DOUGLAS H. HAMILTON
CONSULTING GEOLOGIST

2 BASSETT LANE, ATHERTON, CALIFORNIA 94027
Tel: 650 321 3071 • Fax: 650 328 8712 • email: geoconsult@dhhamilton.com

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California Energy Commission
1516 9th Street
Sacramento, CA 75814
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Tel. 916-654-5076

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To members of the CEC:

Enclosed is a document containing comments regarding topics addressed during the CEC IEPR Seismic Safety Workshop held on July 26, 2011. Comments include discussion and illustrations relating to seismic safety issues for the PG&E Diablo Canyon Nuclear Power Plant.

Douglas H. Hamilton, PhD, CEG
Consulting Geologist

Comments for CEC IEPR Seismic Safety Workshop, July 26, 2011

Douglas H. Hamilton, Ph D., CEG Consulting Geologist

geoconsult@dhhamilton.com

1. General and Background Comment

In May 2010 in compliance with an arrangement set into place by the CEC staff, we made a presentation to CEC staff and seismic advisors (representatives from State Seismic Safety Commission, California Geological Survey, California Coastal Commission, et. al.) based on our report "Seismic and Fault Hazard in the Area of the Diablo Canyon Nuclear Power Plant, San Luis Obispo County, California".

Complete copies of this report were made by CEC staff and provided to all presentation attendees. The report detailed the principal seismic and fault hazard conditions affecting the seismic safety of the DCNPP, all of which had been documented in various publications and reports by Federal and State Agencies as well as submittals by PG&E to the AEC/NRC since the power plant was sited in 1965. But despite this history of documentation two of the four principal hazards to the seismic safety (i.e. the San Luis Range thrust, located at shallow depth directly beneath the plant site and the Diablo Cove fault, cutting the Unit 1 foundation bedrock) have not even been acknowledged to exist in current representations by both PG&E and the USGS and CGS. The seismic hazard from a third source, the Shoreline fault recently identified by Dr. Hardebeck of the USGS but recognizable in evidence presented by PG&E in its 1988 Long Term Seismic Program Final Report, appears to be significantly understated by PG&E's current evaluation of the seismic capability of this fault as a M6.5 or smaller earthquake. Both the overall length of this active strike slip fault, at least 32 km., and its structural relationship to the Hosgri fault, indicate an earthquake capability of $M \geq 7.0$.

Additionally none of the several potential maximum earthquake magnitudes for the Hosgri fault (M6.5, 7.2, 7.5) cited in various reports by PG&E reach the >M7.5 potential of what in 1980 was documented by R. Leslie (USGS OFR 81-430) as a continuous San Simeon-Hosgri fault (an interpretation disputed by PG&E in its 1988 LTSP Final Report, but confirmed in the work

reported for this CEC Workshop by USGS research marine geologist Sam Johnson) hence with a total length at least 50% greater than indicated in PG&E's 1988 LTSP and 2011 Shoreline fault Final Reports.

My report and presentation were dismissed without further discussion or review by the CEC (CEC letter dated August 19, 2010 signed by Melissa Jones). However my interpretations and the published data upon which they were based were subsequently published in the abstract for a poster session presentation at the 2010 American Geophysical Union Fall Meeting, and copies of the poster display have been provided to individuals within the NRC (Dr. Annie Kammerer) the USGS (Dr. Jeanne Hardebeck) and PG&E (Senior Seismologist Marcia McLaren) all of whom expressed interest in the poster display.

But despite the evidence I present that suggests that the DCNPP has been operated with inadequate seismic margins since the day Unit 1 went online in 1985, there appears to have been no consideration or even acknowledgement of this issue by either its owner PG&E or any agency concerned either with research and seismic hazards oversight (USGS, CGS, Coastal Commission, State Seismic Safety Commission) or regulation (NRC).

This condition of either non-recognition, or possibly of willful denial of the actual seismic hazards to the DCNPP, apparently continues at present. Thus the "Fukushma syndrome" of underestimating readily recognizable seismic hazards appears to be alive and thriving here in California.

2. Specific technical comments

Specific comments follow regarding the earthquake and fault hazard to the Diablo Canyon Nuclear Power Plant (DCNPP) located in San Luis Obispo County, California. These comments are based on published information originating with the USGS, the California Geological Survey (CGS), the Northern California Earthquake Data Center (NCEDC) and the NRC, together with submissions to the NRC and other public representations by DCNPP owner/operator Pacific Gas and Electric Company (PG&E).

