3.1 GEOLOGY

The objective of the Beta Unit Geophysical Survey is to provide subsurface imaging of the geologic formations, which lie 3,000 to 5,000 feet (914 to 1,524 meters) below the seafloor within the Beta Unit field. The proposed geophysical survey will encompass an area of approximately 18.885 square miles (48.91 square kilometers). The enhanced imaging of the subsurface geology will enable more efficient recovery of the remaining natural resources within the field. The survey will be used to map the subsurface geology to locate remaining resources thereby reducing the number of wells required to recover the resource.

The following summary of geologic and subsurface conditions pertaining to the Project area has been primarily based on information obtained during recent studies conducted by Fugro West (Fugro) in support of previous Beta projects. These include the Intrafield Pipeline Replacement Project Geohazards Desktop Study (May 2010), Intrafield Pipeline Replacement Project Site Characterization Report (November 2010), and Executive Summary (December 2010).

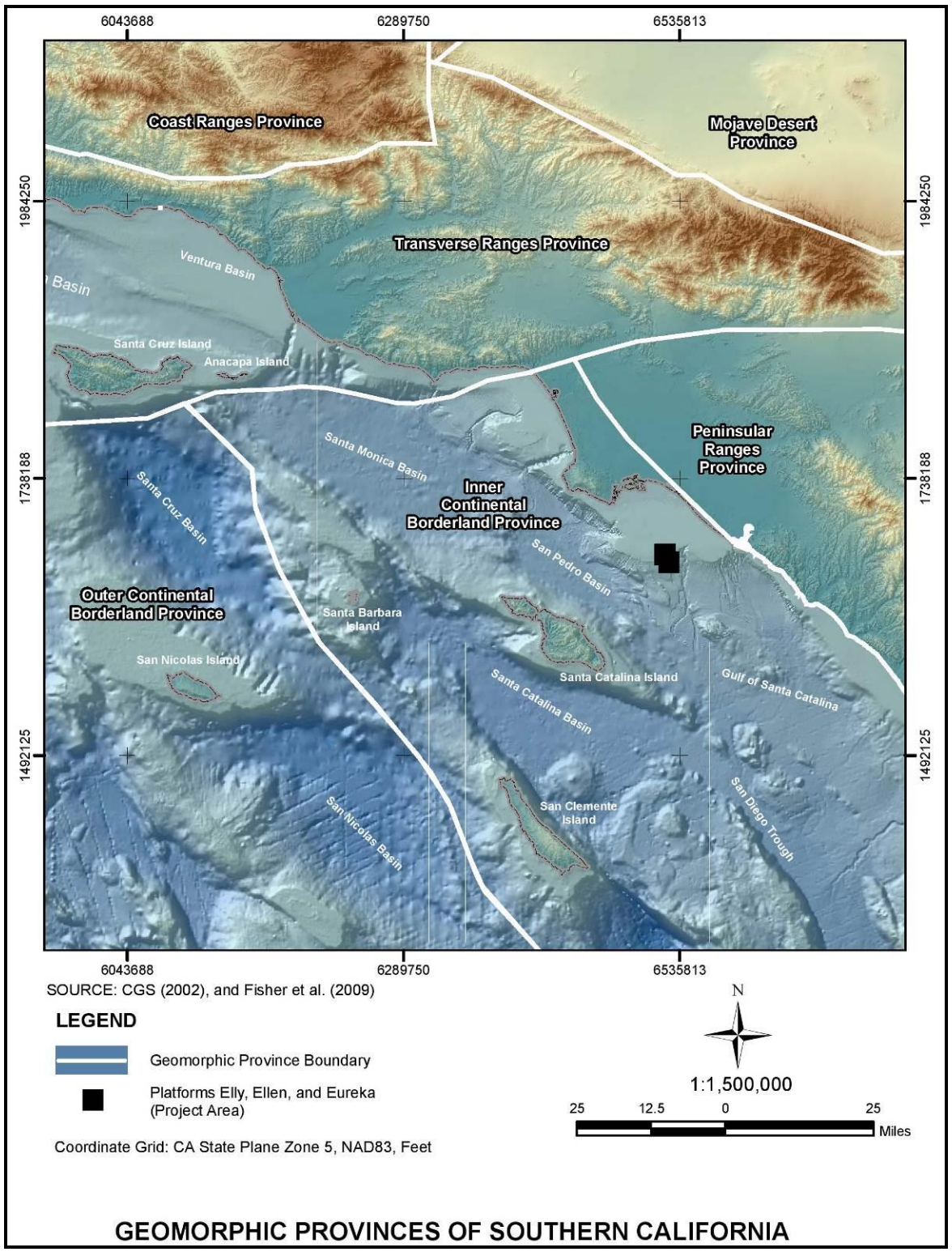
3.1.1 Affected Environment

3.1.1.1 Regional Geology

The Project survey is targeting oil productive formations below the seafloor within the Beta Unit Field. The Beta Unit is located on the northeast shelf and slope of the San Pedro Basin in the offshore portion of the Inner Continental Borderland Province, as shown in Figure 3.1-1 (Geomorphic Processes of Southern California). The Project area is located west of San Gabriel Submarine Canyon in water depths of approximately 148 to 1,083 feet (45 to 330 meters). The Project area is characterized by seafloor slope angles of approximately two to five degrees (2 degrees to 5 degrees) with a gentle southeast tilt. Major structural features in the Project vicinity include the northwest trending Palos Verdes Fault in the western portion of the Beta Field and Newport-Inglewood fault zones. These zones consist of through-going strike-slip faults with components of vertical offset and numerous secondary faults and folds that are typical of the structural style of the region.

