Last Chance Grade Permanent Restoration Project

Preliminary Geotechnical Data Report

Submittal SUB#032

July 2022 – FINAL

EA# 01-0F280

Project EFIS# 0115000099

Del Norte County, U.S. 101,

PM 12.0/15.5

Caltrans

LAST CHANCE GRADE

Contents

TABLES

FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

AGI	Advanced Geosciences, Inc.
ASTM	American Society for Testing and Materials
ATV	acoustic televiewer
BGS	below ground surface
CAL	mechanical caliper
Caltrans	California Department of Transportation
Caltrans Manual	Caltrans 2010 Soil and Rock Logging, Classification, and Presentation Manual
CCD	charged-coupled device
CPT	cone penetration test
CSZ	Cascadia Subduction Zone
DEM	digital elevation model
DGSI	Durham Geo Slope Indicator
DUIN	dual induction
EBRA	Expert-Based Risk Assessment
EF	Large Earthflow Complex
EFS	Engineered Feasibility Study
EM	electromagnetic
EMI	Earth Mechanics, Inc.
ESRI	Environmental Systems Research Institute
FHWA	Federal Highway Administration
gINT	geotechnical integrator software by Bentley Systems, Incorporated
GIS	geographic information system
GPS	global positioning system
H:V	horizontal to vertical
HQ-sized core	rock core with inside diameter of 63.5 mm (2.500 inch)
HWT casing	threaded steel casing with outside diameter of 4 ½ inches
ID	inside diameter
IGM	intermediate geomaterial
ISRM	International Society of Rock Mechanics
LCG	Last Chance Grade

LiDAR	light detection and ranging
NAVD88	National American Vertical Datum of 1988
NG	natural gamma
NGVD29	National Geodetic Vertical Datum of 1929
NLCG	North Last Chance Grade Complex
NQ-sized core	rock core with inside diameter of 47.6 mm (1.874 inch)
OD	outside diameter
OTV	optical televiewer
P-Y curve	numerical model used to simulate response of soil resistance (P, soil resistance per unit length of pile) to the pile deflection (Y) for piles under lateral loading
PA&ED	Project Approval and Environmental Document
PM	post mile
PMT	pressuremeter testing
Project	Last Chance Grade Permanent Restoration Project
PS	PS Suspension
PSR	Project Study Report
Report	Preliminary Geotechnical Data Results report
RQD	rock quality designation
SI	slope inclinometer
SLCG	South Last Chance Grade Complex
SPT	standard penetration test
TDR	time domain reflectometry
US 101	U.S. Highway 101
USBR	U.S. Bureau of Reclamation
VA	Value Analysis
VWP	vibrating wire piezometer
WC	Wilson Creek Complex

1 INTRODUCTION

1.1 Overview

The California Department of Transportation (Caltrans) is studying alternative alignments and design options for the Last Chance Grade Permanent Restoration Project (Project) on U.S. Highway 101 (US 101). These studies are in response to the section of US 101 between post miles (PM) 12.0 and 16.0, extending from Wilson Creek to approximately 9 miles south of Crescent City in Del Norte County (known as "Last Chance Grade" [LCG]) (Figure 1) that has been progressively sliding towards the Pacific Ocean since the roadway was first constructed. Due to continual road deformation resulting from slope movement, ongoing construction and maintenance activities are necessary to keep US 101 open to the traveling public. The Project is considering alternatives that provide a more reliable connection, reduce maintenance costs, and protect the economy, natural resources, and cultural landscapes.

1.2 Report Purpose and Scope

This Preliminary Geotechnical Data Report (Report) presents geologic and geotechnical data gathered by and on behalf of Caltrans through May 31, 2021, in support of the Project Approval and Environmental Document (PA&ED) for the Last Chance Grade Permanent Restoration Project (Caltrans Project ID 0115000099-EA 01-0F280). This exploration phase was defined as Phase 2B.

The Report also presents geotechnical data gathered by or on behalf of Caltrans for previous Last Chance Grade Project studies (Investigation Phase 1 and Phase 2A), as well as published reports relevant to the Project area.

The purpose of the Report is to present:

- A description of the general site conditions and geologic setting of the Project area
- A description of the desktop, field, and laboratory methods and procedures used in Phase 2B geotechnical and geologic investigations
- A compilation of data gathered from the Phase 2B geotechnical and geologic investigations
- A compilation of available geotechnical data and reports prepared by others prior to Phase 2B investigations

1.3 Report Limitations

The data presented in this report represent site conditions during the time period in which the work was performed. Soil, rock, landslide, and groundwater conditions may vary seasonally and over time. The data obtained during this investigation also is from a necessarily limited number of observations, borings, samples, instruments, and tests and is specific to the locations explored. The data does not completely define the subsurface conditions throughout the project site, which can vary within short distances.

1.4 Report Organization

Following this introductory section, Section 2 of this Report presents descriptions of the site and of the Project, followed by a summary of site conditions and the geologic and seismic setting in Section 3. The geotechnical investigation program is described in Section 4. Existing data and remote sensing data used to support the investigation are described in Sections 5 and 6, respectively. Section 7 provides details of the field exploration program, and Section 8 describes the laboratory testing program. Figures and tables follow the text, and data are presented in Appendices A through M.

2 PROJECT DESCRIPTION

2.1 Site Location and Description

The Project is in southern Del Norte County between Wilson Creek and Crescent City (PM 12.0 to 16.0). US 101 rises from a low elevation of approximately 100 feet at PM 12.0, near the Wilson Creek bridge, to a high elevation of approximately 960 feet at PM 16.0. Within these project limits, the highway varies from two to four traffic lanes with a portion of the highway limited to a single traffic lane and traffic light (reverse traffic control) to control traffic flow at a highway repair project due to active landslides. From PM 12.0 to approximately PM 15.57, the highway is positioned on the west flank (ocean-side) of a steeply sloped, northwest-southeast trending ridge that forms the dominant topographic feature of the project. Beginning at PM 15.57, the highway turns northeast away from the ocean and continues along more gently sloped, rolling topography covered in redwood forest where the project terminates at PM 16.0.

Most of the west flank of the ridge and all of US 101 are located within the Redwood State and National Parks that are also designated as a UNESCO World Heritage Site (UNESCO World Heritage List, 2021). Within the southern portion of the project area, 50 prehistoric archaeological sites, 19 historical sites, and at least 21 places of significance have been identified to local American Indian communities that span 4,500 years. Other historical resources include examples of early trails, homestead and ranching, fishing, dairy, mining and logging industries, and military structure.

The east side of the State and National Park lands form a property boundary with Green Diamond Resource Company that generally trends north-south with several east-west stepped sections. This property boundary is roughly congruent with the prominent northwest-southeast trending ridge, with Green Diamond occupying the land east of the ridge where they perform regular logging operations. The Green Diamond property is characterized by several unnamed drainages that flow into Wilson Creek which flows from east to west just south of the project area and forms a dominant drainage valley that extends to the coast.

2.2 Project Description

The purpose of the Project is to identify a permanent solution to address multiple large landslide complexes that have damaged the highway for decades between Wilson Creek and Crescent City (PM 12.0 to 16.0). The project is considering alternatives that provide a more reliable segment of highway than the current highway segment.

The project was initiated in March 2014 when Caltrans established the Last Chance Grade Partnership (Partnership) to work with the agencies and groups that have management responsibilities for lands and resources directly impacted by any realignment of US 101 at LCG. The Partnership initiated an Engineered Feasibility Study (EFS) to identify potential improvement projects that could ensure the safety and reliability of the highway while protecting the area's critical economic, environmental, and cultural resources.

The study was followed by a Project Study Report (PSR) completed in 2016 (Caltrans District 1, 2016). This report provided a more detailed analysis of the alternatives recommended for further study in the EFS as they related to the cost, scope, and schedule of developing the project.

In May 2017, the California Transportation Commission approved $5 million for Caltrans to perform preliminary geotechnical investigations. Because the alternative routes all run through areas of historic landslides, the preliminary geotechnical studies were performed to learn if the alignments could be constructed as proposed or if doing so would result in similar issues that already impact LCG.

Caltrans and the Federal Highway Administration (FHWA) completed an Expert-Based Risk Assessment (EBRA) (BGC, 2018) and Value Analysis (VA) (VMS, 2018) in 2018. The EBRA informs and supports any future recommendation to approve and fund a full realignment project. The EBRA was used as a tool to help the Partnership narrow down the list of alternatives by focusing only on those that meet the need of the project: to improve long-term stability. The VA resulted in eliminating three project alternatives, thereby reducing the cost and complexity of future environmental studies.

In March 2019, the California Transportation Commission approved an additional $45 million for Caltrans to complete the environmental phase of the project. The purpose of this phase, now in progress, is to evaluate environmental issues related to the alternatives and to complete the PA&ED. The geotechnical data collected and presented in this Report support this environmental phase of the project.

Geologic and geotechnical desktop and field exploration programs to collect data in support of the PA&ED were used to assess seven alignment alternatives identified from the previous studies described above. These alternative alignments were configured as follows:

- Maintaining the existing US 101 alignment (Alternative X)
- Locating US 101 higher up on the slope of the main ridge (Alternative L)
- A tunnel constructed below and behind the active landslides (Alternative F)
- Four alternatives located on the east side of the prominent ridge, extending through the Green Diamond property, and located to circumvent the active coastal landslide activity. (Alternatives A1, A2, G1, and G2)

In April 2021, following an alternatives analysis screening process, Caltrans selected two alternatives for further study, Alternative X and Alternative F, and removed other alternatives from consideration.

3 GEOLOGIC AND SEISMIC SETTING

The project area is located within the Coast Ranges geomorphic province of California, near the Klamath Mountains, which lie about 10 miles to the east (see Figure 1). The site is located about 90 miles north of the Mendocino Triple Junction, which is the crustal intersection of the Pacific, North American, and Gorda/Juan de Fuca tectonic plates. North of the triple junction, the Gorda/Juan de Fuca plate is being subducted eastward beneath the North America plate along the Cascadia Subduction Zone (CSZ), which extends approximately 800 miles from northern California to Vancouver Island, British Columbia. As is true for other coastal regions of northern California, Oregon, and Washington, the project site overlies the interface associated with the subducting crustal plate. This subduction interface is a low angle, east-dipping “megathrust” fault.

The site geologic setting is characterized as being within the accretionary prism that has formed (and continues to form) above the CSZ at the leading edge of the North America plate. Geologic materials in the region are primarily associated with the long-term accretionary history, and active tectonic deformation throughout the region occurs as a byproduct of the ongoing subduction process. In addition to the immense seismic potential associated with the CSZ itself, other active seismic sources also occur within the subducting Gorda and Juan de Fuca plates and along secondary faults associated with fold and thrust belts within the over-riding North American plate.

The site area and environs are characterized as a region of high seismic potential. The area south of the project study area near the triple junction is perhaps the most seismically active area in the conterminous United States (Freymueller and others, 1999; Furlong and Schwartz, 2004; Dengler, 2008). The CSZ is capable of generating “great” earthquakes of high magnitude (>M8.5), depending on the length of the rupture (Heaton and Hartzell, 1987; Nelson and others, 2021; PNSN, 2020). A full-length rupture of the entire CSZ would likely exceed magnitude M9. The surface trace of the CSZ is located about 55 miles west of the site (measured from Google Earth Pro), while the fault plane dips eastward about 10 to 15 degrees (McLaughlin et al., 2000) beneath the region. The CSZ detachment fault boundary is therefore located about 9 ½ to 14 miles deep beneath the site.

Recent estimates suggest 17 earthquakes have occurred along the southern and central segments of the CSZ in the past 6,700 years, with earthquake recurrence on the order of 510 to 540 years (Nelson et al., 2021). The most recent major CSZ earthquake occurred on January 27, 1700 and is interpreted as a >M9 full-length CSZ rupture. That earthquake is documented in local native Tribal oral history and in Japanese historical tsunami records and is documented in the field by land level changes from California to British Columbia (Atwater et al., 2005).

The Gorda plate is a relatively small tectonic plate at the southern end of the CSZ, and it is subject to a variety of complex forces as it is being subducted. It is actively deforming and is the most frequent source of felt earthquakes for the northern California coast area (Chaytor et al., 2004; Hemphill-Haley et al., 2020). Due to the internal stresses within the Gorda plate, it is highly sheared, but most notably broken by a series of northeast-trending faults that produce frequent left-lateral earthquakes. Faulting within the Gorda plate produced 20 earthquakes >M5.9, including four >M7 earthquakes, between 1976 and 2010 (Rollins and Stein, 2010). There have been three additional earthquakes >M6.5 since 2010.

Active deformation is occurring in a fold-and-thrust belt terrain south of the project area, responding to northeast-southwest oriented crustal shortening. There is a series of northwest-trending, southwest-vergent (over-riding block moving toward the southwest) thrust faults which include the Mad River fault zone, the Table Bluff fault, and the Little Salmon fault. These faults are located between 37 and 60 miles south of the project area measured along the coastline; although all are known to extend offshore (Clarke, 1992; Clarke and Carver, 1992; Hemphill-Haley et al., 2020). These likely represent the nearest known Holocene-active surface faults to the project site.

A series of suspected older, poorly defined bedrock faults occur north of Big Lagoon and generally south of the Klamath River, all 4 ½ to 10 miles to the south and southeast of the project area. These include the Bald Mountain-Big Lagoon fault zone, the Grogan fault, the Lost Man fault, and the Surpur Creek fault. All of these faults are considered to be “Quaternary” age (Bald Mountain-Big Lagoon fault is listed as “late Quaternary” age) per the U.S. Geological Survey Quaternary Fault and Fold Database. The Grogan fault defines a major geologic bedrock boundary and is interpreted as a high-angle right-lateral strike-slip fault (Hart, 1999; Kelsey and Carver, 1987). The Lost Man and Surpur Creek faults (generally defined by the mapping of Aalto et al., 1981) are poorly located, but represent the nearest mapped faults to the project area. An early map (Aalto et al., 1981) shows a northward extension of the Lost Man fault that crosses the project area; this trace appears on an outdated California Geological Survey Fault Activity Map (active until 2017). The northern extension of the Lost Man fault is not shown north of the Klamath River on more recent mapping (it extends offshore; Kelsey and Carver, 1987) and is not shown on the current national database of Quaternary faults and folds (Bryant, 2017). Evidence for this fault was not observed in the field during previous LCG-related geologic investigations.

The Coast Ranges in the project area are underlain by regionally extensive Mesozoic and Cenozoic age rocks of the Franciscan Complex, an assemblage of mostly marine sedimentary materials accreted (“welded”) to the continental margin. The Franciscan Complex occurs in a series of elongate belts that define specific age materials, material types, and metamorphic grades; these are the Coastal, Central, and Eastern belts. The site occurs within the Eastern belt of the Franciscan Complex (Delattre and Rosinski, 2012; Aalto, 1989), which is the oldest, least penetratively sheared, and most highly metamorphosed of the three belts (McLaughlin et al., 2000).

The Franciscan Complex in the Crescent City region (site vicinity) consists of shale-matrix mélange derived from a large submarine landslide deposit bounded by submarine debris slide deposits (e.g., “turbidites”) that contain lesser amounts of radiolarian chert, pelagic limestone, greenstone, plutonic rocks, and blueschist-facies metamorphic rocks (Aalto, 1989). Subsequent extensive accretion-related deformation (faulting, metamorphism) has resulted in pervasive shearing and complex structural relationships that have resulted in two primary bedrock types in the project area: mélange and “Broken Formation” (Aalto, 1989). Bedrock mapping of the project area has been completed by Ristau (1979), Aalto and Harper (1982), Wills (2000), and Delattre and Rosinski (2012). Delattre and Rosinski (2012) show the project area crossed by an elongate north-trending band of the “Mélange of the Crescent City area,” surrounded on both sides by “Broken Formation”. Mapping by Wills (2000) is shown in Figure 2.

Broken Formation rocks in the project area consist mainly of thickly bedded gray sandstone with lesser siltstone and shale interbeds. The material occurs as relatively intact blocks of varying sizes bounded by shear zones; therefore, bedding is discontinuous and "broken." Due to the preponderance of sandstone, Broken Formation areas are relatively resistant to erosion such that drainages are well-defined and more mature topographic (and forest) conditions develop.

Melange rocks in the project area consist of isolated, rootless rock blocks entrained within a highly sheared, dark gray siltstone (sometimes shaly) or argillite matrix. Rock blocks vary in size, lithology, and location; larger blocks are mappable in scale and typically consist of greenstone, graywacke, chert, or serpentinite (Wills, 2000). Due to the weak nature of the sheared mélange matrix, these areas have a high susceptibility to earthflows and erosion and form a distinct hummocky, low gradient topography.

4 GEOTECHNICAL INVESTIGATION PROGRAM DESCRIPTION

4.1 Program Description

The Phase 2B geotechnical investigation program was planned and performed to support the PA&ED phase of the Project. The program included a desktop study, field explorations, and laboratory testing. The data collected are also anticipated to be used for future, alternative-specific geologic, geotechnical, and groundwater evaluations, modeling, analysis, and design.

4.2 Program Summary

The geotechnical investigation program consisted of the following general activities:

- Desktop study using available LiDAR elevation data, aerial photographs, and review of historical reports and data to develop an exploration plan and to prepare a geologic hazards map (presented in Appendix B)
- Geologic mapping to further collect field data related to features associated with landslide activity within the project area, and to further refine the geologic hazards map completed during the desktop study
- Subsurface explorations to obtain rock and soil samples at strategic locations relative to the seven alignments and identified geologic hazards
- Logging of borings using the Caltrans (2010) Soil and Rock Logging, Classification, and Presentation Manual, and collecting, handling, labeling, and storage of core and soil sample specimens in core boxes in preparation for further classification and future selection of samples for laboratory testing
- Downhole acoustic and optical televiewer surveys, downhole geophysics using PS suspension logging for shear and P-wave velocity data, and downhole pressuremeter testing (PMT) for assessment of states of stress and strain/stiffness characteristics of various rock formations at variable depths
- Packer testing at select intervals and boreholes to obtain hydrogeologic data
- Installation of vibrating wire piezometers (VWPs) and open-hole standpipe type wells to collect groundwater data

- Installation of slope inclinometer (SI) casing and time domain reflectometry cable (TDR) to collect deformation data associated with ground movement
- Surface geophysical surveys to further characterization subsurface conditions and geologic structure, and to obtain information on rippability for earthwork grading
- Installation of weather stations to measure rainfall
- Laboratory testing of rock and soil units for characterization of material physical and engineering properties, mineralogy, shear strength, permeability, suitability for reuse in earthwork, compaction characteristics, and slope stability analysis

4.3 Participants

The following participants were involved with the planning and collection of data for Phase 2B:

- Borings were drilled by Gregg Drilling and Testing of Martinez, California, and Crux Subsurface of Spokane, Washington. The drillers self-performed the packer tests for their respective boreholes and at instructed depth intervals.
- Disposal of drilling cuttings was performed by Dillard of Byron, California.
- Drilling access development and site restoration support was provided by McCullough Construction of Arcata, California.
- Traffic control during drilling operations on US 101 was provided by Construction Area Signs, Inc. of Newcastle, California.
- Drilling oversight and logging was performed by staff from Caltrans District 1, Kleinfelder, ENGEO, and SHN Consulting Engineers and Geologists.
- In-situ borehole PMTs were performed by In-Situ Engineering of Snohomish, Washington.
- Surface geophysics and downhole imaging and in-situ borehole geophysical surveys were performed by GEOVision of Corona, California, and Crux Subsurface.
- Soil and rock laboratory testing were performed by Earth Mechanics, Inc. (EMI) of Fountain Valley, California, and Kleinfelder of Rancho Cordova, California, with thin section petrographic analysis performed by Spectrum Petrographics Inc. of Vancouver, Washington, and corrosion analysis performed by Sunland Analytical of Rancho Cordova.

4.4 Survey Datum and Coordinate System

The project vertical datum is NAVD88. The horizontal control is NAD83 CA Zone I.

5 EXISTING INFORMATION

Table 1 presents a list of references, including cited published and unpublished geologic and seismic papers and maps as well as studies and geotechnical investigations performed by and for Caltrans.