1. San Simeon – Hosgri fault

PG&E's evaluation of the earthquake capability of the Hosgri offshore fault has evolved over time from M6.5 (1973-75 FSAR), M7.2 (LTSP, 1988), and back down to M6.5 (PG&E 2011) although the company was compelled to accept the USGS evaluation of M7.5 in 1976 in order to proceed with obtaining an operating license. Their 1988 LTSP evaluation was based on a Hosgri maximum length of 110 km, separated on the north from the nearby San Simeon fault by a structural feature they referred to as the "Cambria stepover". But a detailed marine geophysical study of the area of this claimed "stepover" conducted in 1980 by R. Leslie and released by the sponsoring USGS as Open File Report 81-430 demonstrated that the San Simeon and Hosgri faults were separately named reaches of a single continuous fault more than 150 km long. This confirmed that the overall San Simeon-Hosgri fault should be considered capable of generating an earthquake at least as large as M7.5 and potentially somewhat larger. The M6.5-M7.2 evaluations by PG&E were therefore clearly inadequate and the 1976 M7.5 evaluation by the USGS may itself have been unconservative.

The recent marine geophysical study reported for this workshop by USGS marine geologist Sam Johnson has provided additional confirmation of Leslie's 1981 finding that there is no structural interruption of the continuity of the San Simeon and Hosgri faults.

2. Shoreline fault

PG&E's evaluation of the length of the recently USGS – identified Shoreline fault and of its (purported) lack of a structural relationship to the Hosgri fault apparently provided the basis for their representation to the NRC that the Shoreline fault's earthquake generation capability is M6.5 or less.

This evaluation by PG&E is wrong on both the structural relationship and the length issues, hence is dangerously inadequate for the earthquake magnitude and hazard issues.

Hardebeck et.al (2011) have published seismological evidence confirming the writer's (2010) interpretation that the Shoreline fault extends to and is structurally linked with the Hosgri fault at its north end. Hardebeck also notes that seismological evidence does not support PG&E's model of a segmented Shoreline fault.

On the south the Shoreline fault appears to continue beyond the point claimed in PG&E (2011) as its south end, based on seismic reflection geophysical mapping submitted to the NRC by PG&E in 1975 (FSAR), 1978 (ASLB testimony) and 1988 (LTSP Final Report). The length between the Hosgri fault intersection on the north and the limit of geophysical data on the south is approximately 32 km but on the south the available data does not constrain a possible continuation of this fault into the Santa Maria Valley onshore.

3. San Luis Range thrust

In 1988 several geologists associated with teams working on PG&E's NRC operating license-mandated Long Term Seismic Program, including both the writer as direct consultant to PG&E and Steven Nitchman of the University of Nevada Reno (UNR) recognized that the then available geomorphic evidence of progressive late Quaternary uplift of the Irish Hills and geologic evidence of reverse faulting along the southwest margin of the San Luis Range southeastward continuation of the Irish Hills, additionally required a continuation of the reverse or thrust faulting observed onshore southeast of San Luis Obispo Bay along the southwest shoreline margin of the Irish Hills. This fault interpretation was reported to PG&E by the writer in late 1987 or early 1988, and was described by Nitchman in his UNR MS thesis entitled "Tectonic Geomorphology and Neotectonics of the San Luis Range, San Luis Obispo County, California" submitted in May 1988. PG&E's response to this input was to discontinue the writer's LTSP involvement, and reference Nitchman's thesis but otherwise dismiss it in their July 1988 LTSP Final Report. Subsequently PG&E presented arguments responding to requests for additional discussion of this issue by the NRC defending their position that there was no fault along the linear southwest shoreline of the Irish Hills, and those arguments were quoted by the NRC in its 1991 SER for the DCNPP. The issue of the necessity for balanced northeast and

southwest late Quaternary uplift of the San Luis Range was addressed by PG&E's introduction of a concept of a "Southwest Boundary Zone" that could involve reverse mechanism earthquakes as large as M7.0 along the range front southeast of San Luis Obispo Bay, but that somehow died out (or at least had no seismic capability) to the northwest, even though the uplift of the San Luis Range-Irish Hills clearly did not die out but instead extended for several km into southeast Estero Bay. But despite its tectonic improbability and its contradiction in Nitchman's UNR thesis, PG&E's interpretation, as noted above, was nonetheless accepted by the NRC. Nitchman's interpretation, however, was subsequently published in the peer-reviewed 1994 GSA Special Paper 292 (Nitchman and Slemmons, 1994) which included a small scale map showing an "Inferred Offshore Fault" ("IOF") as a reverse fault parallel to the Irish Hills shoreline, where such a fault was a tectonic necessity to explain the uplift of the Irish Hills.

