2.0 DATA COLLECTION

Continued seismic monitoring and the acquisition of high-resolution potential field (magnetics and gravity), seismic reflection, bathymetric, and topographic data have significantly improved the ability to resolve geologic and tectonic structures in the vicinity of DCPP since the original LTSP Final Report and Addendum (PG&E, 1988, 1991a).

Many of the regional geophysical data sets discussed in this report were collected as part of the PG&E–USGS CRADA. These new data were combined with onshore and offshore geologic data to update earlier models for the area and were integrated with more site-specific studies of the Shoreline fault zone carried out by PG&E. The following sections summarize the data collection activities from 2008 to 2010. More detailed descriptions of these data sets can be found in the Appendices. Section 2.8 contains definitions for terms used in this report.

2.1 Geology

Onshore and offshore geologic mapping was performed in 2009 and 2010 to prepare a "seamless" onshore/offshore geologic map of the Shoreline fault zone study area (Plate 1). The mapping included (1) detailed mapping of the extensive rock exposures in the sea cliffs and on the wave-cut platform at low tide from Lion Rock (north of Diablo Cove) to south of Rattlesnake Creek, and (2) collection of rock samples offshore.

2.1.1 Onshore Geologic Mapping

The local lithology of the various formations was described, and structures cutting the formations, shear zones, faults, and folds were characterized (Appendix B). Coastline mapping utilized both Light Detection and Ranging (LiDAR) surveys and orthophoto maps (Appendix G). This mapping is more detailed and more accurately located than earlier mapping onshore by Hall (1973) and Hall et al. (1979) and for the LTSP (PG&E, 1988, 1991a). This allowed projecting the onshore geology to the offshore interpretation of the geology based on the multibeam echo sounding (MBES) bathymetry data (Appendix F), magnetic field data (Appendix D), and seismic reflection data (Appendix H).

2.1.2 Offshore Geologic Mapping

Interpretation of the MBES bathymetry image used texture and structures to differentiate various rock units and to identify folds and faults. The magnetic field data helped with differentiation of rock units that have high magnetic signatures, and seismic reflection profiles helped in places with interpretation of folds, faults, and paleoshorelines where the rocks are covered by Quaternary sediments. Fifty new diver samples were collected offshore in July 2010 (see Figure 2-1 for locations and Appendix B) to supplement the diver and drop core samples obtained earlier for the LTSP (PG&E, 1991a). The sampling targeted areas of distinct bathymetric texture as identified from the MBES bathymetry data (Appendix F) and specific locations where preliminary geologic interpretations suggested a conflict between the original LTSP and the current mapping. Diver samples are analyzed to determine bulk physical properties (e.g., density and magnetic

susceptibility). Sample locations are assumed to be accurate to within 10–20 m. The last steps were to complete the offshore geologic interpretations by projecting offshore the formation contacts and structures from the onshore mapping, and to finalize the map shown on Plate 1.

2.2 Seismographic Station Coverage

McLaren and Savage (2001) summarized the seismographic station coverage in the Central Coast region. Aside from early instrumentation installed in 1927 in Santa Barbara and in 1961 at Parkfield, there were very few instruments in this region until about 1981, when the USGS began installing short-period vertical-component instruments with analog telemetry as part of the National Earthquake Hazards Reduction Program (NEHRP) (Lindh et al., 1981) (Figure 2-2). In 1987, PG&E installed the Central Coast Seismic Network (CCSN), consisting of 20 seismographic stations along the coast from Ragged Point to Point Sal. Fifteen of those stations were installed with short-period vertical-component sensors, and five had dual-gain three-component sensors. The minimum magnitude detection threshold value is approximately M 1.0 for onshore earthquakes and M 1.5 for near-offshore events. The network was designed to supplement the USGS network and improve the location accuracy of offshore microearthquakes. The recorded earthquakes were typically located using computer programs that inverted the arrival times from stations to travel times using a one-dimensional (1-D) velocity model. Despite the use of dual gain at the 5 three-component stations, events greater than about M 2.4 at 5–10 km distance from a station were off scale, or clipped, making S-wave arrival picks impossible.

Data processing has consisted of timing P- and S-wave arrivals and locating the earthquakes using the 1-D velocity model of McLaren and Savage (2001) and the location program Hypoinverse (Klein, 1985). Final locations were computed by integrating USGS data. Since about 2003, the PG&E data have been streaming to the USGS for automatic integration with the USGS data for computing locations and for focal mechanisms using the program FPFIT (Reasenberg and Oppenheimer, 1985).

Starting in 2006, PG&E began a five-year program to update approximately 17 of the original 20 stations with digital telemetry and digital recorders for velocity and acceleration (six components). By the end of 2011, PG&E expects to have 16 stations updated (Figure 2-2). The recorded data are markedly improved and should result in more accurate earthquake locations, particularly in the offshore region (Figure 2-2). PG&E is planning to install ocean-bottom seismometers starting in 2011 to further improve offshore locations.

Since 1987, the CCSN has recorded approximately 23,500 earthquakes in the Central Coast region bounded by the area shown on Figure 2-3a. The histogram (Figure 2-3b) shows that most these earthquakes are aftershocks from the moment magnitude (M_w) 6.5 San Simeon earthquake of 2003. The Hardebeck (2010) relocations and focal mechanisms were computed using a subset of the PG&E/USGS seismicity data.

2.3 Potential Field—Magnetic Surveys

Three magnetic surveys were conducted in the DCPP area in 2008 and 2009. These included a regional fixed-wing aeromagnetic survey from San Simeon to Point Concepcion (Langenheim et al., 2009a), a marine magnetic survey from Estero Bay to San Luis Obispo Bay (Sliter et al., 2009), and a helicopter magnetic survey from Point Buchon to Point San Luis (New Sense Geophysics, 2010). All three data sets are described in more detail in Appendix D. Figure 2-4 compares the magnetic data that were available at the time of the original LTSP (PG&E, 1988) with the helicopter magnetic data that were collected in 2009. This comparison illustrates how modern high-resolution data collection techniques have significantly improved imaging the potential field in this area.