Caltrans provided numerous project information files, including engineering technical reports, environmental documents and environmental technical reports, CAD files and drawings, geotechnical and materials reports, and relevant correspondence. Reports from Caltrans Project studies and data from Caltrans investigations conducted within the past five years are described below and are included in Appendix A of this Report. Other investigations performed prior to initiation of the Last Chance Grade Bypass Project, now called the Last Chance Grade Permanent Restoration Project, are not included in this Report.

5.1 Caltrans Studies and Reports

A Project Study Report (PSR) by Caltrans District 1 (2016) proposed seven alternatives in response to landslides and roadway failures at LCG, one of which included maintaining the existing alignment (referred to as the no-build) and six of which included realignment of US 101 with the goal of avoiding the unstable portions of LCG.

An EBRA was prepared by BGC Engineering USA, Inc. (2018) for Caltrans to compare the geotechnical risks for alternative alignments that included major improvements generally along the existing alignment and along previously determined alternatives that bypass the segment on entirely new alignments to the east.

A VA study was prepared by Value Management Strategies, Inc. (2018) for Caltrans to analyze the potential Alignment Alternatives that optimize project scope to meet the project need and purpose while addressing the long list of constraints and challenges.

A Supplement to the PSR by (Caltrans District 1, 2019a) was published to document significant changes since the original PSR and to discuss the project's current scope, alignments, and design concepts. The Supplement to the PSR contains additional information for each alternative, including cost estimates, typical cross-sections, plan layouts, and alignment profiles.

5.2 Previous Caltrans Geotechnical Investigations

The first phase of the geotechnical investigation by Caltrans Office of Geotechnical Design (2018) included literature review, aerial photograph and LiDAR raster review and desktop mapping, field mapping and ground-truthing, geotechnical drilling, instrumentation and monitoring, and seismic refraction surveys at eight key locations along the LCG A-Alignment. Field work was completed between February 5, 2018 and September 27, 2018. The Phase 1 geotechnical investigation memorandum summarizes the activities performed and the preliminary findings.

The second phase of the geotechnical investigation by Caltrans District 1 included seven geotechnical borings (two of which were horizontal borings) and two VWPs. Kleinfelder fully logged two borings (Caltrans District 1, 2019b and 2020), Caltrans fully logged four borings (Caltrans District 1, 2019c through 2019f), and one boring was logged by both Kleinfelder and Caltrans (2019g). Field work was completed between August 19 2019 and February 13, 2020. The Phase 2A field logs are included in Appendix A. The VWPs were completed using air percussion drilling method and, therefore, no field logs were prepared.

Logging methods and terminology used in previous geotechnical investigations by Caltrans may differ from those used for the investigations described in this report. Data from the previous project investigations should be segregated until they have been reviewed and reconciled for consistency with the current data set.

6 REMOTE SENSING DATA SUPPORTING GEOTECHNICAL INVESTIGATIONS

Remote sensing data used for the investigation included LiDAR elevation data, ESRI imagery, Google Earth imagery, Digital Elevation Models (DEMs), and ortho-aerial imagery. Sources and dates associated with these data are as follows:

- LiDAR: Flown and compiled by Towill, Inc., 2016
- ESRI World Imagery Basemap, September 2018
- Google Earth Imagery, August 2019
- DEM: Created June 11, 2020, by HNTB using 2016 LiDAR
- Ortho Aerial Imagery, 2016

7 FIELD EXPLORATION

Table 2 summarizes the field exploration program.

7.1 Geologic and Landslide Mapping

Geologic and landslide mapping was initially developed during a desktop study that included review and use of the following data:

- Published geologic maps within the site vicinity
- Caltrans and consultant unpublished reports for LCG, including the previous 2018 EBRA report by BCG Engineering USA Inc.
- Caltrans and consultant borings (logs) drilled within the existing right-of-way for various previous projects along LCG as well as selected off-site explorations on the Green Diamond Property
- Caltrans and consultant inclinometer plots along LCG
- Prior Caltrans mapping of the Project area
- Elevation and aerial photography including 2016 based LiDAR, Google Earth Imagery, Digital Elevation Models, and ortho aerial imagery

Geologic hazards shown in Appendix B were mapped from topographic variations in elevation relief viewed on LiDAR and DEM and features viewed in aerial photograph imagery. The desktop mapped area included the approximate area bound to the north by the Project limits at PM 16.0, to the west by the ocean/beach boundary and to the south by the Project limits near PM 12.0 and extending northeast along Wilson Creek Road to the east boundary. The east boundary was less defined as it included the eastern most alignment segments and those slopes and/or geologic hazards identified that could potentially impact the alignments.

To characterize the existing landslides/slope instabilities the geologic team used a four-digit classification system. Each of the digits represents a specific classification characteristic that describes the type of landslide. The four characteristics are State of Activity, Certainty of

Identification, Dominant Type of Movement, and estimated Thickness of Deposit. A description of the landslide characteristics is presented on the Landslide Identification Chart, included in Appendix B (page 2 of 2).

In general, the landslides within the project boundaries were classified as either Active, Dormant, or Ancient. Active landslide features, defined by distinct landslide head scarps and side scarps and hummocky, uneven topography, were mapped with high confidence. Less distinct topography and elevation relief were more commonly associated with dormant and ancient landslide features, primarily found to the east of the primary ridge.

Field reconnaissance mapping was performed by geologists from Caltrans, Kleinfelder, and SHN on May 4 through 6, 2020. Two teams of four covered the Project area to evaluate geologic hazards and investigate larger features mapped from the desktop study. The field reconnaissance study area included the area bound to the north by the Project limits at PM 16.0, to the west by US 101 and to the south by the Project limits near PM 12.0 and extending northeast along Wilson Creek Road to the east boundary. Similar to the desktop study, the east boundary was less defined and included only larger landslides that were identified as directly impacting a project alignment. Not all landslides and/or portions of landslides could be mapped or verified during the site reconnaissance due to heavy vegetation that prohibited access. During the field reconnaissance, larger, ancient landslides were interpreted from topographic gradient changes and observed accumulation and distribution of colluvial soils. Smaller, recent landslides were interpreted from evacuated zones with an abnormal or absent sediment accumulation at the base of slopes and drainages. Tilting and bowing of large redwoods were also important in the interpretation of landslide movement and age of initiation.

Certain unstable areas of the overall project site were identified, grouped, and named as large, active landslide complexes based on their locations and type of failure mode. These include the North Last Chance Grade Complex (NLCG), the South Last Chance Grade Complex (SLCG), the Wilson Creek Complex (WC), and the Large Earthflow Complex (EF). With the exception of the EF, the other complexes are considered to be deep translation block landslides that toe out near the base of the slope at or around sea level. The named landslide complexes are labeled on the Geohazards Map in Appendix B.

It was noted that some geologic uncertainty has resulted from historical timber logging activity in the region. Large areas of original topography were extensively altered by earth-moving equipment during logging operations. Heavy vegetation and organic ground cover have also disguised geologic units, with outcrops typically only visible in road cuts.

7.2 Exploratory Borings

7.2.1 Access

Boring locations and associated instrumentation were selected along proposed alignment alternatives to evaluate local geology and assess possible geologic hazards. The project area can be split between three distinct land ownership groups or managers. These are: Green Diamond Resource Company-owned private logging property, old growth redwood forests of Del Norte Coast Redwoods State Park, and Caltrans right-of-way within and adjacent to US 101.

Each land manager required different access agreements and right of entry permits prior to beginning the field program. All borings were permitted by Del Norte County Environmental Health Department.

Borings located on Green Diamond-owned, private logging property were accessible via a private gate across from Wilson Creek Beach. Rock-paved logging roads were accessible year-round while unpaved dirt roads had seasonal limited access. Borings on Green Diamond property were prioritized early in drilling operations due to this seasonal cut-off date. Dirt roads would deteriorate during wet weather, and locations were accessed by track rigs as well as track-mounted support vehicles. Occasionally, four-wheel drive vehicles could visit the boring locations during drier portions of the field work.

Helicopter operations were also supported on Green Diamond property. A helicopter landing zone was constructed on the eastern side of the property and accessible by rock-paved roads for the entirety of the project. Early in the drilling operations, the helicopter was stored overnight at the Crescent City Airport but was frequently grounded due to heavy fog and weather. The addition of an overnight security guard allowed for helicopter storage onsite and minimized delays from inclement weather.

Crux Subsurface utilized the large, open area adjacent to the helicopter landing zone as a staging area for equipment and vehicles. Gregg Drilling staged equipment in several locations within Green Diamond property for security and proximity to the drilling locations. A large storage container was also utilized by logging geologists for geotechnical instrumentation, logging materials, and temporary rock core storage.

Borings located within Del Norte Coast Redwoods State Park were accessed by helicopter transport for drill rigs and equipment. Drill crews and logging personnel could reach boring locations on foot. Boring locations were selected from openings and hollows in the redwood canopy as well as minimal ground cover to prevent significant removal or disturbance of the soil and vegetation. A right-of-entry permit was submitted and approved by the California Department of Parks and Recreation prior to drilling operations. Drill rigs, casing, and tooling equipment were staged at the helicopter landing zone and lowered to prepped drilling pads that met state park requirements and agreements. Water was pumped to each site via plastic tubing from turnouts on US 101. Drill crews and field geologists accessed the drilling locations though forest trails created and maintained to prevent excess forest damage. Trails were regularly maintained according to permitting requirements.

Borings located within Caltrans right-of-way were accessed by truck- or track-mounted drill rigs. Locations could be found on either the active roadway or adjacent shoulders and turnouts. Drilling equipment and crews were supported by traffic closures and traffic control crews provided by Construction Area Signs. Traffic closures were submitted each week to Caltrans District 1 Dispatch, and statuses were supplied at the beginning and end of each closure window. Traffic control coordination was critical when boring operations were adjacent to the current LCG US 101 improvements to maintain legal closure requirements.

Exceptions for Caltrans right-of-way borings include RC-20-006 (B-22) and RC-20-017 (B-18). Boring RC-20-006 (B-22) was located significantly upslope from US 101 and required helicopter support for drill rig and equipment delivery. Boring RC-20-017 (B-18) was located behind a traffic guardrail and utilized a traditional helicopter portable drill rig lowered from a support truck by a crane.

Soil cuttings, spoils, and drilling mud were contained in storage bins within Caltrans right-of-way. Cutting bins were regularly maintained and emptied by Dillard Environmental. Water storage was located to the south of the project area adjacent to US 101 and maintained by McCullough Construction.

7.2.2 Soil and Rock Drilling and Sampling

Twenty exploratory borings were advanced between September 22, 2020, and January 14, 2021. A borehole summary is presented in Table 3, borehole locations are identified on Figure 3, and representative photos of the drill rig operations are presented in Appendix D

The exploration program consisted of three drilling methods: mud rotary rock coring (RC), dynamic sonic drilling (D), and air rotary drilling (P). While only mud rotary drilling was utilized for subsurface soil and rock logging and sampling, each drilling method was used for geotechnical instrument installation. All borings in this phase of exploration were drilled vertically. The information below summarizes the drilling program for the LCG bypass and highlights general drilling issues and individual boring complications.

Fourteen borings were advanced using mud rotary rock coring methods. Drilling was performed by both Crux Subsurface and Gregg Drilling using track-mounted and helicopter-supported limited access rigs. Mud rotary borings were advanced on Green Diamond property, State Park land, and within Caltrans right-of-way.

Mud rotary borings were advanced through soil and softer material with 4 ½-inch outside diameter (OD) HWT casing and a casing advancer bit. Standard Penetration Tests (SPT) were performed at five-foot intervals using a standard split-barrel sampling with 2-inch OD and 1 ⅜-inch inside diameter (ID). The sampler was driven 18 inches into the ground with a 140-pound hammer free-falling 30 inches. The number of blows required to drive the sampler was recorded every 6 inches for the standard penetration blow counts. SPT sampling was performed until refusal, which was quantified by more than 50 blows per 6 inches of penetration. Upon refusal, SPT sampling was no longer performed, and the mud rotary drilling method was switched to HQ rock coring.

Rock coring was performed using triple-tube HQ-series wireline equipment (2 ½-inch ID) and a diamond coring bit. Core runs were generally 5 feet in length, but shorter runs were performed in highly fractured rock to aid in sample recovery. Borings were drilled with water or a polymer-based drilling mud to maintain circulation and borehole stability. HWT casing was advanced when necessary to prevent fluid losses into the subsurface.

Complications arose in mud rotary borings during advancement through the highly fractured rock mass. Borehole caving, collapse, and mud circulation loss occurred frequently during drilling. To mitigate both issues, HWT casing was advanced to the full depth of each borehole upon completion. This facilitated installation of the geotechnical instrumentation and provided adequate annular space for the grout column. Early borings, such as Borehole RC-20-003 (B-13), collapsed upon completion of HQ-coring below the set HWT casing. This precluded installation of the slope inclinometer casing to planned depth. The drilling program was adjusted to include casing advancement to the entire depth of each borehole.

Borehole D-20-002 (B-40) was originally drilled with a mud rotary system but was abandoned at 100 feet below the ground surface due to borehole integrity issues and the lack of sample recovery. The boring was completed with a track-mounted sonic rig to 135 feet. Borehole RC-20-006 (B-22) collapsed after rock coring was completed at 251 feet. HWT casing was only advanced to 200 feet for instrumentation installation. Borehole RC-20-013 (VWP-6) was shortened to 135 feet due to fluid loss and lack of recovery. Large quantities of bentonite-cement grout mixture failed to backfill the borehole, and the borehole collapsed around the instrumentation during casing removal.

Sonic drilling was performed by Gregg Drilling using both truck-mounted and track-mounted sonic rigs on Green Diamond property and Caltrans right-of-way. Sonic drilling is a soil penetration technique that strongly reduces friction on the drill string and drill bit due to liquefaction and a temporary reduction of porosity of the soil. Three borings were advanced using 8-inch-diameter casing for the entire depth to ensure proper installation of geotechnical equipment. Occasionally, smaller diameter casing was first used to advance the boring, followed by the 8-inch casing for borehole widening and geotechnical instrument installation. Sonic runs were generally 5 feet in length, and samples were collected in plastic bags for inspection. Due to the highly disturbed nature of the samples and cuttings, sonic borings were not logged, and only select soil samples were retained.

Complications during sonic drilling occurred when advancing through thick sections of hard rock. Along with low rate of penetration, broken drill bits were common within sonic borings. Borehole D-20-010 (B-24) had 8-inch-diameter casing break off from 82 feet to 122 feet below the ground surface. Attempts were made to over drill and retrieve the lost drill string. Due to failure of the 10-inch-diameter sonic casing, the boring and lost casing were abandoned, and a second borehole was drilled adjacent to the original location after grouting the original borehole.

Air rotary drilling was performed by Gregg Drilling on Green Diamond property and Caltrans right-of-way. This boring method was utilized to drill the large diameter boreholes needed for installation of the 6-inch-diameter standpipe piezometers. Three borings (P-20-008, P-20-012, and P-20-018) were advanced using air rotary drilling methods. Borings were advanced using an 8-inch-diameter pneumatic hammer, and drill cuttings and groundwater were circulated to the surface by a large air compressor. Several similar standpipe piezometer boreholes were eliminated from the drilling program due slow drill rates and installation complications.

Complications with air rotary borings occurred from the large diameter boreholes and the inability to case the borehole. The pneumatic hammer routinely clogged from the quantity of soil and rock cuttings, and the rate of penetration remained low as the boring progressed deeper. Hoses connected to the air compressor routinely blew out from the pressure required to drill and remove cuttings from the larger diameter boreholes.

Borehole P-20-012 (VWP-2 SP) collapsed overnight prior to removal of the pneumatic hammer at full depth. Several attempts were made to retrieve the trapped equipment, including over-drilling the borehole with a sonic rig. All methods failed, and the boring and drill string were abandoned. A second borehole was drilled adjacent to the original location after grouting the original borehole. Borehole integrity was also an issue during well install and development. Due to the lack of casing, sidewall fragments blocked the borehole and prevented the large diameter casing from reaching full depth. Borehole clean-out runs were common, but time restraints on the roadway delayed installation to the following day allowing for new sidewall collapses and blockages. Borehole P-20-018 (VWP-4 SP) originally had a ⅛-inch-diameter TDR cable attached to the piezometer casing; however, the cable snagged on the sidewall during installation and caused the borehole to collapse. The borehole was redrilled to allow for a complete installation.

7.2.3 Soil and Rock Logging

Soil and rock logging procedures were performed by geologists from Kleinfelder, Caltrans, ENGEO, and SHN. Sample identification, handling, and storage were implemented in accordance with the Caltrans (2010) Soil and Rock Logging, Classification, and Presentation Manual (Caltrans Manual). This guidance document was used for definitions and application of the soil and rock logging methods.

Soil samples were classified and logged in the field in accordance with the Caltrans Manual. The Caltrans soil logging classifications are based on the American Society for Testing and Materials (ASTM) D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), and the Engineering Geology Field Manual published by the Bureau of Reclamation. Soil descriptions shown on boring logs represent the field classifications with modifications based on subsequent review and results of laboratory testing. Sample type, depth, recovery, blow counts, boring location, drilling, and sampling equipment, obstructions, and drilling observations were also recorded on the boring logs.

Rock cores were logged in the field soon after they were extracted from the core barrel. Logging procedures were followed in accordance with the Caltrans Manual (2010), which is a hybrid of the International Society of Rock Mechanics (ISRM, 1981) and U.S. Department of the Interior, Bureau of Reclamation (USBR, 2001) standards. Logging procedures were also discussed prior to the field program to emphasize rock characteristics specific to LCG drilling. Boring records recorded the percent of core recovery, rock quality designation (RQD), rock type, color, grain size, degree of weathering, and field estimated relative strength. The spacing, orientation, roughness and alteration of fracture surfaces, and descriptions of significant discontinuity features were also documented on the records.

Boring records were reviewed, and field descriptions were revised based on detailed examination and subsequent laboratory testing. Drilling and coring equipment, groundwater levels, and drilling observations were also recorded on the records.

A full set of the boring records are presented in Appendix C.

7.2.4 Rock Core Photography

Each core sample recovered from mud rotary borings were photographed in the field prior to being measured, logged, and stored in a core box. Individual runs were cleaned of drilling mud and photographed with relevant sample information such as boring number, run interval, date, and field logger. Field photography documented rock quality and discontinuities prior to disturbance from handling and travel.

Secondary core photography was performed in the storage warehouse of each core box. Color digital photographs were taken under controlled conditions (e.g., lighting and vantage). The core boxes were photographed in both a dry and wet state to accentuate any features that might be obscured by one or the other conditions. Final core box photographs are presented in Appendix E.

7.2.5 Sample Storage

Driven SPT samples were immediately stored in gallon-sized freezer bags to preserve moisture content. HQ rock core samples were stored in wooden or plastic core boxes for long-term storage and transport. Certain sample intervals of softer, sheared material were contained in plastic wrap to prevent desiccation prior to lab testing.

Core boxes and driven samples were initially stored onsite at the LCG area until transportation to Eureka, California, and then to Rancho Cordova, California. Laboratory testing samples were removed and shipped to the designated testing laboratory.

7.3 In-Situ Borehole Testing

7.3.1 Borehole Geophysics

Borehole geophysical analyses were completed in eight boreholes during the subject work phase. Borehole geophysical work was completed by GEOVision and then supplemented by televiewer data collected by Crux Subsurface, Inc. PS Suspension (PS), acoustic televiewer (ATV), optical televiewer (OTV), dual induction (DUIN), mechanical caliper (CAL), and natural gamma (NG) data were acquired. The purpose of the borehole geophysical analyses was to obtain information about fracture location, dip, orientation, and aperture, and to acquire shear wave velocities and compressional wave velocities as a function of depth. Borehole geophysical data is included in the report prepared by GEOVision which is presented in Appendix F.

7.3.1.1 Acoustic Televiewer (ATV) Logging

Acoustic televiewer data were collected in five boreholes (RC-20-017, RC-20-014, RC-20-011, RC-21-001, and RC-20-019) by Crux Subsurface, Inc. using an ALT ABI-40 acoustic borehole imager probe. The imager generates an oriented 360-degree image of the borehole wall from which orientations of rock mass structures can be determined with respect to true north. The tool emits ultrasound pulses towards the formation and records the amplitude and the travel time of the reflected signal. The amplitude of the reflection from the borehole wall is representative of the acoustic properties of the formation. The ATV probe requires a fluid-filled borehole for proper operation, which limited imaging to the lower portion of several boreholes. The quality of the imagery was fair.