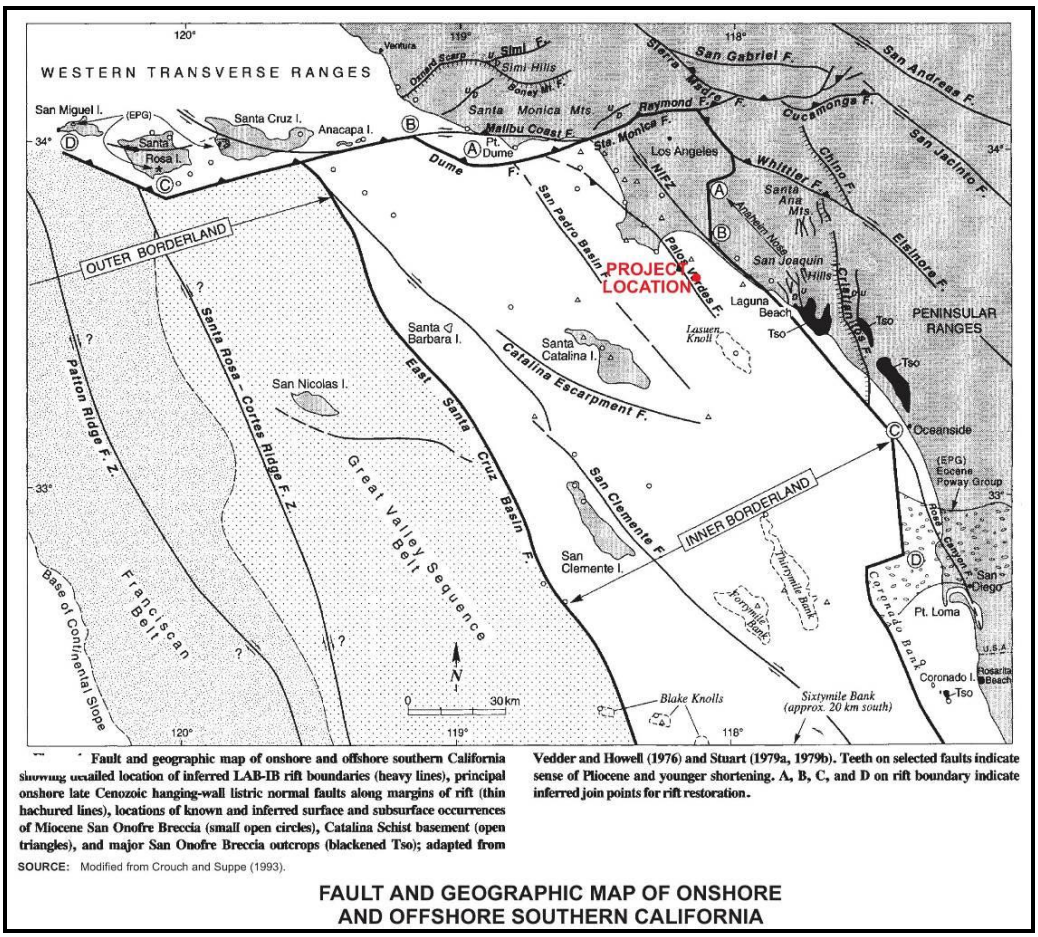
3.1.1.2 Faulting

The Palos Verdes Fault Zone (PVFZ) passes through portions of the Beta Field, and is known to be an active fault. Consequently, it is the most important fault in the Beta Field area. The fault offsets Holocene sediments in the Port of Los Angeles (POLA) with and estimated slip rate of approximately 3 +/- 1 millimeters per year (mm/year) for the past 8,000 years. The PVFZ extends from approximately 66 miles (106 kilometers) southeastward from Santa Monica Bay across the northeast portion of the Palos Verdes Peninsula and offshore across the San Pedro Shelf to Lasuen Knoll (Fugro West, 2010). As shown below in Figures 3.1-2 (Fault and Geographic Map of Onshore and Offshore Southern California), the Palos Verdes Fault runs in a north-south direction directly adjacent and to the west of the platforms.



Source: Fugro West, 2010

Figure 3.1-1. Geomorphic Provinces of Southern California



Fault and geographic map of onshore and offshore southern California showing detailed location of inferred LAB-IB rift boundaries (heavy lines), principal onshore late Cenozoic hanging-wall listric normal faults along margins of rift (thin hachured lines), locations of known and inferred surface and subsurface occurrences of Miocene San Onofre Breccia (small open circles), Catalina Schist basement (open triangles), and major San Onofre Breccia outcrops (blackened Tso); adapted from Vedder and Howell (1976) and Stuart (1979a, 1979b). Teeth on selected faults indicate sense of Pliocene and younger shortening. A, B, C, and D on rift boundary indicate inferred join points for rift restoration.