2.4 Potential Field—Gravity Surveys

The USGS has compiled, edited, and reprocessed nearly 30,000 gravity measurements to produce an isostatic residual gravity map for the region, from Monterey Bay on the north to the Santa Barbara channel on the south (Langenheim et al., 2008). These data are further discussed in Appendix E. Figure 2-5 compares the gravity data available during the original LTSP (PG&E, 1988) with these newer data. While new gravity data have been collected onshore, little, if any, new data have been collected offshore.

2.5 Multibeam Echo Sounding Surveys

MBES bathymetry data for the Estero Bay to San Luis Obispo Bay near-shore region were acquired by the Seafloor Mapping Lab at the California State University Monterey Bay during 2007, 2009, and 2010. Appendix F contains further details of the data collection and reduction. Figures 2-6 and 2-7 compare seafloor bathymetry offshore of DCPP and Olson Hill using data that were available during the original LTSP (PG&E, 1988) and the newer MBES bathymetry data. Part of the improvement in resolution reflects the use of modern swath mapping techniques, and part is due to the fact that mapping could be done closer to shore than in previous surveys.

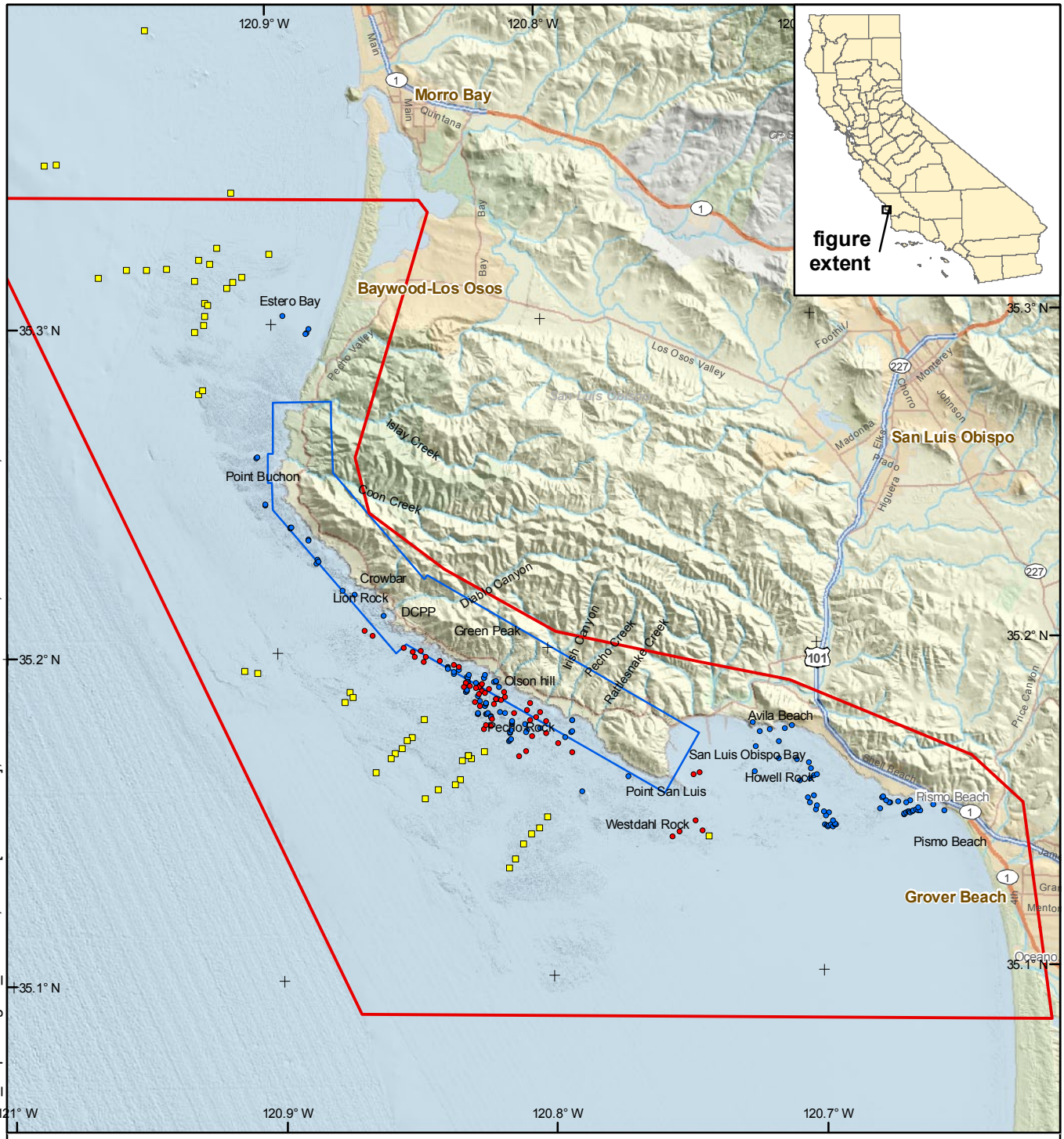
These data are used, in conjunction with high-resolution seismic reflection profile data discussed in Section 2.7, to (1) compile a geologic map of the area offshore of DCPP and map the surface expression of the Shoreline, Hosgri, and other faults in the area (see Plate 1 and Appendix B), and (2) map the depth and distribution of paleowave-cut platforms and strandlines (Appendix I).