7.3.1.2 Borehole Suspension Logging

The OYO Suspension PS Logging System (Suspension System) was used to obtain in-situ horizontal shear and compressional wave velocity measurements in three boreholes (RC-20-014, RC-20-011, and RC-20-019) at 1.6-foot intervals. The system consists of a 22-foot-long probe that is suspended in the borehole with an armored conductor cable. It determines the average velocity of a target segment of the soil column surrounding the borehole by measuring the elapsed time between arrivals of a wave propagating upward through the soil column.

7.3.1.3 Optical Televiewer (OTV) Logging

Optical televiewer data were collected in four boreholes (RC-20-005, RC-20-011, RC-21-001, and RC-20-016). Data was collected from one borehole using an Optical Televiewer (OTV) slimhole probe manufactured by RG and controlled by RG's OTV program. The probe receives control signals from and sends the digitized measurement values to a Micrologger II unit on the ground surface via an armored multi-conductor cable (upon which the probe is suspended). The high-resolution optical televiewer system uses an optical system based on a fisheye lens allowing the probe to survey 360 degrees simultaneously. Data was collected by Crux Subsurface in three boreholes using an ALT OBI-40 optical borehole imager. The optical borehole imager generates a continuous true color, oriented image of the borehole wall using a downhole charged-coupled device (CCD) camera that records the image of the borehole wall in a prism.

7.3.1.4 Dual Induction (DUIN) Logging

Formation conductivity and natural gamma data were collected in three boreholes (RC-20-014, RC-20-011, RC-20-019) using a dual induction probe (DUIN) manufactured by RG. The probe sends data to an RG Micrologger II on the ground surface via an armored four-conductor cable. The DUIN probe generates a primary electromagnetic (EM) field which then generates eddy currents in subsurface materials that give rise to a secondary EM field. The secondary EM field is measured to approximate formation conductivity.

7.3.1.5 Mechanical Caliper Logging (CAL) and Natural Gamma (NG) Logging

Caliper and natural gamma data were collected in four boreholes (RC-20-014, RC-20-011, RC-20-020, and RC-20-019) using a Model 3ACS three-leg caliper probe, manufactured by RG. Natural gamma measurements rely on small quantities of radioactive material contained in soil and rocks to emit gamma radiation as they decay. The survey used a "short arm configuration" that allowed measurement of borehole diameters between 1.6 and 8 inches. With this tool, caliper measurements were collected concurrent with measurement of natural gamma emission from the borehole walls. The length of the probe used in this survey was 6.82 feet. The probe sends data to an RG Micrologger II on the ground surface.

7.3.2 Pressuremeter Testing

Electronic PMT was performed within (in-situ) selected boreholes to assess stress-strain relationships and strength parameters of the various rock types. PMT work was done at two to six different depth intervals within eight boreholes. Testing was done in depth ranges varying from between 13 ½ to 110 feet below the ground surface. The PMT field work, data processing and report preparation was performed by a subconsultant, In-Situ Engineering of Snohomish, Washington. A total of 24 PMTs were attempted, of which 21 were deemed successful and three were considered unsuccessful.

A summary of the PMT locations and general results is presented in Table 4. The full report by In-Situ Engineering with additional details regarding PMT methodology, analyses of data, and interpreted results in table and plotted chart formats is included in Appendix G.

The rock material types tested using PMT varied from Argillite and Greywacke (sandstone) to the Earthflow materials (decomposed sandstone and Argillite). The testing results can be used to evaluate rock material behavior types under load, whether elastic or plastic. The various material properties evaluated from PMT include shear modulus, limiting pressure (that can be applied to the ground), shear strength, and estimates of lateral stress magnitudes. P-Y curves (pressure versus deformation) were also developed and are presented in the report.

The PMT test pocket zones in borehole were formed using both mud rotary drilling and rock coring techniques. The PMT test pockets were drilled with a 2-15/16-inch diameter tri-cone bit for the mud rotary boreholes and then switched to HQ-sized core when rock was encountered. The drillers switched from HQ-sized core to NQ-sized core when the top of a PMT test interval was reached to open the PMT test interval. The PMT is performed by applying pressure to the sidewalls of boreholes and observing the corresponding deformation. The PMT instrument is inserted into the borehole and is supported at test depth. The instrument includes an inflatable flexible membrane which applies even pressure to the walls of the borehole as it expands. As the pressure increases and the membrane expands, the walls of the borehole begin to deform. The pressure inside the instrument is held constant for a specific period of time and the increase in volume required to maintain the pressure is measured and recorded.

7.3.3 Packer Permeability Testing

A total of nine constant-head water injection tests using single and double borehole packers were performed in five boreholes (RC-20-004, RC-20-007, RC-20-011, RC-20-014, and RC-20-017). Five of the tests were successful. The four failing tests were unsuccessful due to various reasons including packer bypass through fractures in the rock mass and in one case, a rupture of one of the packer bladders during testing.

The boreholes were flushed with water prior to testing to remove drilling mud additives. In general, double packer tests were conducted at 10-foot intervals. However, one single packer test was conducted over a 19.2-foot interval. During each test stage, clean water was pumped into the test interval at a constant pressure. The injection pressure was estimated using a pressure gauge at the surface, and then the length of drill rod filled with water above the static level of fluid in the borehole. The pressure and injected volume of water were recorded in one-minute intervals. Pressure stages were applied in increasing then decreasing steps.

Packer permeability test data are presented in Appendix H. A summary of the test results is presented in Table 5.

7.4 Surface-Based Geophysical Surveys

Surface-based geophysical surveys consisting of nine seismic refraction lines and one electrical resistivity line were completed. Three lines were completed along the US 101 right-of-way (SL-41, SL-42, and SL-43), five lines (SL-11, SL-12, SL-13A, SL-13B, and SL-17) were developed in forested areas east of the highway in State or National parkland, and one line (SL-20) was completed on Green Diamond Resource Company property. The geophysical survey line locations were identified and laid out by Caltrans, and off-highway vegetation clearing was completed prior to the surveys by McCullough Construction, Inc. under strict environmental guidelines. Data from the surface geophysical surveys is included in the report prepared by GEOVision which is presented in Appendix J.

The survey line endpoints were flagged in the field in advance. The end points and most receiver locations were then field mapped with a Trimble R10 GPS system with CenterPoint RTX real-time corrections. GPS data quality was better along the highway due to the absence of canopy and was often degraded in forested areas.

7.4.1 Seismic Refraction Surveys

Seismic refraction equipment used during the investigation consisted of two Geometrics Geode 24-channel signal enhancement seismographs (to record up to 48 live channels), 4.5 Hz vertical geophones with Kooter-style takeouts, seismic cables with +13-foot takeouts, piezo hammer switches, a Betsy Seisgun loaded with electrically primed seismic ammunition, a 20-pound sledgehammer, a 40-kilogram accelerated weight drop, and an aluminum strike plate. A minimum of 10 shot points were acquired per line to facilitate tomographic modeling. Shot points included off-end shots (where possible), end shots, and multiple interior shot points. Space, access, and topography limited or prohibited the placement of some off-end shots.

First-arrival times for the refraction surveys were selected using the manual picking routines in the SeisImagerTM software suite (Geometrics, Inc. v5.8.02). Errors in the first-arrival times were variable, with the error generally increasing with distance from the shot point, especially where data quality was affected by wave action, construction activities, and traffic noise. Noise levels were significant. Given the proximity to noise sources, the signal to geophones far from the energy source was often poor.

7.4.2 Electrical Resistivity Survey

An electrical resistivity survey was completed at SL-43 using an Advanced Geosciences, Inc. (AGI) Supersting R8/IP transceiver, 18-inch stainless-steel electrode stakes, and sealed multi-core electrode cable takeouts. Electrodes were spaced at 10-foot intervals, using the same locations as for the geophones from the seismic refraction survey. After data processing of the raw data for errors, the average apparent resistivity data were input into EarthImager2D (AGI) for two-dimensional modeling. The final model cross-sections for the resistivity survey are derived from smooth-model inversion results of the dipole-dipole data.

7.5 Instrumentation and Monitoring

7.5.1 Observation Wells

Three observation wells (piezometer P-20-008, P-20-012 and P-20-018) were constructed and developed for groundwater monitoring and testing. The piezometers were located within 10 feet of associate geotechnical boreholes and instrumentation. The piezometers are constructed with a 6-inch-diameter PVC casing consisting of a 90- to 135-foot-long screened section at the bottom of the borehole. The screened casing is surrounded by sand filter pack in the annular space. A bentonite seal with a minimum thickness of 2 feet was utilized to isolate the testing zone.

The piezometers were constructed so that aquifer testing could be conducted. The aquifer testing will provide data needed to estimate groundwater flow and recharge rates for possible dewatering efforts. A summary of piezometers' construction information can be found in Table 6a, and their construction details are presented in Appendix I.

7.5.2 Vibrating Wire Piezometers

A total of 44 fully grouted VWPs were installed in 17 boreholes during Phase 2B investigations. Each borehole received at least one VWP transducer near the base of the installation with other boreholes receiving up to a maximum of five transducers at various depths. Each VWP is identified by the borehole in which it is installed and its depth below the ground surface [e.g., RC 20-004 (B-11) 180'].

VWP transducers measure water pressure at the depth of installation within the rock mass. Prior to installation, each transducer was submerged in water for fifteen minutes to eliminate air in the VWP housing. "Zero" readings were taken at regular atmospheric pressures and compared to factory calibration sheets for accuracy. Each transducer was attached individually to slope inclinometer casing with electrical tape at predetermined depths for groundwater measurements.

The annular space around the VWP transducers was backfilled with a manufacturer-recommended grout mix. The grouted-in installation method using the diaphragm-type piezometer tips requires only a very small fluid volume change for pressure equalization, and the grout can transmit this volume over the short distance from the formation to the tip quickly. The mixture of 94 pounds of Portland cement and 25 pounds of bentonite per 30 gallons of water mimics the strength of the rock mass and allows for water pressure to influence the grouted transducers with only a very short delay in response to the changes in pressure. The grout was backfilled in the annular space utilizing the tremie method through either a small diameter sacrificial tremie pipe (method used by Crux Subsurface) or through a grout valve at the base of the inclinometer casing (method used by Gregg Drilling). This grout-in method also allowed for the installation and attachment of multiple VWP transducers to the outside of slope inclinometer casing in the same borehole. Each transducer cable was labeled at the surface by serial number and depth and connected to a multi-channel data logger that will collect and store groundwater pressure data for recovery at a later date.

An installation summary of the VWPs for this Phase 2B can be found in Table 6b, and the schematic diagrams for the instrumentation installed in the 17 boreholes can be found in Appendix I.

Each of the VWPs installed during this phase of the project were added to an existing of network of VWPs previously installed by Caltrans. Collectively, this VWP network currently includes 62 VWPs installed in 31 boreholes. A single VWP transducer was installed in 15 boreholes, with 16 boreholes receiving multiple transducers.

The groundwater information stored in each data logger has been periodically collected by Caltrans and is presented in Appendix K. For each borehole VWP, Appendix K includes figures showing the apparent groundwater (potentiometric) elevation and pressure for the duration of the data collection period. Appendix K also includes a table of all the readings collected from each VWP data logger and available as of June 4, 2021.

A summary of data provided in Appendix K is presented in Table 7. For each VWP, Table 7 provides the maximum and minimum values for pore pressure, hydrostatic head (feet of water above each transducer), groundwater potentiometric depth below the ground surface, and groundwater potentiometric elevation.

7.5.3 Slope Inclinometers

A total of 17 slope inclinometers were installed in the mud rotary and sonic boreholes. All installations used 2.75-inch-diameter OD casing constructed of ABS plastic. Casing was typically installed the full depth of the borehole. Exceptions include boreholes RC-20-003 (B-13), RC-20-007 (B-16), and RC-20-013 (VWP-6), which utilized a grout valve at the base of the casing for backfill. Borehole RC-20-006 (B-22) collapsed after coring to a depth of 251 feet below the ground surface. The borehole was reamed with HWT casing to 200 feet for instrumentation installation, based upon the subsurface conditions encountered. Slots within the SI casing were oriented parallel with the estimated major vector of slope movement for future manual surveys or GeoFlex remote readout installation. The slope inclinometer casing also provided the substrate for installation of both the TDR cable and all VWPs.

Slope inclinometer installation depths are presented in Table 6b, and a summary of displacement measurements is presented in Table 8. Graphic plots of the inclinometer surveys are presented in Appendix L.

7.5.4 Time Domain Reflectometry

Seventeen (17) TDR cables were installed in the boreholes and attached to the inclinometer casings. Electrical signals sent through the ½ inch-diameter dielectric coaxial cable can measure displacement depths through deformation in the cable system. TDR cable was attached directly to the SI casing using electrical tape. Exposed wire at the base of the cable was waterproofed with silicone to prevent errors in the electrical signals. The TDR cable extends to the base of the SI casing in every borehole with minor offsets to allow for proper installation.

TDR installations and depths in each boring can be found in Table 6b. No TDR data were available from Caltrans as of May 30, 2021.

7.5.5 GeoFlex Remote Readout

GeoFlex remote readout systems were installed in four SI casings. All boreholes drilled with helicopter access drill rigs utilized the remote system for displacement measurements and data acquisition. The GeoFlex system, developed by Durham Geo Slope Indicator (DGSI), consists of a vertical string of sensor nodes installed in the inclinometer casing. The system spans the zone of movement, and the sensor nodes reflect movement in the casing. Measurements of slope displacement are recorded at set time intervals and can be downloaded remotely. Inclination measurements are processed to provide graphs of the casing profile. TDR readings and VWP data are also connected to the data logger at these locations for remote data acquisition.

GeoFlex remote readout installation information can be found in Table 6c, with displacement measurements available as of May 21, 2021, shown in Table 8. Graphic plots of the GeoFlex survey data are presented in Appendix L.

7.5.6 Weather Stations

Eight weather stations were installed in the project vicinity on November 3, 2020 by staff from Caltrans, WRECO, and HNTB. Weather stations consisted of data-logging rain gauges. Prior to June 3, 2021, Caltrans maintained and collected data from the eight weather stations. Collected data were sent to WRECO for processing and distribution. After June 3, 2021, RMM took over maintaining and collecting data from the eight weather stations. RMM provides the weather station data to WRECO for processing and distribution. Compiled data will be summarized in monthly memoranda. Rainfall data accumulated since November 2, 2020 are presented in:

> Caltrans (2021). *Last Chance Grade Permanent Restoration Project, Weather Station Data Memo*, *November 3, 2020 to February 22, 2021*, SUB#027-2, EA# 01-0F280, Project EFIS# 0115000099, Del Norte County, U.S. 101, PM 12.0/15.5, March 27, 2021, 20 p.

The data in this memorandum were not yet processed as of May 31, 2021.

8 GEOTECHNICAL LABORATORY TESTING

A laboratory testing program was developed and performed to assess the index and engineering properties of subsurface materials. Laboratory testing was performed on samples collected during Phases 2A and 2B. The materials selected for laboratory testing ranged from near-surface soil to transitional intermediate geomaterial (IGM) and rock at variable depths below the ground surface. The testing program was planned to evaluate the range of strengths in the variable geologic conditions in the LCG project area.

Samples for laboratory testing were selected from recovered rock core, cuttings from borings advanced by the sonic drilling method, and samples recovered from split-spoon samplers. Samples were selected to characterize materials at depths of interest and materials representative of site conditions. Laboratory samples selected for testing were handled, transported, and stored using chain-of-custody procedures.

The specific types and frequencies of laboratory testing for LCG samples collected during exploration Phases 2A and 2B were assigned after field logging and detailed logging at the sample storage warehouse facility for examination of variable ground conditions, sample quality and quantity, and applicability of the proposed testing methods to the samples recovered. Some samples were found unsuitable for proposed testing because of insufficient quantity or quality.

Laboratory testing for index, strength, and compressibility/consolidation properties was performed by EMI of Fountain Valley, California, and Kleinfelder of Rancho Cordova, California. Thin section petrographic analyses were performed by Spectrum Petrographics, Inc. of Vancouver, Washington. Tests were performed in general accordance with relevant ASTM, Caltrans, and ISRM standards.

A tabulated list of laboratory test types for the testing program is presented in Table 9, and summaries of laboratory test results are presented in Table 10. Geotechnical laboratory test data are presented in Appendix M. No laboratory testing was performed during previous project geotechnical investigations.

TABLES

Table 1. Reference List

Aalto, K.A. (1989). "Franciscan Complex Olistostrome at Crescent City, Northern California", in *Sedimentology* (1989) v. 36, p. 471-495.
Aalto, K.A. and Harper, G.D. (1982). *Geology of the Coast Ranges in the Klamath and Ship Mountain quadrangles, Del Norte County, California*, California Division of Mines and Geology Open-File Map QFR 82-16-SF, map scale 1:62,500.
Atwater, B.F., Musumi-Rokkaku, S., Satake, K., Tsuji, Y., Ueda, K., and Yamaguchi, D.K. (2005). *The Orphan Tsunami of 1700 – Japanese Clues to a Parent Earthquake in North America (Second Edition).* University of Washington Press and U.S. Geological Survey Professional Paper 1707. https://doi.org/10.3133/pp1707.
*BGC Engineering USA Inc. (BCG) (2018). *Last Chance Grade Expert-Based Risk Assessment, Final,* prepared for California Department of Transportation, Project No.: 1776001. June 14, 2018, 61 p.
Bryant, W.A., compiler (2017). "Fault Number 147, Lost Man Fault," in *Quaternary Fault and Fold Database of the United States*: U.S. Geological Survey website. https://earthquake.usgs.gov/cfusion/qfault/show_report_AB_archive.cfm?fault_id=147&section_id=, accessed 06/09/2021.
Caltrans DES-OGDW. (2010). *Soil and Rock Logging, Classification, and Presentation Manual, 2010 Edition*. State of California Department of Transportation, Division of Engineering Services, Geotechnical Services.
*Caltrans DES-OGDW. (2018). *Summary of Phase 1 Geotechnical Investigation*. California Department of Transportation, Division of Engineering Services, Geotechnical Services. File: 01-DN 101-PM 12.0 to 15.5, EA 01-0F280, EFIS: 0115000099. May 17, 2018.
*Caltrans DES-OGDW. (2019a). Slope Inclinometer Cumulative Displacement since 7/24/2018. LCGA, 01-DN-101-PM 13.5. California Department of Transportation, Division of Engineering Services, Geotechnical Services, Office of Geotechnical Design West, Orinda Field Station.
*Caltrans DES-OGDW. (2019b). Slope Inclinometer Cumulative Displacement since 10/2/2018. LCGA, 01-DN-101-GREEN DIAMOND. California Department of Transportation, Division of Engineering Services, Geotechnical Services, Office of Geotechnical Design West, Orinda Field Station.
*Caltrans DES-OGDW. (2019c). Slope Inclinometer Cumulative Displacement since 12/4/2019. LCGA Phase II, 01-DN-101-PM 14.34, 15.58 and 13.36. California Department of Transportation, Division of Engineering Services, Geotechnical Services, Office of Geotechnical Design West, Orinda Field Station.