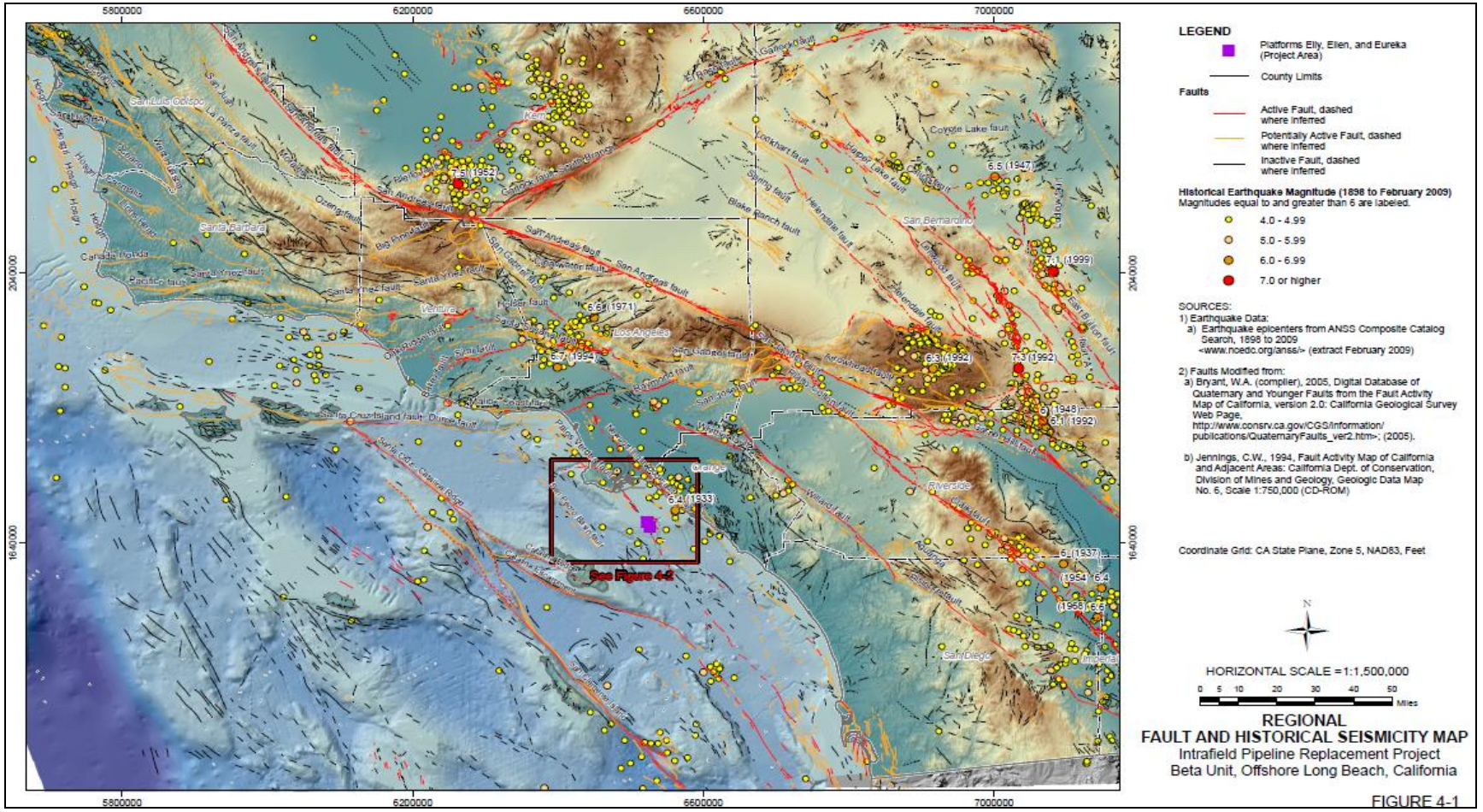
SOURCE: Modified from Crouch and Suppe (1993).

FAULT AND GEOGRAPHIC MAP OF ONSHORE AND OFFSHORE SOUTHERN CALIFORNIA

Figure 3.1-2. Fault and Geographic Map of Onshore and Offshore Southern California

3.1.1.3 Seismicity

The major fault system that runs through the San Pedro Basin is the PVFZ. The PVFZ is capable of generating large magnitude earthquakes. There are numerous other known faults in the region, with varying degrees of activity, that are also capable of producing strong ground motions within the Project area. In 2008, the United States Geological Survey (USGS) released an update of the United States (U.S.) National Seismic Hazard Maps, previously released in 2002. This update utilized Next Generation Attenuation (NGA) Relations developed from new ground-motion records to replace previous ground-motion prediction equations for crustal faults. These NGA equations allow for direct calculations of ground motions for a shear wave velocity of 760 meters per second (m/s) in the upper 30 meters (98 feet) of crust. This update also incorporated revised fault data from the Uniform California Earthquake Rupture Forecast Version 2 for Southern California, which includes fault data from the Community Fault Model. These new data sources were used to produce updated seismic hazard maps for California and Nevada. Earthquake epicenters are found throughout the area. Figure 3.1-3 below shows the location of earthquake epicenters in the region recorded between 1898 and 2009 and local faults.



Source: Fugro West, 2010

Figure 3.1-3. Regional Fault and Historical Seismicity Map

3.1.1.4 Bathymetry

In 2010, Fugro conducted a marine seismic reflection survey to collect subbottom and multibeam bathymetric data at the Project site. Additionally, side scan sonar data were collected to further characterize seafloor features along the proposed pipeline replacement route. Further, a remotely operated vehicle (ROV) survey was performed to obtain sonar images and video of the seafloor.

In summary, bathymetric elevations in the Beta Field range from approximately -170 feet (-52 meters) for Platform Edith to approximately -700 feet (-213 meters) for Platform Eureka. Platform Elly is located in an area with a bathymetric elevation of approximately -250 feet (76 meters) on the uppermost portion of the San Pedro Slope. Two slope gullies, which originate near the shelf break, are present within the Beta Field and are visible in the bathymetric data. The gullies are rather broad (500 to 700 feet wide [152 to 213 meters]) and shallow (up to 15 feet deep [4.6 meters]).