2.6 LiDAR Survey

As noted in the Introduction (Section 1.2.1), the difficulties of surveying in shallow water have limited the ability to image the seafloor. Therefore, to provide seamless coverage of bathymetry and topography in the intertidal zone, PG&E contracted TetraTech to conduct a LiDAR survey from fixed-wing aircraft during one of the lowest tides of the year (–1.5 feet relative to mean lower low water [MLLW] at 3:02 p.m. on 28 January 2010). Figure 2-1 shows the area of the LiDAR survey. This data set is described in more detail in Appendix G.

2.7 High-Resolution Seismic Reflection Profiling

High-resolution single-channel seismic reflection data were acquired by the USGS in 2008 and 2009 between Piedras Blancas and Pismo Beach, along shore-perpendicular transects spaced 800 meters (m) apart extending from close to shore to beyond the 3-mile limit of California State waters. These data were collected, along with the marine magnetic data described in Section 2.3, as part of the PG&E–USGS CRADA, the California State Waters Mapping Program, the USGS Coastal and Marine Geology Program, and the USGS Earth Surface Processes Program and have been published as USGS Open File Report 2009-1100 (Sliter et al., 2009). Appendix H contains further details. High-resolution seismic reflection profiling provides greater definition of the top few hundred meters beneath the seafloor and is valuable for the identification of recent fault offsets (Appendix B) and for interpretation of paleowave-cut platforms and strandlines (Appendix I).



LEGEND

- Study area
- LIDAR survey extent (This study, Appendix G)
- Diver Samples (This Study, Appendix B: Table B-4 and Attachment 1)
- Diver Samples (PG&E, 1988; Appendix B: Table B-3)
- Dropcore Samples (PG&E, 1988; Appendix B: Table B-2)

N W E S

0 1 2 Miles
0 2 4 Kilometers

Map projection and scale: NAD 1983, UTM Zone 10N, 1:200,000

Offshore samples obtained during the LTSP and in 2010 for this study overlain with the extent of 2010 LiDAR survey

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Figure **2-1**

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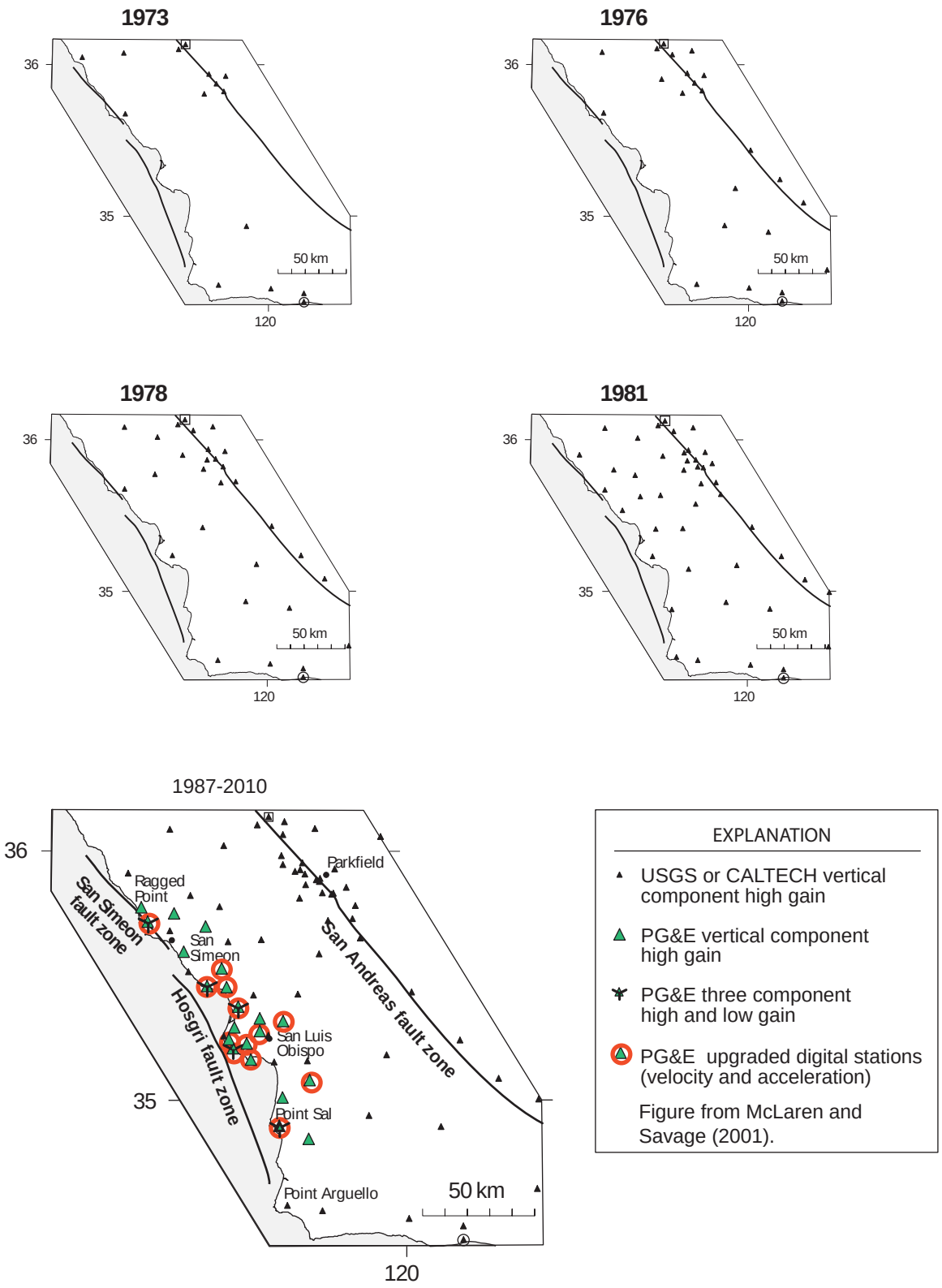

Maps of seismographic station coverage of the California Central Coast region for selected years