Table 1. Reference List

*Caltrans District 1. (2016). *Project Study Report, Last Chance Grade Permanent Restoration. California Department of Transportation*. 01-DN-101 PM 12.0/151, EA 01-0F280K/EFIS, 0115000099, Program Code 20.XX.201.131, June 2016.
*Caltrans District 1. (2019a). *Addendum to the 2016 Project Study Report, Last Chance Grade Permanent Restoration Project*. California Department of Transportation. 01- DN-101-12.0/151, EA 01-0F280K - 01 1500 0099 - (PPNO), Program Code 20.XX.201.131, July 2019.
*Caltrans District 1. (2019b). Phase 2A Boring RC-19-001 Soil Field Log and Rock Field Log, dates: 8/19-8/22/2019. Last Chance Grade, 01-DN-101-PM 13.4-16.0.
*Caltrans District 1. (2019c). Phase 2A Boring RC-19-006 Rotary Field Notes, dates: 10/15-12/5/2019. Last Chance Grade, 01-DN-101-PM 14.81.
*Caltrans District 1. (2019d). Phase 2A Boring RC-20-001 Rotary Field Notes, dates 1/6-1/30/2020. Last Chance Grade Bypass, 01-DN-101-PM 15.
Caltrans. (2021). Last Chance Grade Permanent Restoration Project, Weather Station Data Memo, November 3, 2020 to February 22, 2021, SUB#027-2, EA# 01-OF280, Project EFIS# 0115000099, Del Norte County, U.S. 101, PM 12.0/15.5, March 27, 2021, 20 p.
Chaytor, J.D., Goldfinger, C., Dziak, R.P., and Fox, C.G. (2004). "Active Deformation of the Gorda Plate: Constraining Deformation Models with New Geophysical Data", in *Geology*, v. 32, no. 4) p. 353.
Clarke, S.H., Jr. (1992). "Geology of the Eel River Basin and Adjacent Region: Implications for Late Cenozoic Tectonics of the Southern Cascadia Subduction Zone and Mendocino Triple Junction." *AAPG Bulletin*, v. 76, no. 2, p. 199-224.
Clarke, S.H., Jr. and Carver, G.A. (1992). "Late Holocene Tectonics and Paleoseismicity of the Southern Cascadia Subduction Zone, Northwestern California". *Science*, v. 255, p. 188-192.
Delattre, M. and Rosinski, A. (2012). *Preliminary Geologic Map of Onshore Portions of the Crescent City and Orick 30' X 60' Quadrangles, California,* map and pamphlet, California Department of Conservation California Geological Survey, map scale 1:100,000.
Dengler, L.A. (2008). "The 1906 Earthquake on California's North Coast." *Bulletin of the Seismological Society of America*, v. 98, no. 2, 918-930.
Freymueller, J.T., Murray, M.H., Segall, P. and Caltillo, D. (1999). "Kinematics of the Pacific-North America Plate Boundary Zone, Northern California." *Journal of Geophysical Research: Solid Earth*, v. 104, no. B4, p. 7419-7441.
Furlong, K.P. and Schwartz, S.Y. (2004). "Influence of the Mendocino Triple Junction on the Tectonics of Coastal California." *Annual Review of Earth & Planetary Sciences*, v. 32, no. 1, p. 403-433.

Table 1. Reference List

Hart, E.W., compiler (1999). "Fault Number 11, Grogan Fault," in *Quaternary Fault and Fold Database of the United States*, U.S. Geological Survey website. https://earthquake.usgs.gov/cfusion/qfault/show_report_AB_archive.cfm?fault_id=11&section_id=, accessed 06/09/2021.
Heaton, T.H. and Hartzell, S.H. (1987). "Earthquake Hazards on the Cascadia Subduction Zone." *Science*, v. 236, no. 4798, p. 162-168.
Hemphill-Haley, M.A., Hemphill-Haley, E. and Wunderlich, W. (2020). "Overview of Geological Hazards." *California North Coast Offshore Wind Studies,* .M. Severy, Z. Alva, G. Chapman, M. Cheli, T. Garcia, C. Ortega, N. Salas, A. Younes, J. Zoellick, and A. Jacobson (Eds.) Humboldt, CA: Schatz Energy Research Center. 126 p. schatzcenter.org/pubs/2020-OSW-R16.pdf.
International Society for Rock Mechanics (ISRM). 1981. *Rock Characterization, Testing, and Monitoring, ISRM Suggested Methods,* E.T. Brown, ed., Oxford: Pergamon Press, p. 75-77.
Kelsey, H.M., and Carver, G.C. (1988). "Late Neogene and Quaternary tectonics associated with northward growth of the San Andreas Transform Fault, northern California. Journal of Geophysical Research: Solid Earth, v. 93, no. B5, p. 4797-4819.
McLaughlin, R.J., Ellen, S., Blake Jr. M., Jayko, A.S., Irwin, W., Aalto, K. Carver, G., and Clarke, Jr. S. (2000). *Geology of the Cape Mendocino, Eureka, Garberville, and Southwestern Part of the Hayfork 30 x 60 Minute Quadrangles and Adjacent Offshore Area, Northern California*: U.S. Geological Survey Miscellaneous Field Studies MF-2336.
Nelson, A.R., DuRoss, C.B., Witter, R.C., Kelsey, H.M., Engelhart, S.E., Mahan, S.A., Gray, H.J., Hawkes, A.D., Horton, B.P., and Padgett, J.S. (2021). "A Maximum Rupture Model for the Central and Southern Cascadia Subduction Zone- Reassessing Ages for Coastal Evidence of Megathrust Earthquakes and Tsunamis", *Quaternary Science Reviews,* v. 261 (2021), article no. 106922.
PNSN. (2020). *Cascadia Subduction Zone*. Pacific Northwest Seismic Network, https://pnsn.org/outreach/earthquakesources.
Ristau, D. (1979). *Geologic Map, Klamath 15' Quadrangle*: California Department of Forestry, Title II Geologic Data Compilation Project, unpublished, map scale 1:62,500.
Rollins, J.C., and Stein, R.S. (2010). "Coulomb Stress Interactions Among M>5.9 Earthquakes in the Gorda Deformation Zone and on the Mendocino Fault Zone, Cascadia Subduction Zone, and Northern San Andreas Fault", *Journal of Geophysical Research*, v. 115, B12306, p. 1-19.
UNESCO World Heritage List (2021). *Redwood National and State Parks.* https://whc.unesco.org/en/list/134.

Table 1. Reference List

U.S. Department of the Interior, Bureau of Reclamation (USBR). (2001). *Engineering Geology Field Manual*, 2nd Edition.
*Value Management Strategies, Inc. (VMS) (2018). *Final Value Analysis Study Report, D-1 Del Norte 101 Last Chance Grade*. PN 0115000099, 01-DN-101-PM 12.0-15.5, Contract No. 53A0208, Task Order No. 1045, October 2018.
Wills, C.J. (2000). *Landslides in the Highway 101 Corridor Between Wilson Creek and Crescent City, Del Norte County, California*. California Geological Survey Special Report 184, 26 p, 2 plates.

NOTE:

* References presented in Appendix A.

Table 2. Field Exploration Program Summary

Method	Quantity
Field Geologic and Landslide Mapping	2 4-person teams for 3 days each
Boreholes	20
Acoustic Televiewer Logging	5 boreholes
Borehole Suspension Logging	3 boreholes
Optical Televiewer Logging	4 boreholes
Dual Induction Logging	3 boreholes
Mechanical Caliper and Natural Gamma Logging	4 boreholes
Pressuremeter Tests	24 tests in 8 boreholes
Packer Permeability Tests	9 tests in 5 boreholes
Seismic Refraction Lines	9
Electrical Resistivity Lines	1
Observations Wells (Standpipe Piezometers) Installed	3
Vibrating Wire Piezometers Installed	44 installations in 17 boreholes
Slope Inclinometers Installed	17
Time Domain Reflectometers Installed	17
DGSI Geoflex System Installations	4
Weather Stations Installed	8

Table 3. Borehole Summary

Borehole Identification Number	Initial ID	Borehole Location	Coordinates*		Ground Surface Elevation* (ft)	End of Borehole	
			Northing (ft)	Easting (ft)		Total Borehole Depth (ft)	Borehole Bottom Elevation* (ft)
D-20-002	B-40	Green Diamond	2489208.417	5985460.159	834.5	135.0	699.5
RC-20-003	B-13	Green Diamond	2487932.195	5986035.288	774.8	155.0	619.8
RC-20-004	B-11	Green Diamond	2488300.126	5985985.573	793.5	185.9	607.6
RC-20-005	B-28	State Park	2484488.630	5984431.755	859.1	250.0	609.1
RC-20-006	B-22	Caltrans Right-of-Way	2482739.493	5984385.015	619.3	251.3	368.0
RC-20-007	B-16	Green Diamond	2487641.200	5985892.459	751.2	152.0	599.2
P-20-008	B-13 SP	Green Diamond	2487941.194	5986034.069	774.3	155.0	619.3
D-20-009	VWP-2	Caltrans Right-of-Way	2484215.999	5984166.940	633.8	266.0	367.8
D-20-010	B-24	Caltrans Right-of-Way	2480179.307	5984998.757	438.9	151.0	287.9
RC-20-011	B-32	Caltrans Right-of-Way	2485835.490	5983413.964	698.5	302.6	395.9
P-20-012	VWP-2 SP	Caltrans Right-of-Way	2484241.431	5984148.822	633.3	266.0	367.3
RC-20-013	VWP-6	Caltrans Right-of-Way	2488457.428	5983446.153	830.5	135.0	695.5
RC-20-014	B-29	State Park	2485183.482	5983987.610	805.1	300.2	504.9
RC-20-015	B-30	State Park	2486022.874	5983827.999	883.4	301.0	582.4
RC-20-016	VWP-3	Caltrans Right-of-Way	2485154.425	5983543.472	674.4	300.5	373.9
RC-20-017	B-18	Caltrans Right-of-Way	2488343.080	5983459.356	829.4	300.0	529.4
P-20-018	VWP-4 SP	Caltrans Right-of-Way	2486074.346	5983409.278	714.8	201.0	513.8
RC-20-019	B-50	Caltrans Right-of-Way	2480954.393	5984842.403	474.7	151.9	322.8
RC-20-020	B-46	Caltrans Right-of-Way	2476836.949	5986058.169	210.4	151.0	59.4
RC-21-001	B-47	Caltrans Right-of-Way	2479547.482	5984956.757	408.4	150.0	258.4

* Borehole locations were surveyed using the project vertical datum NAVD88 and the horizontal control NAD83 CA Zone I.

Table 4. Summary of Pressuremeter Test Results

Test	Borehole Identification Number	Initial ID	Test Depth (ft)	Material	Limit [5] Pressure (psi)	K_0 Sand Model	Shear Modulus (psi)	Friction Angle (°)	Test Pocket Quality	Material Behavior
LCG-001	D-20-002	B-40	45.0	Argillite	117	0.35	2330	29	3	Ø - C
LCG-002	D-20-002	B-40	43.5	Argillite	101	0.35	1500	25	3	Ø - C
LCG-003	RC-20-003	B-13	110.0	Sandstone (Broken Formation)	25469	0.8	801000	45	4	Ø
LCG-004	RC-20-003	B-13	108.5	Sandstone (Broken Formation)	19853	0.8	813400	44	4	Ø
LCG-005	RC-20-004	B-11	60.7	Argillite	491	0.43	6800	41	3	Ø
LCG-006	RC-20-004	B-11	59.2	Argillite	665	0.45	13700	41	3	Ø
LCG-007	RC-20-006	B-22	53.5	Sandstone	---	0.4	---	---	0	Oversize
LCG-008	RC-20-006	B-22	60.0	Argillite	---	0.4	---	---	0	Oversize
LCG-009	RC-20-006	B-22	58.5	Argillite	---	0.4	---	---	0	Oversize
LCG-010	RC-20-006	B-22	66.5	Argillite	87	0.4	390	27 [7]	1	C [7]
LCG-011	RC-20-006	B-22	65.0	Argillite	346	0.46	6150	36	4	Ø - C
LCG-012	RC-20-007	B-16	35.0	Sandstone (Broken Formation)	8432	0.8	542000	49	3	Ø
LCG-013	RC-20-007	B-16	33.5	Sandstone (Broken Formation)	8839	0.8	566000	50	3	Ø
LCG-014	RC-20-011	B-32	93.6	Argillite	2089	0.55	95600	38	3	Ø
LCG-015	RC-20-011	B-32	92.1	Sandstone (Broken Formation)	1213	0.46	51000	38	3	Ø [6]
LCG-016	RC-20-019	B-50	15.0	Decomposed Sandstone	189	0.7	11780	34	3	Ø - C
LCG-017	RC-20-019	B-50	13.5	Decomposed Sandstone	153	0.7	8000	34	3	Ø - C
LCG-018	RC-20-019	B-50	20.0	Decomposed Sandstone	331	0.9	16300	36	3	Ø - C
LCG-019	RC-20-019	B-50	18.5	Decomposed Sandstone	222	0.85	17000	32	3	Ø - C
LCG-020	RC-20-019	B-50	35.0	Argillite	483	0.5	19000	36	4	Ø [6]
LCG-021	RC-20-019	B-50	33.5	Decomposed Sandstone	440	0.53	33400	35	4	Ø [6]
LCG-022	RC-20-020	B-46	43.5	Argillite	326	0.83	21600	29 [7]	4	C [7]
LCG-023	RC-20-020	B-46	53.7	Sandstone (Landslide Failure Zone)	526	0.7	43600	33 [7]	4	C [7]
LCG-024	RC-20-020	B-46	74.0	Argillite	296	0.45	11900	32 [7]	4	C [7]

NOTES:

Material Behavior:

- C Cohesive material behavior
- Ø Frictional material behavior
- Ø - C Test material behaved both as frictional and cohesive
- --- Blank values indicate that no data could be derived from the test OR no analysis performed

Test Pocket Quality:

- 0 Poor test, oversized hole, no usable data
- 1 Fair hole with some degree of oversize, insufficient data to determine strength of material
- 2 Good hole size, but instrument failed /membrane rupture during test. Partial data may be used
- 3 Good hole with some percentage of oversizing but good usable data quality
- 4 Very good tight hole, excellent usable data quality

Other Notes:

[5] The shear strength by log method shown may not be strictly applicable for materials with frictional component as the theory is based upon purely cohesive, non-dilative material. However, it can be used in the onsite materials to give an indication of the strength and limit pressure that can be applied to the ground.

[6] Primarily frictional material but consists cohesive properties.

[7] Primarily cohesive material but consists frictional properties.

Table 5. Summary of Packer Permeability Test Results

Borehole Identification Number (stage pressures in psi)[1]	Initial ID	Pressure Measurement Method[2]	Top (feet)	Bottom (feet)	Packer Test Results	Notes[3]
RC-20-004 **(50,60,70,80,70,60,50)**	B-11	Surface Gauge	111.6	130.8	Dilation Lugeon value 0.79	Successful test, no anomalies, single packer
RC-20-007 **(120,130,140)**	B-16	Surface Gauge	42.5	48	Failed Test	Packer seating failure, double packer
RC-20-011 **(30, 40, 50)**	B-32	Surface Gauge	272	292	Failed Test	Packer seating failure, double packer
RC-20-014 **(10,20)**	B-29	Surface Gauge	163	173	Failed Test	Packer seating failure, double packer
RC-20-014 **(20,50,100,50,20)**	B-29	Surface Gauge	220	230	Laminar Lugeon Value 1.39	Successful test, no anomalies, double packer
RC-20-014 **(30,70,140,70,30)**	B-29	Surface Gauge	290	300	Void Filling Lugeon Value 0.18	Successful test, no anomalies, single packer
RC-20-017 **(20,40,80,40,20)**	B-18	Surface Gauge	170	180	Void Filling Lugeon Value 1.29	Successful test, no anomalies, double packer
RC-20-017 **(20,50,100,50,20)**	B-18	Surface Gauge	206	216	Wash-out Lugeon Value 5.32	Successful test, no anomalies, double packer
RC-20-017 **(30,70,30)**	B-18	Surface Gauge	275	285	Failed Test	Packer seating failure, double packer

NOTES:
[1] Stage pressures are in addition to in-situ hydrostatic pressures.
[2] Where transducer measurement method is not listed, transducer experienced technical problems and transducer data is not available.
[3] All tests used double packer configuration, except where noted.

Table 6. Instrumentation Summaries

Table 6a. Standpipe Piezometer Install Details

Borehole Identification Number	Initial ID	Install Date	Ground Surface Elevation* (ft)	Total Well Depth (ft)	Well Screen Interval (ft)	Filter Pack Interval (ft)
P-20-008	B-13 SP	10/13/2020	774.3	154.0	64.0 to 154.0	61.0 to 154.0
P-20-012	VWP-2 SP	12/5/2020	633.3	265.0	130.0 to 265.0	127.0 to 265.0
P-20-018	VWP-4 SP	1/11/2020	714.8	201.0	93.0 to 193.0	90.0 to 201.0

* Borehole locations were surveyed using the project vertical datum NAVD88 and the horizontal control NAD83 CA Zone I.

Table 6. Instrumentation Summaries (continued)

Table 6b. Slope Inclinometer/Time Domain Reflectometer/Vibrating Wire Piezometer Install Details

Borehole Identification Number	Initial ID	Install Date	Ground Surface Elevation* (ft)	Slope Inclinometer Total Depth (ft)	Time Domain Reflectometer Cable Total Depth (ft)	Vibrating Wire Piezometer Depth (ft)
D-20-002	B-40	10/9/2020	834.5	135.0	135.0	100.0, 130.0
RC-20-003	B-13	9/29/2020	774.8	150.0	150.0	152.0
RC-20-004	B-11	10/7/2020	793.5	185.9	185.9	125.0, 180.0
RC-20-005	B-28	10/25/2020	859.1	250.0	250.0	155.0, 232.0, 250.0
RC-20-006	B-22	10/23/2020	619.3	200.0	200.0	60.0, 129.0, 199.5
RC-20-007	B-16	10/11/2020	751.2	150.0	150.0	145.0
D-20-009	VWP-2	10/12/2020	633.8	264.5	264.5	95.0, 195.0, 260.0
D-20-010	B-24	10/25/2020	438.9	150.0	150.0	66.0, 149.0
RC-20-011	B-32	11/16/2020	698.5	302.6	302.6	144.0, 199.0, 300.0
RC-20-013	VWP-6	11/8/2020	830.5	135.0	135.0	133.0
RC-20-014	B-29	11/18/2020	805.1	300.2	300.2	166.0, 225.0, 290.0
RC-20-015	B-30	11/22/2020	883.4	299.3	299.3	159.0, 255.0, 290.0
RC-20-016	VWP-3	12/8/2020	674.4	300.5	300.5	136.0, 173.0, 192.0, 255.0, 287.0
RC-20-017	B-18	12/15/2020	829.4	300.0	300.0	150.0, 182.0, 217.0, 253.0, 282.0
RC-20-019	B-50	1/5/2021	474.7	151.4	151.4	75.0, 150.0
RC-20-020	B-46	1/6/2021	210.4	151.0	151.0	35.0, 150.0
RC-21-001	B-47	1/6/2021	408.4	150.0	150.0	30.0, 49.0, 149.0

* Borehole locations were surveyed using the project vertical datum NAVD88 and the horizontal control NAD83 CA Zone I.

Table 6c. DGSI Geoflex System Install Details

Borehole Identification Number	Initial ID	Install Date	Ground Surface Elevation* (ft)	Casing Above Ground Surface (ft)	Total Install Length (ft)	Dummy Length (ft)	Geoflex Sensor Length (ft)
RC-20-005	B-28	11/19/2020	859.1	2.9	250.0	30.0	220.0
RC-20-006	B-22	11/11/2020	619.3	-	190.0	-	190.0
RC-20-014	B-29	11/20/2020	805.1	2.9	300.0	30.0	270.0
RC-20-015	B-30	12/4/2020	883.4	3.0	300.0	30.0	270.0

* Borehole locations were surveyed using the project vertical datum NAVD88 and the horizontal control NAD83 CA Zone I.

