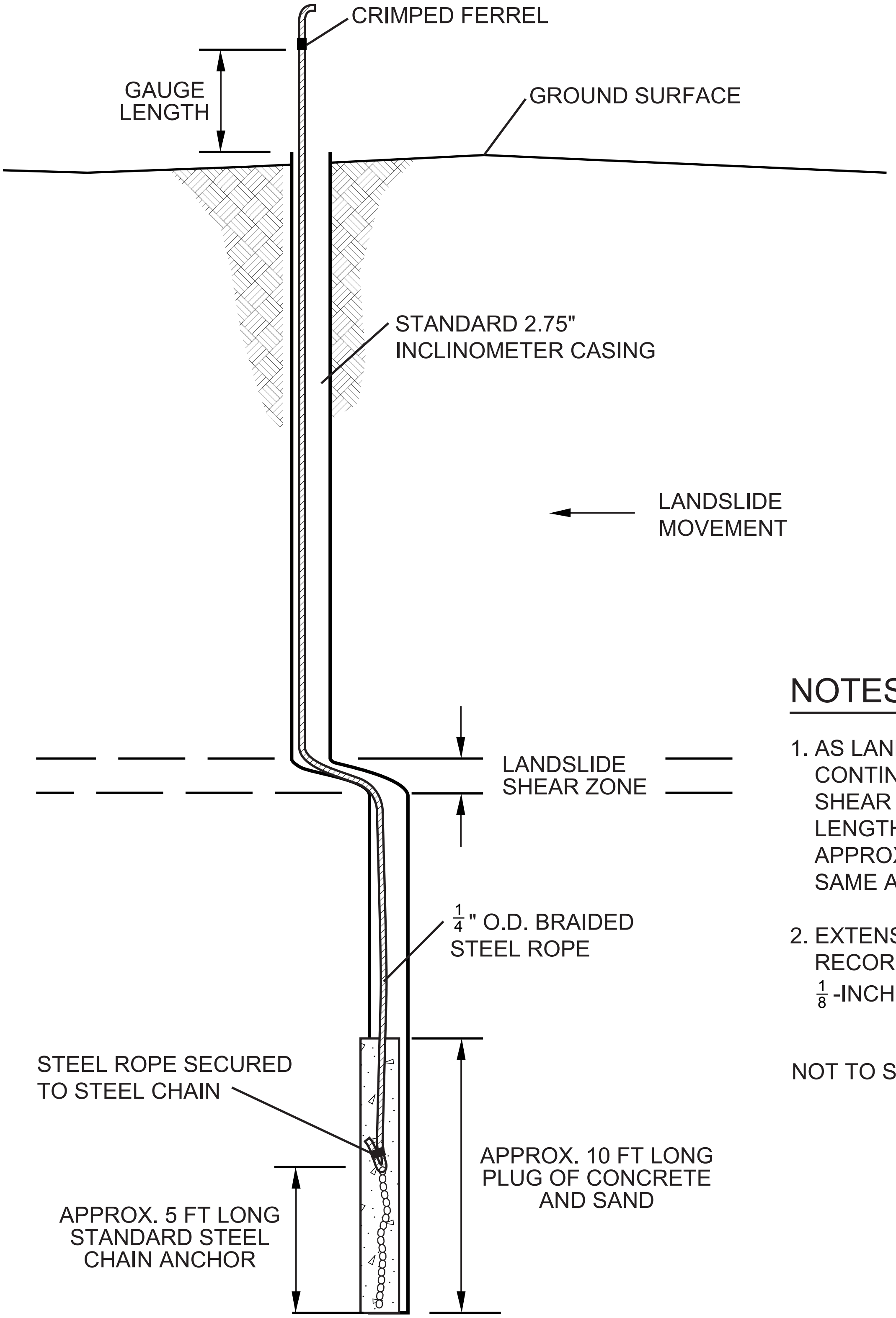
FIG. 8



NOTES:

1. AS LANDSLIDE MOVEMENTS CONTINUE ACROSS THE SHEAR ZONE THE GAUGE LENGTH WILL DECREASE APPROXIMATELY THE SAME AMOUNT.

2. EXTENSOMETER READINGS RECORDED TO THE NEAREST $\frac{1}{8}$-INCH.

NOT TO SCALE

1460\F09 MWT

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Phone 503-452-1200 Fax 503-452-1528

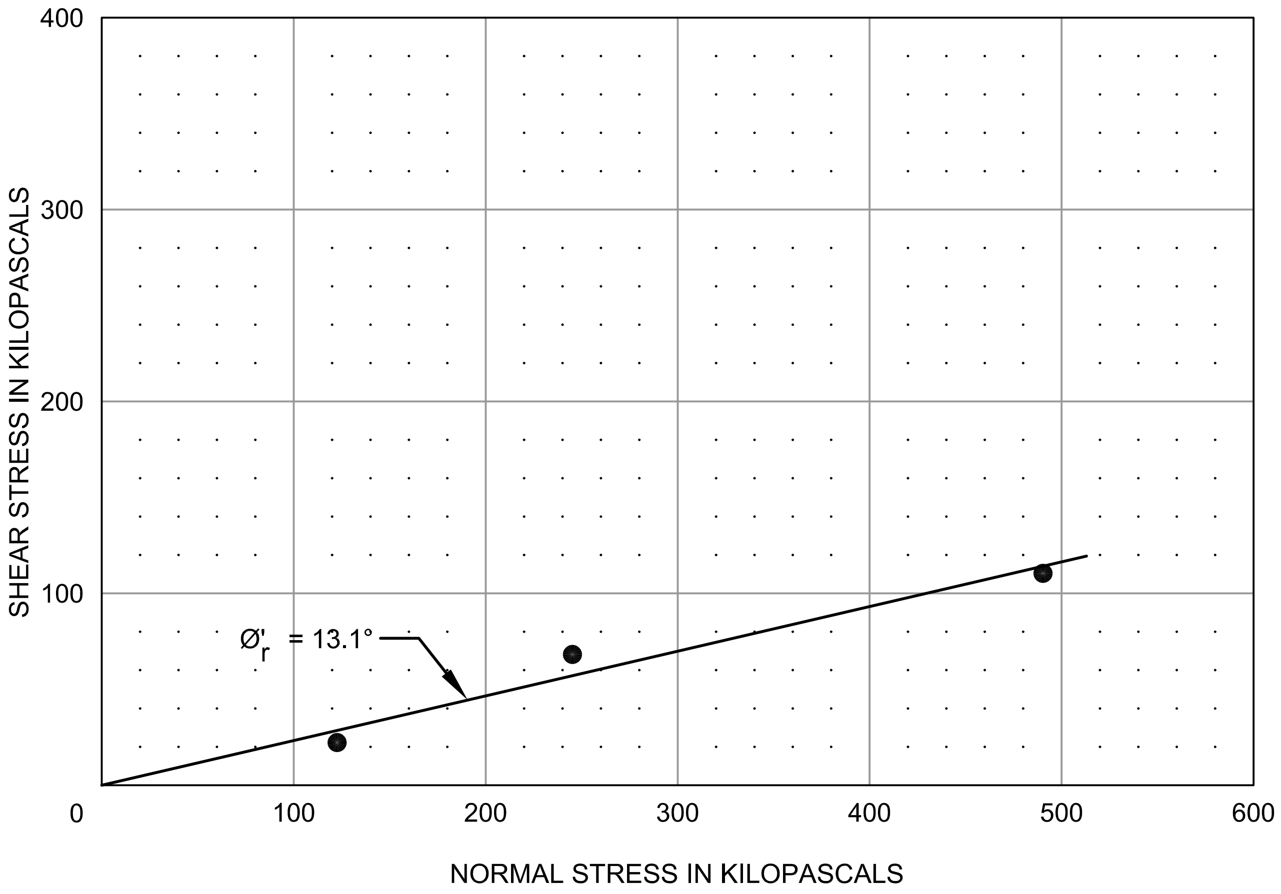
FIXED BOREHOLE EXTENSOMETER

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 9



Boring No. LT-2 Sample No. R-9 Depth of Sample 18.0 m (59.0 ft)

Soil Description SOFT, slightly clayey, sandy SILT

RESULTS:

● Remolded

RESIDUAL STRENGTH PARAMETERS:

c'_r = 0 kPa

$\text{Ø}'_r$ = 13.1°

1460\F10 MWT

CORNFORTH CONSULTANTS

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Portland, Oregon 97223
Phone 503-452-1100 Fax 503-452-1528

RING SHEAR TEST
MOHR STRENGTH ENVELOPE

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LINCOLN COUNTY, OREGON

JUN 2003

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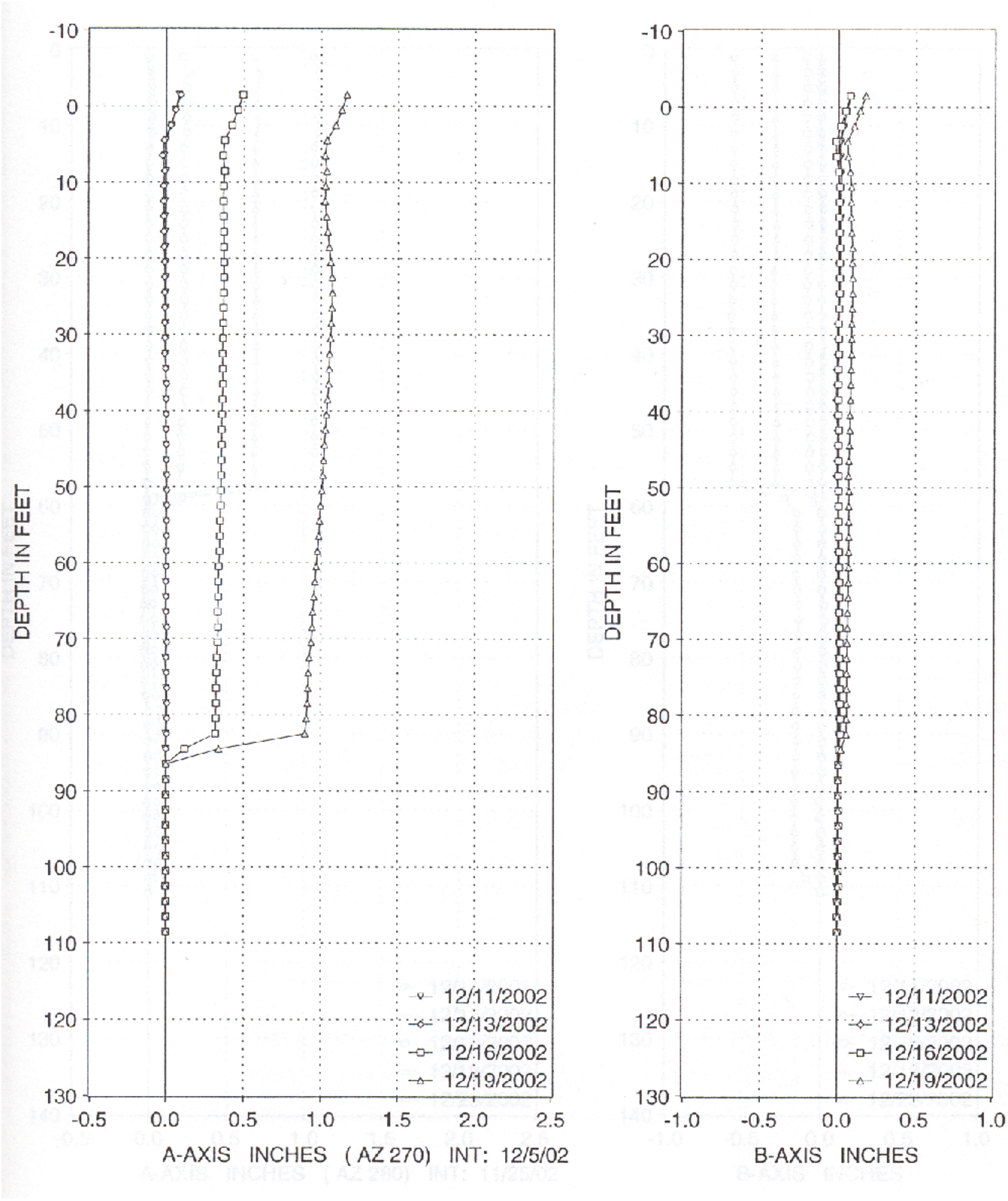
FIG. 10



1460\F11 MWT

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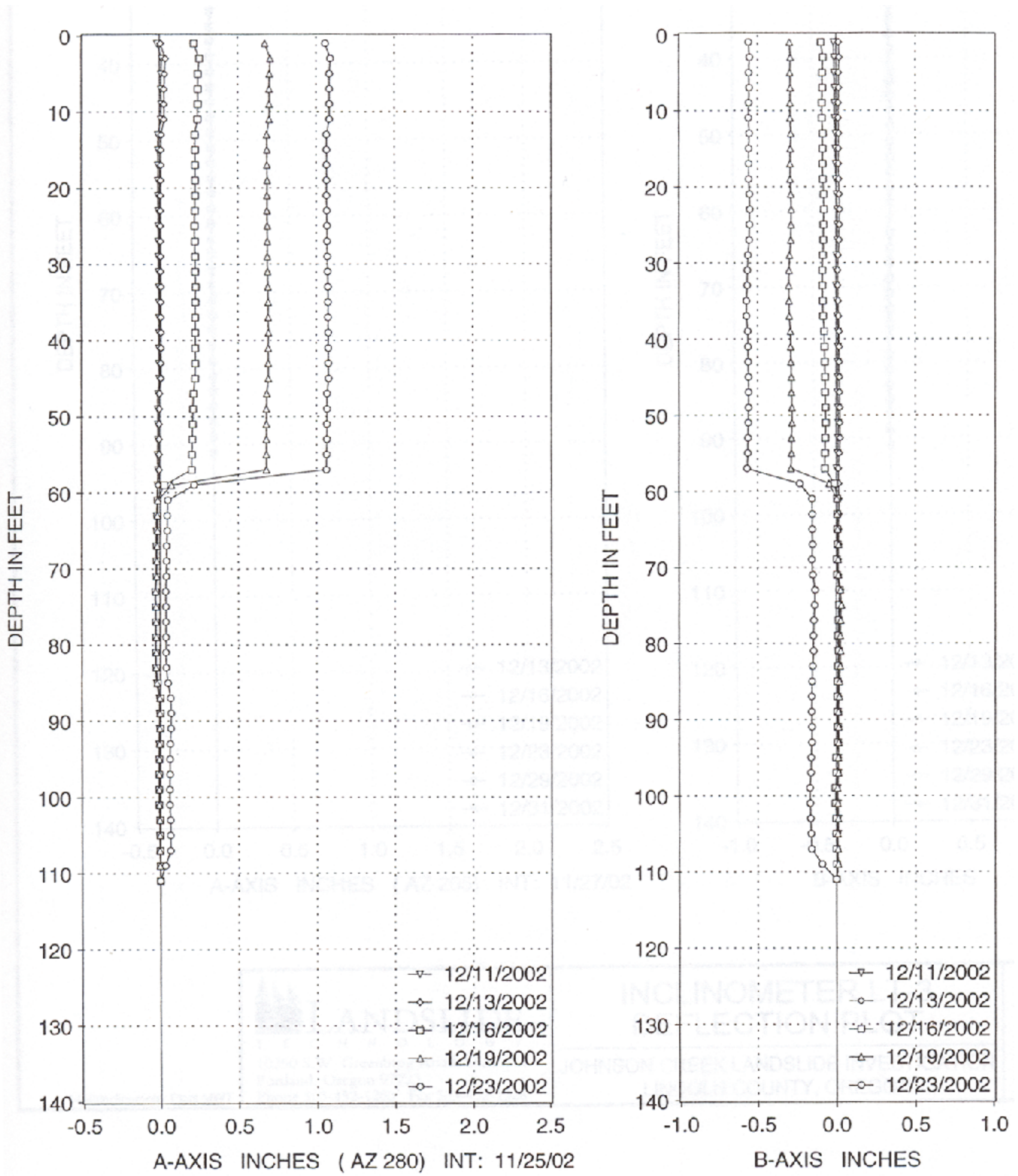
INCLINOMETER LT-1 DEFLECTION PLOT