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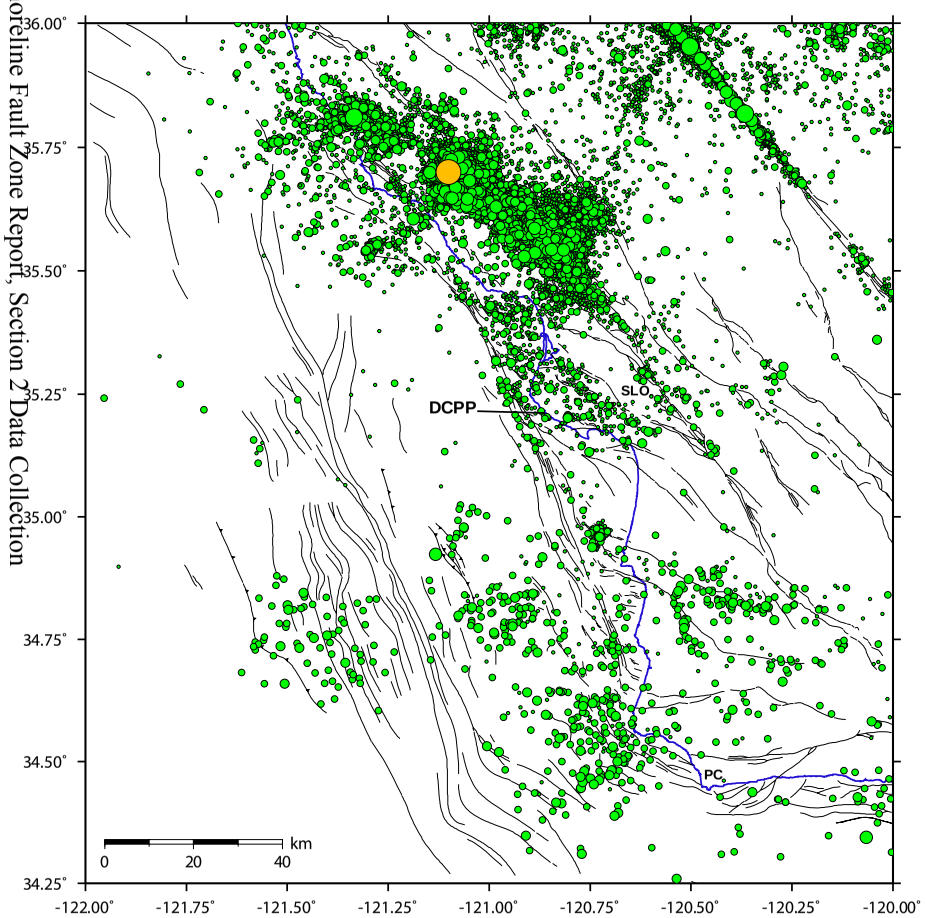
a)

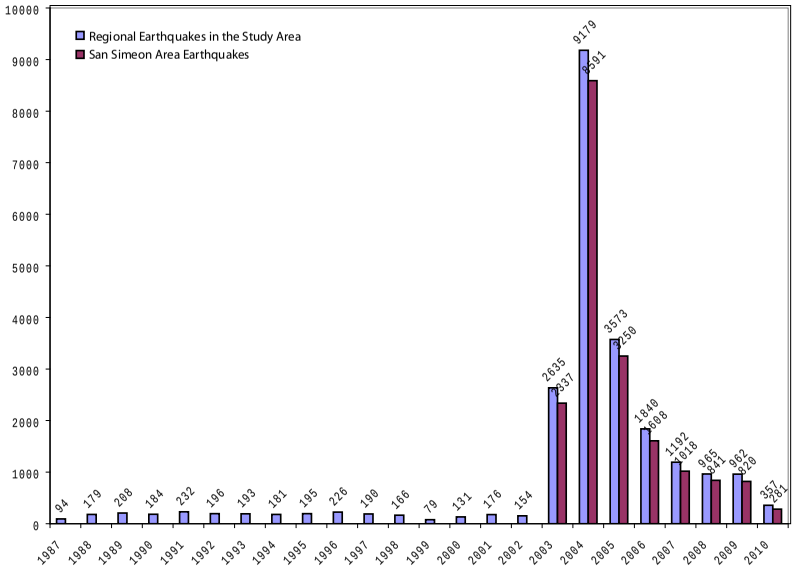


Earthquake Magnitudes
(NCEDC, 2010)

- < 2.0
- 2.0 - 2.99
- 3.0 - 3.99
- 4.0 - 4.99
- 5.0 - 5.99
- M6.5 San Simeon Earthquake

SLO = San Luis Obispo
PC = Point Conception

b)