Table 7. Summary of Groundwater Elevations/Pore Water Pressure Measurements

Borehole Identification Number	Initial ID	Ground Surface Elevation (feet)	VWP Depth Below Ground Surface (BGS) (feet)	VWP Elevation (feet)	Maximum Pore Pressures (psi)	Minimum Pore Pressures (psi)	Maximum Head (feet of water)	Minimum Head (feet of water)	Maximum Groundwater Potentiometric Depth BGS (feet)	Minimum Groundwater Potentiometric Depth BGS (feet)	Maximum Groundwater Potentiometric Elevation (feet)	Minimum Groundwater Potentiometric Elevation (feet)	Collection Range for Groundwater Data (Date)
RC-18-001	B-1	345.1	69.8	275.3	27.9	23.89	64.43	55.17	14.6	5.4	339.7	330.5	12/4/2018 - 12/3/2020
RC-18-003	B-8	988.8	97.9	890.9	38.101	30.727	87.99	70.96	26.9	9.9	978.9	961.9	12/3/2018 - 5/10/2021
RC-18-004	B-9	908.4	96.5	811.9	28.905	22.616	66.76	52.23	44.3	29.7	878.7	864.1	12/3/2018 - 4/14/2021
RC-18-006	B-7A	885.1	52.6	832.5	13.06	12.06	30.16	27.85	24.8	22.4	862.7	860.3	12/4/2018 - 5/1/2021
RC-18-008	B-6A	778.1	57.3	720.8	21.68	16.86	50.07	38.94	18.4	7.2	770.9	759.7	12/4/2018 - 5/10/2021
RC-18-010	B-5A	704.9	54.2	650.7	16.35	12.12	37.76	27.99	26.2	16.4	688.5	678.7	12/4/2018 - 5/25/2021
RC-18-012	B-3A	554.6	37.5	517.1	14.04	11.03	32.42	25.47	12	5.1	549.5	542.6	12/3/2018 - 5/25/2021
RC-18-013	B-2	618.8	99	519.8	12.07	3.92	27.88	9.05	89.9	71.1	547.7	528.9	12/4/2018 - 5/25/2021
RC-19-002	B-15	957.5	60.5	897.0	18.299	15.499	42.26	35.79	24.7	18.2	939.3	932.8	8/28/2019 - 4/20/2021
RC-19-003	B-17	840.5	90	750.5	33.862	31.676	78.2	73.15	16.9	11.8	828.7	823.6	9/23/2019 - 4/19/2021
RC-19-004	B-12	289.4	48.5	240.9	18.968	17.934	43.81	41.42	7.1	4.7	284.7	282.3	3/18/2020 - 2/15/2021
RC-19-005	B-10	624.7	188	436.7	22.985	0.857	53.08	1.98	186	134.9	489.8	438.7	10/17/2019 - 5/26/2021
P-19-007	VWP-1	585.5	295	290.5	32.7	29.0	75.6	67.1	228.0	219.4	366.1	357.5	12/20/2019 - 4/27/2021
			195	390.5	20.5	18.9	47.4	43.7	151.3	147.6	437.9	434.2	
			95	490.5	4.9	1.5	11.2	3.5	91.5	83.8	501.7	494.0	
D-20-002	B-40	834.5	130	704.5	51.9	49.7	119.9	114.8	15.2	10.1	824.4	819.3	11/5/2020 - 3/16/2021
			100	734.5	37.2	35.3	85.9	81.5	18.5	14.2	820.3	816.0	
P-20-002	VWP-4	713.4	246	467.4	7.9	5.2	18.3	12.1	233.9	227.7	485.7	479.5	2/14/2020 - 4/27/2021
			195	518.4	16.8	2.4	38.8	5.6	189.4	156.2	557.2	524.0	
			130	583.4	3.5	-0.7	8.1	-1.6	131.6	121.9	591.5	581.8	
RC-20-003	B-13	774.8	152	622.8	22.9	18.0	52.9	41.6	110.4	99.2	675.6	664.4	11/5/2020 - 3/16/2021
RC-20-004	B-11	793.5	180	613.5	66.5	65.8	153.6	152.0	28.0	26.4	767.1	765.5	1/22/2021 - 3/2/2021
			125	668.5	43.8	43.0	101.1	99.4	25.6	23.9	769.6	767.9	
RC-20-005	B-28	859.1	250	609.1	6.8	-0.7	15.7	-1.6	251.6	234.3	624.8	607.5	1/23/2021 - 6/3/2021
			232	627.1	1.7	0.0	3.9	0.0	232.0	228.1	631.0	627.1	
			155	704.1	4.9	0.6	11.2	1.4	153.6	143.8	715.3	705.5	
RC-20-006	B-22	619.3	199.5	419.8	54.5	53.8	125.8	124.2	75.3	73.7	545.6	544.0	1/23/2021 - 6/3/2021
			129	490.3	27.5	26.8	63.4	61.9	67.1	65.6	553.7	552.2	
			60	559.3	-0.5	-1.2	-1.1	-2.8	62.8	61.1	558.2	556.5	
RC-20-007	B-16	751.2	145	606.2	42.4	41.5	98.3	95.8	49.2	47.0	704.2	702.0	1/21/2021 - 3/17/2021
D-20-009	VWP-2	633.8	260	373.8	95.4	69.4	220.2	160.3	99.8	39.8	594.0	534.0	12/18/2020 - 6/1/2021
			195	438.8	19.0	14.1	44.0	32.5	162.5	151.1	482.7	471.3	
			95	538.8	0.1	-0.8	0.3	-1.9	96.9	94.7	539.1	536.9	
D-20-010	B-24	438.9	148.6	290.3	67.8	67.3	156.6	155.5	-6.9	-8.0	446.9	445.8	12/18/2020 - 5/26/2021
			66	372.9	32.3	31.6	74.7	73.0	-7.0	-8.7	447.6	445.9	
RC-20-011	B-32	698.5	300	398.5	58.0	47.4	134.0	109.4	190.6	166.1	532.4	507.9	12/18/2020 - 6/1/2021
			199	499.5	22.4	5.1	51.7	11.8	187.2	147.3	551.2	511.3	
			144	554.5	-0.1	-0.6	-0.3	-1.4	145.4	144.3	554.2	553.1	
RC-20-013	VWP-6	830.5	133	697.5	21.7	2.2	50.1	5.2	127.8	82.9	747.6	702.7	12/18/2020 - 6/1/2021

Table 7. Summary of Groundwater Elevations/Pore Water Pressure Measurements

Borehole Identification Number	Initial ID	Ground Surface Elevation (feet)	VWP Depth Below Ground Surface (BGS) (feet)	VWP Elevation (feet)	Maximum Pore Pressures (psi)	Minimum Pore Pressures (psi)	Maximum Head (feet of water)	Minimum Head (feet of water)	Maximum Groundwater Potentiometric Depth BGS (feet)	Minimum Groundwater Potentiometric Depth BGS (feet)	Maximum Groundwater Potentiometric Elevation (feet)	Minimum Groundwater Potentiometric Elevation (feet)	Collection Range for Groundwater Data (Date)
RC-20-014	B-29	805.1	290	515.1	52.7	49.5	121.8	114.4	174.0	168.2	636.9	631.1	1/23/2021 - 6/3/2021
			225	580.1	24.3	21.0	56.1	48.6	176.4	168.9	636.2	628.7	
			166	639.1	7.0	2.9	16.2	6.6	159.4	149.8	655.3	645.7	
RC-20-015	B-30	883.4	290	593.4	20.7	17.5	47.7	40.4	249.6	242.3	641.1	633.8	1/22/2021 - 6/3/2021
			255	628.4	43.3	34.9	100.0	80.5	174.5	155.0	728.4	708.9	
			159	724.4	5.1	-0.6	11.8	-1.3	160.3	147.2	736.2	723.1	
RC-20-016	VWP-3	674.4	287	387.4	28.7	23.4	66.4	54.0	233.0	220.6	453.8	441.4	12/18/2020 - 4/16/2021
			255	419.4	5.4	4.6	12.4	10.7	244.3	242.6	431.8	430.1	
			192	482.4	-0.1	-0.6	-0.3	-1.3	193.3	192.3	482.1	481.1	
			173	501.4	8.4	3.9	19.4	9.0	164.0	153.6	520.8	510.4	
			136	538.4	5.5	5.2	12.7	12.0	124.0	123.3	551.1	550.4	
RC-20-017	B-18	829.4	282	547.4	23.9	22.9	55.3	52.9	229.1	226.7	602.7	600.3	12/18/2020 - 6/1/2021
			253	576.4	13.4	12.8	31.0	29.5	223.6	222.0	607.4	605.8	
			217	612.4	4.0	-0.5	9.3	-1.3	218.3	207.7	621.7	611.1	
			182	647.4	1.5	-0.3	3.5	-0.6	182.6	178.5	650.9	646.8	
			150	679.4	5.2	3.9	11.9	9.1	141.0	138.1	691.3	688.4	
RC-20-019	B-50	474.7	150	324.7	40.6	39.1	93.7	90.4	59.6	56.3	418.4	415.1	1/19/2021 - 6/2/2021
			75	399.7	21.8	19.2	50.4	44.4	30.6	24.6	450.1	444.1	
RC-20-020	B-46	210.4	150	60.4	44.7	43.9	103.3	101.5	48.5	46.8	163.6	161.9	1/16/2021 - 6/4/2021
			35	175.4	10.5	9.3	24.4	21.6	13.4	10.6	199.8	197.0	
RC-21-001	B-47	408.4	149	259.4	54.2	51.8	125.1	119.7	29.3	23.9	384.5	379.1	1/16/2021 - 6/3/2021
			49	359.4	16.1	13.5	37.2	31.2	17.8	11.8	396.6	390.6	
			30	378.4	1.3	-0.2	3.1	-0.5	30.5	26.9	381.5	377.9	

NOTES:

1. Negative pore pressure readings or negative head measurements indicates the absence of water.
2. Details are presented in Appendix K.
3. Borehole locations were surveyed using the project vertical datum NAVD88 and the horizontal control NAD83 CA Zone I.

Table 8. Summary of Displacement Measurements

Borehole Identification Number	Initial ID	Ground Surface Elevation* (feet)	Baseline Survey Date	Most Recent Survey Date	Displacement Depth (feet)	Cumulative Vector Displacement (inches)
HZ-18-001**	n/a	-	1/23/2018	10/3/2018	16.4-21.3	0.5512
					55.8-59.1	0.3819
					67.3-73.8	1.0354
RC-18-002**	B-1A	346.1	7/24/2018	4/20/2021	65.0-67.0	2.0201
RC-18-005**	B-7	883.6	10/2/2018	7/15/2020	n/a	n/a
RC-18-007**	B-6	777.6	10/2/2018	7/15/2020	n/a	n/a
RC-18-009**	B-5	704.0	10/2/2018	7/15/2020	n/a	n/a
RC-18-011**	B-3	554.7	10/2/2018	4/24/2019	n/a	n/a
RC-18-020**	Wilson SI-4	-	7/10/2018	4/20/2021	36.0-38.0	1.0298
RC-18-021**	Wilson SI-5	-	7/10/2018	4/20/2021	50.0-56.0	1.0739
RC-18-022**	Wilson SI-6	-	12/5/2018	4/20/2021	12.0-20.0	0.8767
RC-19-001**	B-21	538.8	12/4/2019	4/26/2021	n/a	n/a
RC-19-002**	B-15	957.5	12/3/2019	4/26/2021	n/a	n/a
RC-19-003**	B-17	840.5	12/4/2019	4/26/2021	n/a	n/a
RC-19-004**	B-12	289.4	12/4/2019	2/6/2020	45.0-49.0	1.3927
RC-19-005**	B-10	624.7	12/3/2019	3/27/2020	n/a	n/a
HZ-19-006**	B-31	-	2/6/2020	12/29/2020	131.2-149.3	0.1969
D-20-002	B-40	834.5	11/24/2020	1/20/2021	n/a	n/a
RC-20-003	B-13	774.8	11/24/2020	1/20/2021	n/a	n/a
RC-20-004	B-11	793.5	11/24/2020	1/20/2021	n/a	n/a
RC-20-005	B-28	859.1	2/5/2021	5/21/2021	155.0-157.0	0.4225
RC-20-006	B-22	619.3	1/27/2021	5/21/2021	78.0-80.0	0.5255
RC-20-007	B-16	751.2	11/24/2020	1/20/2021	n/a	n/a
D-20-009	VWP-2	633.8	12/22/2020	4/21/2021	74.0-80.0	0.0971
					98.0-102.0	0.0606
					118.0-122.0	0.0666
					230.0-234.0	0.0276
					258.0-260.0	0.0299
D-20-010	B-24	438.9	12/22/2020	4/21/2021	62.0-68.0	0.0949
					96.0-102.0	0.0642

RC-20-011	B-32	698.5	12/22/2021	4/20/2021	n/a	n/a
RC-20-013	VWP-6	830.5	12/22/2020	4/20/2021	n/a	n/a
RC-20-014	B-29	805.1	2/7/2021	5/21/2021	39.0-41.0	0.1088
					69.0-77.0	0.1374
RC-20-015	B-30	883.4	2/5/2021	5/21/2021	91.0-97.0	0.623
RC-20-016	VWP-3	674.4	12/22/2020	4/20/2021	192.0-198.0	0.0249
					270.0-276.0	0.0524
RC-20-017	B-18	829.4	12/22/2020	4/20/2021	n/a	n/a
RC-20-019	B-50	474.7	1/18/2021	4/21/2021	n/a	n/a
RC-20-020	B-46	210.4	1/15/2021	4/27/2021	n/a	n/a
RC-21-001	B-47	408.4	1/15/2021	4/27/2021	90.0-96.0	0.2455

* Borehole ground surface elevations were surveyed using the project vertical datum NAVD88.

** Inclinometer installed during previous investigation.

Table 9. Geotechnical Laboratory Testing Summary

Laboratory Test	Test Method	Quantity
Unit Weight	ASTM D2937	9 tests on samples from 6 borings
Water Content	ASTM D2216	16 tests on samples from 6 borings
Sieve Analysis	ASTM D6913	9 tests on samples from 5 borings
Hydrometer Analysis	ASTM D7928	7 tests on samples from 4 borings
Atterberg Limits	ASTM D4318	12 tests on samples from 9 borings
Consolidation	ASTM D2435	1 test on sample from 1 boring
Unconsolidated Undrained Triaxial Shear	ASTM D2850	8 tests on samples from 5 borings
Unconfined Compressive Strength (Rock)	ASTM D7012	11 tests on samples from 7 borings
Direct Shear (Soil)	ASTM D3080	2 tests on samples from 2 borings
Point Load Strength Index	ASTM D5731	9 tests on samples from 3 borings
Cerchar Abrasiveness	ASTM D7625	6 tests on samples from 5 borings
Slake Durability	ASTM D4644	5 tests on samples from 3 borings
Splitting Tensile Brazilian	ASTM D3967	8 tests on samples from 3 borings
Relative Compaction	CTM 216	1 test on sample from 1 boring
Petrographic Analysis	ISRM	8 analyses on samples from 5 borings

Table 10. Summary of Geotechnical Laboratory Test Results

Borehole Identification Number	Initial ID	Sample Depth (ft)	Boring Log Description [1]	Dry Unit Weight (pcf)	Water Content (%)	Sieve Analysis [2] (%)			Hydrometer Analysis [2] (%)		Atterberg Limits			Consolidation Test [2]	UU Triaxial [2]	Unconfined Compressive Strength [2]		Direct Shear [2]		Point Load		Cerchar Abrasivity Index	Slake Durability (%)	Brazilian Indirect Tension	Relative Compaction		Bulk Mohs Hardness [2]
						Passing 3/4"	Passing #4	Passing #200	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Undrained Shear Strength (psf)	Bulk Density (pcf)	Max. Unconfined Comp. Stress (psi)	Cohesion (psf)	Friction (deg)	Strength Index, $I_{s(50)}$ (psi)	Correlated Uniaxial Comp. Strength (psi)			Splitting Tensile Strength (psi)	Max. Wet Density (pcf)	Optimum Water Content (%)	
				ASTM D2937	ASTM D2216	ASTM D6913			ASTM D7928		ASTM D4318			ASTM D2435	ASTM D2850	ASTM D7012		ASTM D3080		ASTM D5731		ASTM D7625	ASTM D4644	ASTM D3967	CTM 216		ISRM
D-20-002	B-40	30.0-70.0	ARGILLITE	136.6	8.6						21	12	9		5205										148.0	8.4	
D-20-002	B-40	30.0-70.0	ARGILLITE	136.6	8.6										6075												
D-20-002	B-40	30.0-70.0	ARGILLITE	136.4	8.6										6150												
D-20-002	B-40	30.0-70.0	ARGILLITE	136.5	8.6										6285												
RC-20-003	B-13	15.0-28.0	SANDSTONE																	107	2630						
RC-20-003	B-13	39.0-60.0	SANDSTONE																	107	2610						
RC-20-003	B-13	95.5-96.0	SANDSTONE													167.3	14620										
RC-20-005	B-28	26.9-38.8	SANDSTONE																	507	12420						
RC-20-005	B-28	62.3-75.0	SANDSTONE																	439	10760			650			
RC-20-005	B-28	62.3-75.0	SANDSTONE																					560			
RC-20-005	B-28	62.3-75.0	SANDSTONE																					1280			
RC-20-005	B-28	73.7-74.8	SANDSTONE													168.5	10600										
RC-20-005	B-28	154.1	LANDSLIDE BASAL FAILURE ZONE (ARGILLITE)	145.7	2.4										6280												
RC-20-005	B-28	173.8-174.1	ARGILLITE																	73	---[3]	1.62					
RC-20-005	B-28	205.0-205.9	SANDSTONE																			2.35					
RC-20-005	B-28	216.4	SANDSTONE													167.1	3580										
RC-20-006	B-22	5.0-21.5	FAT CLAY with SAND (CH)		0.4	97.0	81.0	25.5	16.6	8.9	28	16	12														
RC-20-006	B-22	25.0-41.5	CLAYEY SAND with GRAVEL (SC)		9.2	30.0	49.0	21.0			22	12	10														
RC-20-006	B-22	71.8-72.3	ARGILLITE		1.3																		41.0				
RC-20-006	B-22	79.8-80.8	ARGILLITE	143.6	1.6										13300												
RC-20-007	B-16	14.0-16.0	SANDSTONE			91.0	71.0	30.0			28	22	6														
RC-20-007	B-16	35.0-35.6	SANDSTONE													167.5	8320										
RC-20-007	B-16	43.0-51.0	SANDSTONE																	---[4]	---[4]						
RC-20-007	B-16	63.0-63.4	SANDSTONE													167.0	4890										
RC-20-011	B-32	81.1-82.9	SANDSTONE																					1820			
RC-20-011	B-32	81.1-82.9	SANDSTONE																					2450			
RC-20-011	B-32	81.1-82.9	SANDSTONE																					2970			
RC-20-011	B-32	132.8-133.1	SANDSTONE																					660			
RC-20-011	B-32	140.0-140.5	ARGILLITE																					non-testable [5]			
RC-20-011	B-32	163.6-166.1	SANDSTONE																			2.03					
RC-20-011	B-32	168.9-169.6	SANDSTONE													168.9	12220										6.0
RC-20-013	VWP-6	16.0-17.5	ARGILLITE								23	12	11														

Table 10. Summary of Geotechnical Laboratory Test Results

Borehole Identification Number	Initial ID	Sample Depth (ft)	Boring Log Description [1]	Dry Unit Weight (pcf)	Water Content (%)	Sieve Analysis [2] (%)			Hydrometer Analysis [2] (%)		Atterberg Limits			Consolidation Test [2]	UU Triaxial [2]	Unconfined Compressive Strength [2]		Direct Shear [2]		Point Load		Cerchar Abrasivity Index	Slake Durability (%)	Brazilian Indirect Tension	Relative Compaction		Bulk Mohs Hardness [2]
						Passing 3/4"	Passing #4	Passing #200	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index		Undrained Shear Strength (psf)	Bulk Density (pcf)	Max. Unconfined Comp. Stress (psi)	Cohesion (psf)	Friction (deg)	Strength Index, $I_{s(50)}$ (psi)	Correlated Uniaxial Comp. Strength (psi)			Splitting Tensile Strength (psi)	Max. Wet Density (pcf)	Optimum Water Content (%)	
RC-20-013	VWP-6	27.0-27.3	SANDSTONE																	706.5	---[3]						5.8
RC-20-013	VWP-6	27.5	SANDSTONE																	349.1	---[3]						
RC-20-013	VWP-6	27.6-28.0	SANDSTONE																	707.9	---[3]						
RC-20-014	B-29	87.1-87.6	SANDSTONE													167.8	16350										4.4
RC-20-014	B-29	111.6-112.0	SANDSTONE													173.4	19830										5.8
RC-20-014	B-29	243.7-248.0	SANDSTONE																			1.54					
RC-20-014	B-29	270.0	SANDSTONE																								6.0
RC-20-014	B-29	280.4-280.9	SANDSTONE													167.9	16810										5.9
RC-20-015	B-30	199.25	SANDSTONE																			2.30					
RC-20-015	B-30	262.6	FAILURE ZONE													146.7	190										
RC-20-016	VWP-3	89.5	LANDSLIDE FAILURE ZONE								22	14	8					1116	36.5								
RC-20-017	B-18	31.2-32.7	SANDSTONE	141.6	5.3										3725												
RC-20-017	B-18	37.7-39.7	SANDSTONE		1.9																		72.7				
RC-20-017	B-18	42.9-44.9	ARGILLITE and SANDSTONE			89.0	48.0	3.1	2.3	0.8																	
RC-20-017	B-18	46.9-48.2	SANDSTONE		5.5	98.0	74.0	16.6	11.1	5.5	23	13	10														
RC-20-017	B-18	65.0-67.0	ARGILLITE		1.2																		94.8				
RC-20-017	B-18	99.0-101.0	SANDSTONE																			2.77					
RC-20-017	B-18	101.0-101.7	SANDSTONE													168.1	14480										
RC-20-019	B-50	11.8-17.9	SANDSTONE				97.0	40.3	32.8	7.5	28	22	6														
RC-20-019	B-50	36.6-38.8	SANDSTONE																				87.6				
RC-20-019	B-50	38.4-40.4	SANDSTONE																				88.2				
RC-20-019	B-50	127.0-127.7	ARGILLITE	134.5	7.2									---[6]													
RC-20-019	B-50	55.0	SANDSTONE with thinly bedded ARGILLITE																								5.8
RC-20-020	B-46	5.0-16.5	SANDY FAT CLAY (CH) LEAN TO FAT CLAY (CL-CH) FAT CLAY (CH)		28.4						38	22	16														
RC-20-020	B-46	66.6	ARGILLITE	133.7	6.4										1870												
RC-21-001	B-47	39.6-41.6	ARGILLITE			100.0	88.0	19.0	13.3	5.7	19	12	7														
RC-21-001	B-47	76.9-80.3	ARGILLITE			92.0	74.0	17.5	11.1	6.4	20	11	9														
RC-21-001	B-47	93.6	ARGILLITE															1152	33.2								
RC-21-001	B-47	94.6-96.1	ARGILLITE			96.0	88.0	41.9	25.7	16.2	24	10	14														
RC-21-001	B-47	99.9-100.0	ARGILLITE																								3.6

NOTES:

[1] Dual classifications of bedrock parent material weathered and/or sheared to intermediate geo-material descriptions are provided on boring logs.