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 11



1460\F12 MWT

LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

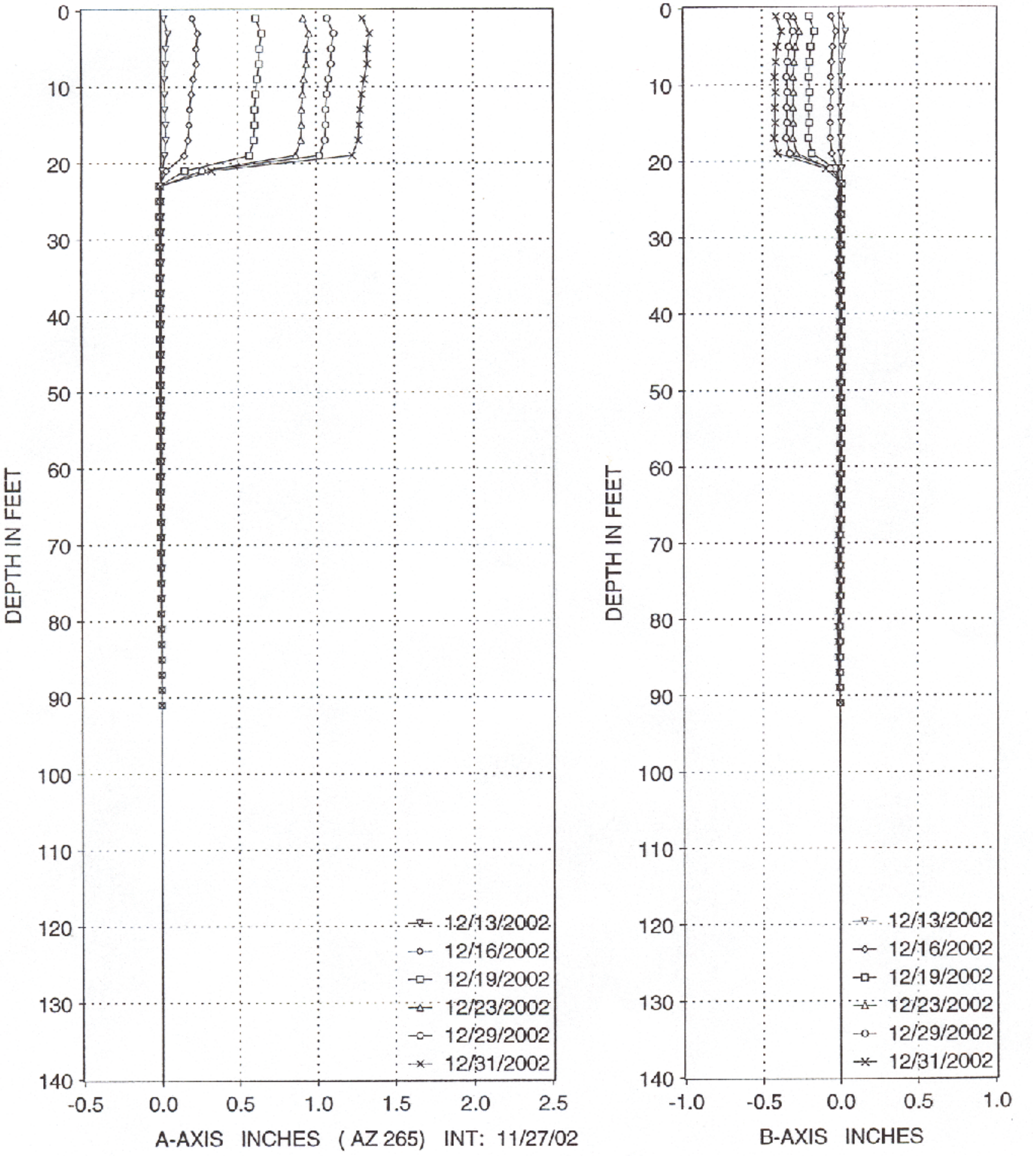
INCLINOMETER LT-2 DEFLECTION PLOT

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 12



1460\F13 MWT

LANDSLIDE TECHNOLOGY

10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

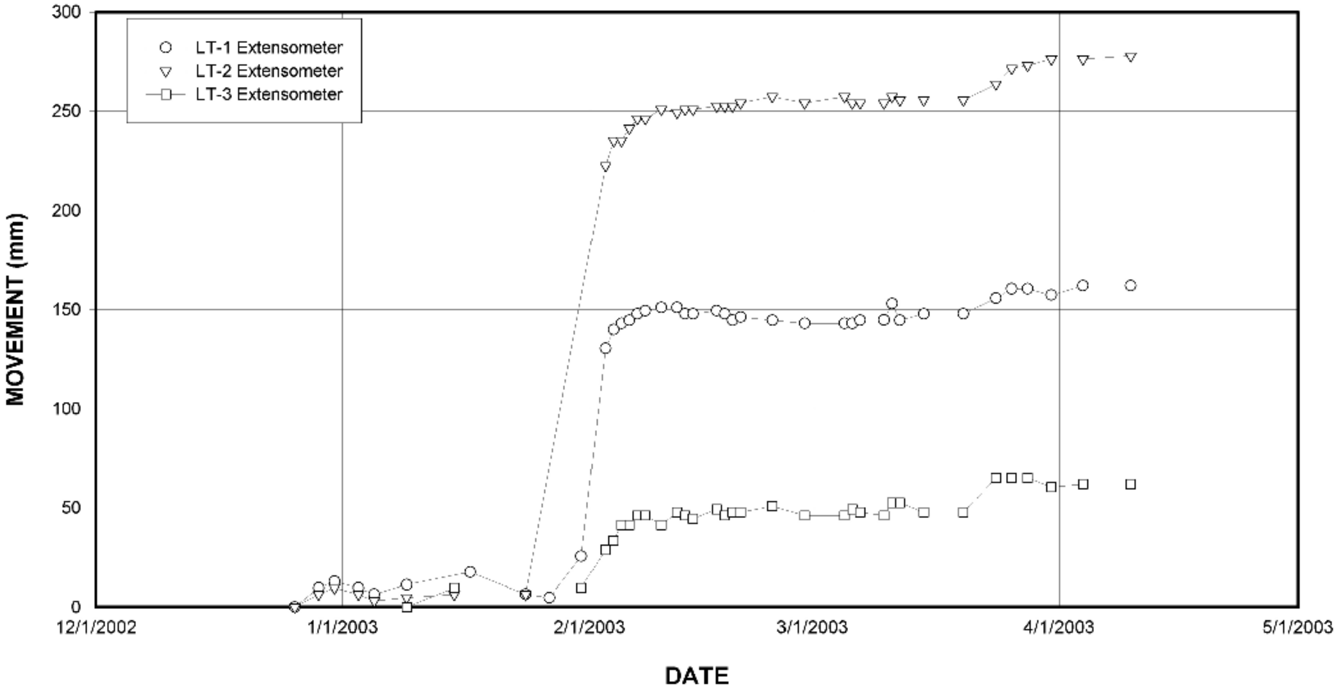
INCLINOMETER LT-3 DEFLECTION PLOT

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 13



1460\F14 MWT

LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

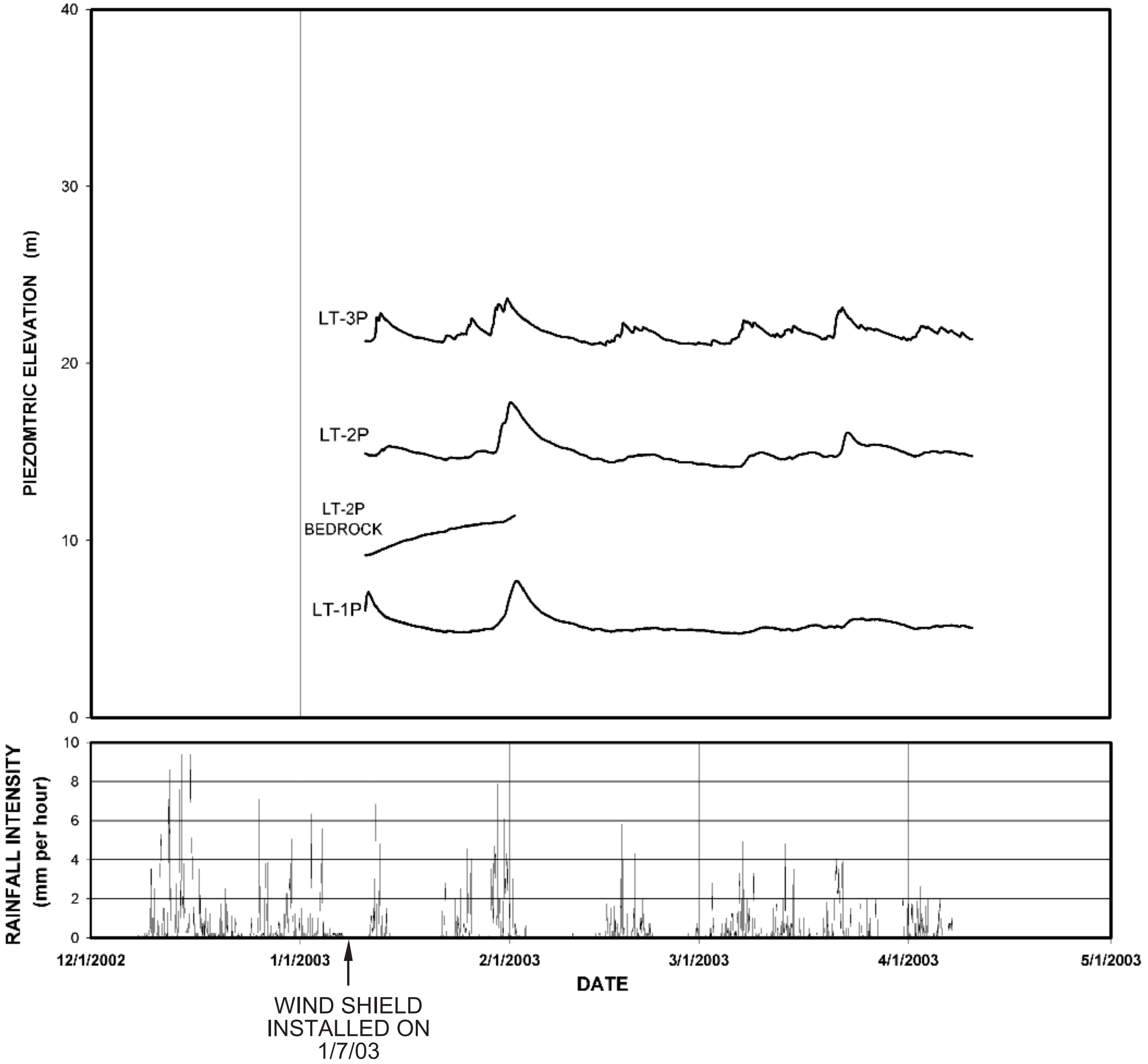
EXTENSOMETER MOVEMENT PLOT

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 14



LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

PIEZOMETERS AND PRECIPITATION PLOT

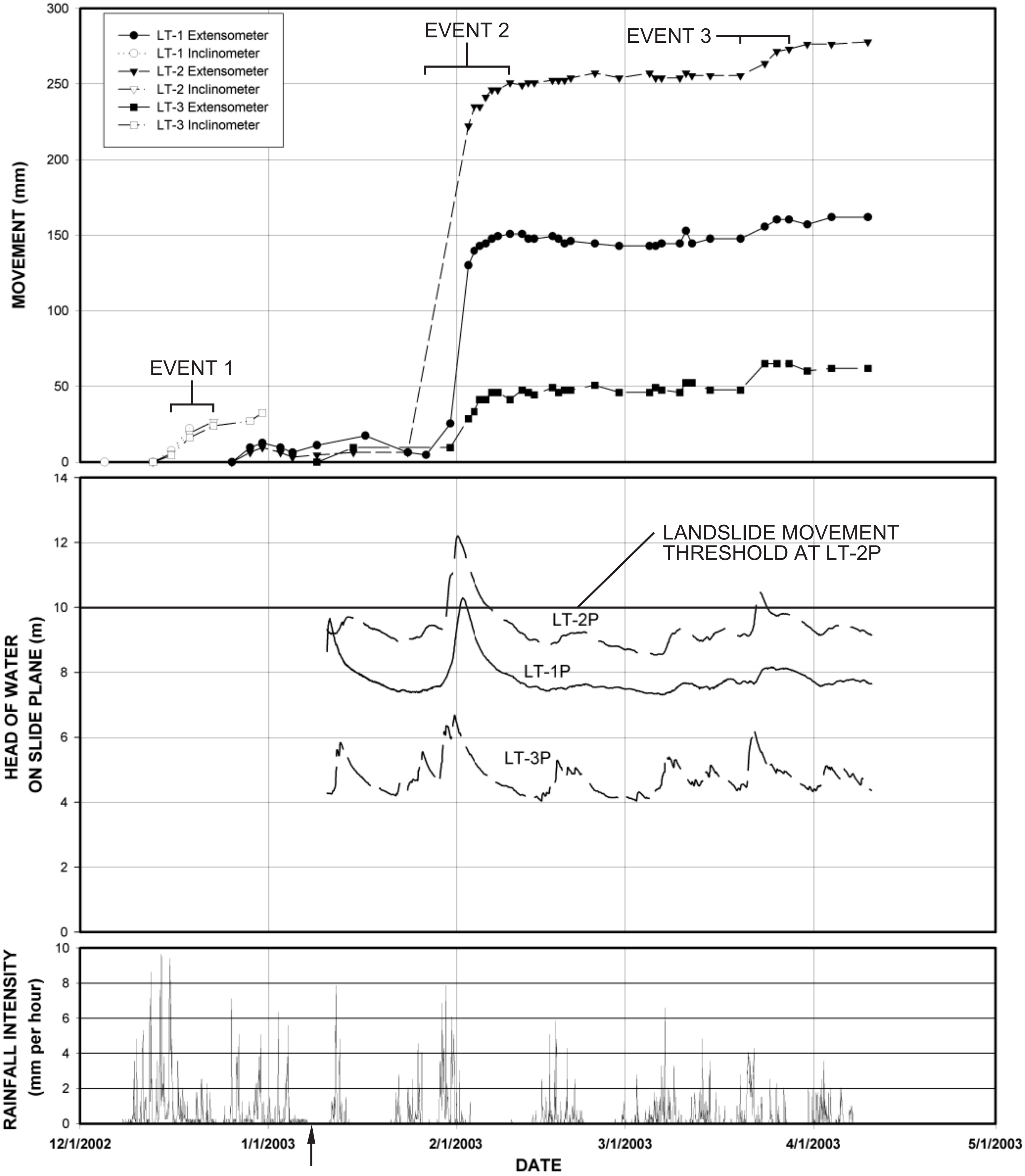
JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 15

1460\F15 MWT



WIND SHIELD
INSTALLED ON
1/7/03

LANDSLIDE
TECHNOLOGY

10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

SLIDE MOVEMENT, PIEZOMETERS AND PRECIPITATION PLOT

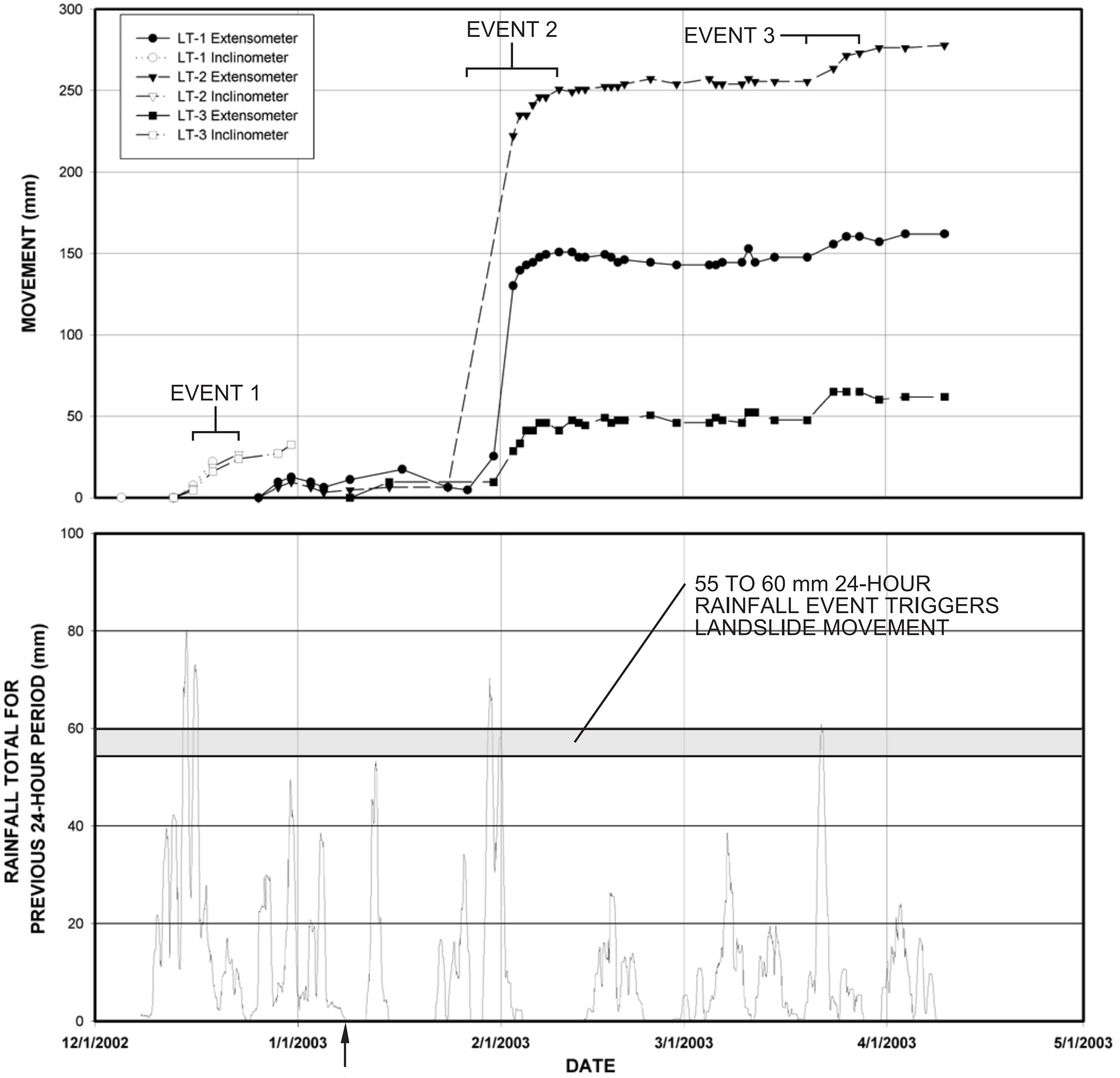
JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 16

1460\F16 MWT



WIND SHIELD
INSTALLED ON
1/7/03

LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

SLIDE MOVEMENT AND PRECIPITATION DURATION

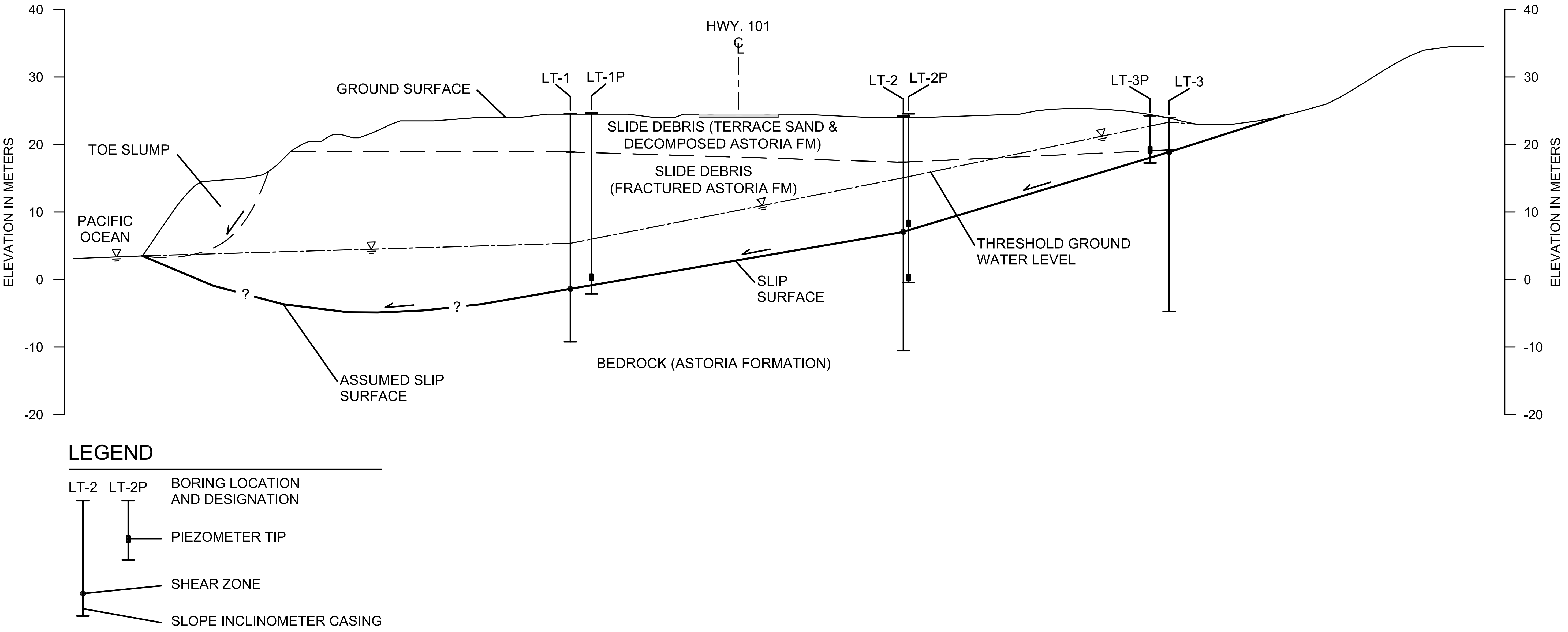
JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 17

1460\F17 MWT



VERTICAL DATUM: 1988 NAVD

0 10 20 40

SCALE IN METERS

(1:600)

1460\SECTIONS MWT

LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503/452-1200 Fax 503/452-1528

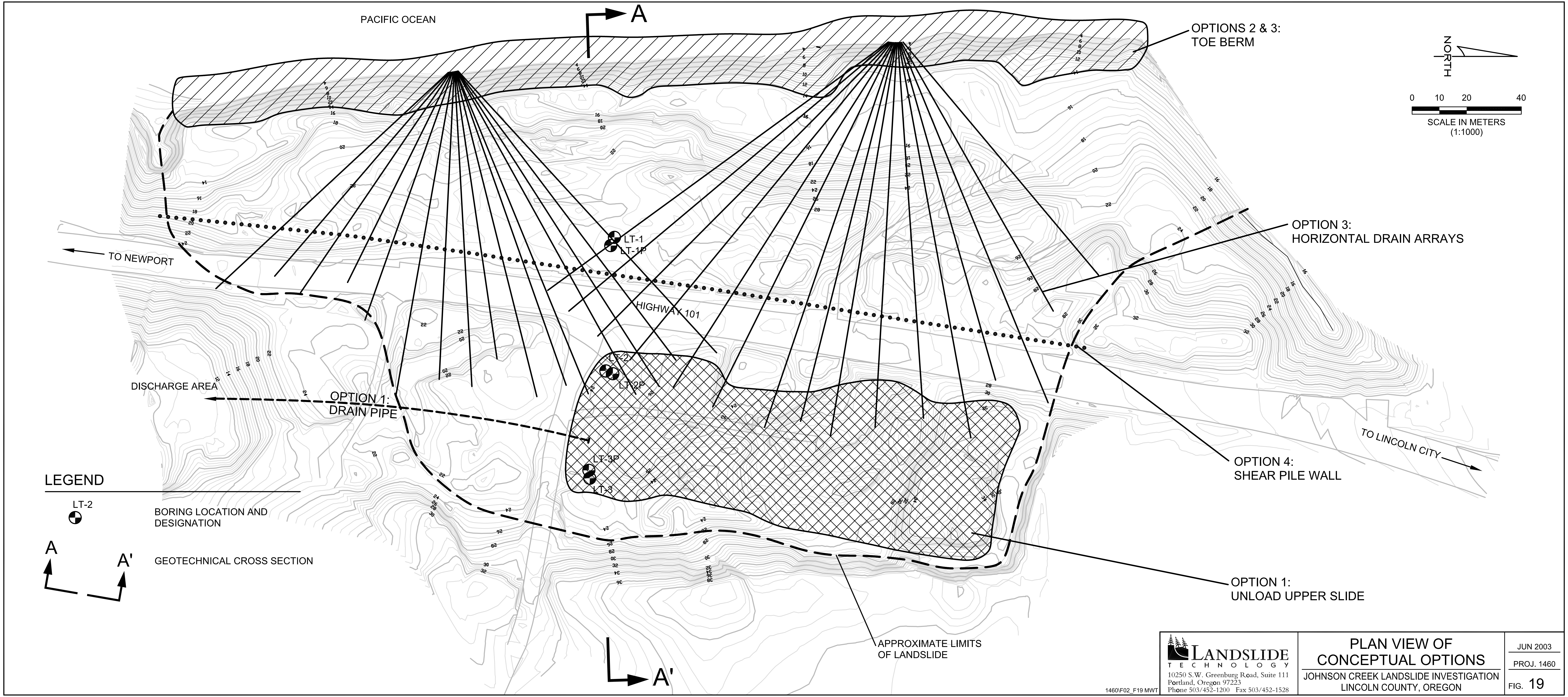
GEOTECHNICAL ANALYSIS
CROSS SECTION A-A'

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

PROJ. 1460

FIG. 18

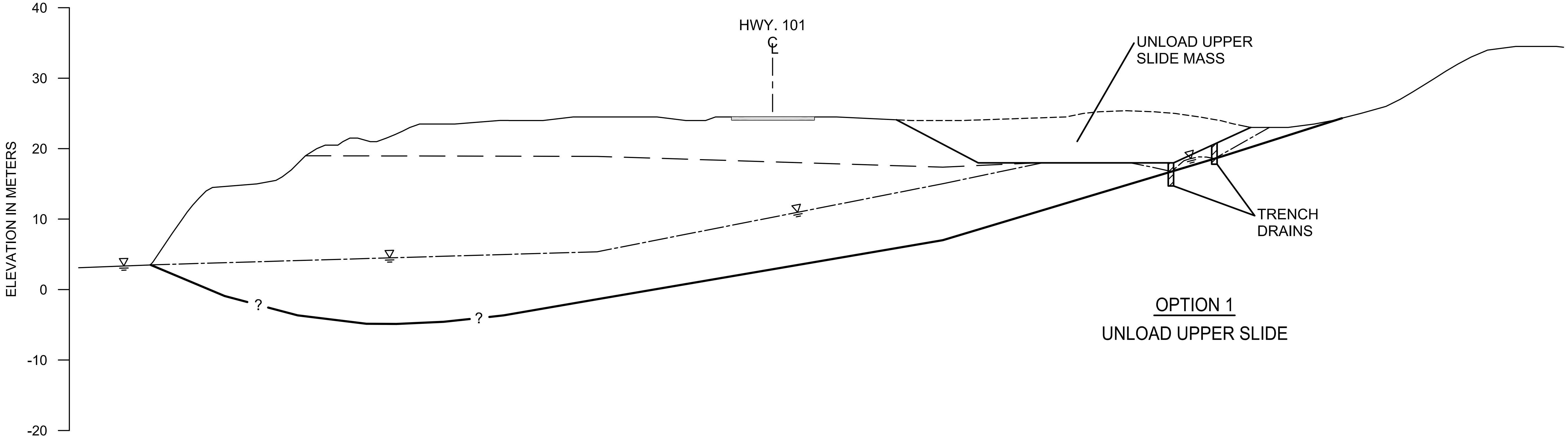


1460\F02_F19 MWT

LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503/452-1200 Fax 503/452-1528

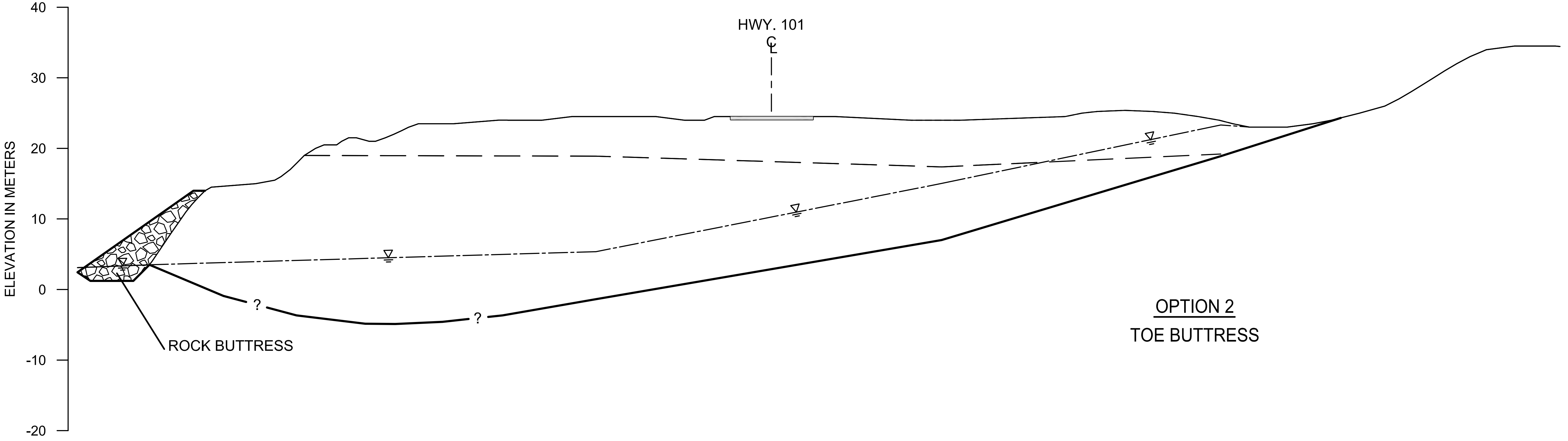
PLAN VIEW OF
CONCEPTUAL OPTIONS
JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003
PROJ. 1460
FIG. 19



OPTION 1

UNLOAD UPPER SLIDE



OPTION 2

TOE BUTTRESS

VERTICAL DATUM: 1988 NAVD

0 10 20 40

SCALE IN METERS
(1:600)

1460\SECTIONS MWT

LANDSLIDE
TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503/452-1200 Fax 503/452-1528

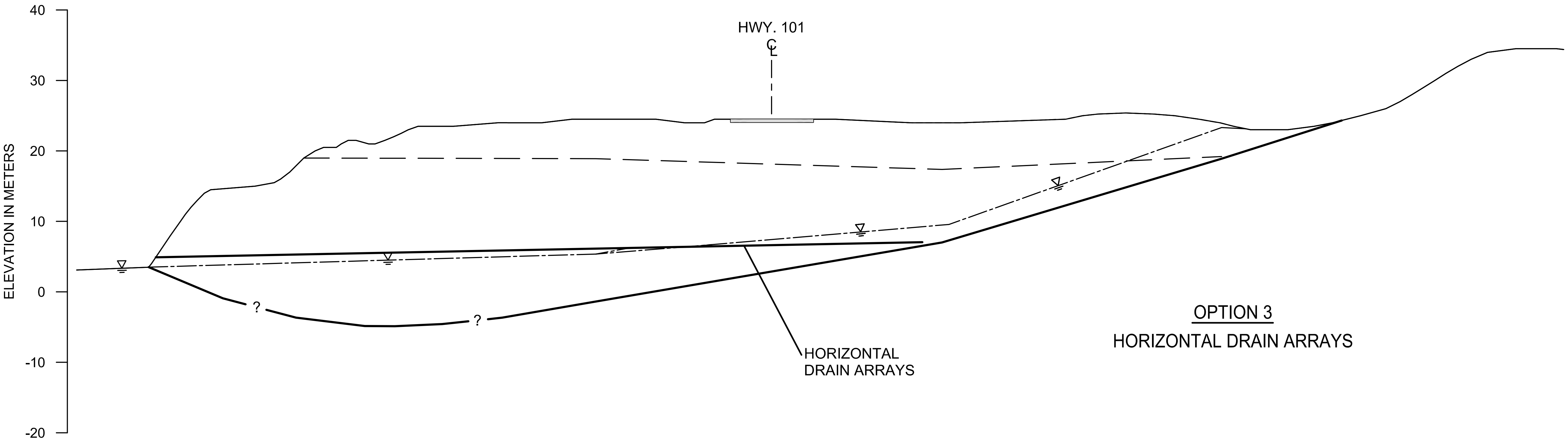
CONCEPTUAL OPTIONS 1 AND 2

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003

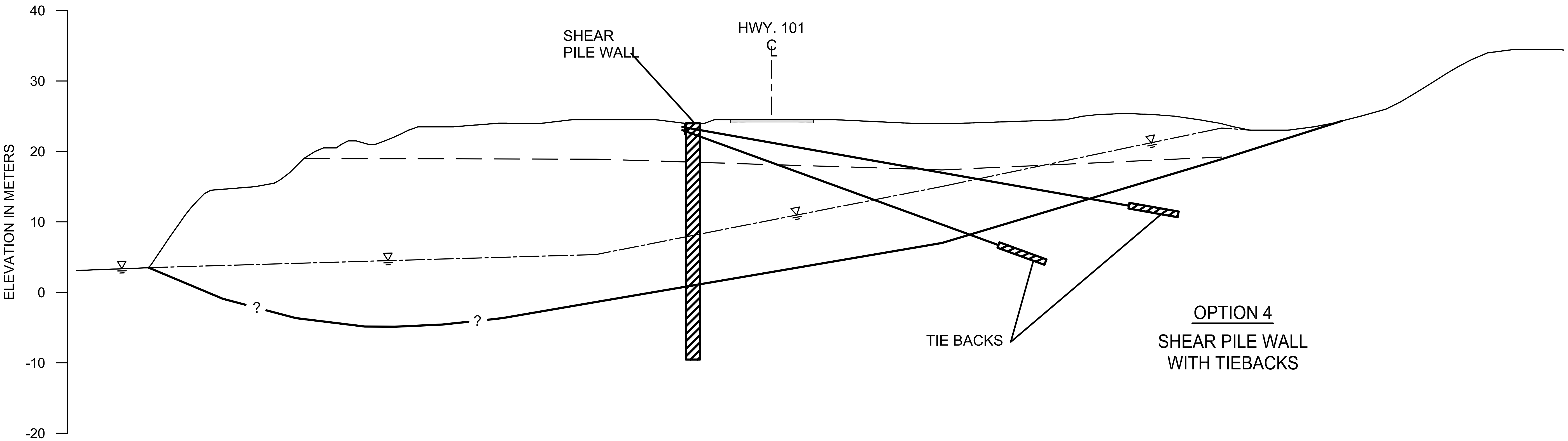
PROJ. 1460

FIG. 20



OPTION 3

HORIZONTAL DRAIN ARRAYS



OPTION 4

SHEAR PILE WALL WITH TIEBACKS

VERTICAL DATUM: 1988 NAVD

SCALE IN METERS
(1:600)

1460\SECTIONS MWT

LANDSLIDE TECHNOLOGY
10250 S.W. Greenburg Road, Suite 111
Portland, Oregon 97223
Phone 503/452-1200 Fax 503/452-1528

CONCEPTUAL OPTIONS 3 AND 4

JOHNSON CREEK LANDSLIDE INVESTIGATION
LINCOLN COUNTY, OREGON

JUN 2003
PROJ. 1460
FIG. 21

APPENDIX A

Previous Investigations

Johnson Cr. Landslide [illegible] Inclinometer logs

P 749

FORM 81-734-3030

OREGON STATE HIGHWAY DIVISION
INTER-OFFICE CORRESPONDENCE

FILE:

Jan. 9, 1988

FROM: Robert H. West

SUBJECT: Johnson Cr. Slide
HWY #9 - MP. 133.3
Lincoln County

TO: Memo to File

The slope meter tubes on the above slide have fulfilled their need & have been abandoned. The following chart gives the basic data obtained from the tubes.