The seafloor in the area of the platforms is essentially featureless and slopes to the southeast at approximately two degrees. Specifically, Platform Elly is located on the southerly edge of the San Pedro shelf at a water depth of 260 feet (979 meters), on a slope of about 3.6 percent (two degrees). The San Gabriel submarine canyon is located east of the Project Site.

3.1.1.5 Soil Conditions

Soils in the vicinity of the Project Platforms are marine Holocene and fluvial-marine Late Pleistocene clastic sediments. Surficial soils or modern sediments cover most of the Project vicinity and range from a depth of approximately 10 to 33 feet (three to ten meters) (Westec, 1984). Several borings were completed near the Platforms in 2010 to depths of approximately 60-500 feet (18-152 meters). The borings indicated that soils consisted of interlayered sands, silts and clays. The sand and silty sand encountered were primarily medium dense to dense, fine to coarse grained, with gravel in the shallower portions of some borings. Below the shelf break mean grain sizes decrease significantly, and silt and clay sediments characterize the slope areas.

3.1.2 Regulatory Setting

The criteria used to estimate fault activity in California are described in the Alquist-Priolo Special Studies Zones Act of 1972. The Act only addresses the hazard of surface fault- rupture and is not directed toward other earthquake hazards. The Act defines an "active fault" as a fault that has had surface displacement within Holocene time (approximately the last 11,000 years).

The Seismic Hazards Mapping Act of 1990 (Public Resources Code [PRC] Sec. 2690 and following as Division 2, Chapter 7.8) addresses non-surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides. Special Publication 117A (Revised), Guidelines for Evaluating and Mitigating Seismic Hazards in California (California Geological Survey, 2008), constitutes the guidelines for evaluating seismic hazards other than

surface fault-rupture and for recommending mitigation measures as required by PRC Section 2695(a).

3.1.3 Impact Assessment

The proposed survey activities do not include any test drilling, sampling, or placement of anchors. The Project is intended to obtain subsurface geologic information regarding the oil producing unit beneath the Beta Field and would have no effect on local or regional geology.

The Project design accordingly limits potential impacts to very minor seafloor disturbance to sediments during deployment/recovery of the 730 nodal receiver units. Multibeam bathymetry, side scan sonar, and subbottom profile data were acquired at the Project site in October 2010. Based on these surveys, seafloor conditions within the Project area are generally soft-bottom and gradually sloping. However, several areas of irregular seafloor topography have been mapped between the Platforms. No geologic impacts are expected as a result of placing the autonomous nodes on the seafloor. However, during deployment of the nodes, the contractor will avoid areas containing topographic anomalies and irregular features if possible to mitigate any potential impacts.

This information would be made available to the public and to research facilities to better characterize offshore faulting in this area. These studies are important to understanding and minimizing the risks to life and safety. Such collaboration and data sharing will result in benefits to the regional understanding of subsurface geologic conditions including the potential refinement in the location of fault lines and related earthquake potential.

3.1.4 References

Bureau of Ocean Energy and Management (BOEM), 2016. Gulf of Mexico OCS Proposed Geological and Geophysical Activities Draft PEIS. Volume I: Chapters 1-8.

California Geological Survey. 2008. Special Publication 117A – Guidelines for Evaluating and Mitigating Seismic Hazards in California. Originally adopted March 13, 1997 by the State Mining and Geology Board in Accordance with the Seismic Hazards Mapping Act of 1990. Revised and Re-adopted September 11, 2008 by the State Mining and Geology Board in Accordance with the Seismic Hazards Mapping Act of 1990.

Fugro West, May 2010. Intrafield Pipeline Replacement Project Geohazards Desktop Study prepared for Beta Offshore.

Fugro West, November 2010. Intrafield Pipeline Replacement Project Site Characterization Report prepared for Beta Offshore.

Fugro West, December 2010. Intrafield Pipeline Replacement Project Executive Summary prepared for Beta Offshore.

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