[2] Test and analysis details are presented in Appendix M.

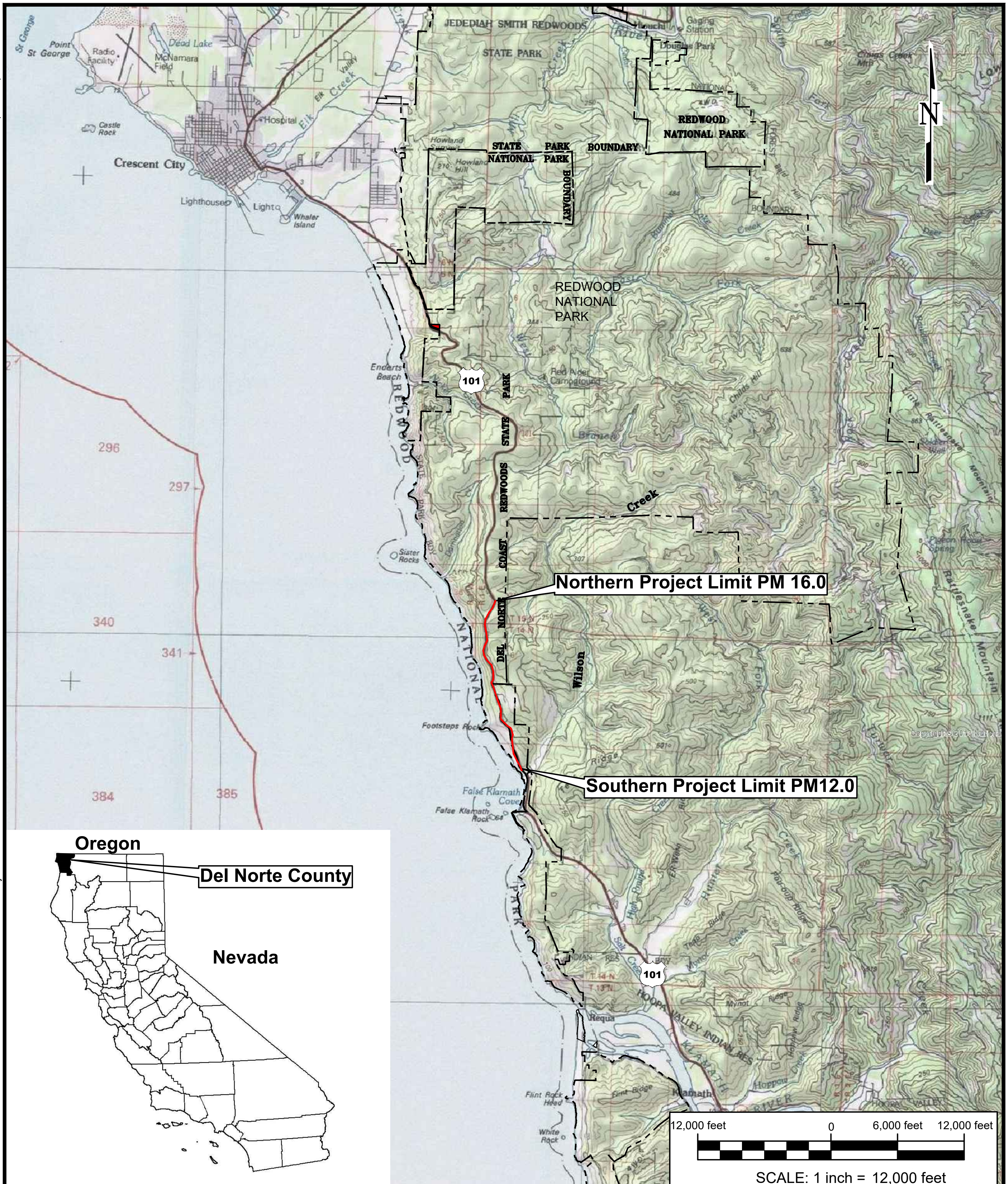
[3] Correlated Uniaxial Strength not provided by laboratory.

[4] Point Load Strength Index and Correlated Uniaxial Strength not provided due to only one valid test.

[5] Laboratory received shattered core sample.

[6] Test performed and results presented in Appendix M.

FIGURES



LAST CHANCE GRADE PERMANENT RESTORATION PROJECT

PRELIMINARY GEOTECHNICAL DATA REPORT
APRIL 2022

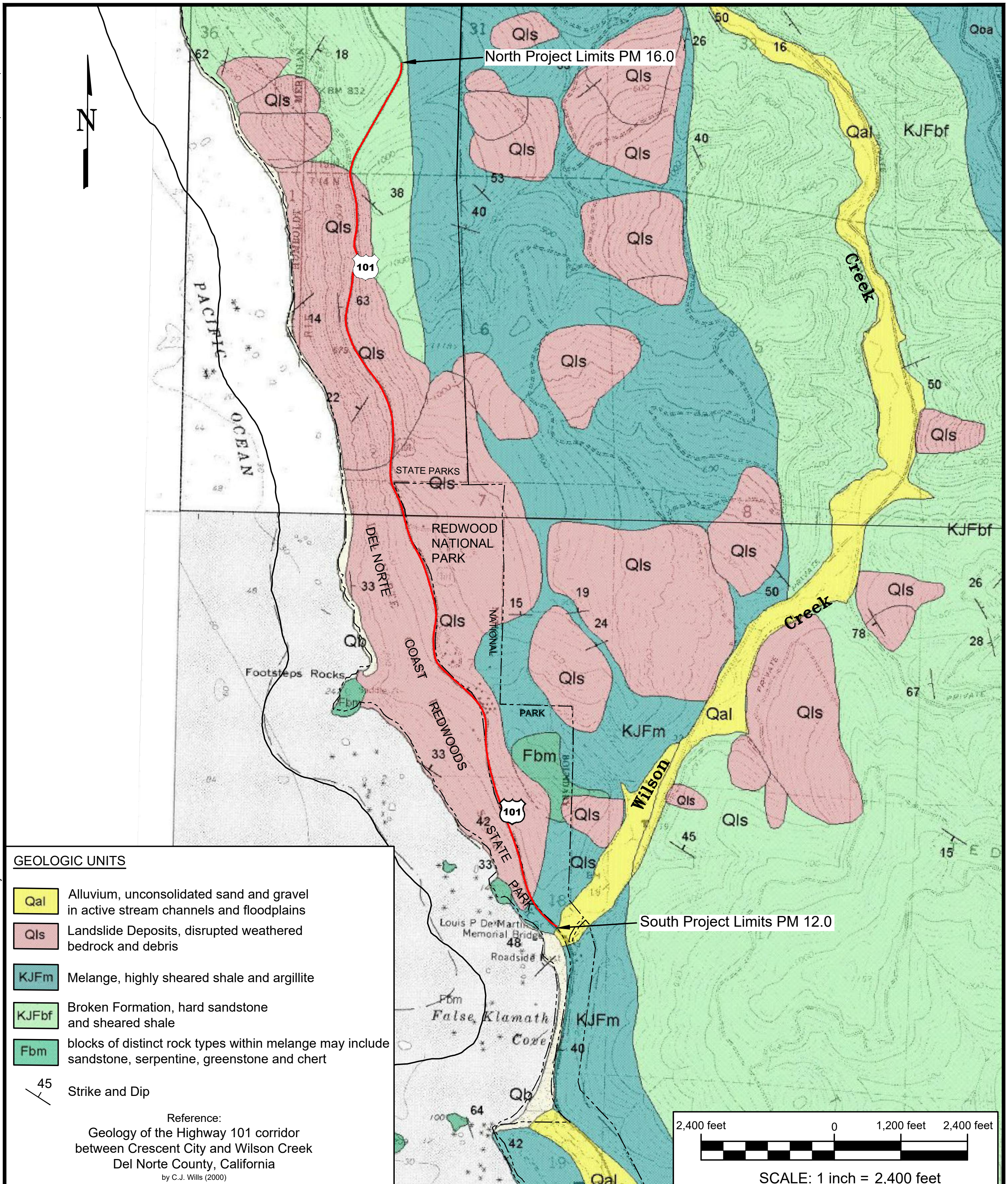
SITE LOCATION PLAN

FIGURE

1

PLOTTED: 13 Jul 2021, 9:51am, DRoss

CAD FILE: K:\2020 PROJECTS\20208000.001A LAST CHANCE GRADE\FIGURES\ LAYOUT: Layout1



LAST CHANCE GRADE PERMANENT RESTORATION PROJECT

PRELIMINARY GEOTECHNICAL DATA REPORT
APRIL 2022

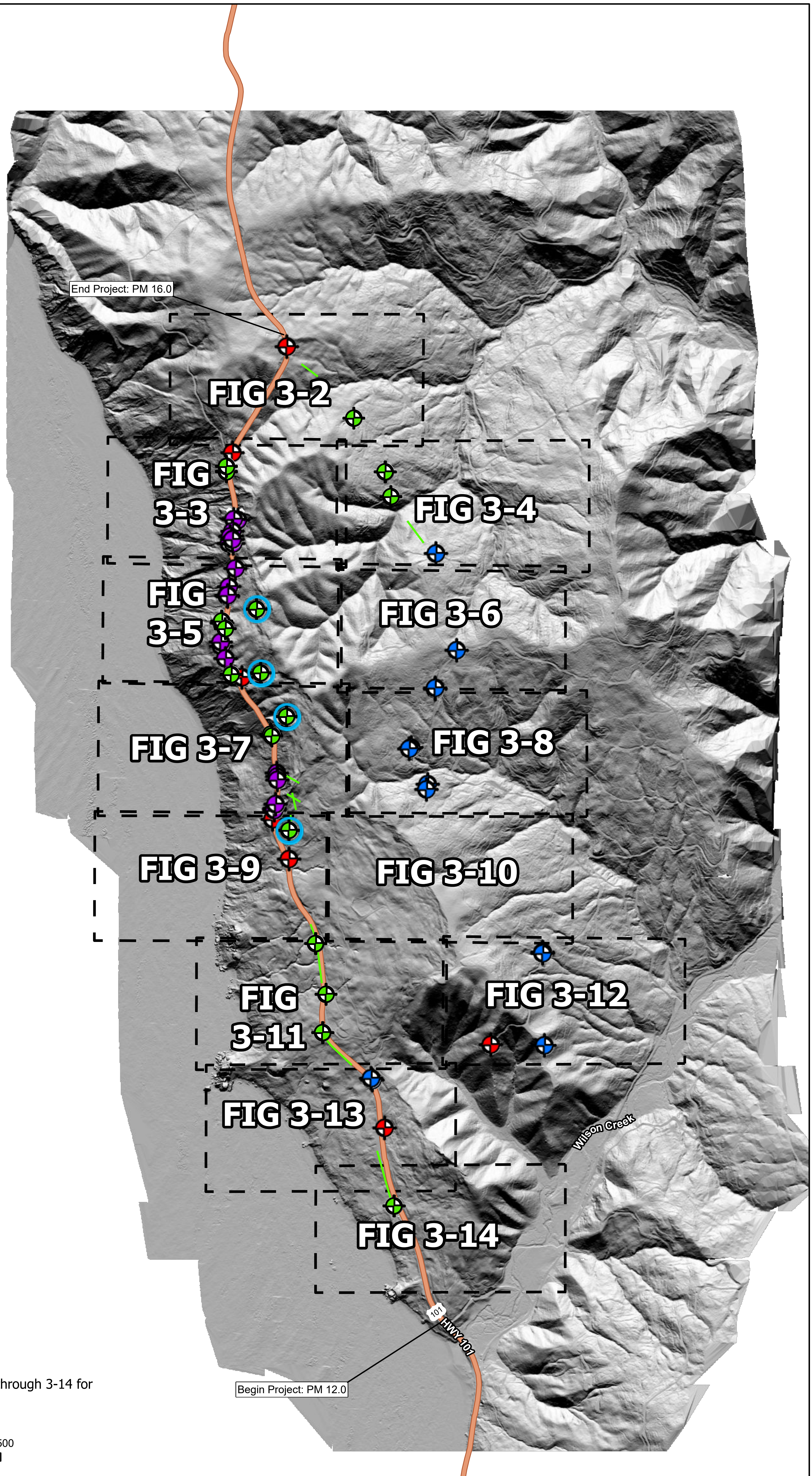
REGIONAL GEOLOGIC MAP

FIGURE

2

PLOTTED: 13 Jul 2021, 10:08am, DRoss

CAD FILE: K:\2020 PROJECTS\20208000.001A LAST CHANCE GRADE\FIGURES\ LAYOUT: Layout1



Note: See Figures 3-2 through 3-14 for explanation of symbols

N

0 750 1,500
FEET

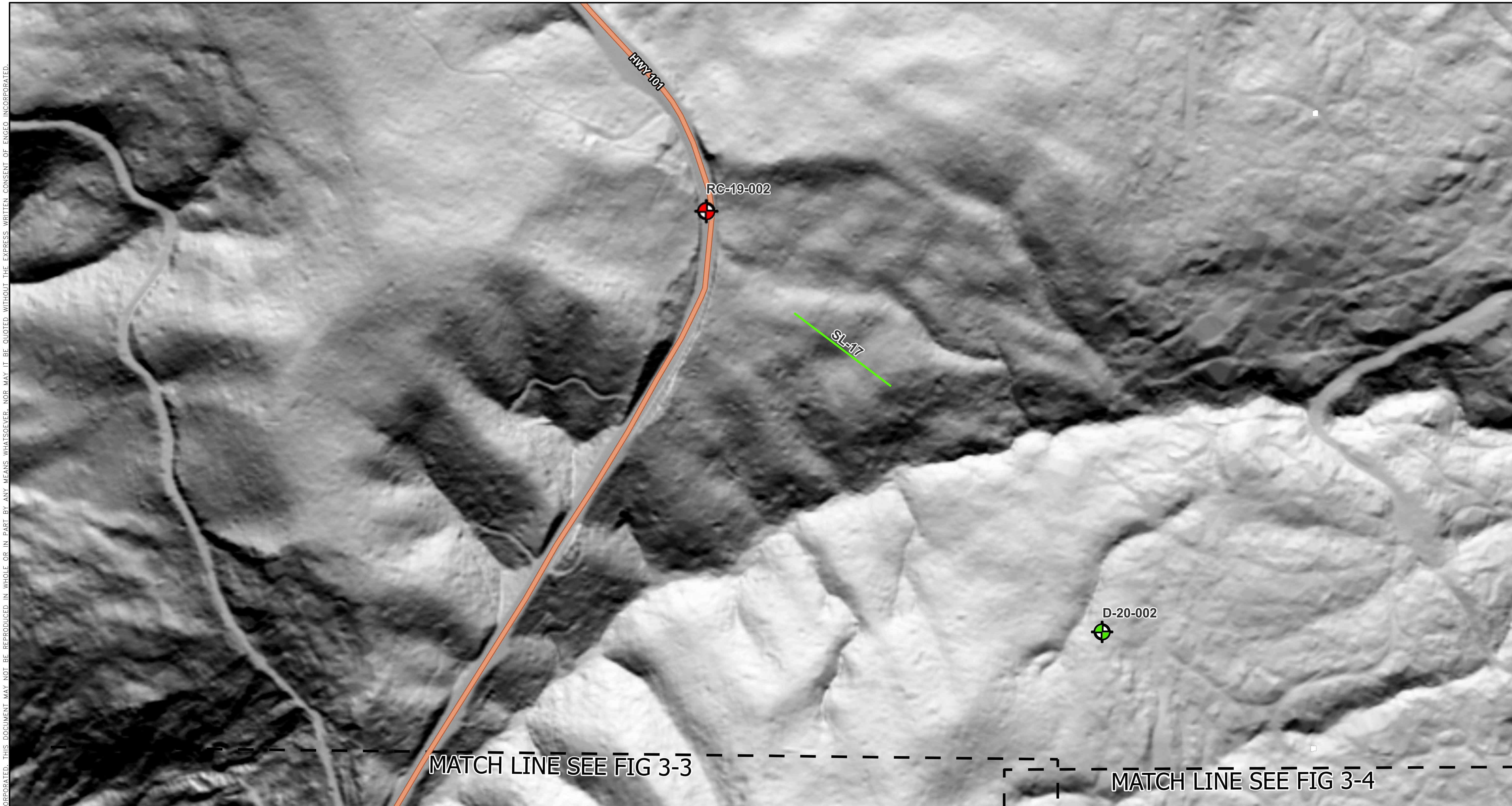
BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

KEY MAP
LAST CHANCE GRADE PROJECT PA/ED
DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099
SCALE: AS SHOWN
DRAWN BY: QRL
CHECKED BY: BA
FIGURE NO. 3-1