Grnd. ele.	Tube No.		Elev. of Slip Plane	Elev. of Water Table			
+ 72.77'	72-1		45'	20'	(-53')	below	surf
+ 67.0'	73-1	Pinched off at -55'	15'	--			
+ 70.98'	76-1		37'	60'	(-11')	"	"
+ 83.0'	76-2	ok (Pinched off at -64').	~~6'~~ (+12')	34'	(-49')	"	"
+ 85.0'	76-3		7' ?	18'	(-66')		
+ 87.0'	76-4		2'	48'	(-39')	"	"

76-2

72	73	83	83
37	45	12	36
35	28'	71'	47'

73 10'

Oregon State Highway Division
SOILS AND GEOLOGICAL EXPLORATION LOG

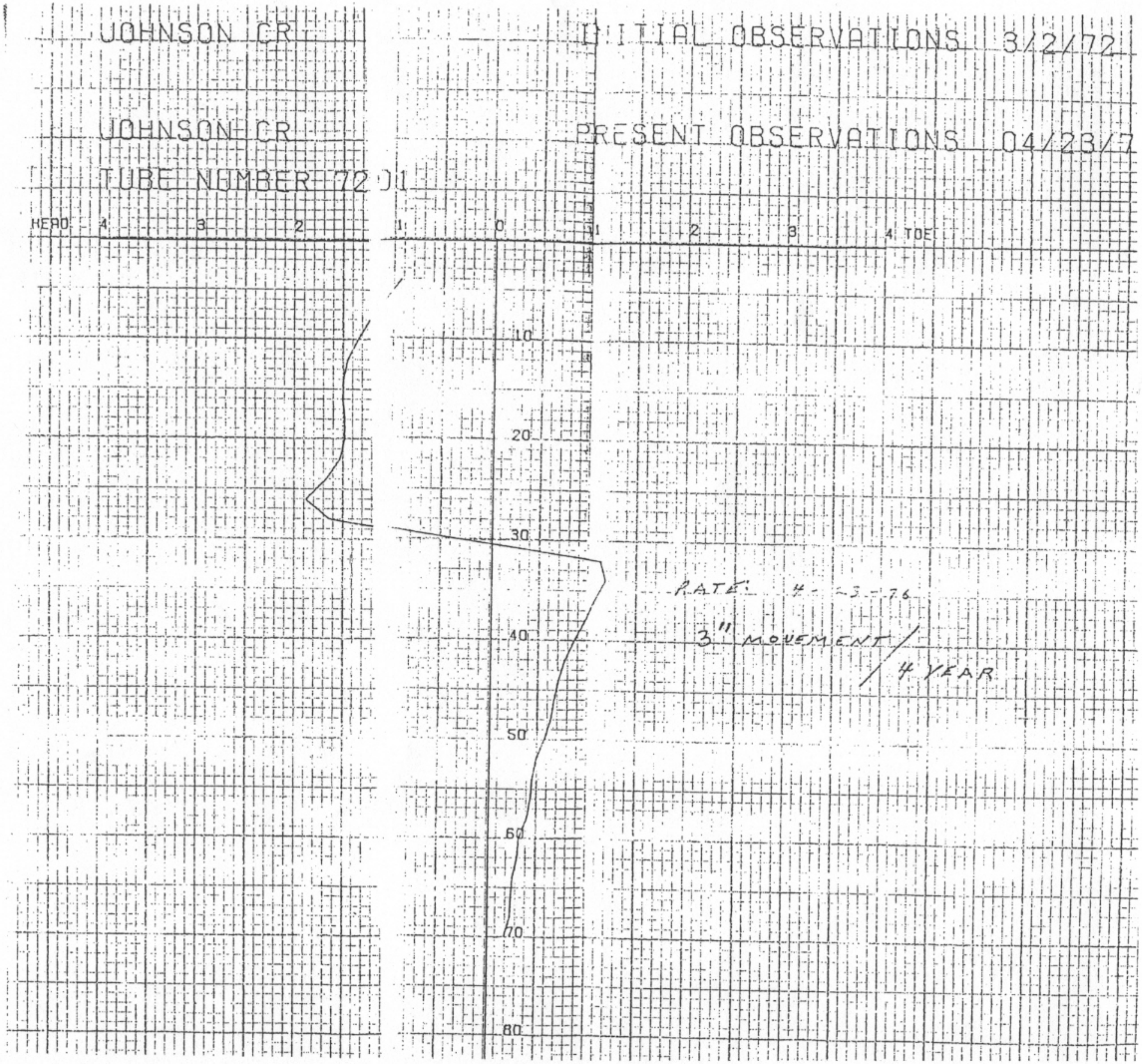
Project JOHNSON CREEK SLIDE Date FEB. 24, 1972
Highway OREGON COAST - #9 County LINCOLN
Hole Location WEST SIDE of EXISTING HWY Prefix 21-4419-144
Engineer H. H. PATTERSON Driller R. PRODZINSKI Recorder R. WEST
Equipment Used 4" MOBILE AUGER & 2" SPLIT-TUBE SAMPLER
Depth 70' Station "L" 15+01 @ 19' RT. of STAKES Ground Elev. APT. 73
Purpose of Work SLIP PLANE Water Level at Completion
Drive sampler OD 2" ID Hammer wt 140# Fall 30" Hole No. 72-1

Depth Sampled		Driving Resistance Blows/6 in.	% Moisture	% Recovery	Depth FT.	Description Color Plastic Wet-Dry Soft-Hard % Water Return Fresh-Weathered Joints, Spacing Broken % Gravel, Sand, Silt and Clay
From	To					
					0	COARSE TAN BEACH SAND.
					3	
4	6	3-2-3-3	87	100		PEAT
					13	
15	17	2-2-2-2	30	100		SOFT, WEATHERED SHALE AND UNCONSOLIDATED SAND WITH CLAY BINDER. MOSTLY FELDSPAR WHICH IS WEATHERING TO KAOLINITE. $(AL_2O_3 \cdot 2SiO_2 \cdot 2H_2O)$
					17	RUST COLORED SANDY CLAY. MOIST TO DRY.
					23	FIRM DRY GRAY SHALE WITH LENSES of RUST.
					49	HARD DRY GRAY SANDY SHALE.
					70	

JOHNSON CR INITIAL OBSERVATIONS 3/2/72

JOHNSON CR PRESENT OBSERVATIONS 04/23/7

TUBE NUMBER 7201



RATE: 4-23-76

3" MOVEMENT / 4 YEAR

[illegible] read in
1973; pinched off at 55' when read at 1976 relog. Inclin. gage
Lost.

Oregon State Highway Division

SOILS AND GEOLOGICAL EXPLORATION LOG

Project JOHNSON CREEK SLIDE Date MAR. 20, 1973
Highway OREGON COAST County LINCOLN
Hole Location WEST SIDE of HWY Prefix 21-4419-144
Engineer H. H. PATTERSON Driller PRODZINSKI Recorder PRODZINSKI
Equipment Used 4" MOBILE AUGER
Depth 95' Station M.P. 133.26 Ground Elev.
Purpose of Work SLIP PLANE Water Level at Completion
Drive sampler OD ID Hammer wt Fall Hole No. 73-1

Depth Sampled		Driving Resistance Blows/__in.	% Moisture	% Recovery	Depth FT.	Description: Color, Plastic, Wet-Dry, Soft-Hard, % Water Return; Fresh-Weathered, Joints, Spacing, Broken, % Gravel, Sand, Silt and Clay
From	To					
					0	BROWN - GRAY MOIST CLAY.
					5	
						BROWN - BUFF BEACH SAND. WET AT 10'.
					16	GRAY PEATY PLASTIC SANDY CLAY.
					21	FIRMER SANDY CLAY. PLASTIC - BROWN - GRAY.
					28	FIRM GRAY CLAY.
					42	
						HARD GRAY CLAY.
					95	END OF HOLE

OREGON STATE HIGHWAY DIVISION

SOILS AND GEOLOGICAL EXPLORATION LOG

Project JOHNSON CR. SLIDE M.P. 133.3 Date 7-13-76
Highway #9 - OREGON COAST County LINCOLN Bridge No.
Hole Location 100' EAST SIDE of HWY. Prefix 21-4419-181
ation Ground Elev. Depth 70'
Purpose of work SLIP PLANE & MAT'L TYPE.
Engineer FRETWELL Depth to free water
Driller PRODZINSKI Water level at completion
Recorder WEST
Test: ☐ Auger depth ☒ Diamond core barrel depth 0' - 70'
☐ Split barrel sampler: 2" O.D., 144# Hammer, 30" Fall; Depth
☐ Miniature pile: 5' Probe, 400# Hammer, 30" Fall; Depth

H. D. Sheet No. Test: Hole No. 76-1

DEPTH TESTED From - To	DRIVING RESISTANCE BLOWS/___ in.	% MOISTURE	MEASURED RECOVERY (FT.)	LENGTH OF CORE RUN (FT.)	% CORE RECOVERY	DEPTH (Ft.)	GRAPHIC LOG	MATERIAL DESCRIPTION COLOR FRESH-WEATHERED PLASTICITY JOINTS-BROKEN WET-DRY SAND-SILTY-CLAY SOFT-HARD ORGANIC CONTENT
0 - 19			1	19		0'		MULTICOLOR CLAYEY FINE SAND.
						19		
19 - 25			0	6				GRAY CLAY SHALE, BROKEN. NO
								RECOVERY.
						25		
25-30			1	5				GRAY CLAY SHALE. BADLY FRACTURED
-35			4	5				SHORT PIECES. SHALES ARE OF ASTORIA
						34		FORMATION TYPE.
								SAME MAT'L. CRUSH ZONE.
						35		
35- 40			4.6	5				SAME MAT'L. BROKEN ZONE.
						36		
								SAME MAT'L. CRUSH ZONE.
						38		
								SAME MAT'L. BROKEN ZONE.
						39		
								SAME MAT'L. CLAY ZONE.
						41		
40 - 45			5	5	100			SAME MAT'L. BROKEN ZONE.
						43		
								SAME MAT'L. CLAY ZONE.
						45		
45-50			5	5	100			SAME MAT'L. BROKEN ZONE.
						48		
								HARD, SOLID GRAY CLAY SHALE.
50-55			5	5	100			THIN CLAY SEAMS AT 52' & 54'.
								NO OTHER PROBLEMS.
						58		
								SAME MAT'L. THIN CLAY SEAMS
								AND CRUSHED ZONE.
			5	5	100	60		
55-60								

OREGON STATE HIGHWAY DIVISION

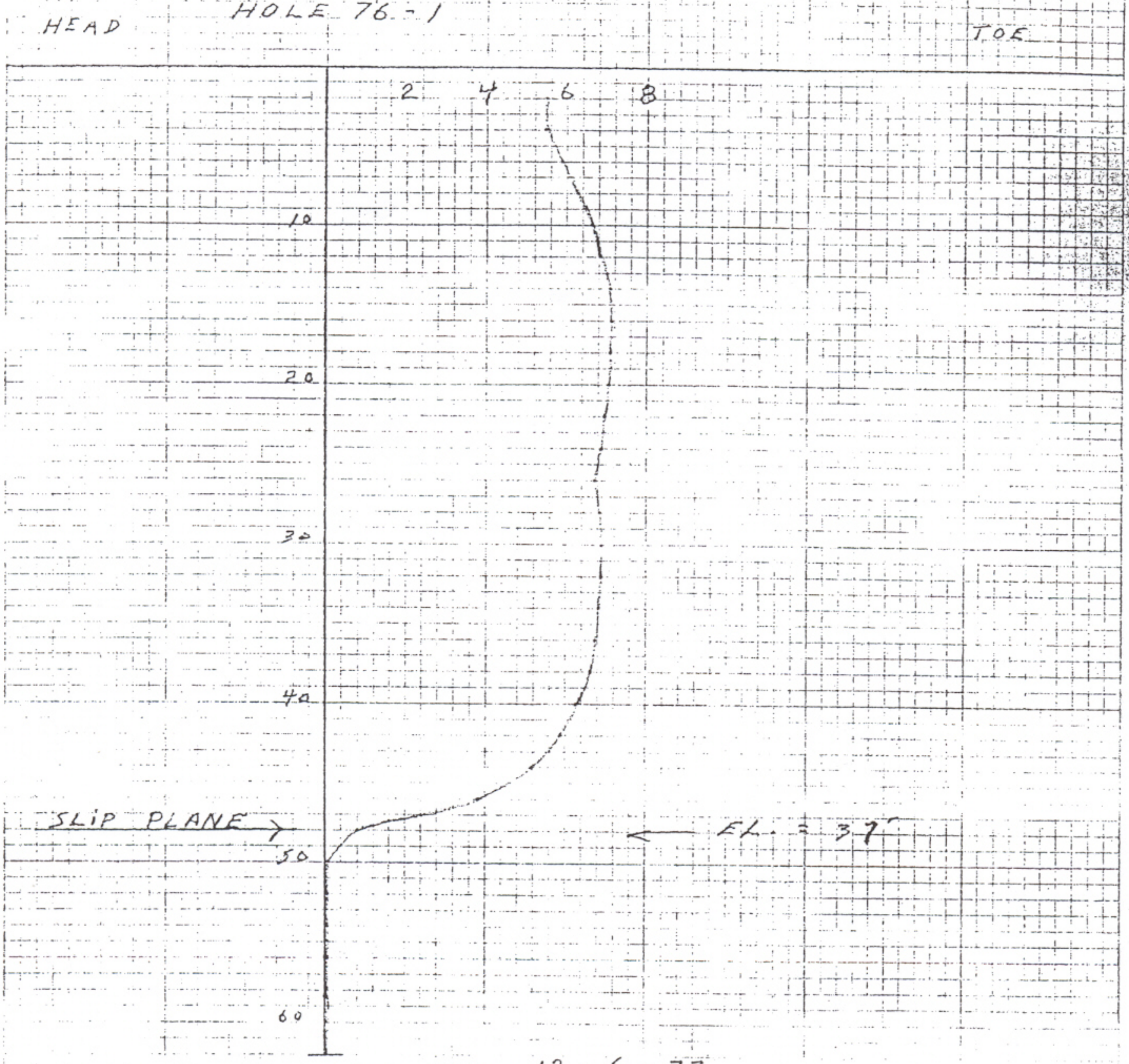
SOILS AND GEOLOGICAL EXPLORATION LOG

Project JOHNSON CR. SLIDE Date 7-13-76
Highway #9 - OREGON COAST County LINCOLN Bridge No.
Hole Location 100' EAST OF HWY Prefix 21-4419-181
Station Ground Elev. Depth 70'
Purpose of work SLIP PLANE & MAT'L TYPE
Engineer FRETWELL Depth to free water
Driller PRODZINSKI Water level at completion
Recorder WEST
Test: ☐ Auger depth ☒ Diamond core barrel depth 0 - 70'
☐ Split barrel sampler: 2" O.D., 144# Hammer, 30" Fall; Depth
☐ Miniature pile: 5' Probe, 400# Hammer, 30" Fall; Depth

H. D. Sheet No. Test: Hole No. 76-1 CON'T

DEPTH TESTED From - To	DRIVING RESISTANCE BLOWS/___ in.	% MOISTURE	MEASURED RECOVERY (FT.)	LENGTH OF CORE RUN (FT.)	% CORE RECOVERY	DEPTH (Ft.)	GRAPHIC LOG	MATERIAL DESCRIPTION COLOR / FRESH-WEATHERED PLASTICITY / JOINTS-BROKEN WET-DRY / SAND-SILTY-CLAY SOFT-HARD / ORGANIC CONTENT
						60		
								SAME MAT'L. SOLID CORE.
						64		
60-65			5	5	100			SAME MAT'L. CRUSHED ZONE.
						67		
								SAME MAT'L. SOLID CORE BUT WITH SLICKENSIDES ON FRACTURES AT 69' AND 70' DEPTHS.
65-70			5	5	100	70		
								END OF HOLE

JOHNSON CR. SLIDE



12 - 6 - 77

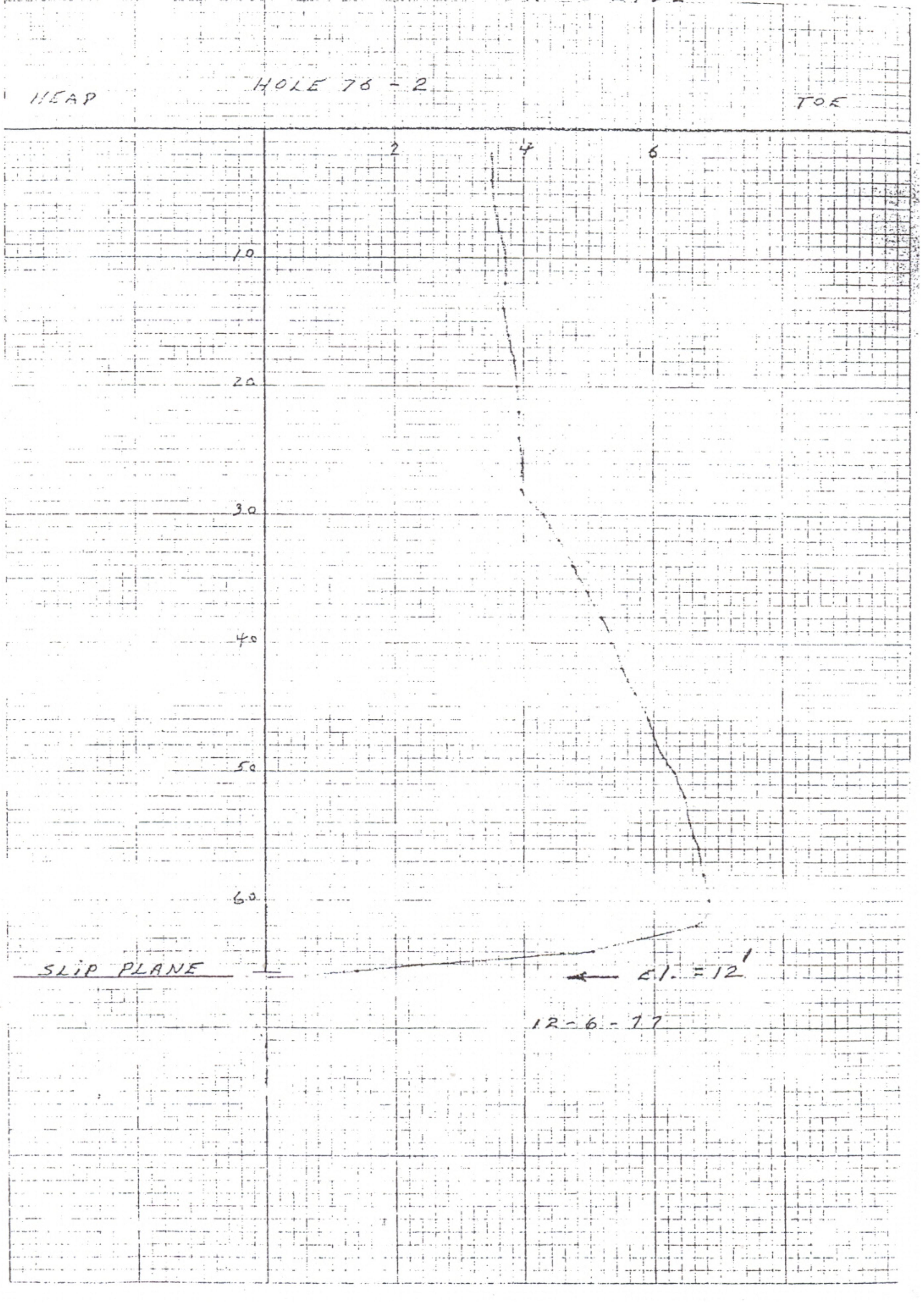
OREGON STATE HIGHWAY DIVISION
SOILS AND GEOLOGICAL EXPLORATION LOG

Project JOHNSON CREEK SLIDE M.P. 133-3 Date 7-15-76
Highway #9 - OREGON COAST County LINCOLN Bridge No.
Hole Location ON OLD 101 Prefix 21-4419-181
Station Ground Elev. Depth 20'
Purpose of work SLOPE METER TUBE
Engineer FREIWELL Depth to free water
Driller PRODZINSKI Water level at completion DRY
Recorder PRODZINSKI,
Test: ☒ Auger depth 20' - 70' ☐ Diamond core barrel depth
☒ Split barrel sampler: 2" O.D., 144# Hammer, 30" Fall; Depth 0 - 20'
☐ Miniature pile: 5' Probe, 400# Hammer, 30" Fall; Depth

H. D. Sheet No. Test: Hole No. 76-2

DEPTH TESTED From – To FT.	DRIVING RESISTANCE BLOWS/6 in.	% MOISTURE	MEASURED RECOVERY (FT.)	LENGTH OF CORE RUN (FT.)	% CORE RECOVERY	DEPTH (Ft.)	GRAPHIC LOG	MATERIAL DESCRIPTION COLOR, PLASTICITY, WET-DRY, SOFT-HARD, FRESH-WEATHERED, JOINTS-BROKEN, SAND-SILTY-CLAY, ORGANIC CONTENT
						0		
								A/C AND ROCK.
						1		
								RUSTY COLORED MOIST SANDY CLAY. PLASTICITY INCREASE WITH DEPTH.
						6		
8½-10	11-17-24							BROWN-GRAY MULTICOLOR SANDY CLAY. MOIST & FIRM.
						10		
14-15	17-25							VERY FIRM MOIST GRAY FINE SANDY CLAY SHALE. TO FIRM TO SPLIT-TUBE
19-20	25-25/4"							
						20		END of HOLE

JOHNSON CR. SLIDE



OREGON STATE HIGHWAY DIVISION

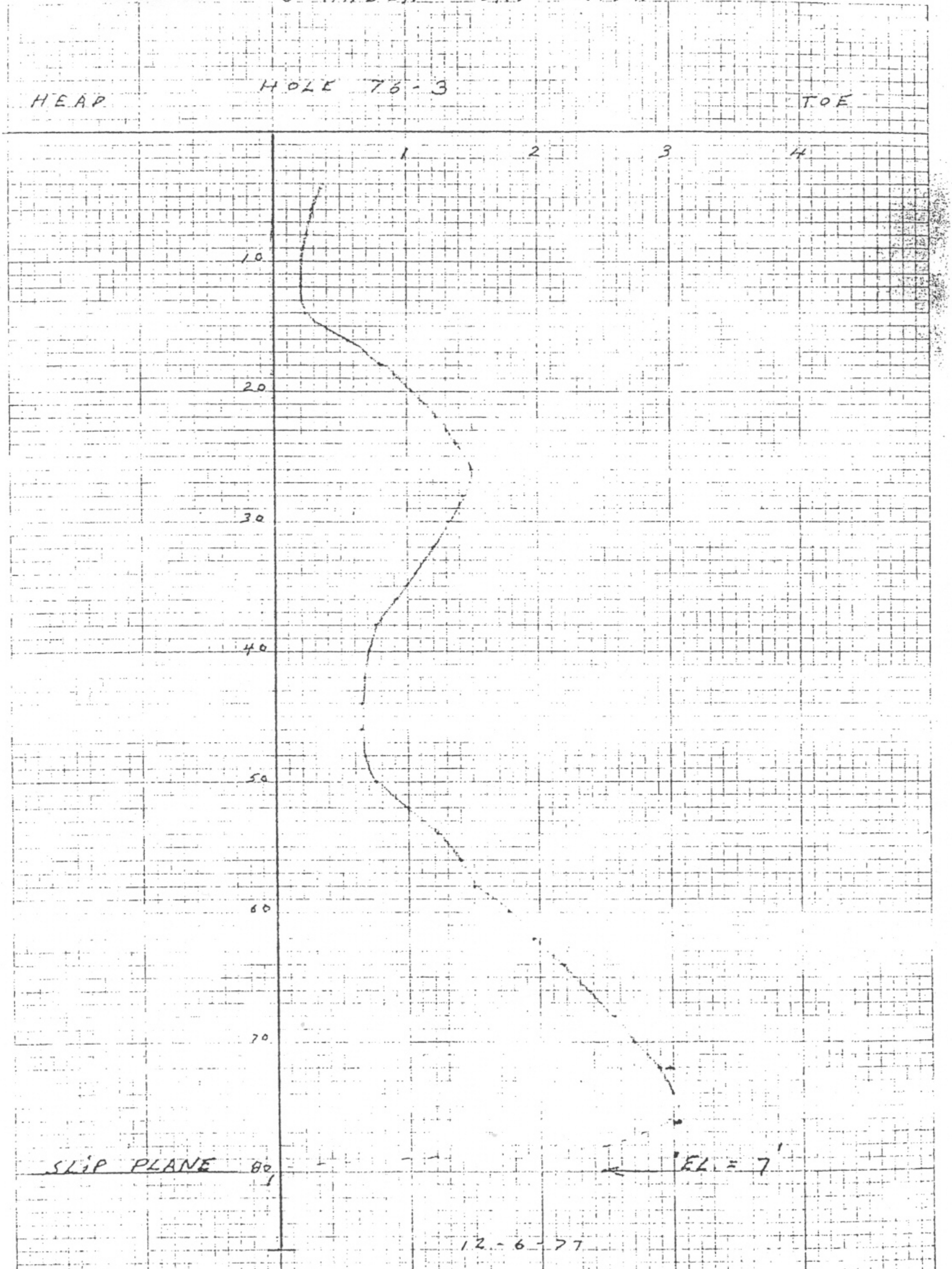
SOILS AND GEOLOGICAL EXPLORATION LOG

Project JOHNSON CR. SLIDE M.P. 133.3
Date 9-20-76
Highway #9- OREGON COAST
County LINCOLN
Bridge No.
ole Location CENTER OF SLIDE ON EAST SHOULDER
Prefix 21-4419-181
Station
Ground Elev.
Depth 80'
Purpose of work SLIP PLANE & MAT'L TYPE
Engineer FRETWELL
Depth to free water
Driller PRODZINSKI
Water level at completion
Recorder PRODZINSKI
Test: ☒ Auger depth 0 - 86'
☐ Diamond core barrel depth
☐ Split barrel sampler: 2" O.D., 144# Hammer, 30" Fall; Depth
☐ Miniature pile: 5' Probe, 400# Hammer, 30" Fall; Depth

H. D. Sheet No.
Test:
Hole No. 76-3

DEPTH TESTED From	DEPTH TESTED To	DRIVING RESISTANCE BLOWS/___ in.	% MOISTURE	MEASURED RECOVERY (FT.)	LENGTH OF CORE RUN (FT.)	% CORE RECOVERY	DEPTH (Ft.)	GRAPHIC LOG	MATERIAL DESCRIPTION COLOR PLASTICITY WET-DRY SOFT-HARD FRESH-WEATHERED JOINTS-BROKEN SAND-SILTY-CLAY ORGANIC CONTENT
							0		
									MOIST BEACH SAND.
							6		
									MOIST TO DAMP DIRTY
									BROWN SANDS.
							12		
									RUSTY-COLORED MOIST
									LAYERS OF CLAY & SAND.
							19		
									GRAY SANDY CLAY, DAMP
									BECOMING MOIST AND FIRM
									WITH DEPTH. NEVER DRY, NOR
							86		HARD. MAT'L DRILLED EASILY.
									END OF HOLE