Seismicity recorded by PG&E and the USGS 1987 through August 2010

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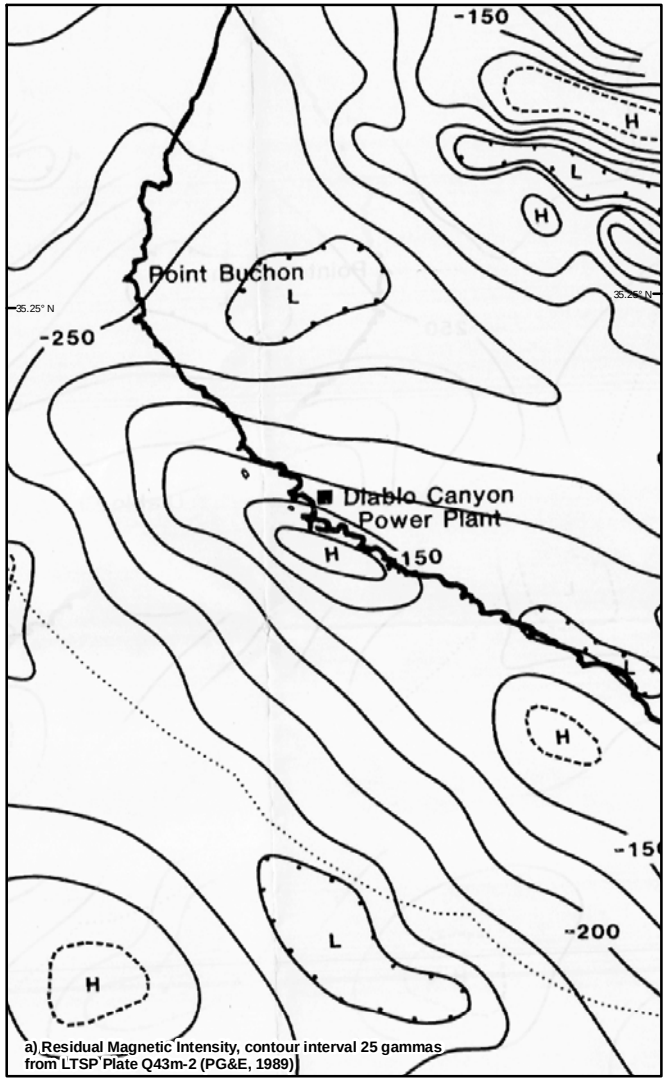
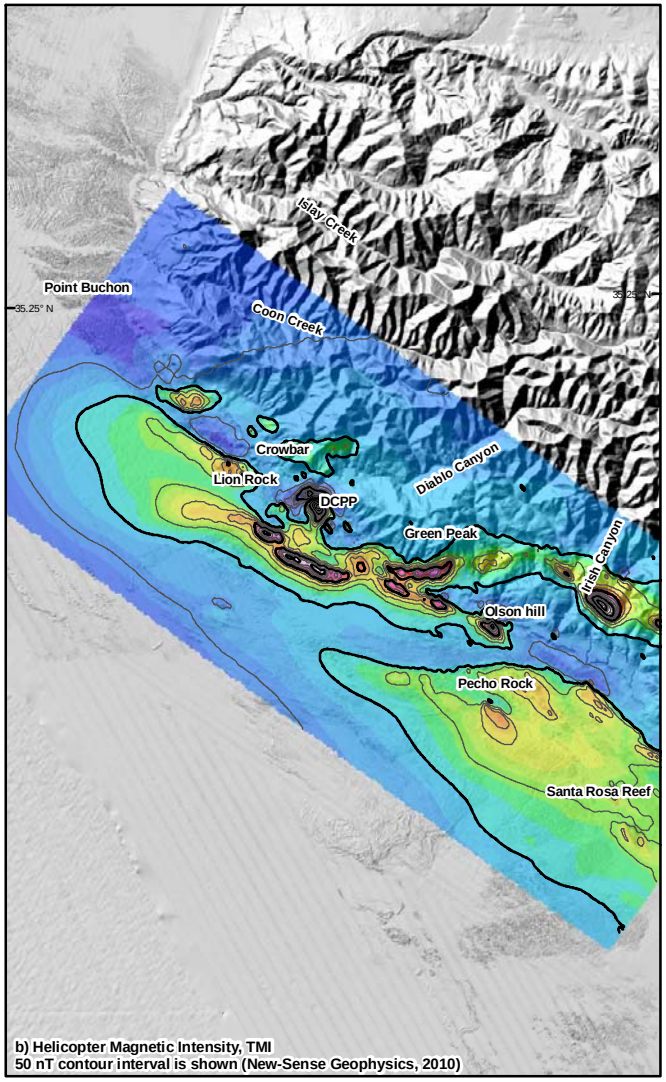
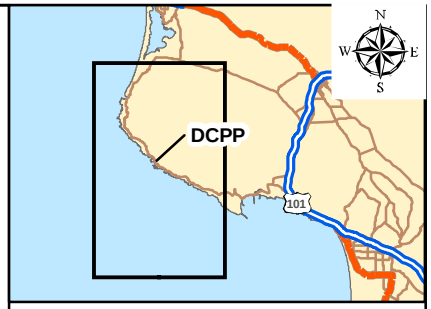
Figure **2-3**



a) Residual Magnetic Intensity, contour interval 25 gammas from LTSP Plate Q43m-2 (PG&E, 1989)



b) Helicopter Magnetic Intensity, TMI
50 nT contour interval is shown (New-Sense Geophysics, 2010)



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Helicopter Magnetics
(TMI, in nT)

- > 48,160
- 48,100
- 48,000
- 47,900
- 47,800
- 47,700
- < 47660

Map scale: 1:100,000
Map projection: NAD 1983, UTM Zone 10 North

0 1 2 Miles
0 2 4 Kilometers

Comparison of 1989 LTSP Residual Magnetic Intensity with 2009 Helicopter Total Magnetic Intensity anomaly map