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

PA&ED Phase 2B Seismic Line

Completed Boring (Phase 2A Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS

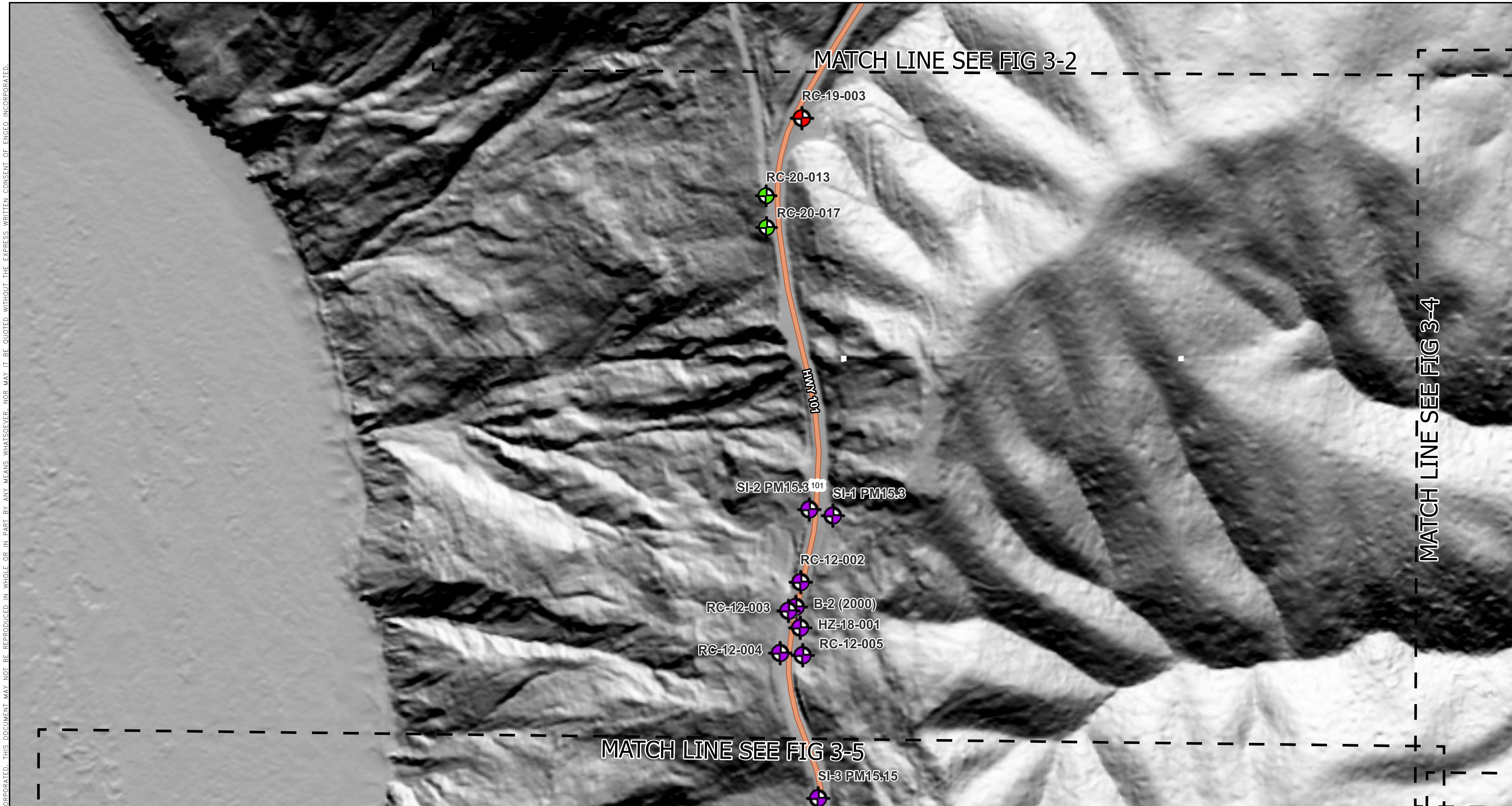
LAST CHANCE GRADE PROJECT PA/ED

DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099	FIGURE NO. 3-2
SCALE: AS SHOWN	
DRAWN BY: QRL	CHECKED BY: BA

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- Completed Boring (Pre-2018 Location)
- Completed Boring (Phase 2A Location)
- Completed Boring (Phase 2B Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099 SCALE: AS SHOWN DRAWN BY: QRL CHECKED BY: BA	FIGURE NO. 3-3

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR

EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- PA&ED Phase 2B Seismic Line
- Completed Boring (Phase 1 Location)
- Completed Boring (Phase 2B Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS

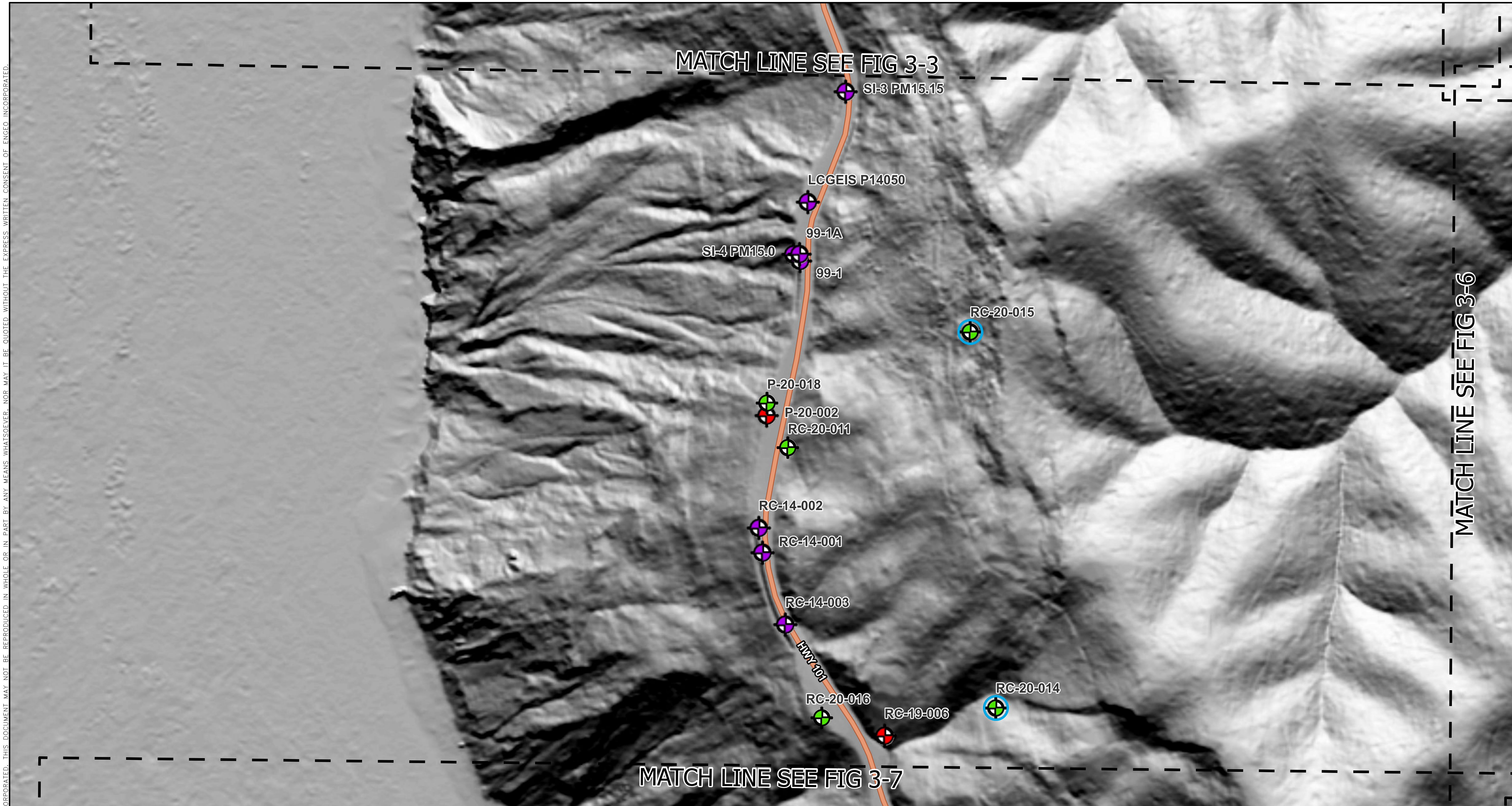
LAST CHANCE GRADE PROJECT PA/ED

DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099	FIGURE NO. 3-4
SCALE: AS SHOWN	
DRAWN BY: QRL	CHECKED BY: BA

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- Completed Boring (Pre-2018 Location)
- Completed Boring (Phase 2A Location)
- Completed Boring (Phase 2B Location)
- Completed Helicopter Boring (Phase 2B Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS

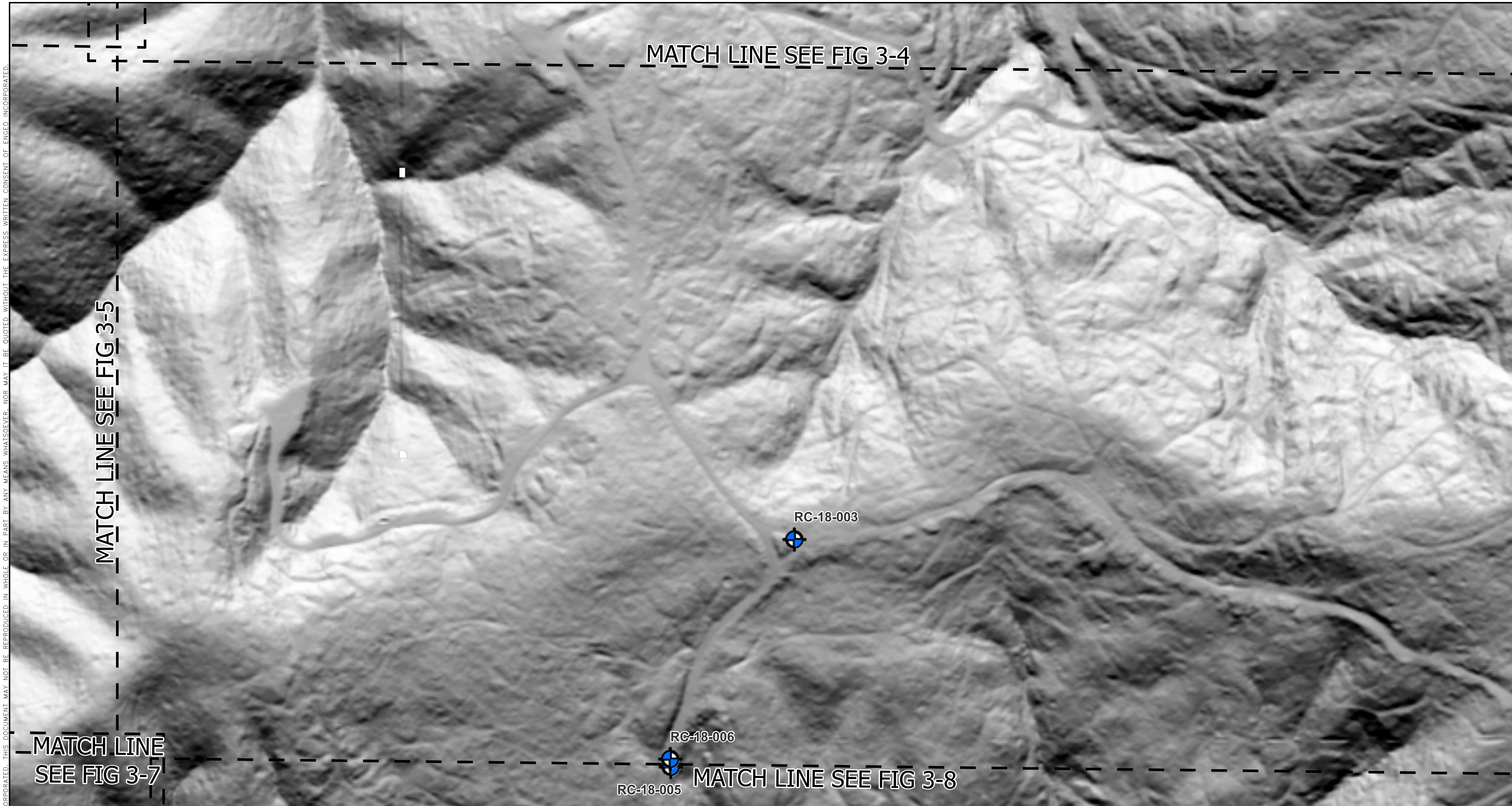
LAST CHANCE GRADE PROJECT PA/ED

DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099	FIGURE NO. 3-5
SCALE: AS SHOWN	
DRAWN BY: QRL	CHECKED BY: BA

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

Completed Boring (Phase 1 Location)

N

0 125 250

FEET

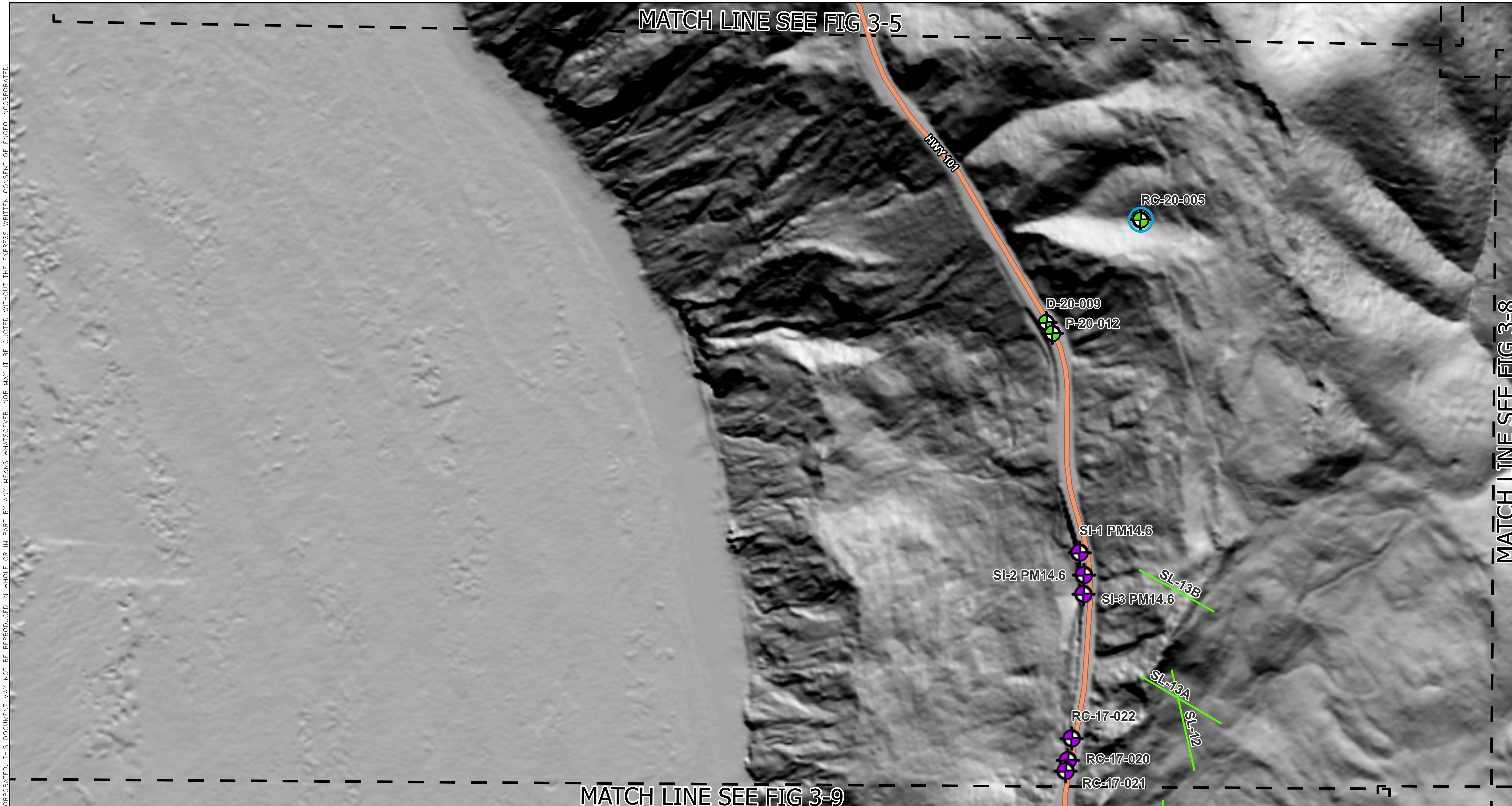
* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099		FIGURE NO. 3-6
	SCALE: AS SHOWN		
	DRAWN BY: QRL	CHECKED BY: BA	

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- PA&ED Phase 2B Seismic Line
- Completed Boring (Pre-2018 Location)
- Completed Boring (Phase 2B Location)
- Completed Helicopter Boring (Phase 2B Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS

LAST CHANCE GRADE PROJECT PA/ED

DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099

SCALE: AS SHOWN

DRAWN BY: QRL

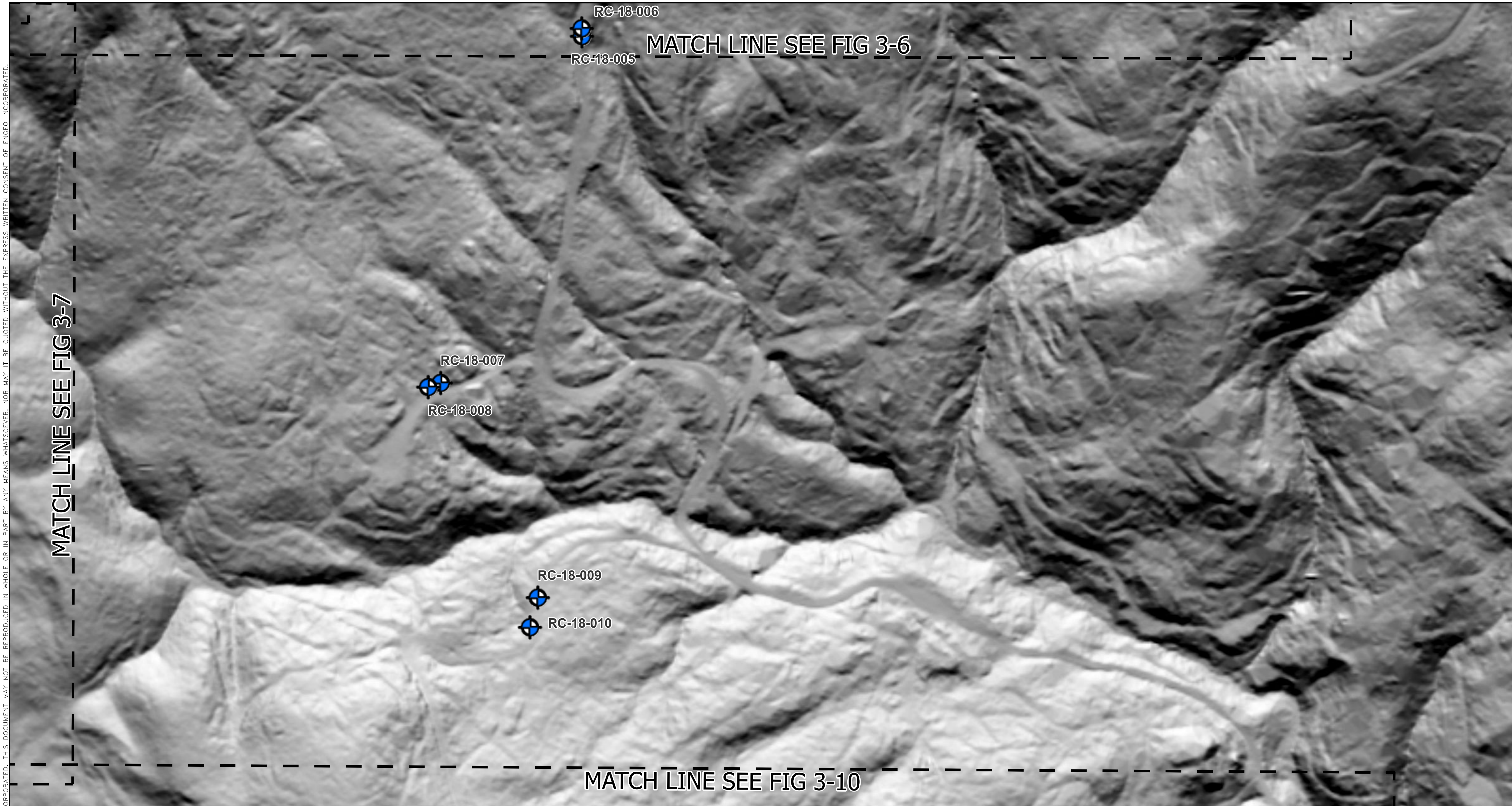
CHECKED BY: BA

FIGURE NO.