JOHNSON CR. SLIDE



12-6-77

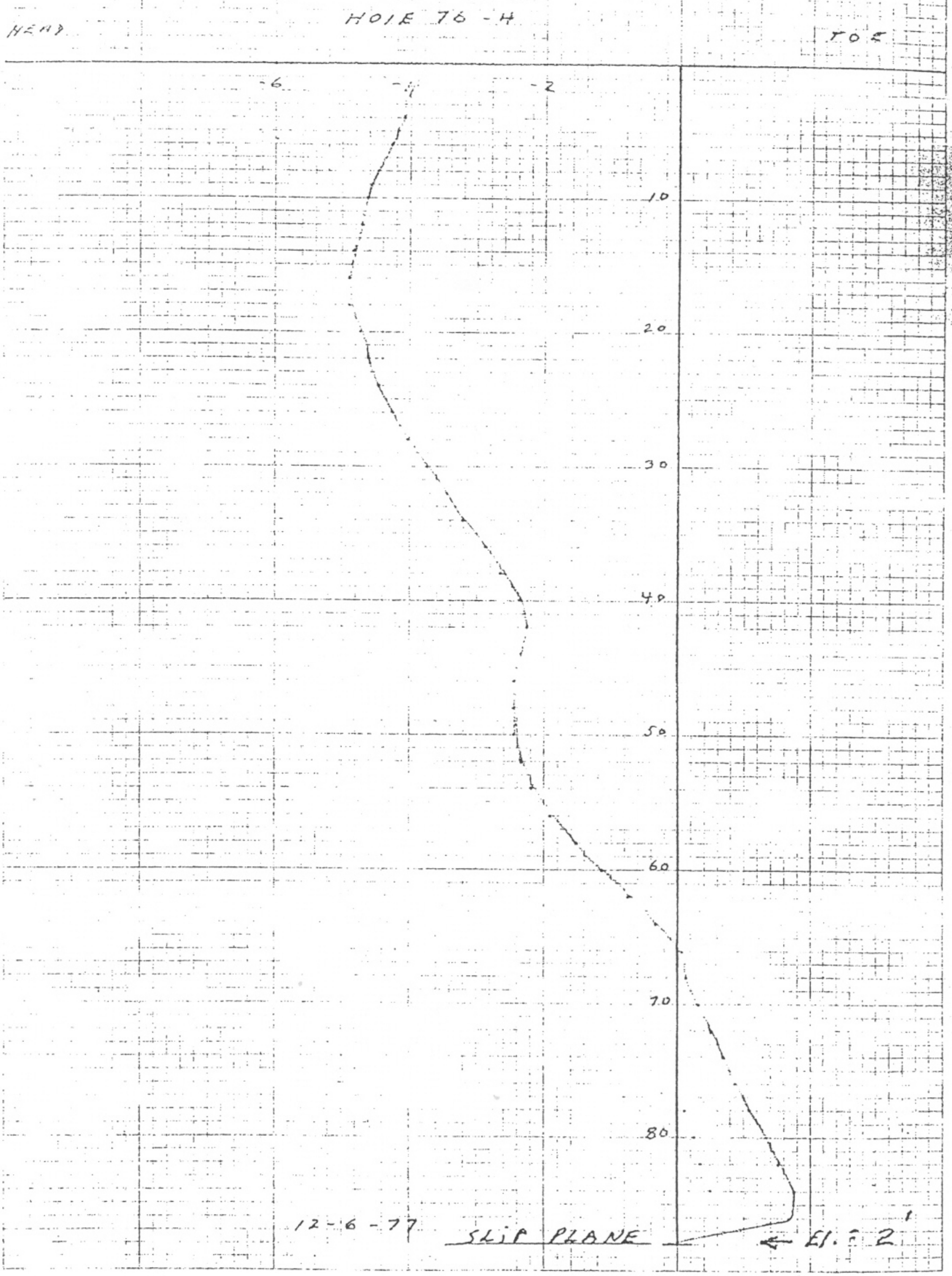
SOILS AND GEOLOGICAL EXPLORATION LOG

Project JOHNSON CR. SLIDE M.P. 133.3
Date 8-23-76
Highway #9 - OREGON COAST
County LINCOLN
Bridge No.
Hole Location No. END of SLIDE & IN WEST SHOULDER
Prefix 21-4419-181
ition
Ground Elev.
Depth 85'
Purpose of work SLIP PLANE & MAT'L TYPE
Engineer FRETWELL
Depth to free water
Driller PRODZINSKI
Water level at completion
Recorder WEST
Test: ☒ Auger depth 0 - 25 ☒ Diamond core barrel depth 25' - 85'
☐ Split barrel sampler: 2" O.D., 144# Hammer, 30" Fall; Depth
☐ Miniature pile: 5' Probe, 400# Hammer, 30" Fall; Depth

H. D. Sheet No. Test: Hole No. 76-4

DEPTH TESTED From	DEPTH TESTED To	DRIVING RESISTANCE BLOWS/___ in.	% MOISTURE	MEASURED RECOVERY (FT.)	LENGTH OF CORE RUN (FT.)	% CORE RECOVERY	DEPTH (Ft.)	GRAPHIC LOG	MATERIAL DESCRIPTION COLOR, PLASTICITY, WET-DRY, SOFT-HARD, FRESH-WEATHERED, JOINTS-BROKEN, SAND-SILTY-CLAY, ORGANIC CONTENT
							0		WET, PLASTIC FINE SANDY CLAY. VERY SOFT. BUFF TO TAN.
							11		WET WHITE COARSE SAND. SOFT.
							14		MOIST TO DAMP, LIGHT BROWN, MEDIUM-GRAINED BEACH SAND.
							23		RUSTY-COLORED FIRM SANDY CLAY.
							25		SOFT GRAY SILTSTONE AND CLAYSTONE. THE CORE CRUMBLES EASILY. ALSO, THE SHALE IS BADDLY BROKEN THROUGHOUT AND EXHIBITS CRUSHED ZONES. ONE PIECE OF CORE IS 22" LONG, BUT THE AVERAGE IS ABOUT 1 - 1½ INCHES.
							85		END of HOLE

JOHNSON CR. SLIDE



APPENDIX B

Geology Map

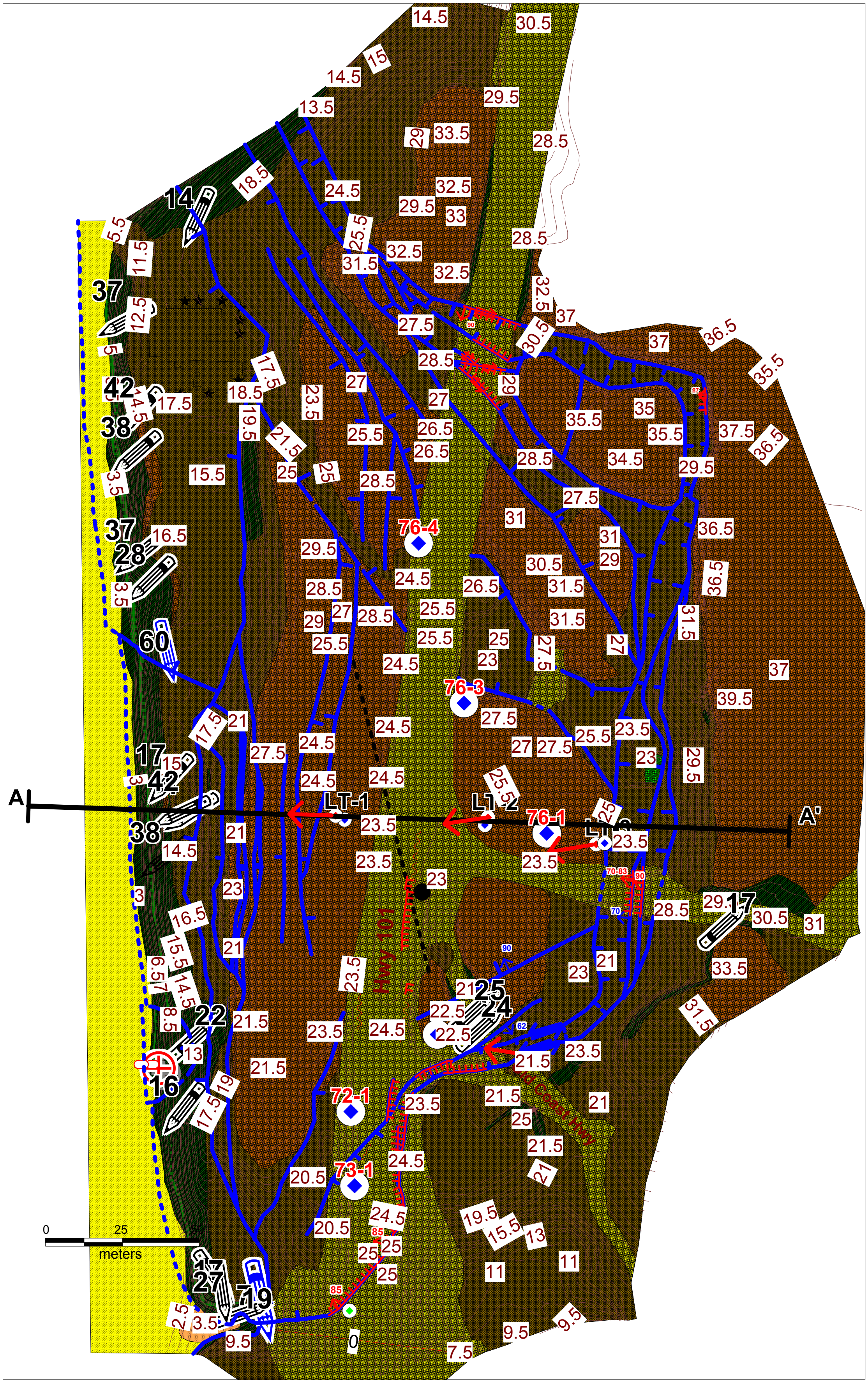
EXPLANATION

MAP

🟫	Fill
🟨	Modern beach sand
🟩	Holocene sandy marsh deposit
🟫	Holocene colluvium
🟫	Quaternary marine terrace deposits
⬛	Tertiary Astoria Formation mudstone
🟩	Tertiary Astoria Formation sandstone
⇄ 60	Slide block scarp with tooth on downthrown side: arrows show lateral offset; scarp dip in degrees in direction of arrow. dotted where covered.
⇄ 87	Slide scarp active in 2002-2003; teeth on downthrown side; arrows show lateral displacement; scarp dip in degrees in direction of arrow.
〰	Cracks and fissures active in 2002-2003
●	Buried fault; bar and ball on down thrown side
✎ 38	Strike and dip of bedding
✎ 7	Strike and dip of sheared surface
←	Net landslide slip direction inferred from local geotechnical data.
◆ LT-1	Inclinometer hole with hole number
◆ LT-1	Piezometer hole with hole number
◆ 76-1	Inclinometer hole from 1970's drilling by ODOT
⊕	Trench in toe of landslide; cross with circle at survey reference pin for trench location.

CROSS SECTION

🟫	Fill
🟨	Modern beach sand
🟨	Beach cobble + boulder deposit
🟫	Holocene colluvium
🟫	Quaternary marine terrace deposits
⬛	Tertiary Astoria Formation mudstone (siltstone)
🟩	Tertiary Astoria Formation sandstone "D"
🟨	Tertiary Astoria Formation sandstone "C"
🟥	Tertiary Astoria Formation sandstone "B"
🟦	Tertiary Astoria Formation sandstone "A"
╱	Main slide plane
╲	Slide plane
╲	Inferred fault
LT-1	Inclinometer hole with hole number


Hwy 101
Old Coast Hwy
76-4
76-3
76-1
72-1
73-1
LT-1
LT-2
LT-3
A
A'
0
25
50
meters
14.5
30.5
15
14.5
29.5
13.5
33.5
28.5
18.5
24.5
32.5
29.5
33
28.5
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31.5
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25
27.5
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23.5
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28.5
30.5
31
33.5
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21
23
21.5
23.5
25
24
22.5
22.5
21.5
21
21.5
25
21
19.5
15.5
13
11
11
9.5
9.5
7.5
0
25
25
25
24.5
24.5
20.5
20.5
23.5
24.5
23.5
21.5
21.5
21
23
21
14.5
16.5
15.5
14.5
8.5
13
19
17.5
9.5
3.5
2.5
14
37
42
38
37
28
60
17
42
38
22
16
27
19
17
5.5
11.5
12.5
17.5
14.5
3.5
15.5
16.5
3.5
17.5
18.5
19.5
21.5
25
25
23.5
27
27
26.5
26.5
28.5
29.5
28.5
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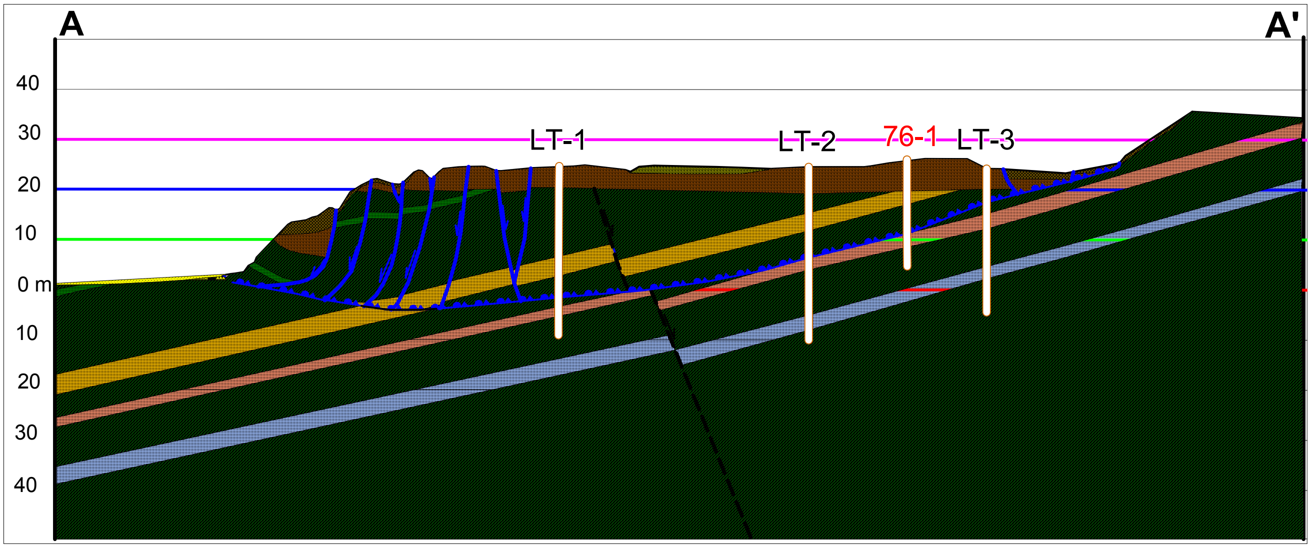
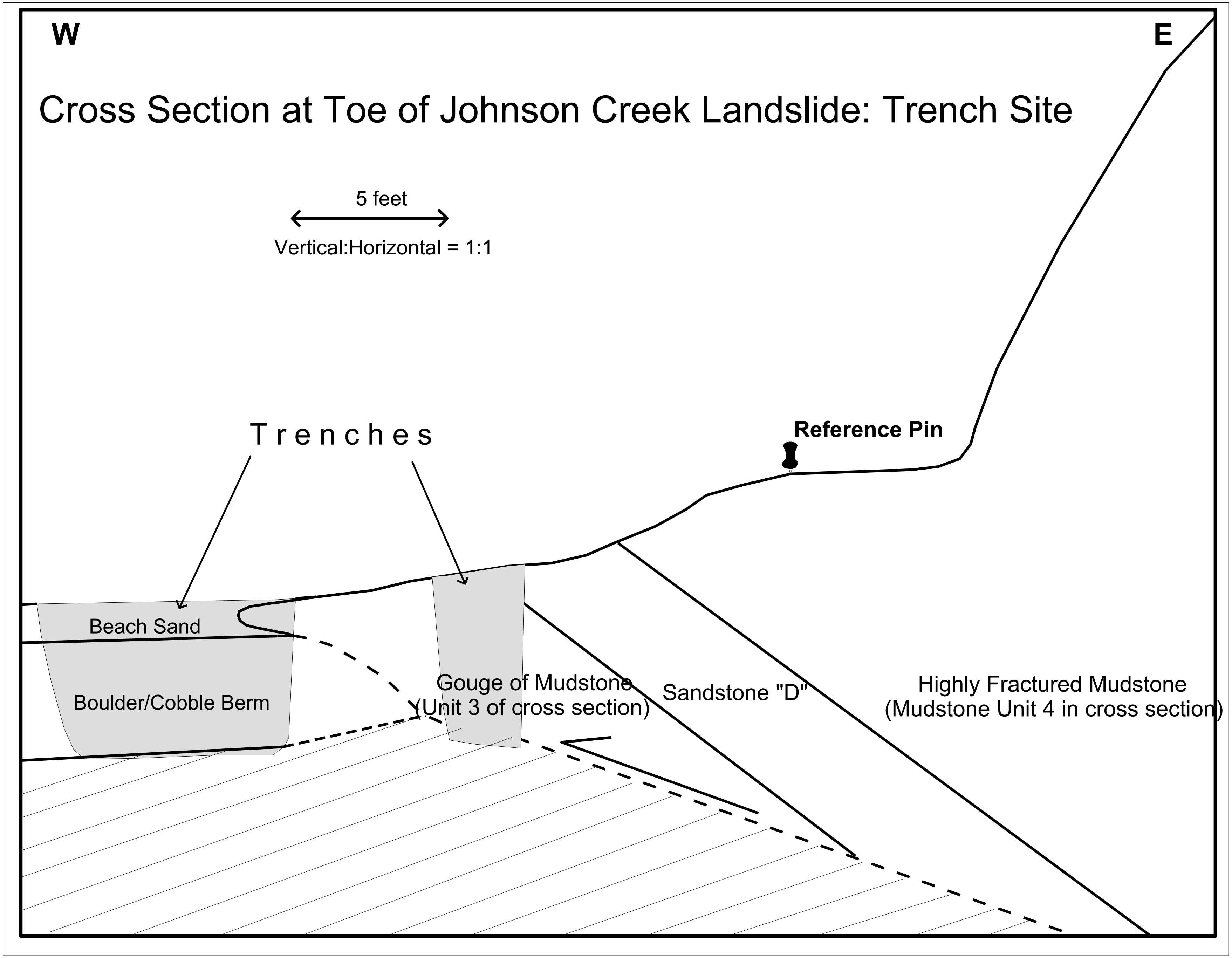
28.5
25.5
24.5
24.5
27.5
24.5
24.5
85
85
90
70
62

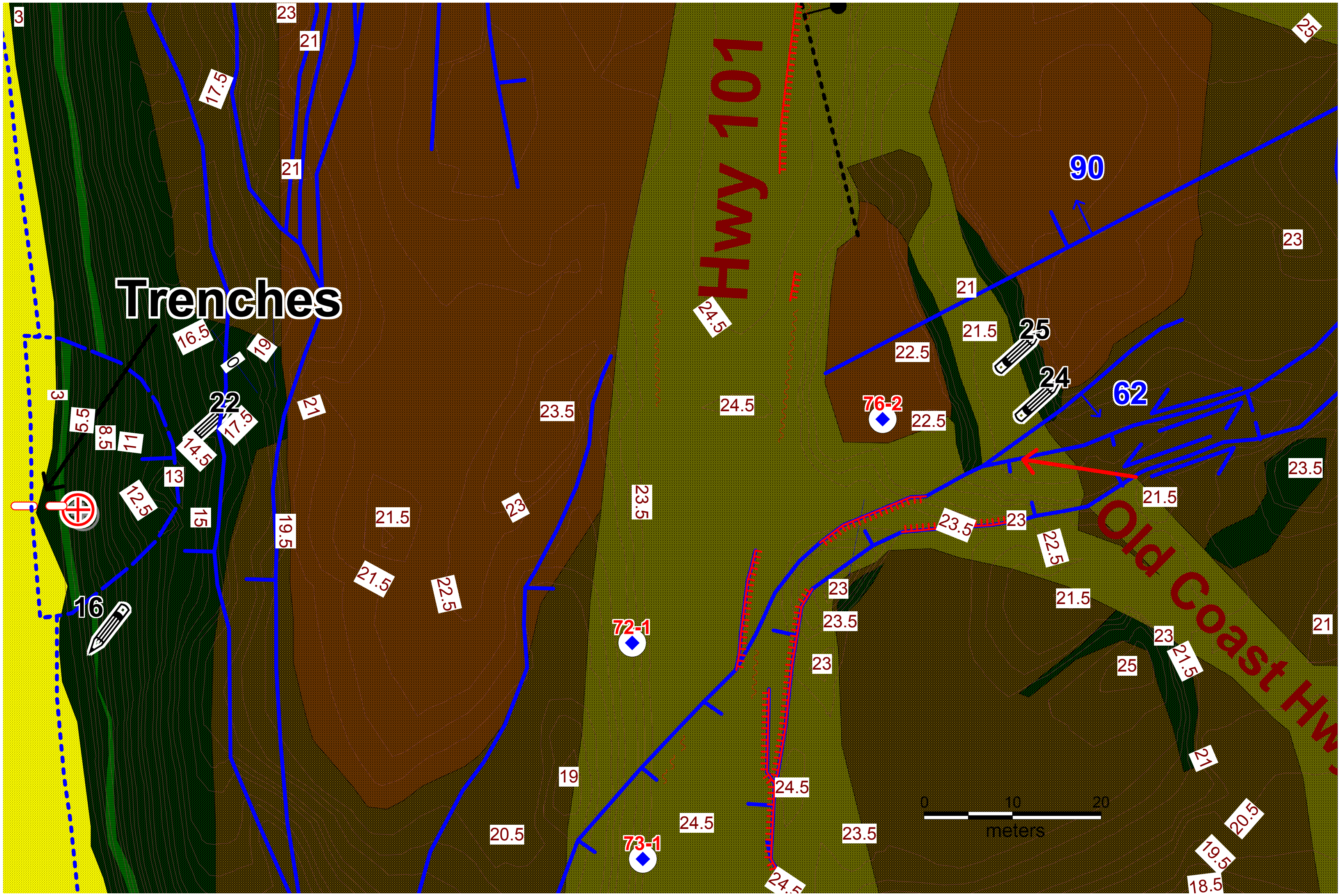

A
A'
40
30
20
10
0 m
10
20
30
40
LT-1
LT-2
76-1
LT-3

APPENDIX C

Test Pit Exploration



Cross Section at Toe of Johnson Creek Landslide: Trench Site


Trenches
Hwy 101
Old Coast Hwy
90
62
22
16
25
24
76-2
72-1
73-1
3
23
21
17.5
16.5
19
0
5.5
8.5
11
13
14.5
12.5
15
19.5
21.5
22.5
23.5
24.5
20.5
18.5
19.5
25
0
10
20
meters

EXPLANATION

MAP

🟫	Fill
🟨	Modern beach sand
🟩	Holocene sandy marsh deposit
🟫	Holocene colluvium
🟫	Quaternary marine terrace deposits
⬛	Tertiary Astoria Formation mudstone
🟩	Tertiary Astoria Formation sandstone
60	Slide block scarp with tooth on downthrown side: arrows show lateral offset; scarp dip in degrees in direction of arrow. dotted where covered.
87	Slide scarp active in 2002-2003; teeth on downthrown side; arrows show lateral displacement; scarp dip in degrees in direction of arrow.
〰	Cracks and fissures active in 2002-2003
●	Buried fault; bar and ball on down thrown side
38	Strike and dip of bedding
7	Strike and dip of sheared surface
←	Net landslide slip direction inferred from local geotechnical data.
◆ LT-1	Inclinometer hole with hole number
◆ LT-1	Piezometer hole with hole number
◆ 76-1	Inclinometer hole from 1970's drilling by ODOT
⊕	Trench in toe of landslide; cross with circle at survey reference pin for trench location.