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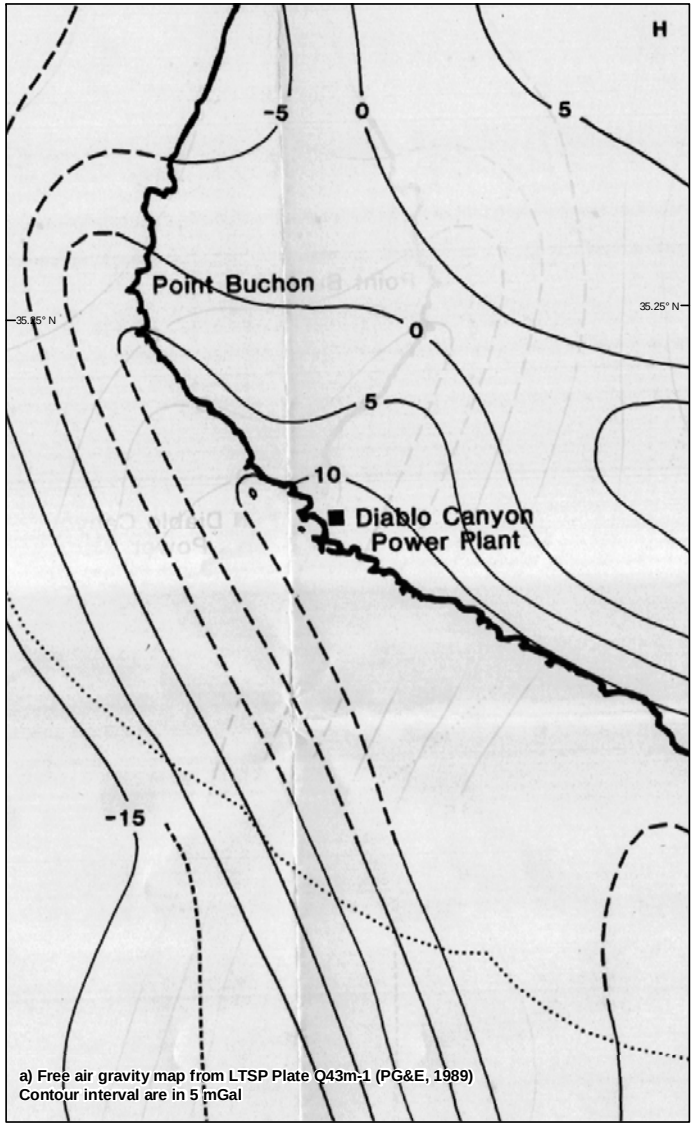
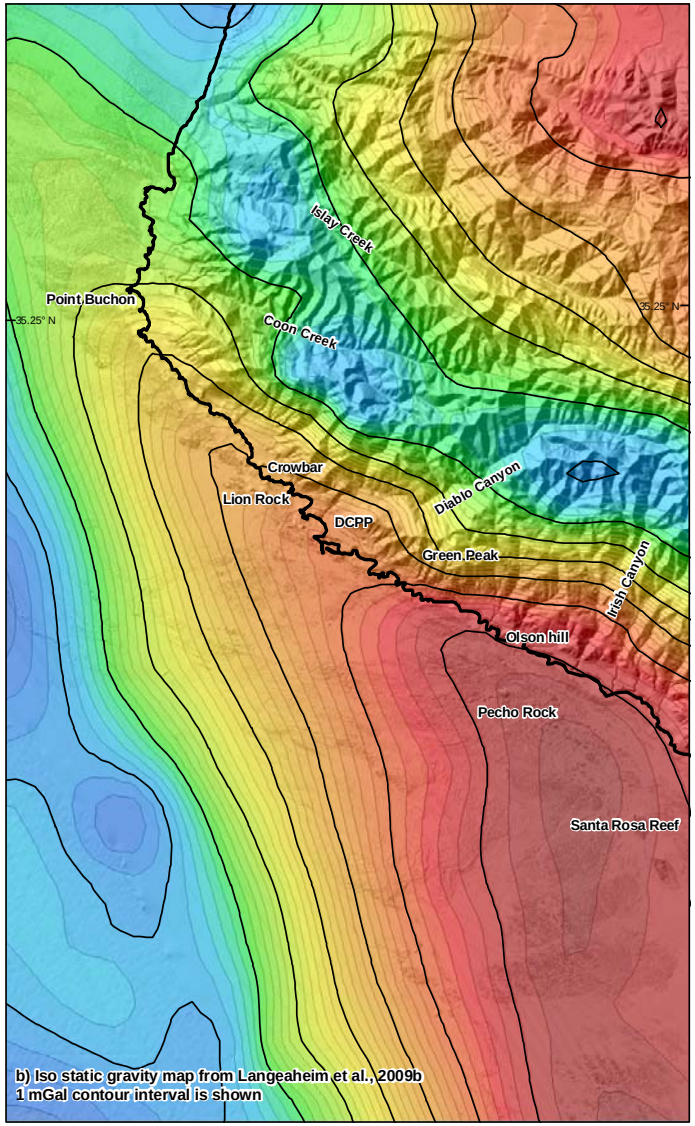
Figure **2-4**

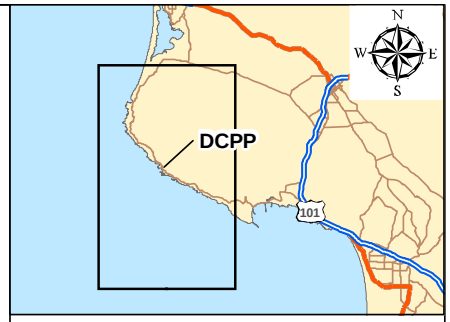
File path: S:\13800\13838\13838.002\Figures\20101112_Report\Appendix_D\Figure_D-1.mxd; Date: [12/21/2010]; User: Serkan Bozkurt, AMEC Geomatrix, Inc.



a) Free air gravity map from LTSP Plate Q43m-1 (PG&E, 1989)
Contour interval are in 5 mGal



b) Iso static gravity map from Langeaheim et al., 2009b
1 mGal contour interval is shown



LEGEND

Isostatic Gravity (mGal)

Map scale: 1:100,000
Map projection: NAD 1983, UTM Zone 10 North

0 1 2 Miles
0 2 4 Kilometers

Comparison of 1989 LTSP gravity anomaly map with the 2009 USGS garvity anomaly map