3-7

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

Completed Boring (Phase 1 Location)

N

0 125 250

FEET

* See figure 1 for explanation

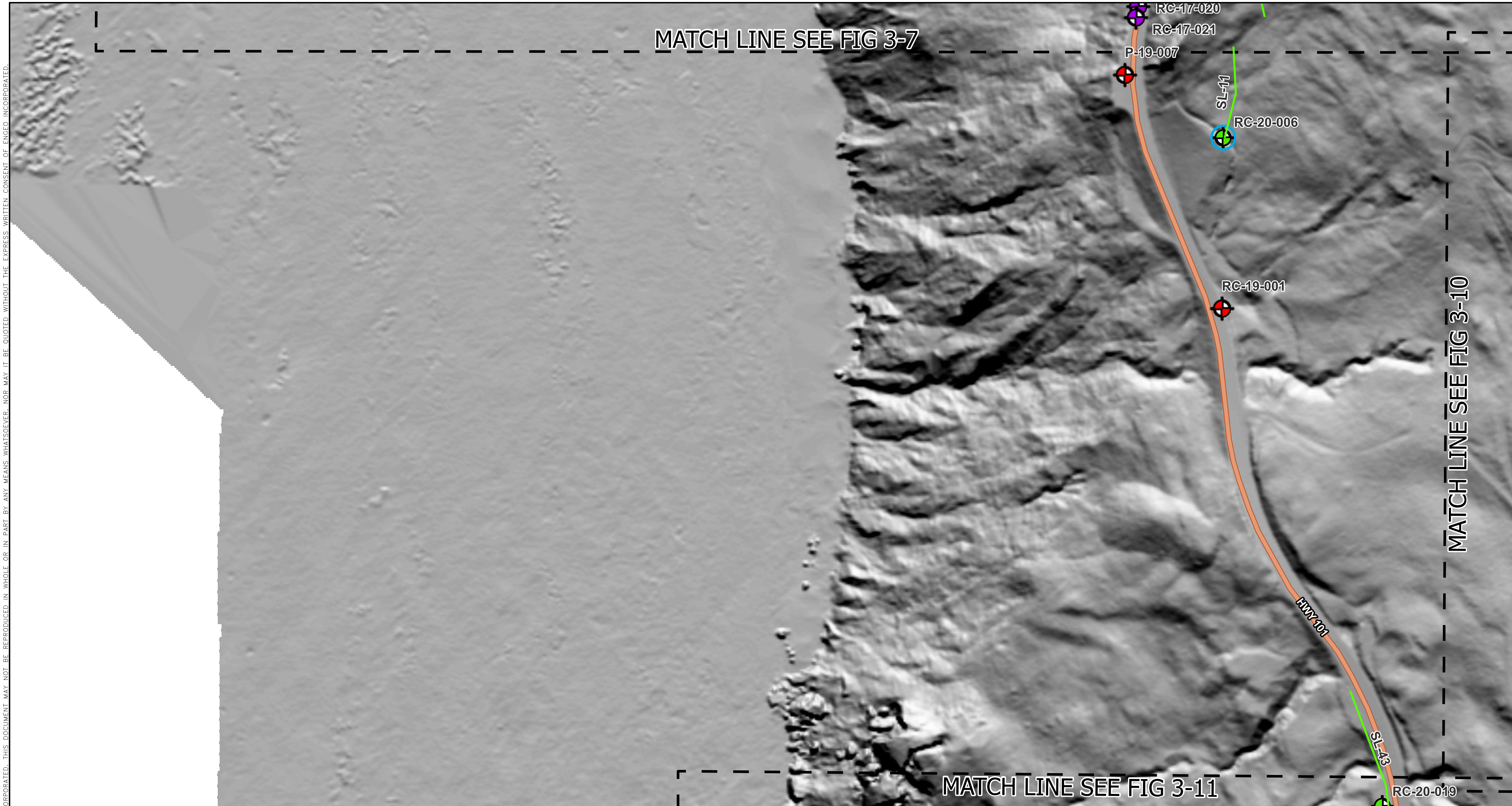
BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS

LAST CHANCE GRADE PROJECT PA/ED

DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099	FIGURE NO. 3-8
SCALE: AS SHOWN	
DRAWN BY: QRL	CHECKED BY: BA



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- PA&ED Phase 2B Seismic Line
- Completed Boring (Pre-2018 Location)
- Completed Boring (Phase 2A Location)
- Completed Boring (Phase 2B Location)
- Completed Helicopter Boring (Phase 2B Location)

N

0 125 250

FEET

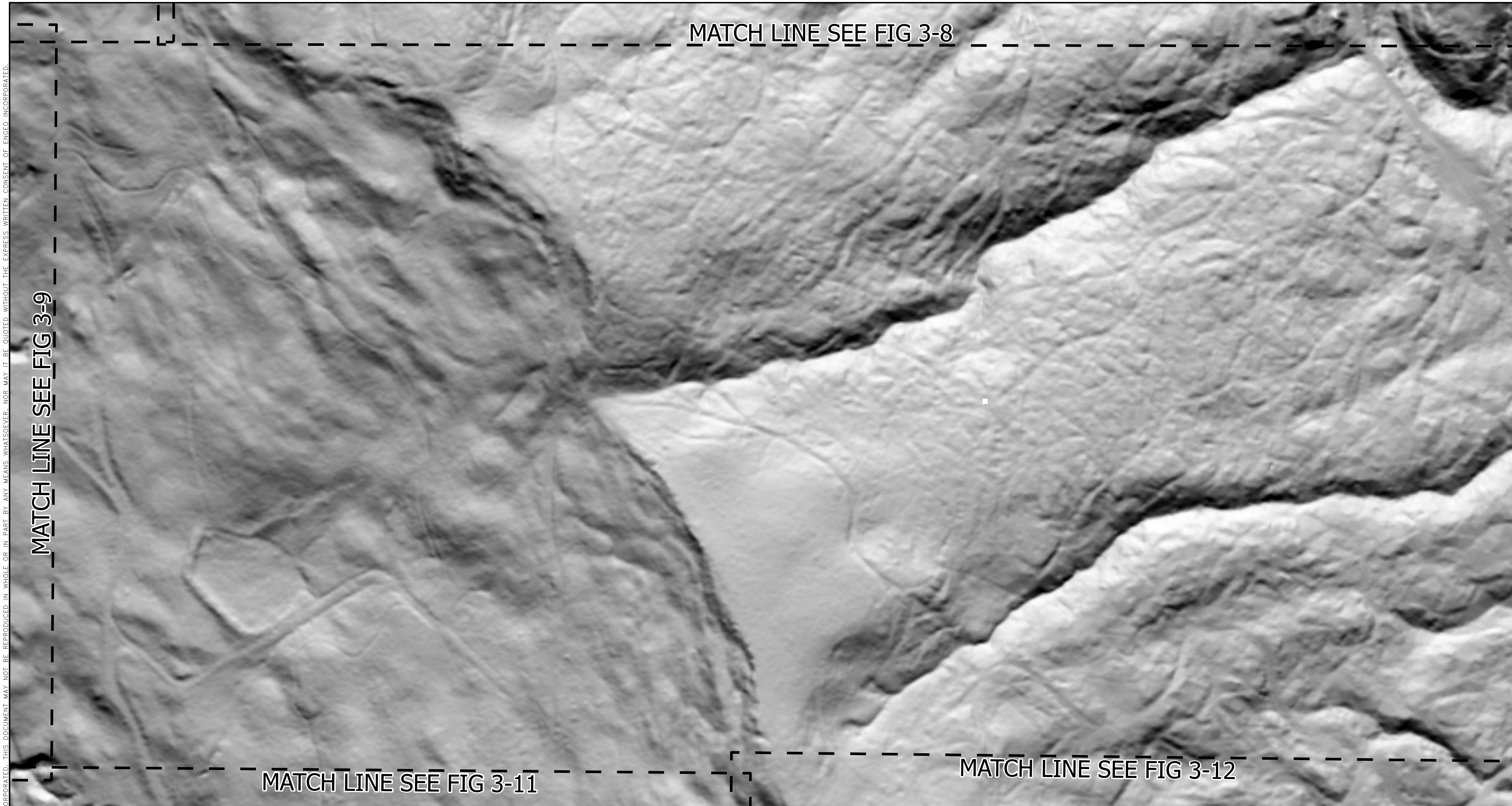
* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

	GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099 SCALE: AS SHOWN DRAWN BY: QRL CHECKED BY: BA	FIGURE NO. 3-9

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

N

0 125 250

FEET

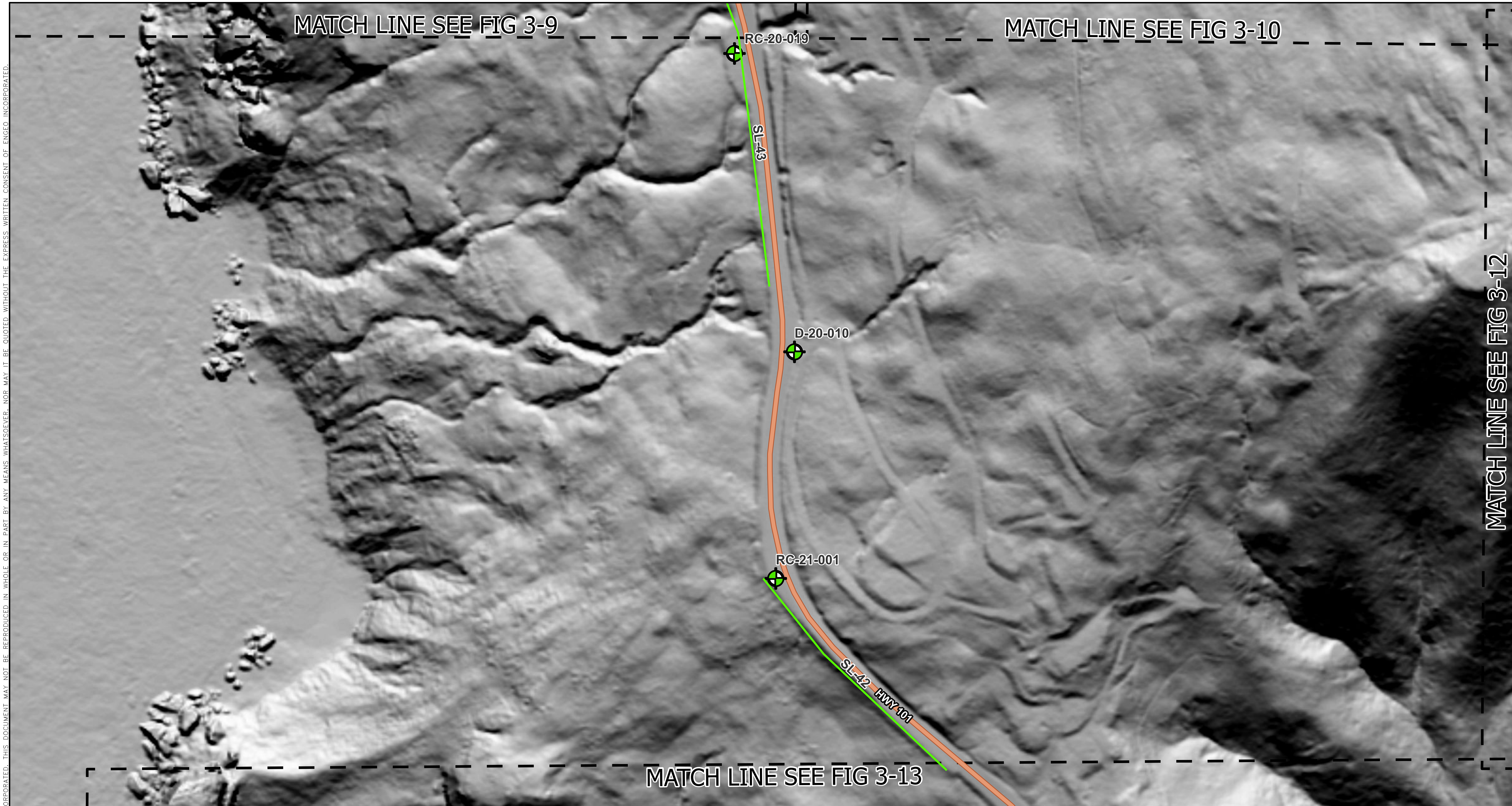
* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

	GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099 SCALE: AS SHOWN DRAWN BY: QRL CHECKED BY: BA	FIGURE NO. 3-10

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- PA&ED Phase 2B Seismic Line
- Completed Boring (Phase 2B Location)

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

N

0 125 250

FEET

GEOTECHNICAL INVESTIGATION LOCATIONS

LAST CHANCE GRADE PROJECT PA/ED

DEL NORTE COUNTY, CALIFORNIA

PROJECT NO.: 0115000099

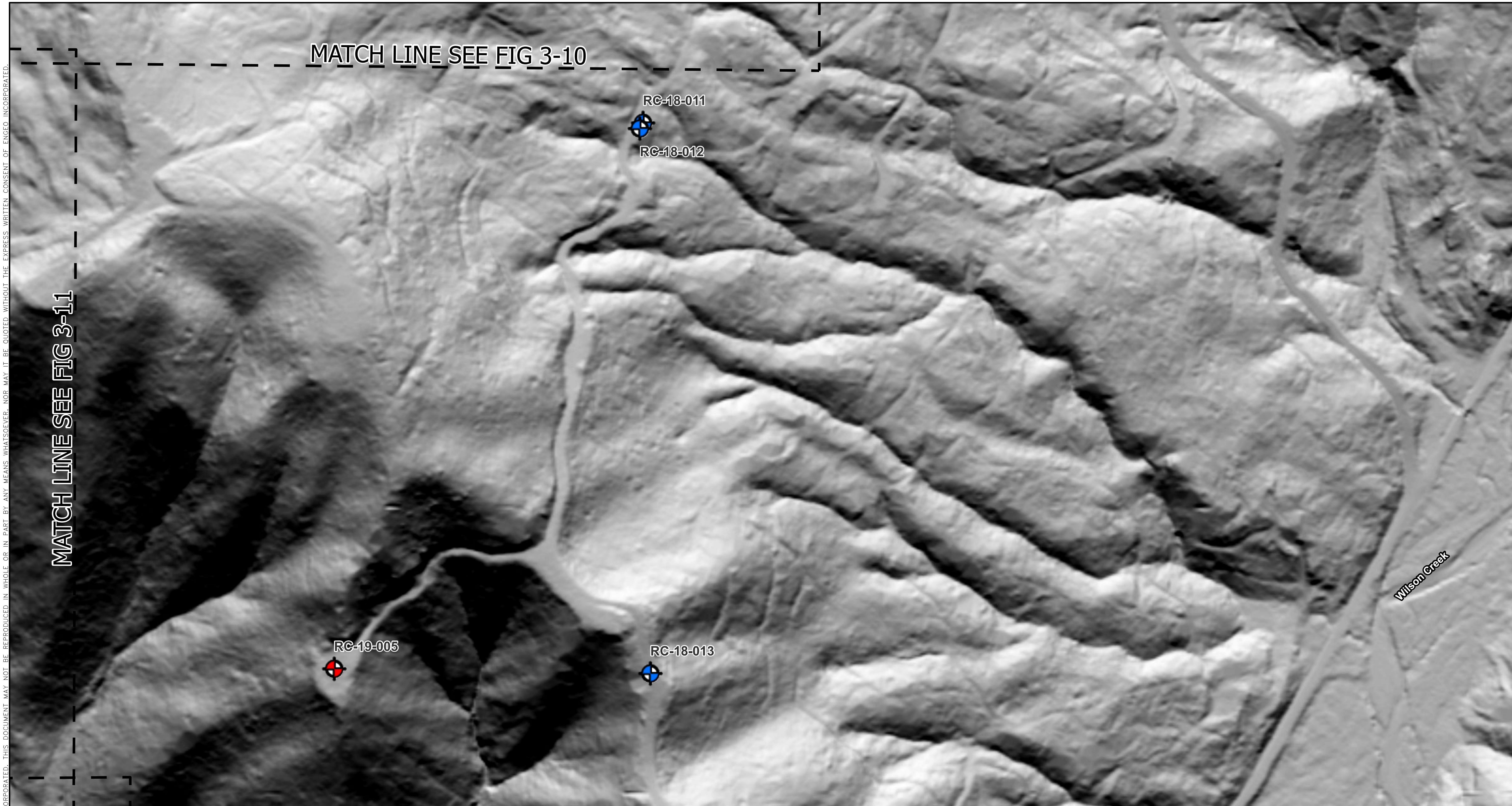
SCALE: AS SHOWN

DRAWN BY: QRL CHECKED BY: BA

FIGURE NO. 3-11

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- Completed Boring (Phase 1 Location)
- Completed Boring (Phase 2A Location)

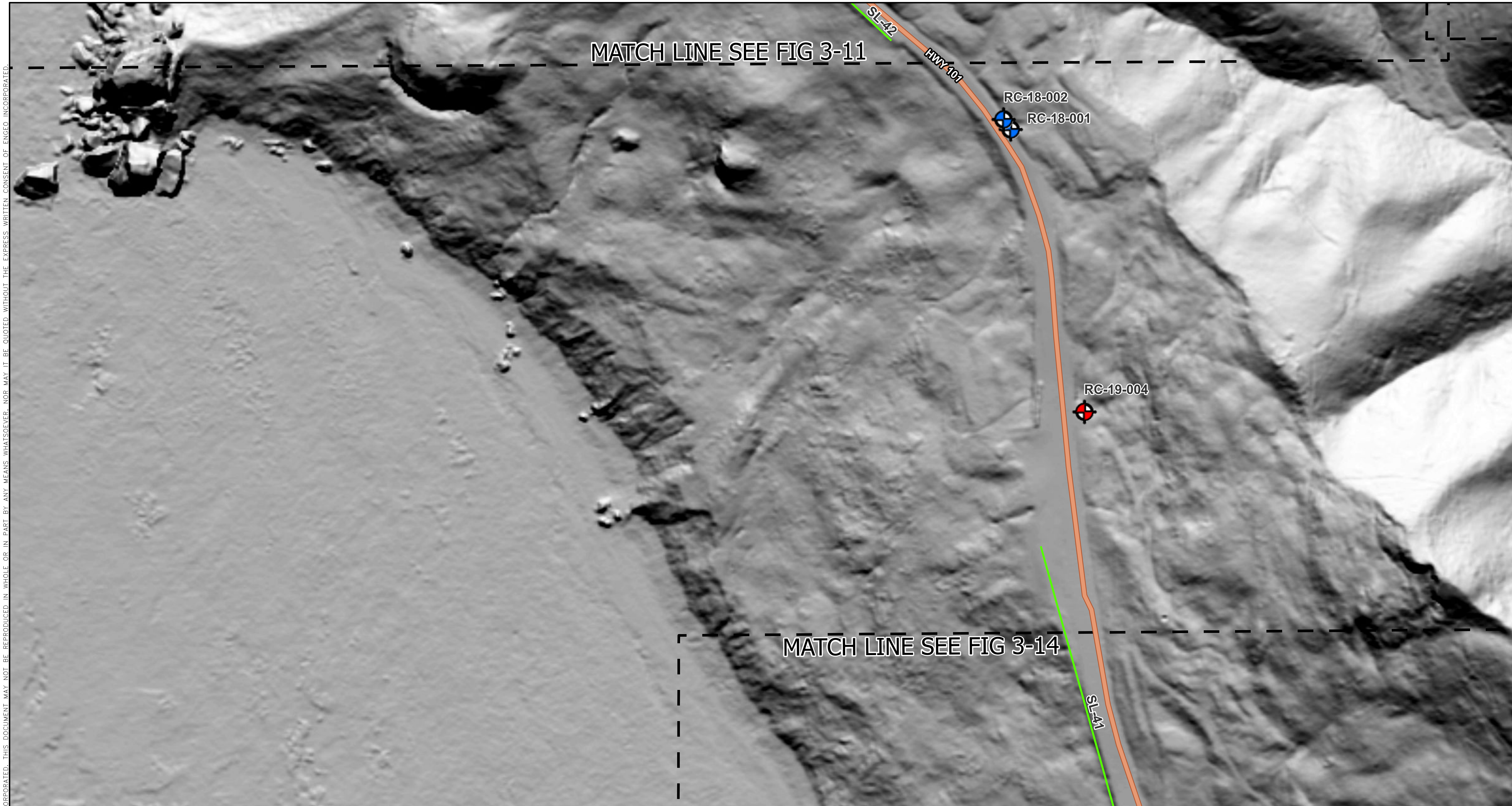
0 125 250
FEET
N

* See figure 1 for explanation
BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099 SCALE: AS SHOWN DRAWN BY: QRL CHECKED BY: BA	FIGURE NO. 3-12

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR



EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- PA&ED Phase 2B Seismic Line
- Completed Boring (Phase 1 Location)
- Completed Boring (Phase 2A Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099		FIGURE NO. 3-13
	SCALE: AS SHOWN		
	DRAWN BY: QRL	CHECKED BY: BA	

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR

EXPLANATION

ALL LOCATIONS ARE APPROXIMATE

- PA&ED Phase 2B Seismic Line
- Completed Boring (Phase 2B Location)

N

0 125 250

FEET

* See figure 1 for explanation

BASEMAP SOURCE: HNTB CORP., KLEINFELDER, ENGEO, SHN

GEOTECHNICAL INVESTIGATION LOCATIONS LAST CHANCE GRADE PROJECT PA/ED DEL NORTE COUNTY, CALIFORNIA	PROJECT NO.: 0115000099 SCALE: AS SHOWN DRAWN BY: QRL CHECKED BY: BA	FIGURE NO. 3-14

PATH: G:\ACTIVE PROJECTS_16000 TO 17999\17134\17134.000.000\GIS\17134\17134.APRX

ORIGINAL FIGURE PRINTED IN COLOR