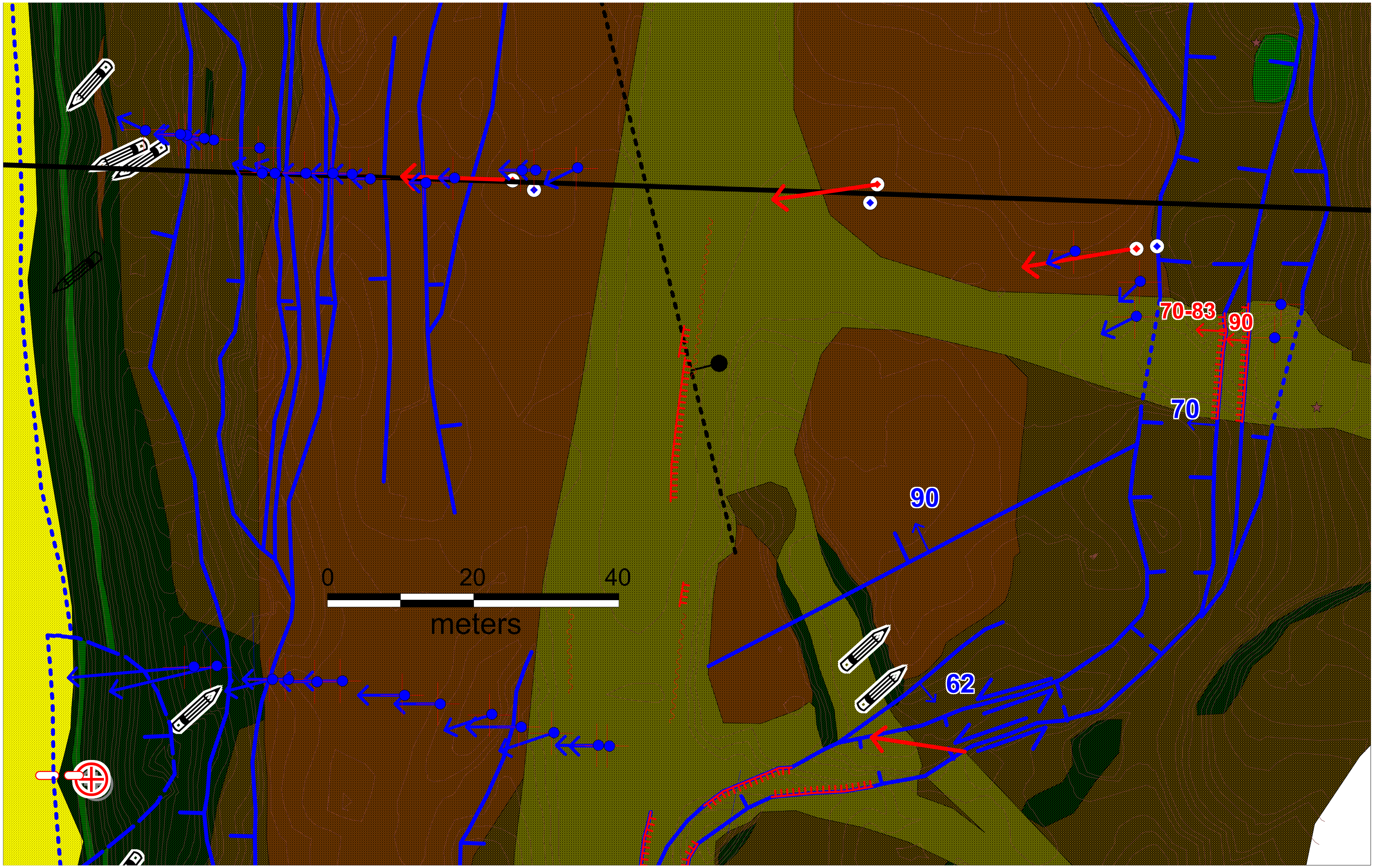
CROSS SECTION

🟫	Fill
🟨	Modern beach sand
🟨	Beach cobble + boulder deposit
🟫	Holocene colluvium
🟫	Quaternary marine terrace deposits
⬛	Tertiary Astoria Formation mudstone (siltstone)
🟩	Tertiary Astoria Formation sandstone "D"
🟨	Tertiary Astoria Formation sandstone "C"
🟧	Tertiary Astoria Formation sandstone "B"
🟦	Tertiary Astoria Formation sandstone "A"
⁀	Main slide plane
↘	Slide plane
╲	Inferred fault
LT-1	Inclinometer hole with hole number

APPENDIX D

Ground Surface Survey Vector Movement


13.0
13.5
14.5
15.0
15.5
16.5
17.0
17.5
18.5
19.0
19.5
21.0
21.5
5.5
12.5
11.5
9.5
20.5
17.5
17.0
27.5
31.0
36.5
35.5
36.5
2123
2122
2121
3.5
7.0
17.0
2081
2080
2124
2126
2127
2128
2129
2131
2132
2133
2135
29.0
30.5
23.0
2082
3.5
35.5
16.5
8.5
4.5
7.5
23.5
24.5
3.5
25.0
27.0
29.5
33.5
13.5
25.5
5.5
3.0
36.5
2078
2076
2077
2075
2074
2071
2070
2073
2072
2068
2069
2067
2066
2065
2064
2063
35.0
34.5
2119
2120
2118
2117
2116
2115
33.0
32.5
2114
13.0
3.0
31.5
2112
2113
15.5
15.0
26.5
28.5
31.5
3.5
9.0
5.0
2111
14.5
2062
2061
3.0
2059
2058
2056
2057
2055
2054
2053
2051
2052
2050
2007
11.0
2006
6.5
23.5
17.5
22.5
21.5
20.5
21.0
19.5
18.5
17.5
16.5
15.5
17.0
15.0
14.5
12.5
11.5
13.0
10.5
11.0
10.5
2.5
17.0
18.5
2003
19.0
13.5
9.5
8.5
9.0
3.0
25.0
9.0
9.5
8.5
24.5
23.0
N
10
0
10
20
30
40
Meters



Qualitative overview of slide vectors from change in survey points between October, 2002 and April, 2003 (blue arrows). Red arrows at inclinometer holes are bearings from inclinometer data. Red arrow at south margin is qualitative displacement direction of old coast highway.

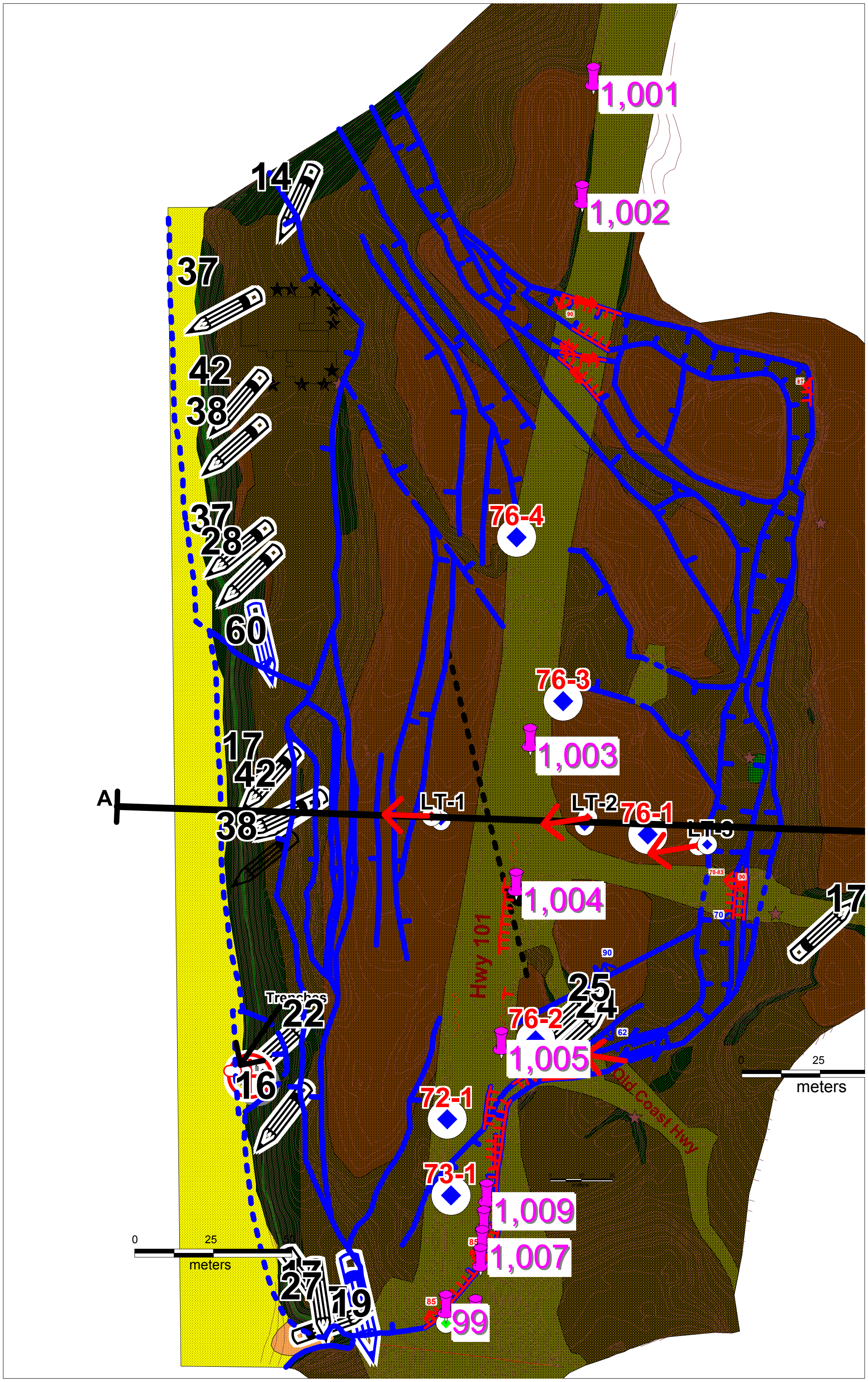
Table D-1
Ground Surface Survey Vector Movement
Oct. 2003 to Apr. 17, 2003

Oct. 2002 Data Point Label	Movement Direction Azimuth (degrees)	Vector Movement (m)
	NORTH POINTS	
2123	27	0.04
2122	342	0.03
2121	288	0.03
2082	276	0.09
2081	281	0.05
2080	270	0.05
2124	259	0.05
2126	243	0.07
2127	344	0.15
2128	234	0.09
2129	216	0.09
2131	221	0.09
2132	72	0.03
2133	76	0.08
2135	82	0.07
	MIDDLE POINTS	
2079	282	0.24
2078	277	0.25
2077	279	0.24
2076	277	0.24
2075	275	0.25
2074	272	0.26
2073	274	0.28
2072	272	0.29
2071	272	0.28
2070	268	0.26
2069	268	0.27
2068	268	0.28
2067	268	0.26
2066	266	0.26
2065	265	0.24
2064	272	0.25
2063	262	0.21
2119	243	0.18
2120	236	0.18
2118	250	0.15
2117	101	0.05
2116	135	0.03
2115	117	0.07
2114	135	0.07
2113	121	0.06
2112	135	0.10
2111	146	0.11
	SOUTH POINTS	
2062	264	1.23
2061	254	0.85
2059	265	0.47
2058	267	0.44
2057	275	0.37
2056	270	0.32
2055	268	0.30
2054	266	0.30
2053	266	0.31
2052	266	0.31
2051	264	0.28
2050	257	0.26
2007	254	0.26
2006	252	0.13
2003	45	0.04

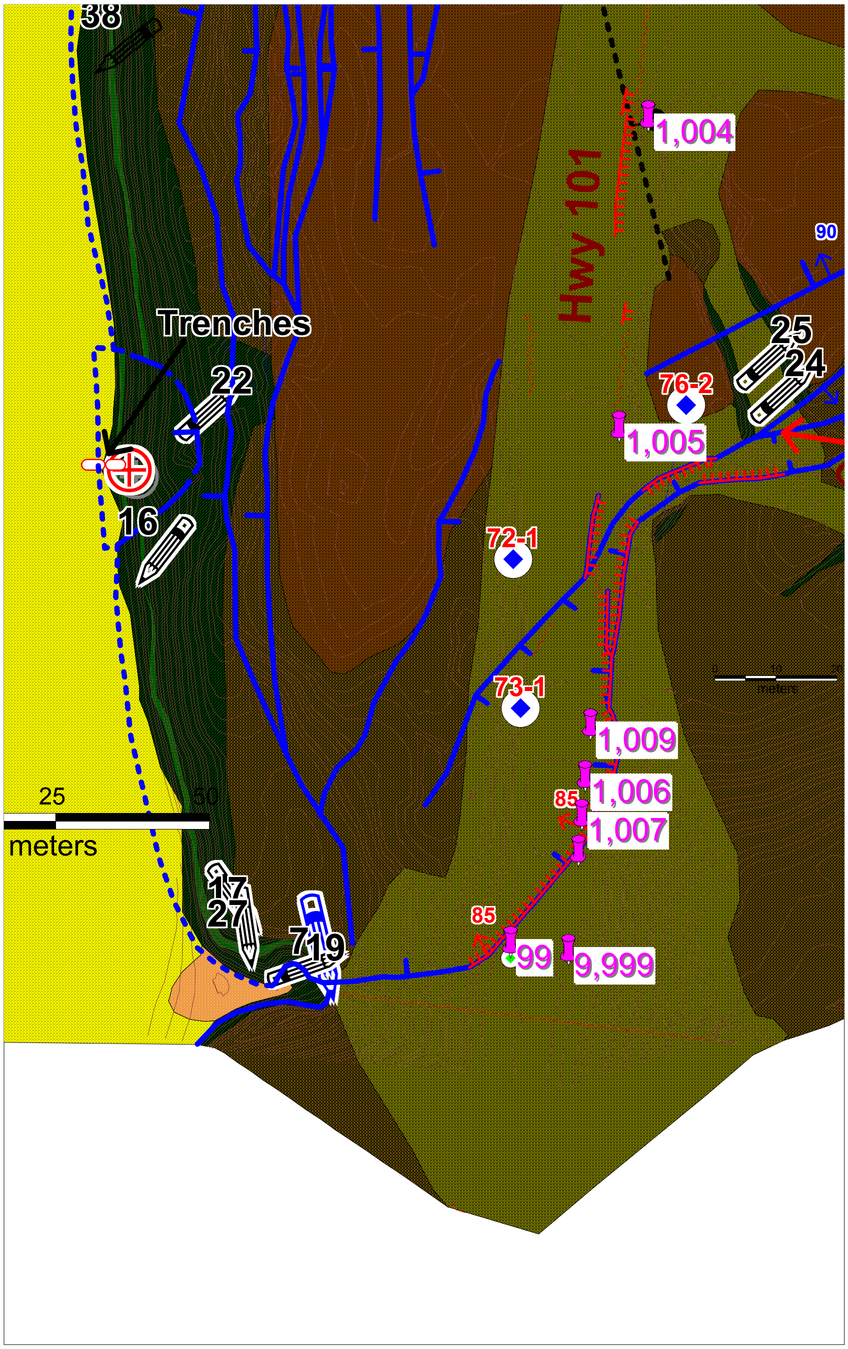
APPENDIX E

Line-of-Sight Survey

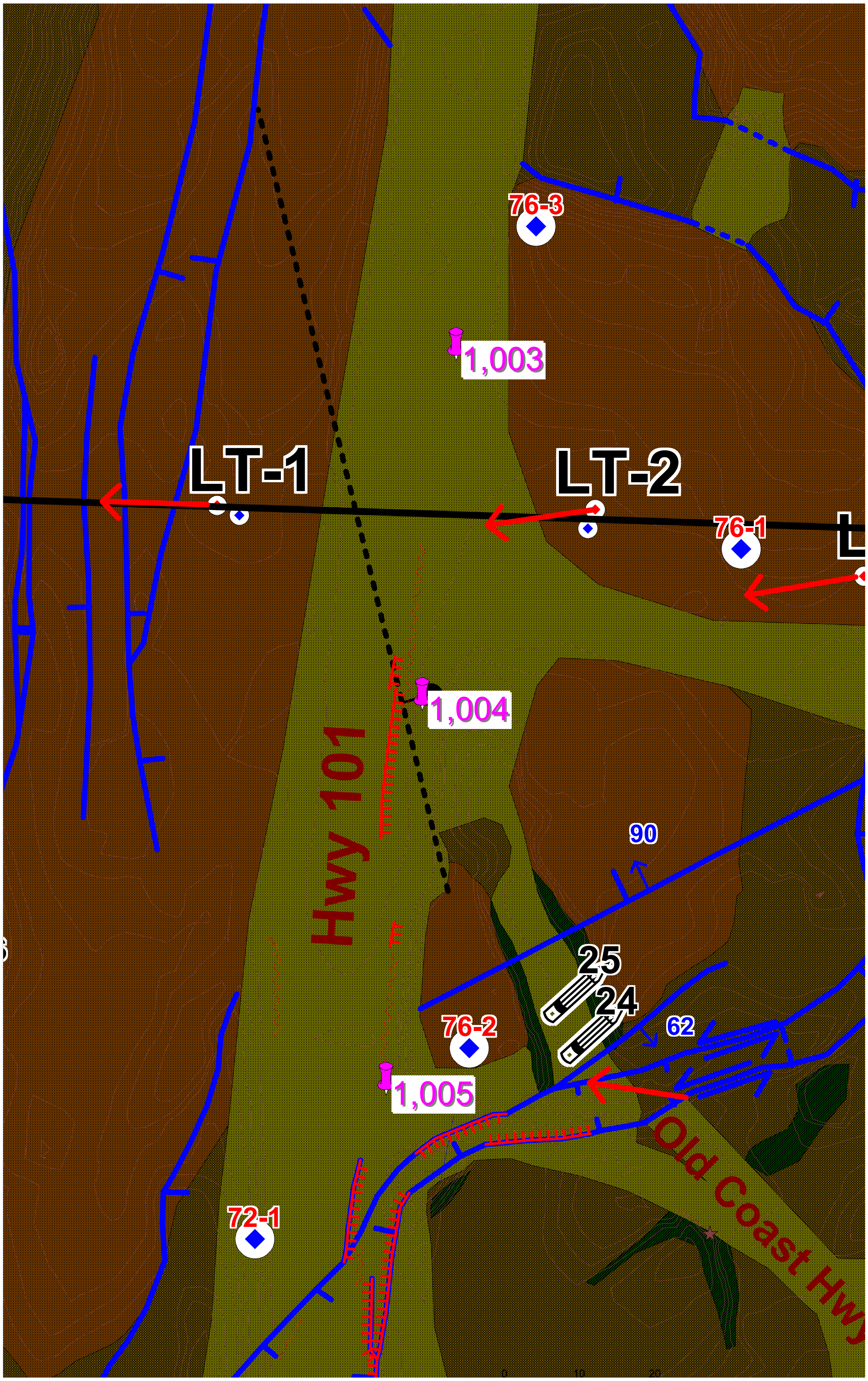
LOCATIONS OF SURVEY PINS FOR LINE-OF-SIGHT EXPERIMENT ON HWY 101



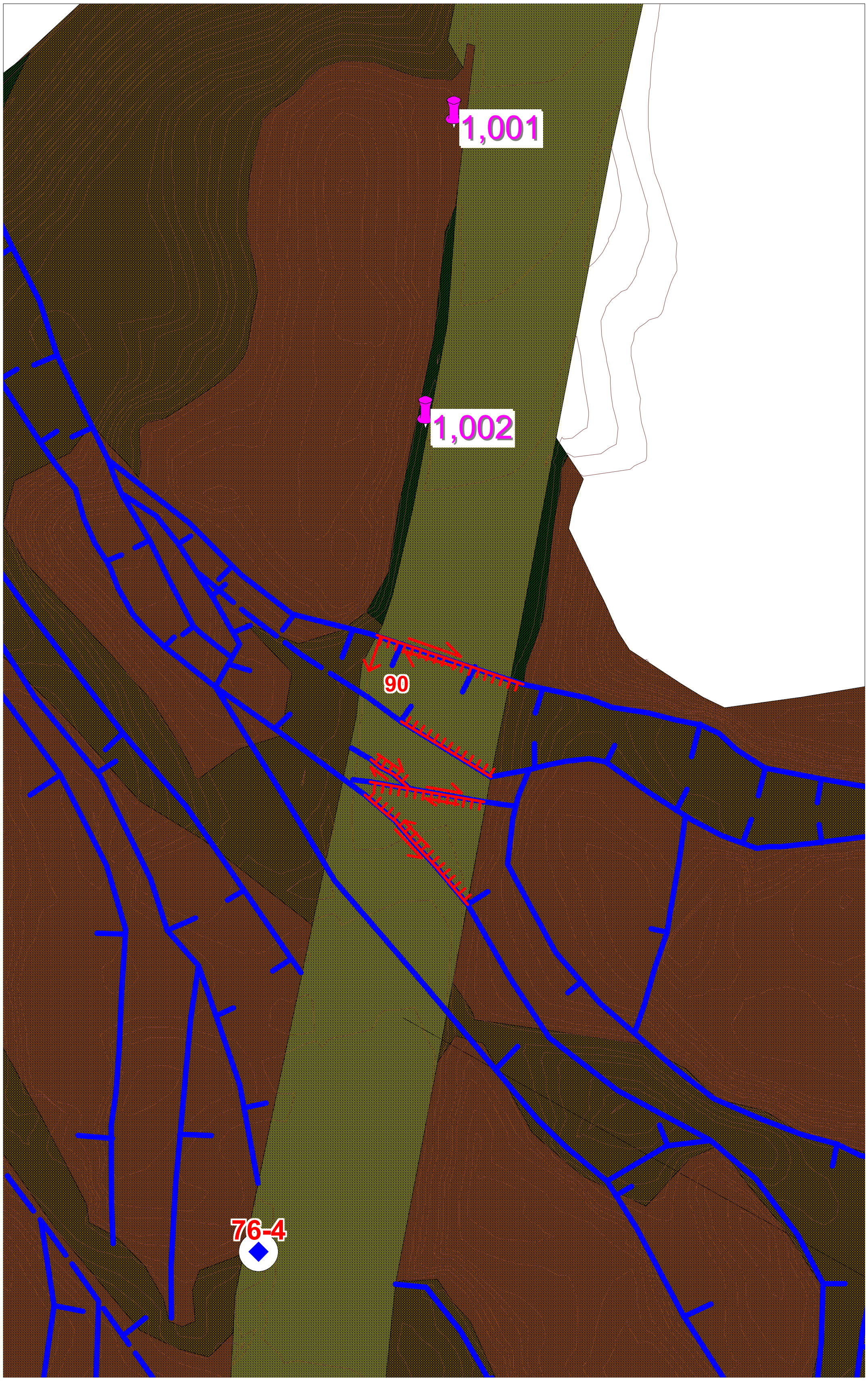
Pin locations are in purple.



Pin locations at south end of landslide.

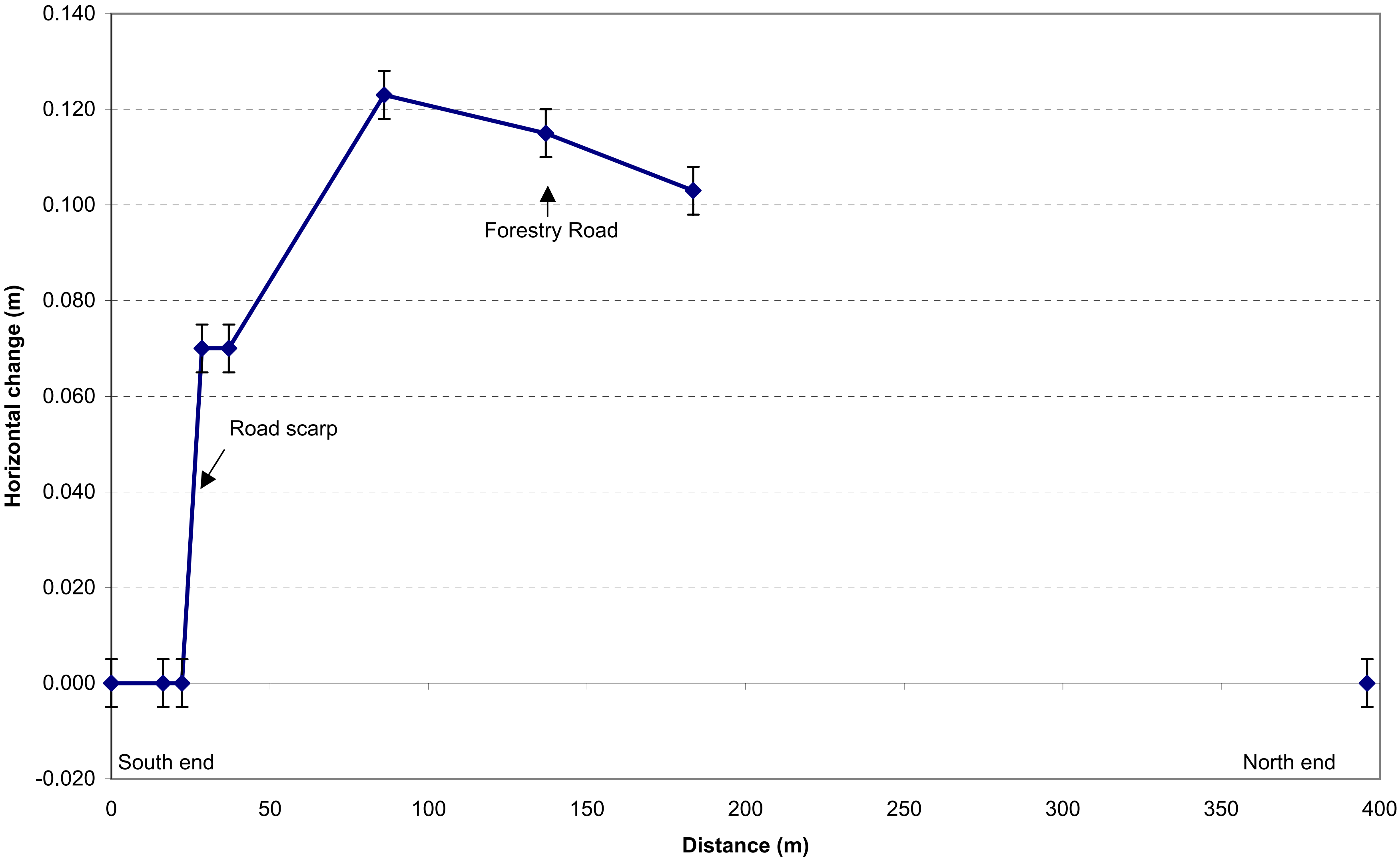


Pin locations in the central part of the landslide.



Pin locations in the north part of the landslide.