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Figure **2-5**

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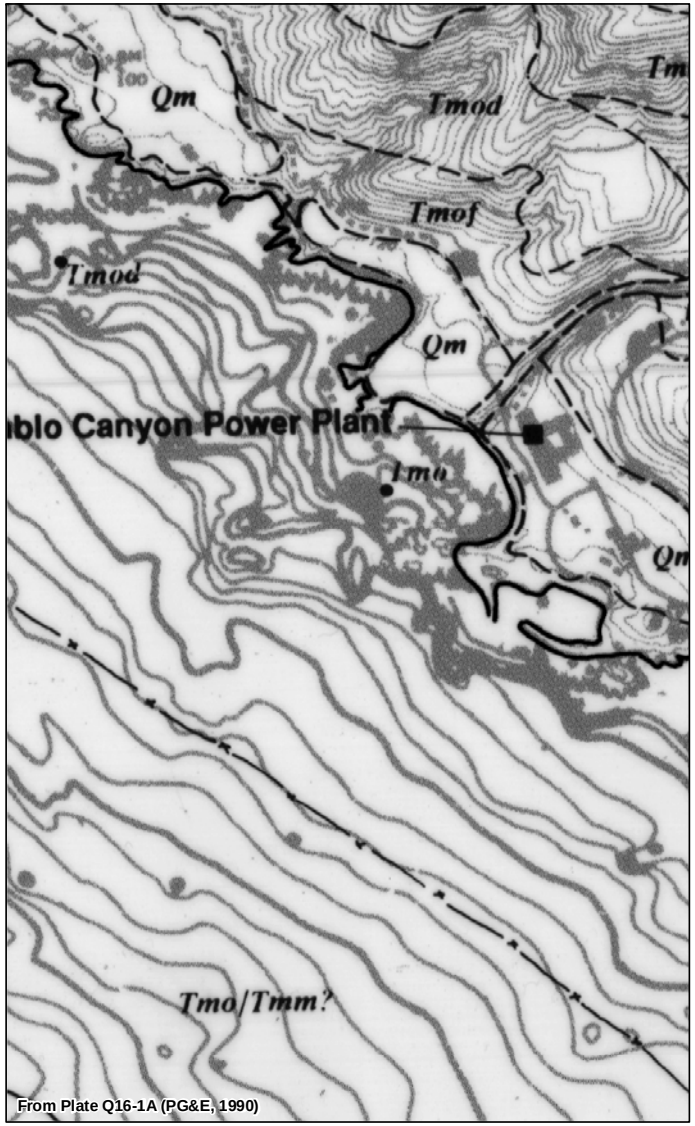

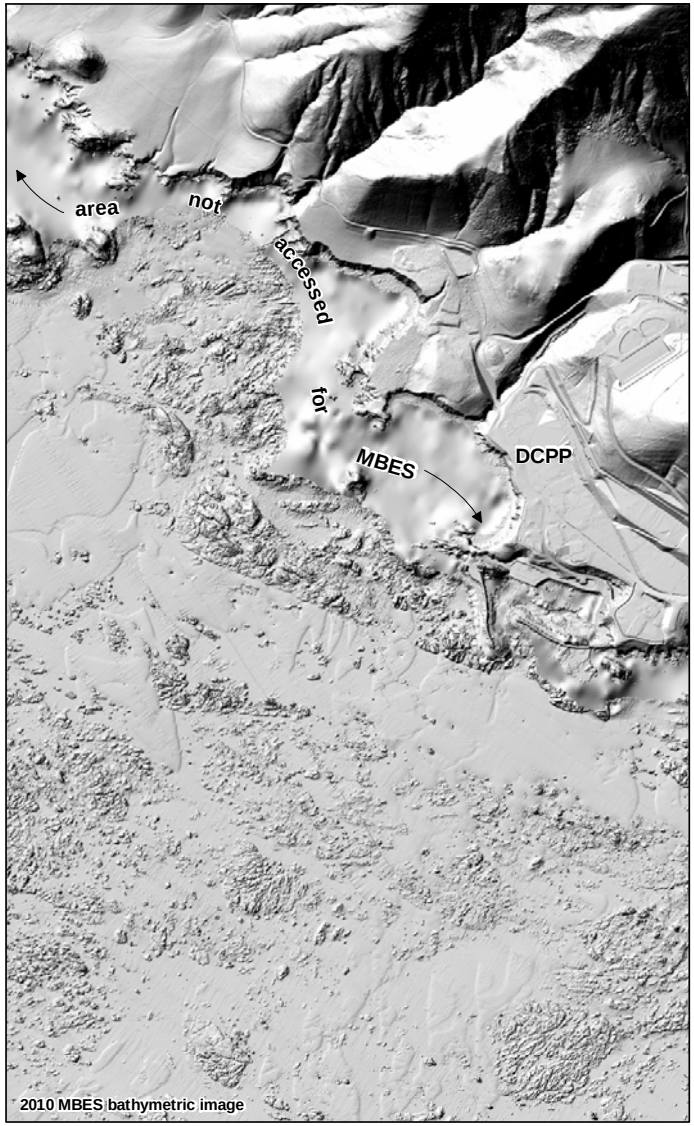

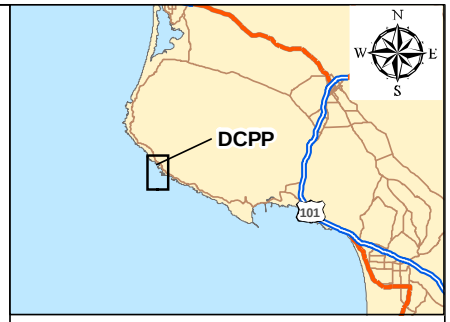

Map scale: 1:15,000
Map projection: NAD 1983, UTM Zone 10 North

0 0.1 0.2 0.3 0.4 0.5 Miles
0 0.2 0.4 0.6 0.8 Kilometers

Comparison of 1990 LTSP bathymetry with the 2009 MBES bathymetry - offshore DCPP area