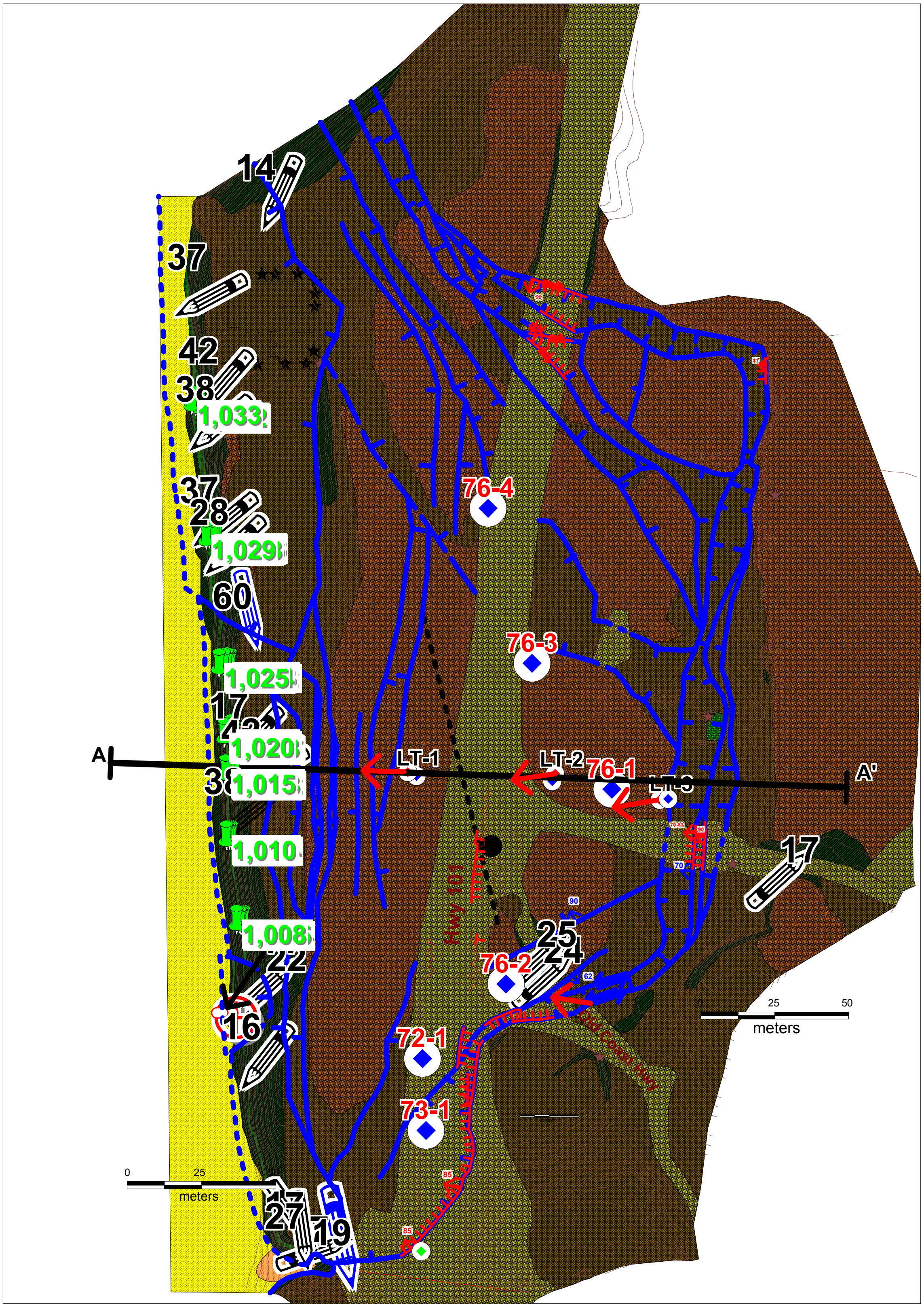
Measured horizontal change (south to north along Highway 101)



APPENDIX F

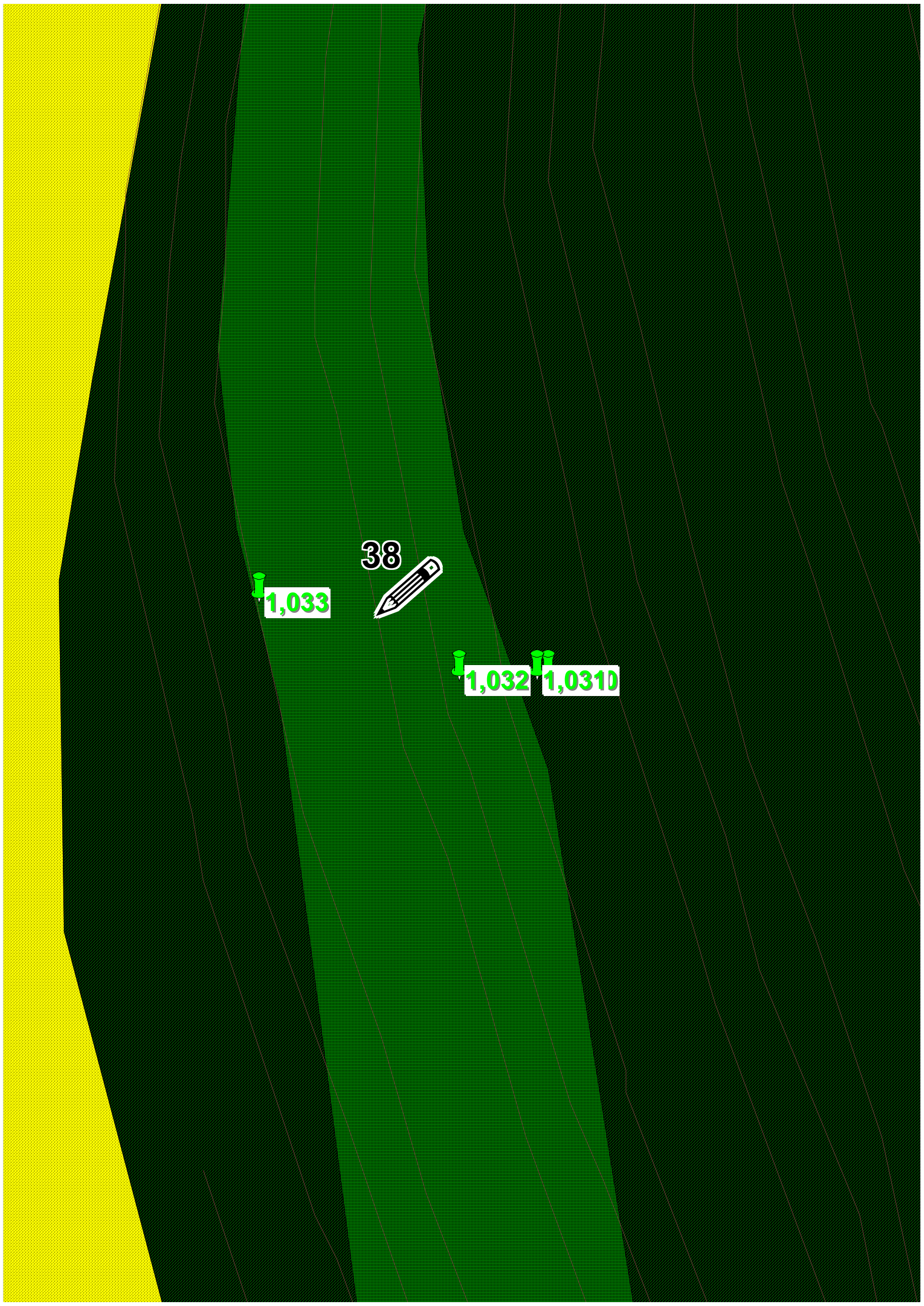
Erosion Pin Survey

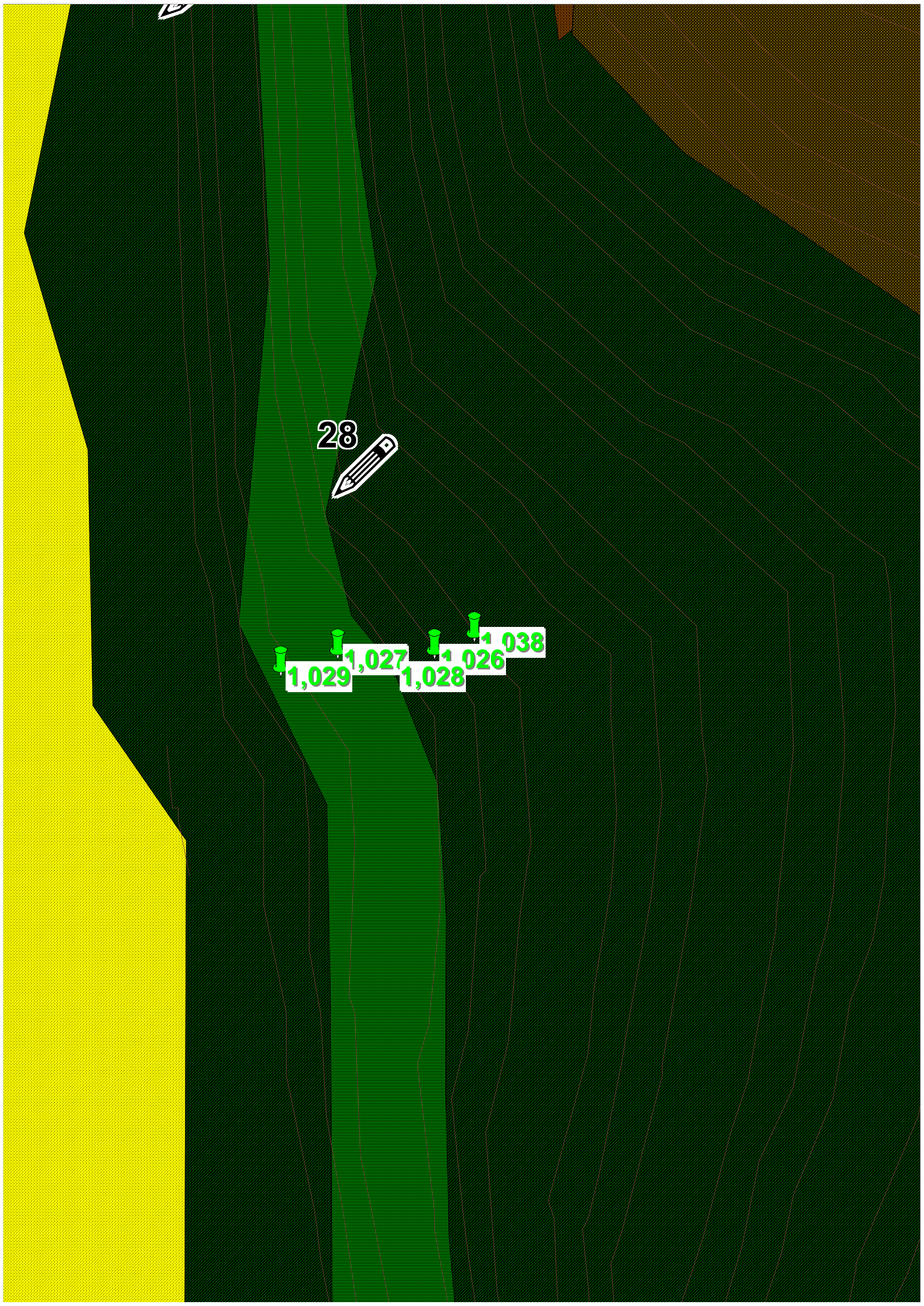
LOCATIONS OF EROSION MONITORING PINS

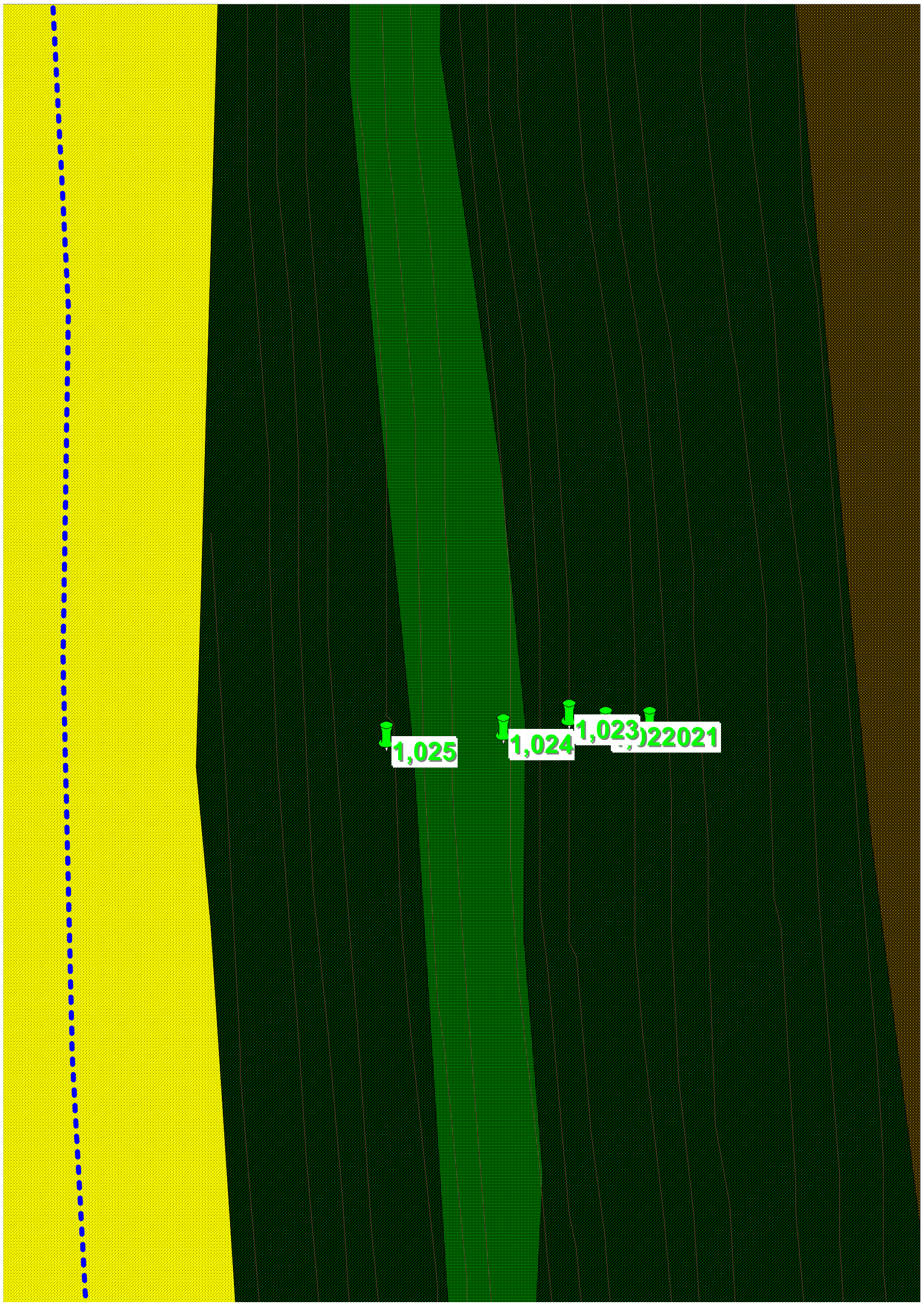


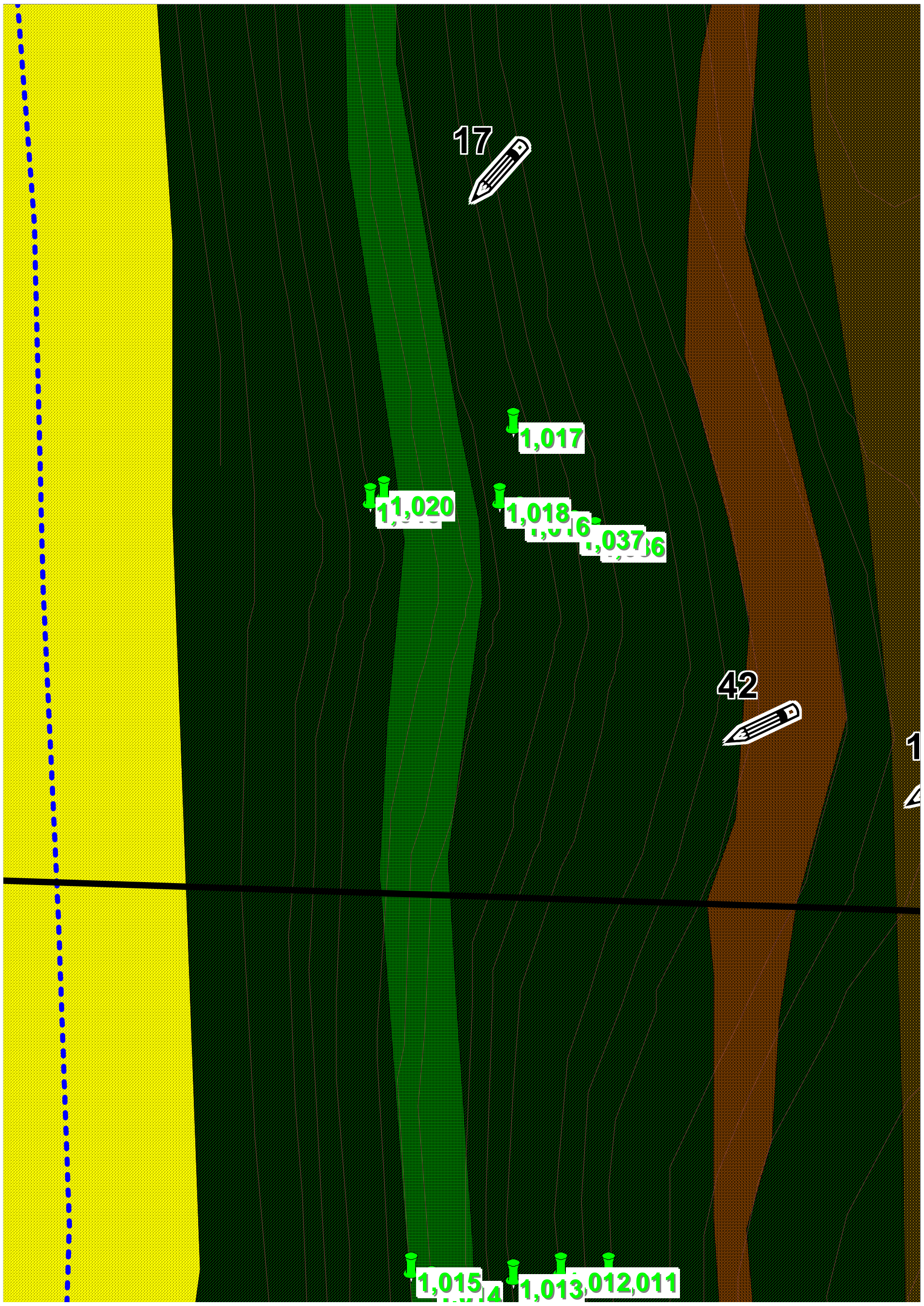
Erosion pin locations with lowest pin number (green) at each vertical transect.

CLOSE UP OF EACH TRANSECT FROM NORTH TO SOUTH

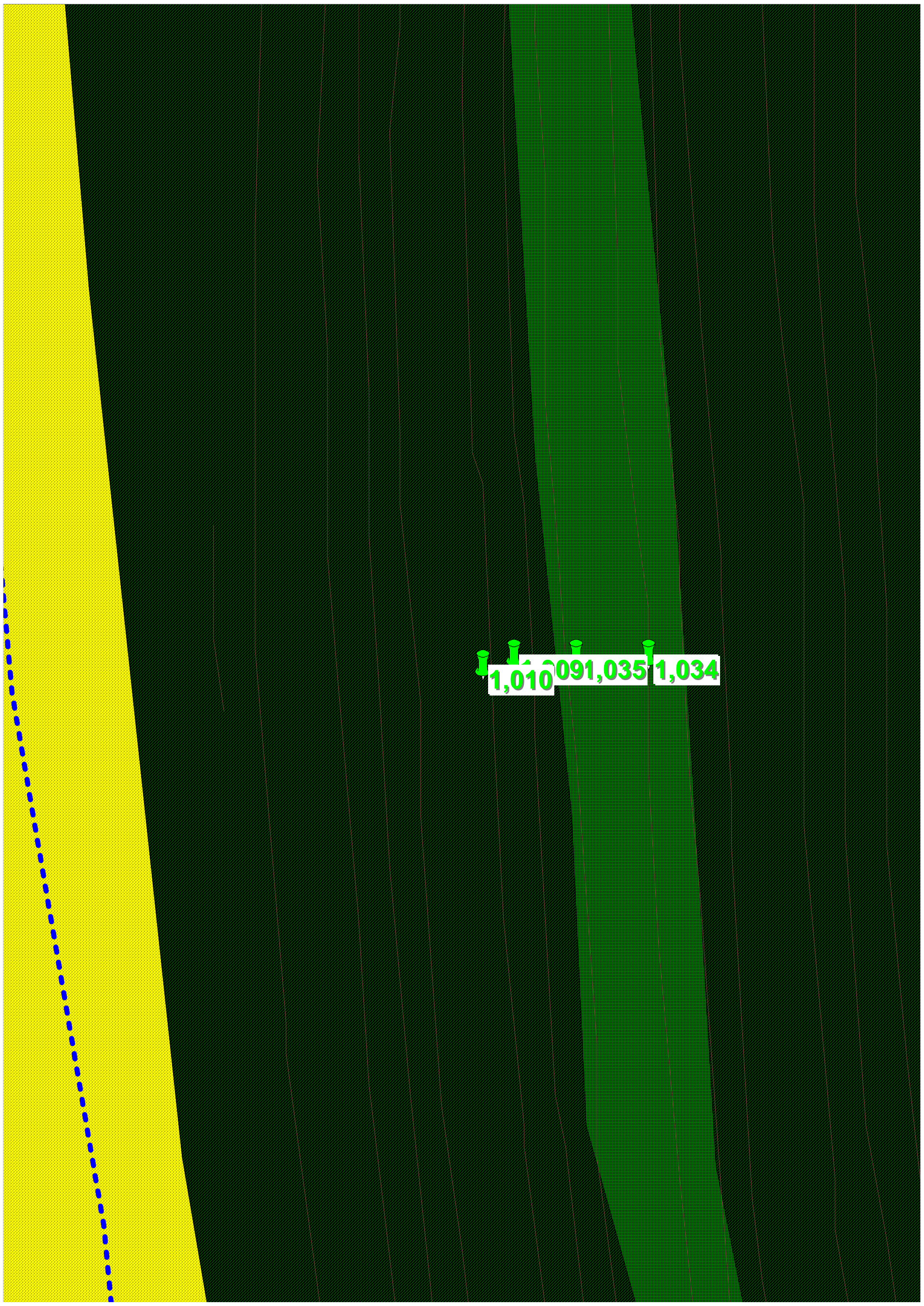


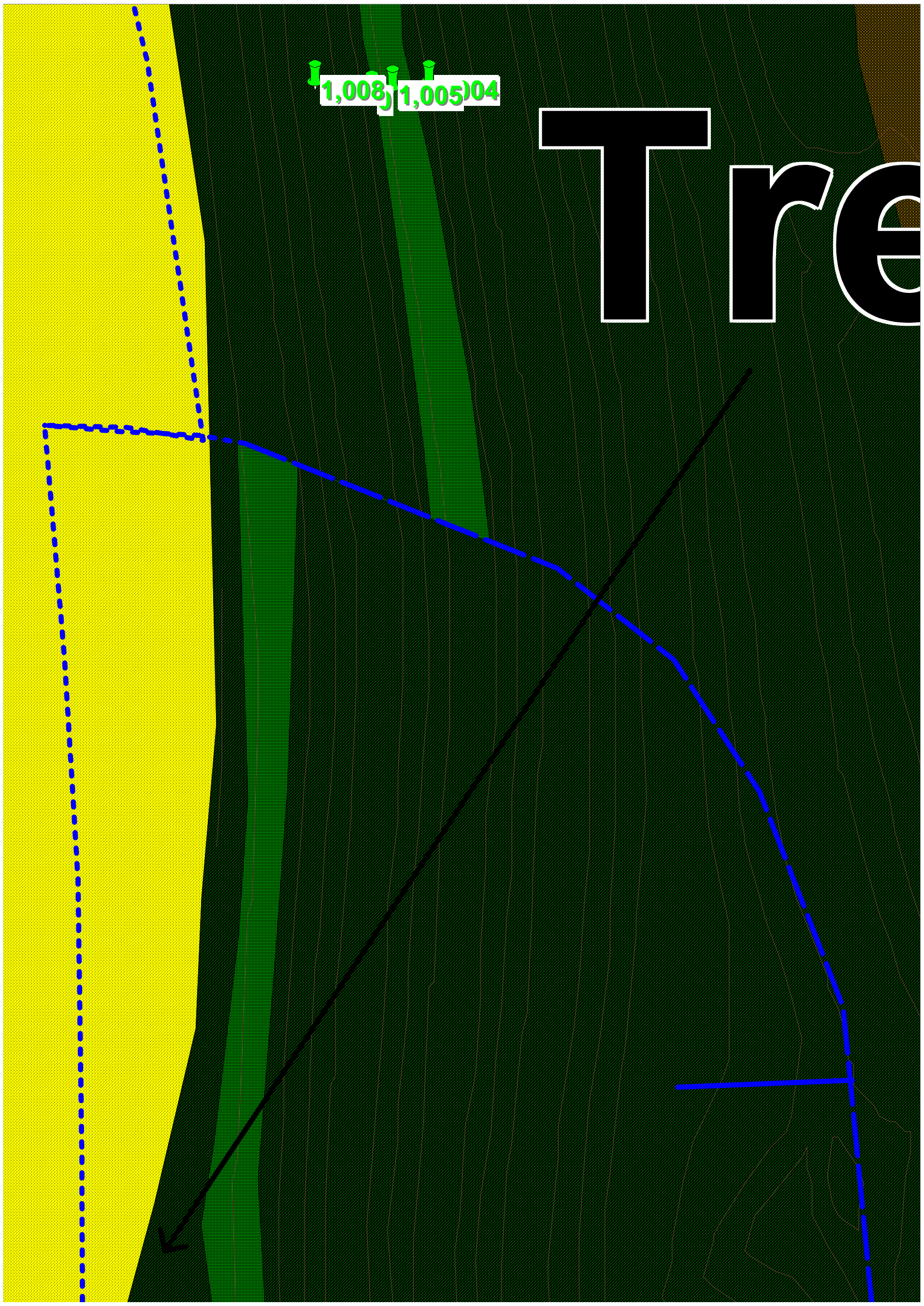

28
1,038
1,027
1,026
1,029
1,028


1,025
1,024
1,023
022021

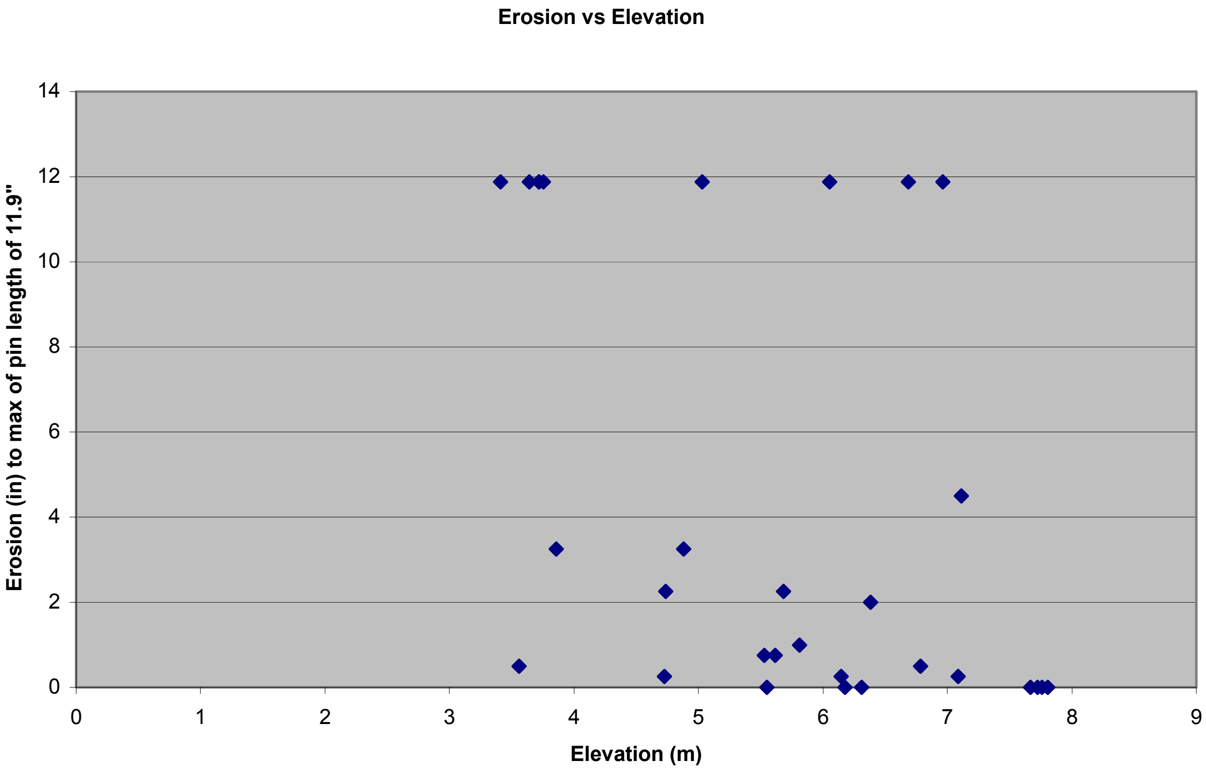

17
1,017
1,020
1,018
1,037
42
1,015
1,013
1,012
1,011

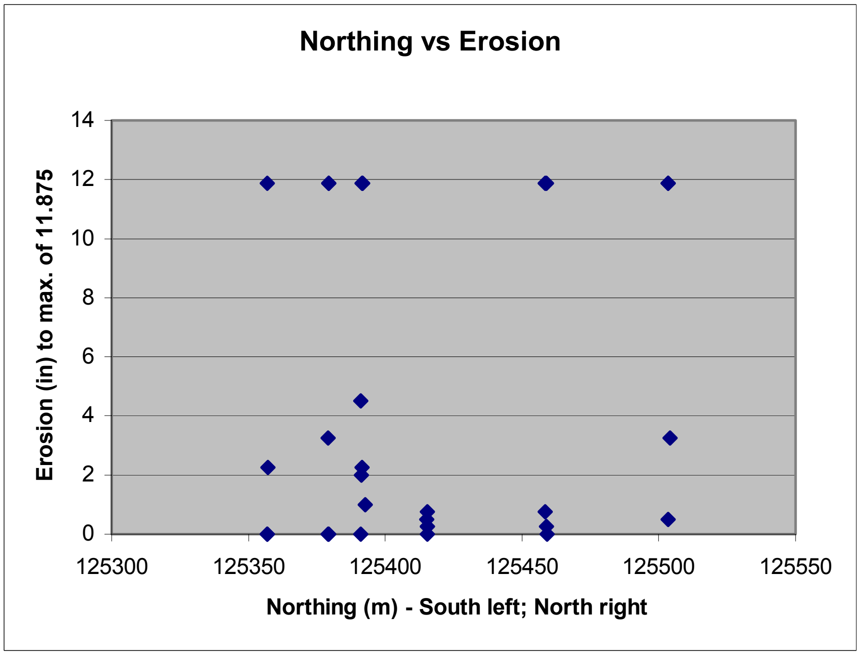

1,015
1,014
1,013
1,012
1,011
38


1,010
1,009
1,035
1,034


1,008
1,005
004
Tre

EROSION MEASURED BEHIND MARKER NAILS IN SEA CLIFF





Bluff erosion data for December 9, 2002 to April 10, 2003. Note no obvious correlation of erosion and bluff height or position north-south. The maximum length of pins was 11.875", so no larger amount could be measured; that is why there are a number of points at this value on the graphs. Where pins were gone, this was generally caused by a block of rock falling out of the sea cliff that was similar in size or larger than the pin.

APPENDIX G

Beach Sand Movement Survey

Beach Profile Data

Beach profile information have been derived from analyses of Light Detection and Ranging Data (LIDAR) measured by the US Geological Survey, and from topographic surveys undertaken at the end of the winter season (April 2003). Some beach surveys were also carried out during the winter. However, storms between December 2002 and January 2003 eroded the benchmarks. As a result, we have been unable to reoccupy the study sites.

Figure 1 presents a location map that identifies the position of the beach profile sites studied. Figure 2 presents a three-dimensional image of the beach, while Figure 3 presents the cross-section information. It is worth noting that at the time of the LIDAR flight in September 2002, a large rip embayment had become established in front of the landslide. The rip embayment has remained throughout the winter months and has probably contributed to localized erosion along the central portion of the bluff face over the winter months.

Total volumetric change in the amount of sand in front of the landslide is estimated to be 47,700 m^3 of sand (i.e. erosion of this amount over the duration of the winter, September 2002 to April 2003).

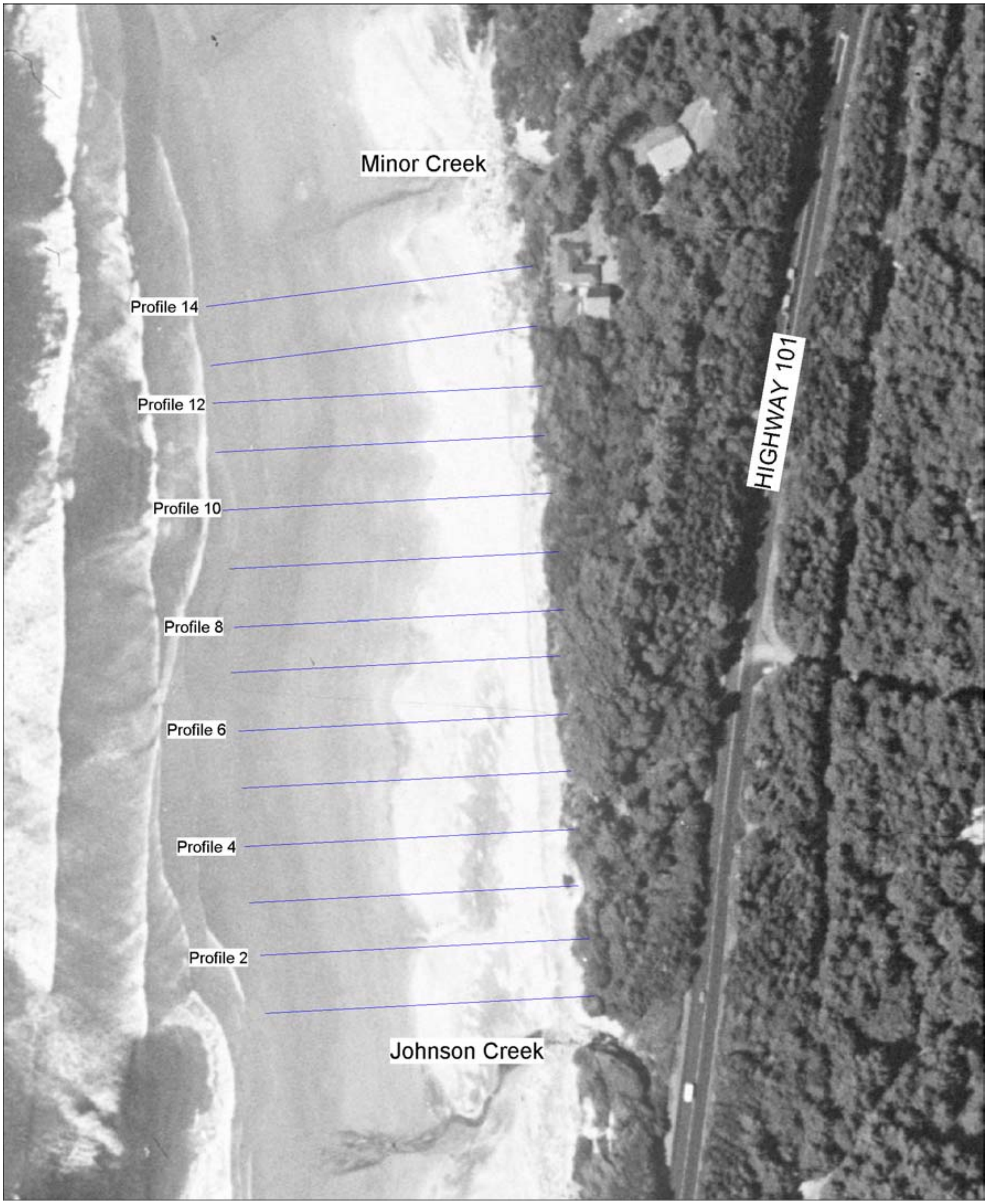


Figure 1: Location map of beach profiles.

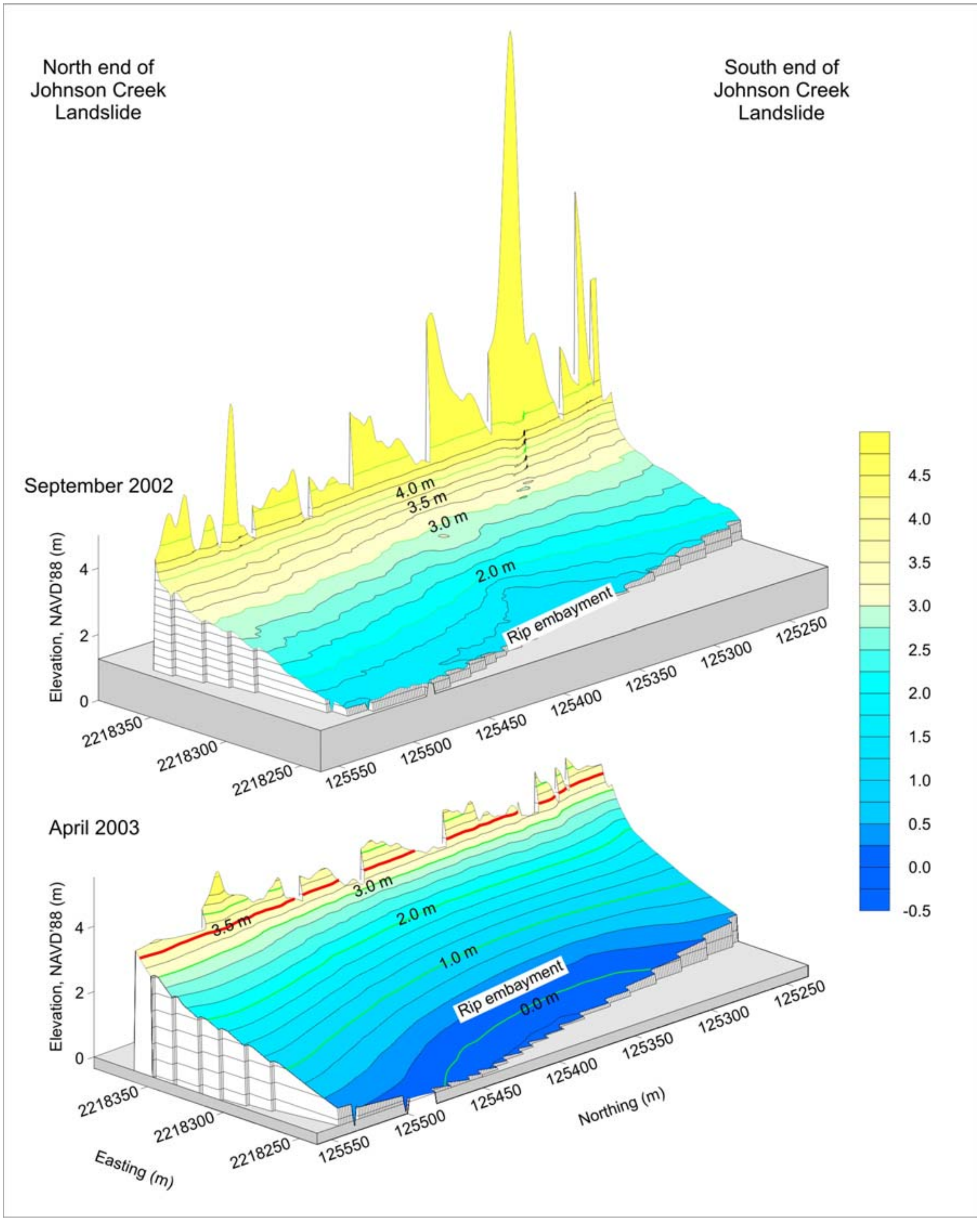
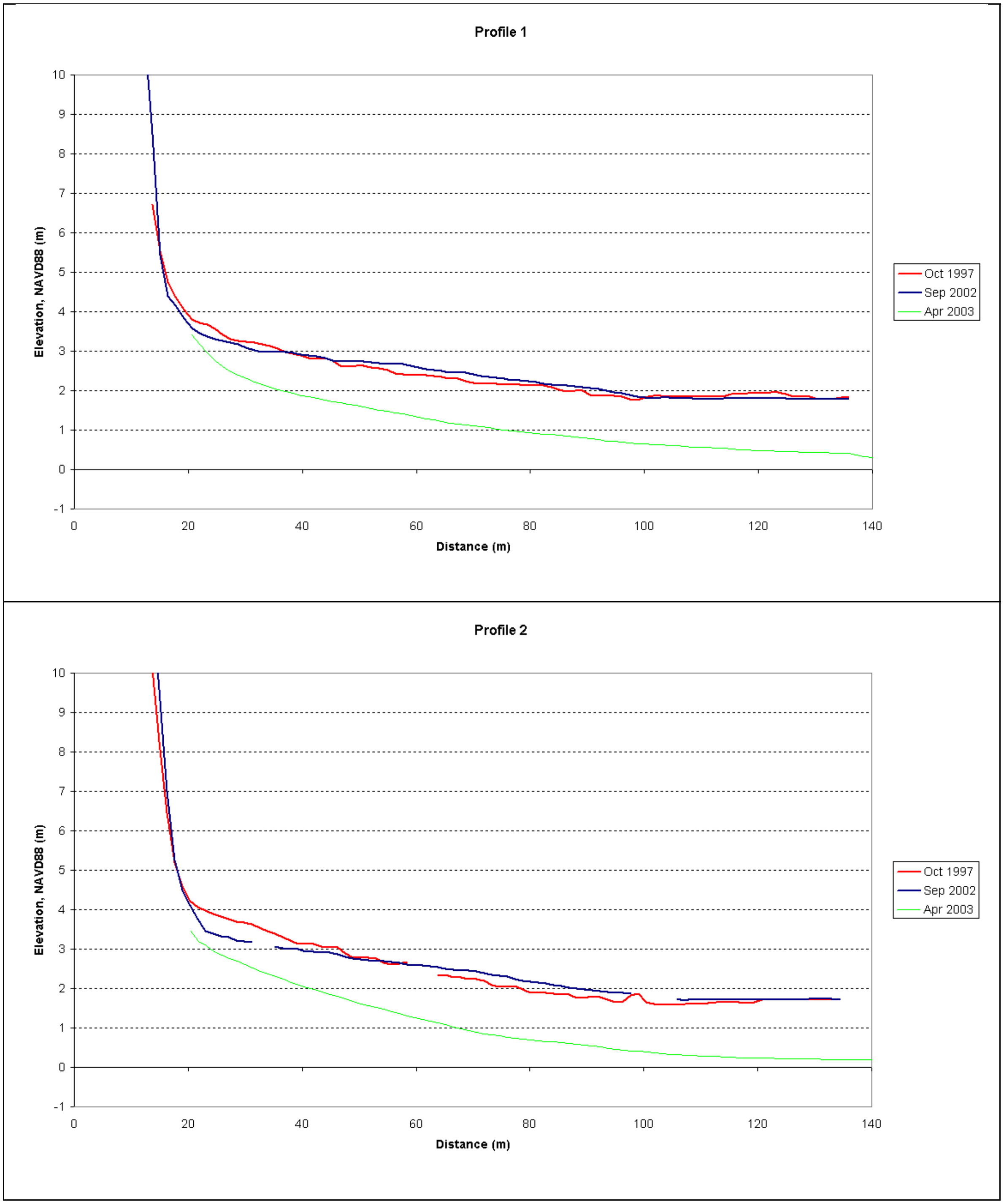
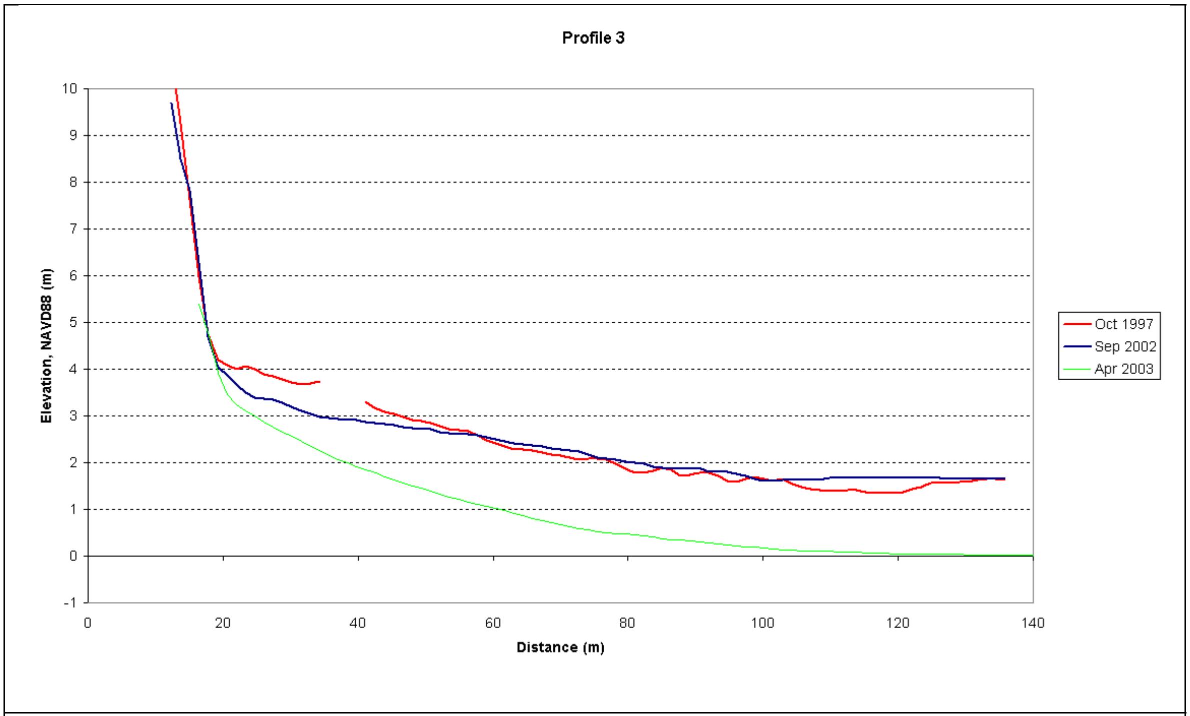
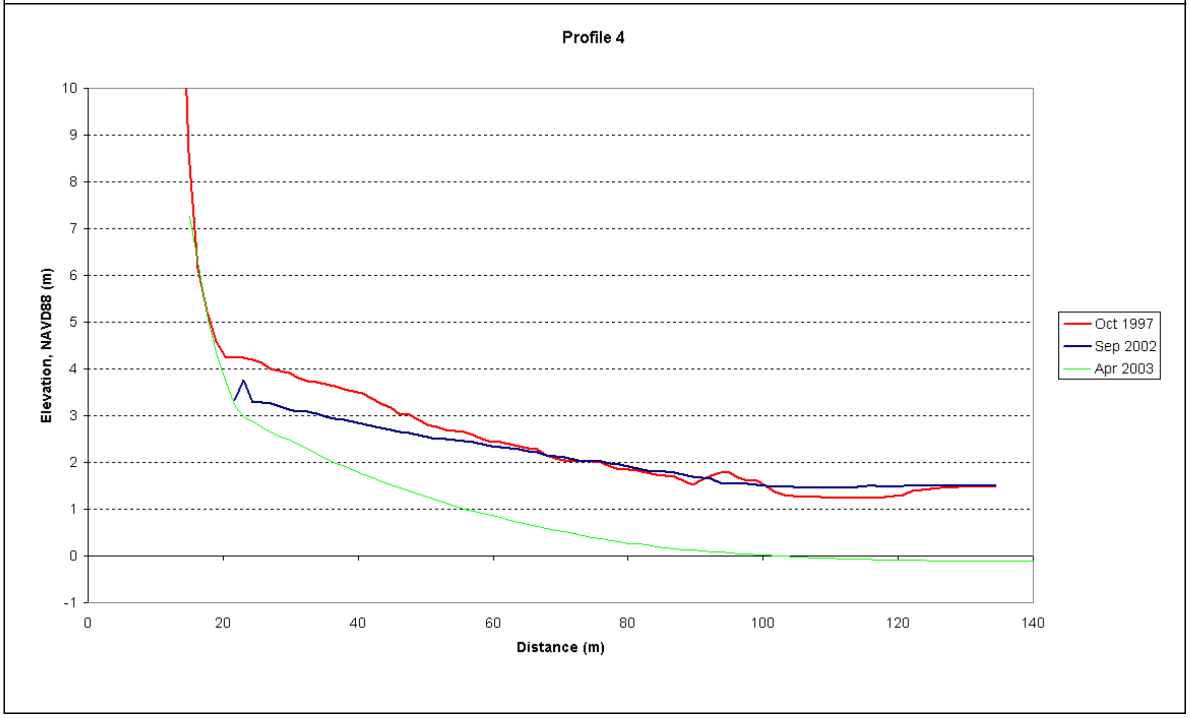


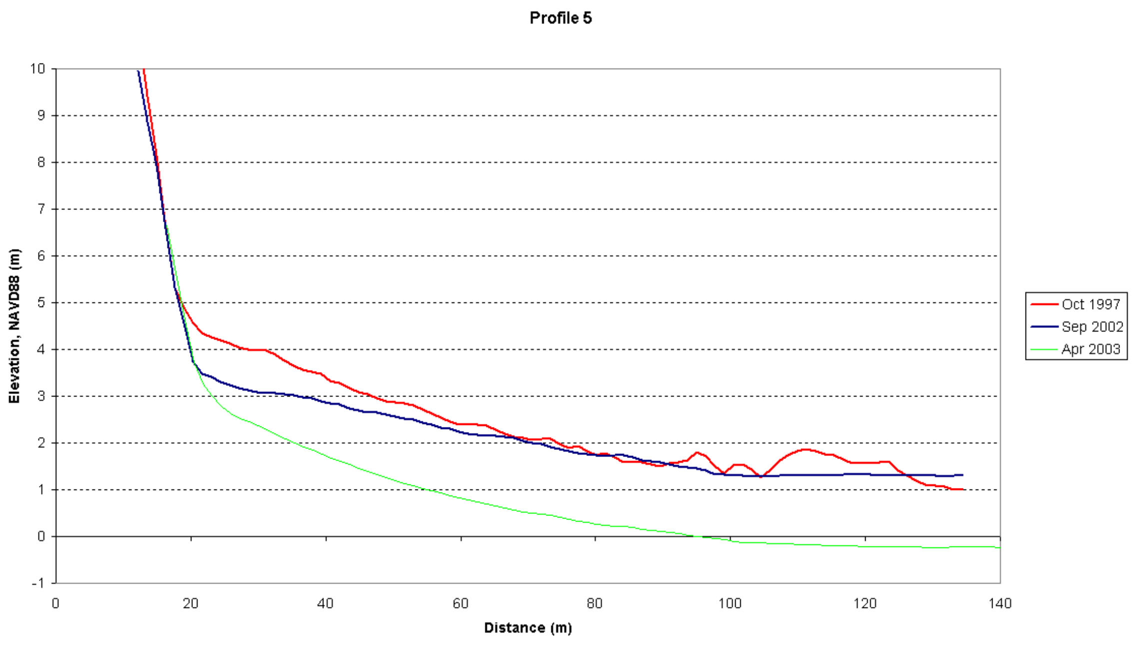
Figure 2: 3-D perspective overlooking the beach in front of the Johnson Creek landslide. View is towards the south-east. Contour elevations are 0.25 m, with 1.0 m contours delineated by the green line. The red line denotes the approximate location of the mudstone/beach contact in April 2003. The beach experienced a vertical drop of 1 – 2 m over the 2002-03 winter storm season.

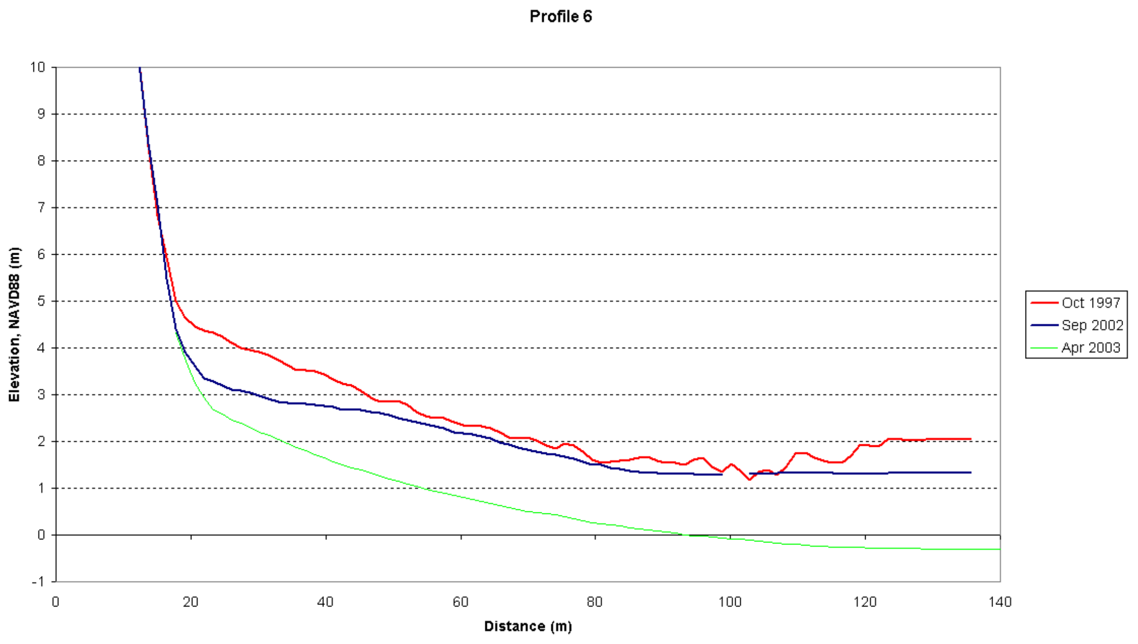
Figure 3: Beach profile surveys derived from LIDAR data and from the April 2003 topographic survey.