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Figure **2-6**

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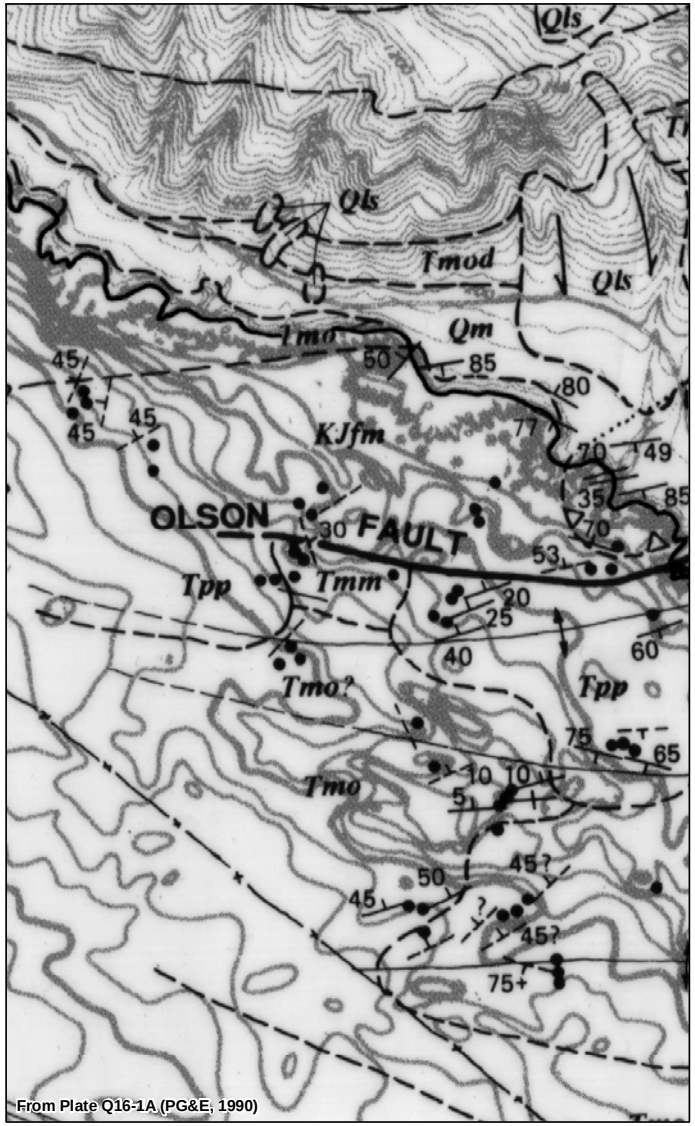

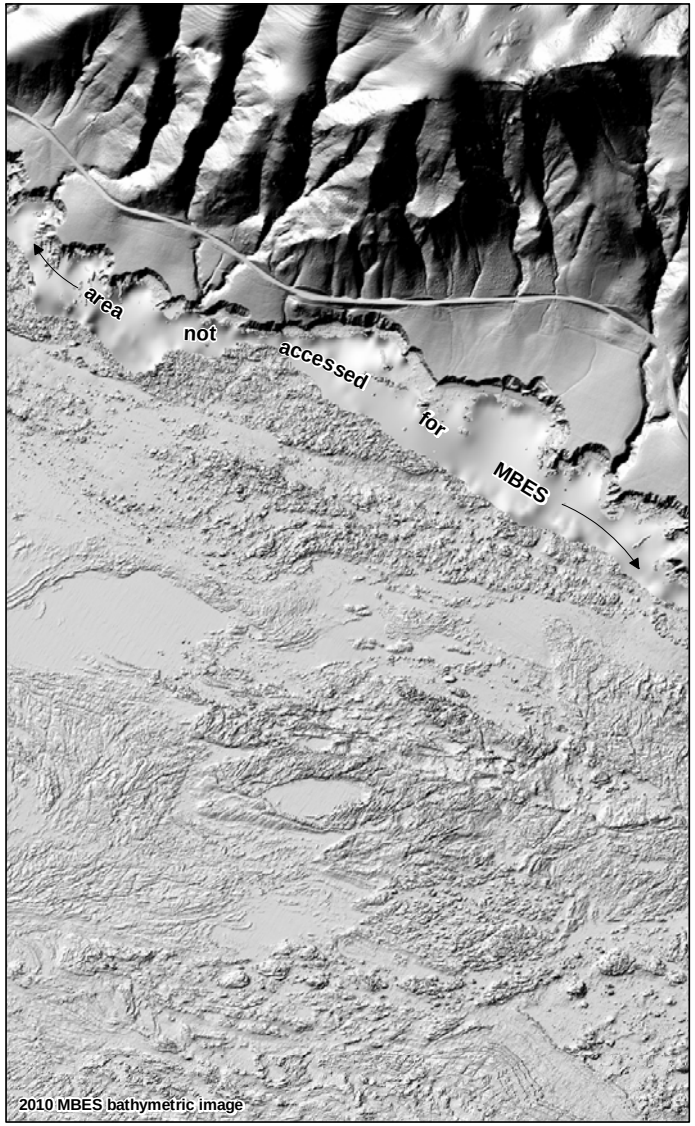

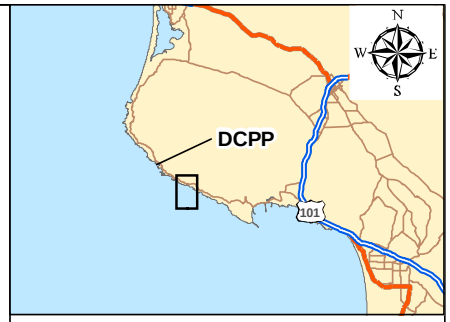

Map scale: 1:15,000
Map projection: NAD 1983, UTM Zone 10 North

0 0.1 0.2 0.3 0.4 0.5 Miles
0 0.2 0.4 0.6 0.8 Kilometers

Comparison of 1989 LTSP bathymetry with the 2009 MBES bathymetry - offshore Olson Hill area

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Figure **2-7**

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