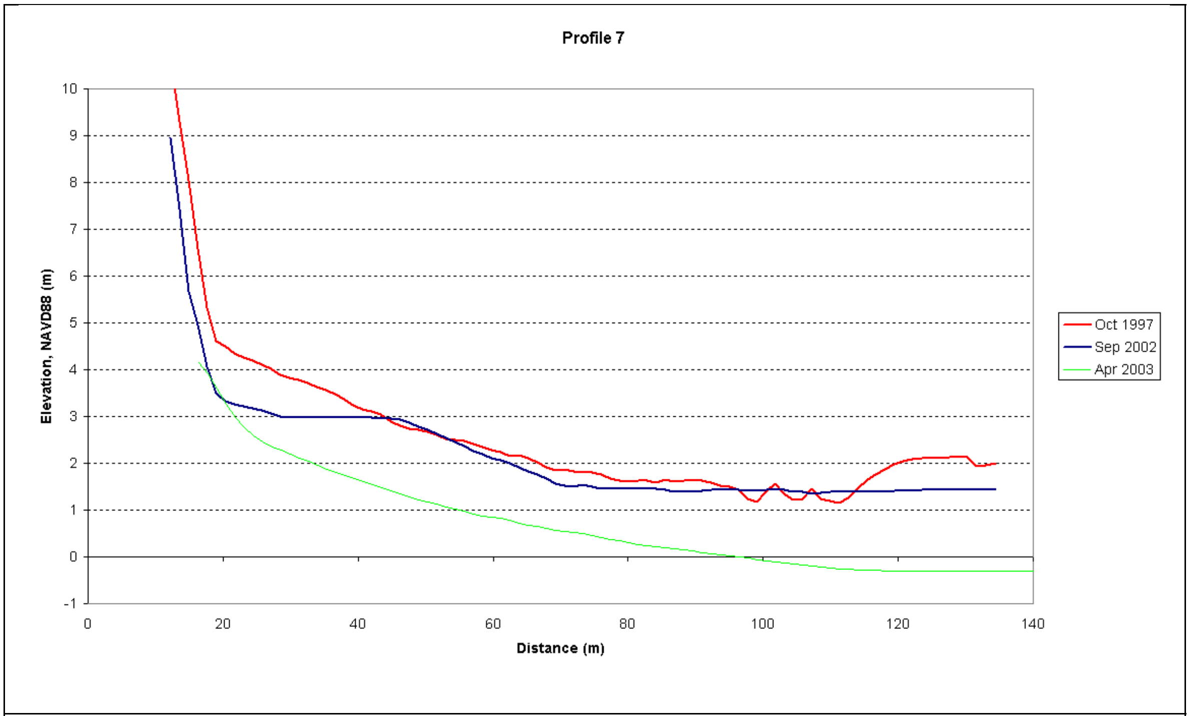



Profile 3
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003

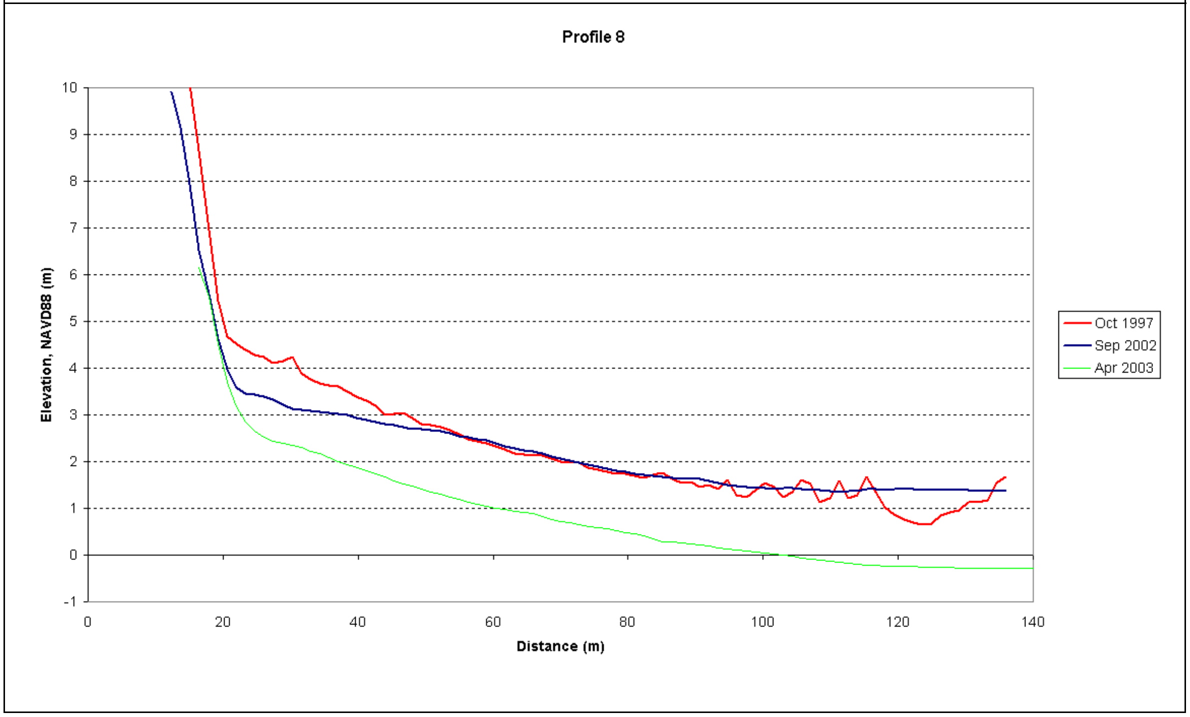

Profile 4
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003


Profile 5
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003

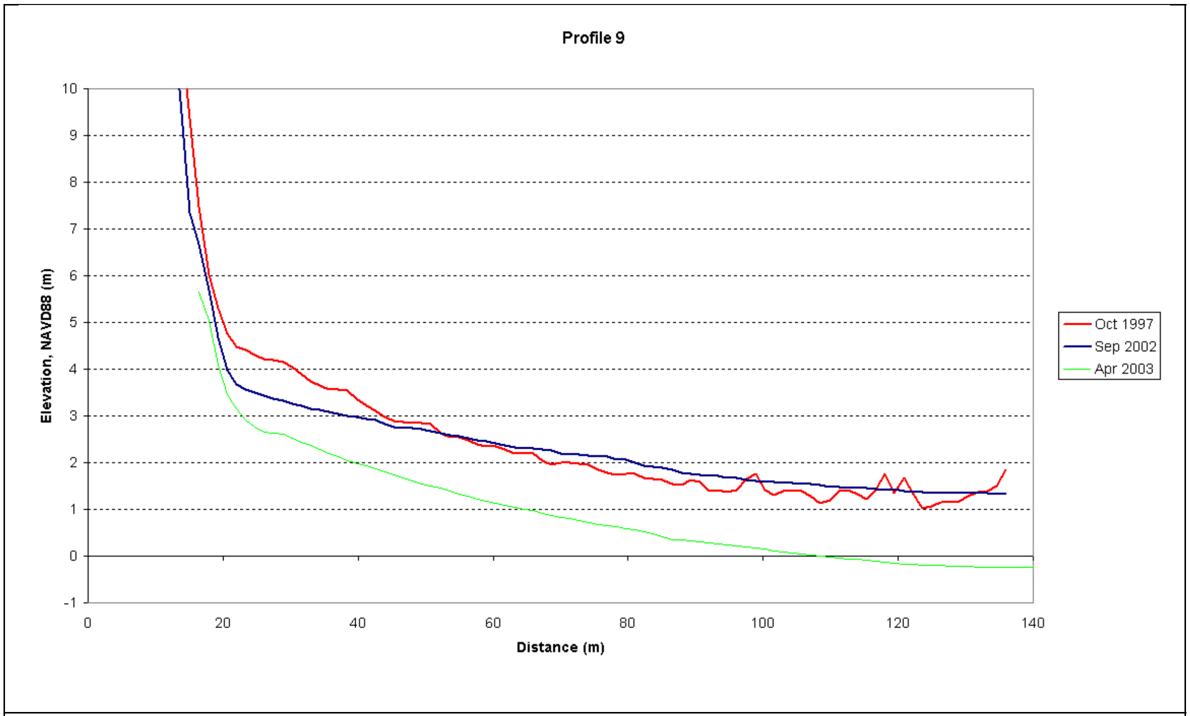

Profile 6
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003

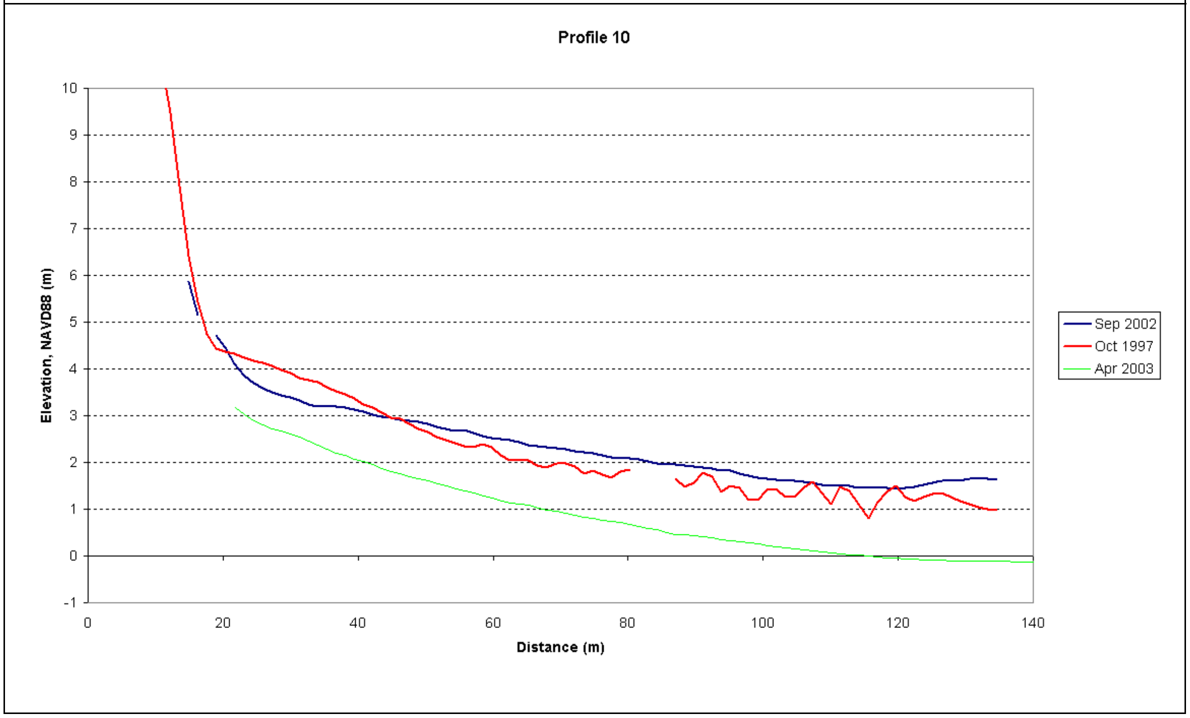


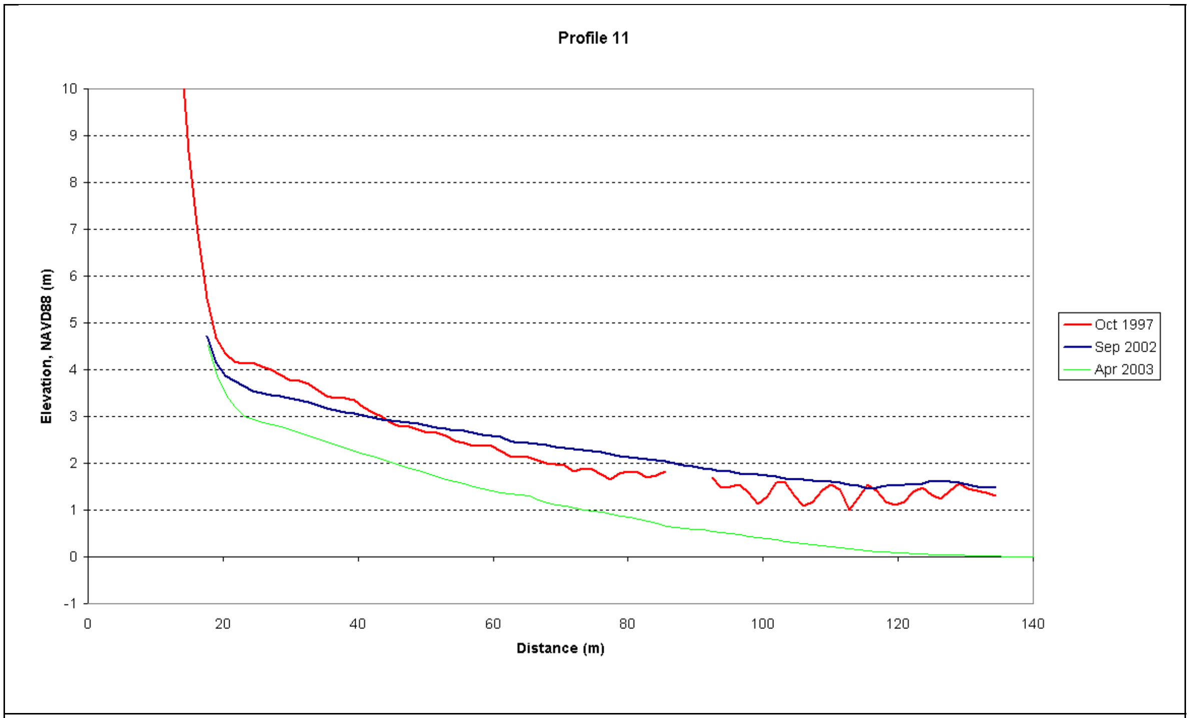
Profile 7

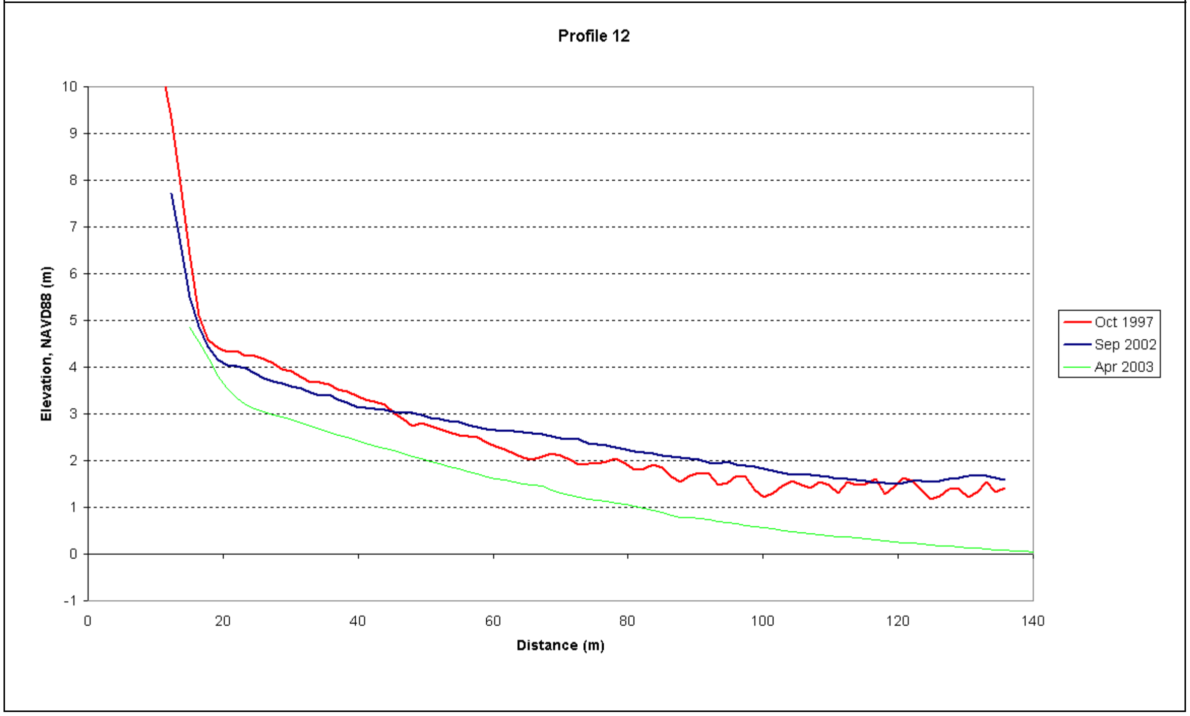


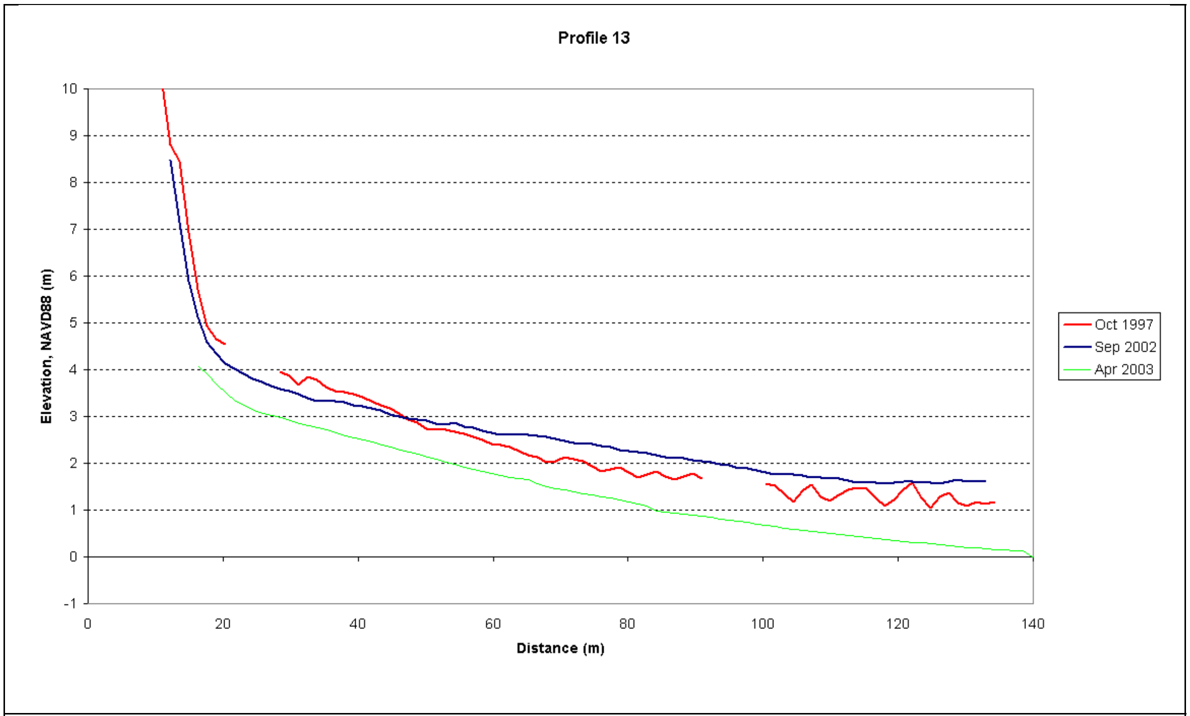
Profile 8

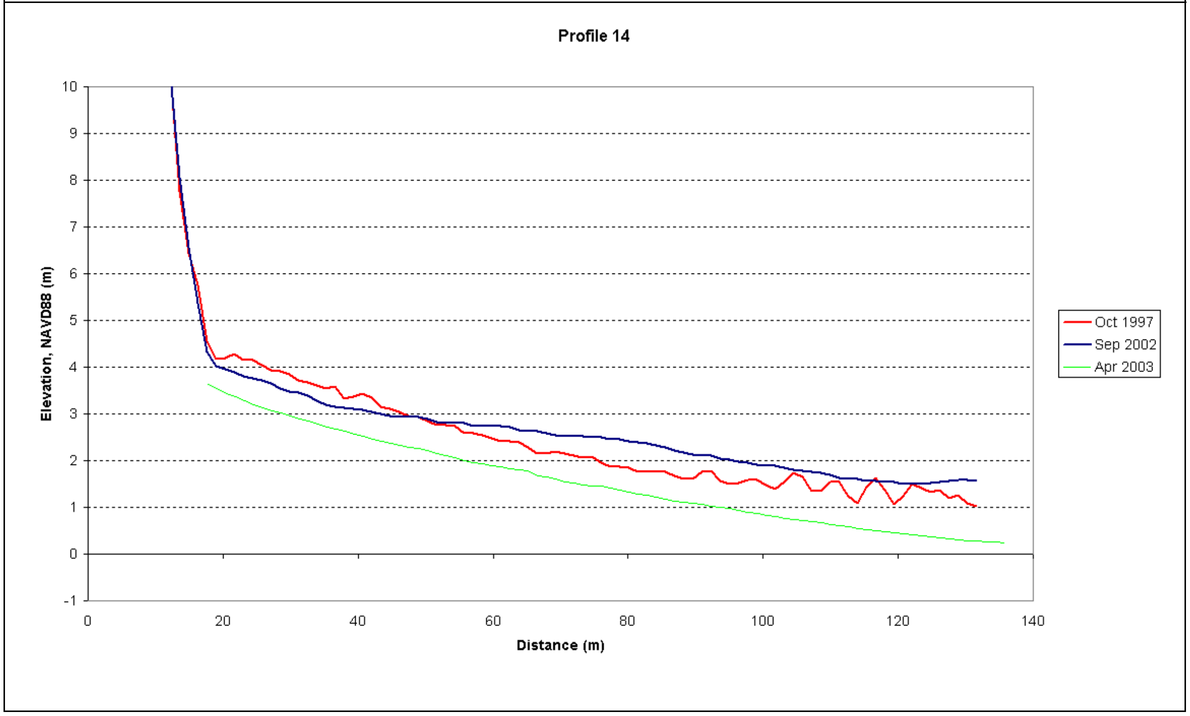

Profile 9
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003


Profile 10
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Sep 2002
Oct 1997
Apr 2003


Profile 11
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003

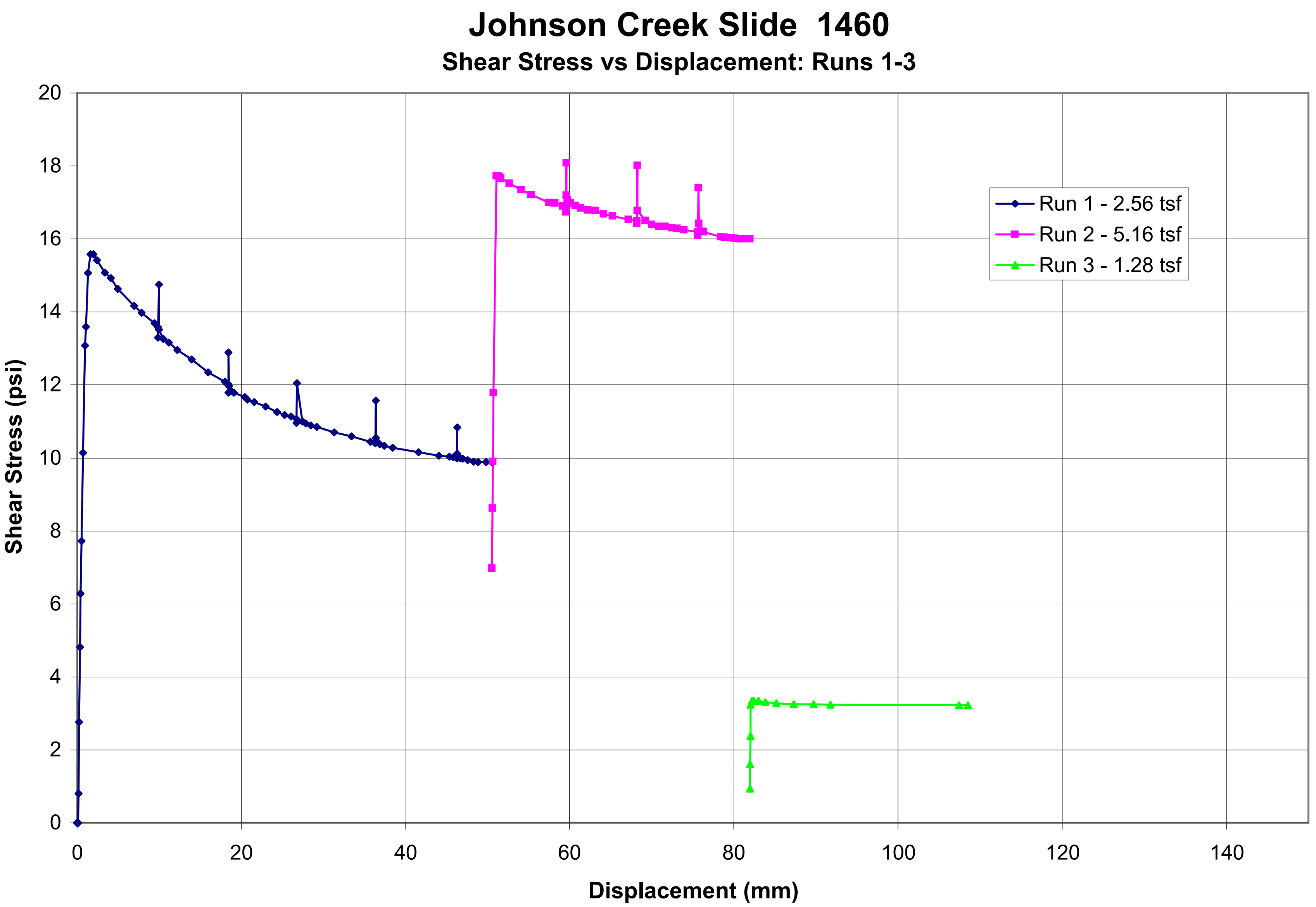

Profile 12
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003


Profile 13
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003


Profile 14
Elevation, NAVD88 (m)
10
9
8
7
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
Distance (m)
Oct 1997
Sep 2002
Apr 2003

APPENDIX H

Ring Shear Test Plot



Ring Shear Test Data - 1460.xls