PG&E's Southwest Boundary Zone later became the basis for the "San Luis Range fault" with M7.0 earthquake capability, shown in the 1998 CDMG publication "Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada" (Peterson et. al., 1998) However the CDMG map followed PG&E's interpretation that no earthquake need be considered for its "Southwest Boundary Zone" northwest of its San Luis Bay fault crossing the coastal terrace bench 6 km southeast of the DCNPP.

Following the superseding of the CDMG 1998 map in 2007, the next mention of PG&E's Southwest Boundary Zone as such was in its Shoreline Fault Final Report released in January 2011, where the 1988 LTSP earthquake parameters for the zone were reiterated, without mention of a San Luis Range fault earthquake source as specified by the CDMG in 1998.

But in the meantime, in March 2008 a hypocenter profile plot of NCEDC catalogue earthquakes beneath the Irish Hills and adjacent offshore and onshore regions prepared for the writer showed rather clear seismologic evidence for a vertical fault along the Irish Hills shoreline, and for a northeast dipping thrust fault underlying the San Luis Range. This evidence appeared to support Nitchman's (1988) concept of an "IOF" and also to show that the uplift of the range was structurally and tectonically separated from any northwesterly offshore continuation of PG&E's onshore "Southwest Boundary Zone" to the southeast. At that time the vertical near shore

seismicity source was yet to be recognized by the USGS (Hardebeck), and no mention of the northeast dipping pattern of earthquake hypocenters had been made either by PG&E or the USGS. Nor was any suggestion made either in 2008 or subsequently that the pattern of earthquake hypocenters beneath the Irish Hills resembled both the aftershock pattern in the vicinity of the 2003 M6.5 San Simeon earthquake beneath the Santa Lucia Range 40 km to the north, or of the 1971 San Fernando and 1994 Northridge earthquakes in southern California. However the writer provided documentation of this resemblance in his unpublished 2009/2010 report "Seismic and Fault Hazard in the Area of the Diablo Canyon Nuclear Power Plant ---" and of the thrust fault tectonics in his 2010 AGU poster abstract "Dual-system Tectonics of the San Luis Range and Vicinity, Coastal Central California". This information appears to demonstrates that the Irish Hills and San Luis Range continuing to the southeast, have the same "popup wedge" structural form as the Santa Lucia Range where the 2003 "San Simeon" earthquake occurred.

The San Luis Range thrust as thus defined, underlies the DCNPP at a depth as shallow as one km, is clearly seismically active, and has dimensions that suggest a deterministic earthquake generation capability in the range of M6.75≥M7.0. As such, this thrust fault appears to have the potential to provide the controlling vibratory ground motion at the DCNPP site.

4. Diablo Cove fault

The Diablo cove fault was first recognized in its natural outcrop in the Obispo Formation exposed in the south headland of the canyon of lower Diablo Creek by PG&E consultant Prof. R.H. Jahns, during his feasibility stage geologic mapping of the (then) proposed DCNPP site in 1966. Trench-wall exposures of faulting in the site Obispo Formation bedrock beneath apparently unfaulted marine and overlying non marine terrace deposits in the Unit 1 area of the (by then) planned DCNPP were then mapped by Jahns in 1967. Finally the faulting along the Diablo Cove trend exposed in the Unit 1 foundation excavation bedrock was mapped by Jahns in 1969. His mapping (along with the mapping of the Unit 2 foundation excavation geology by the writer in 1971) was made part of PG&E's FSAR and ASLB Testimony documentation in 1973 and 1978. This mapping documentation was not shown nor acknowledged in any post-1978

PG&E submittal. In 2010, however recently acquired CSMB Seafloor Mapping Laboratory Multibeam imaging of outcrops on the sea floor offshore from Diablo Cove included with its January 5 presentation to the NRC showed a distinct disturbance of the rock structure along the projected seaward trend of the onshore Diablo Cove fault across the 600 m. wide near-shore gap in the Multibeam imagery. This disturbance clearly affected the outcrop pattern of the Shoreline fault, which crosses the Diablo Cove fault trend at a high angle.

This and other considerations described and discussed in Appendix C of the writer's report presented to the CEC staff in May 2010, provides the basis for regarding the Diablo Cove fault as probably "capable" according to current NRC criteria. This suggests that potential for future renewed surface movement along the Diablo Cove fault, in the Unit 1 foundation beneath the turbine-generator power block, the Unit 1 containment, and probably, the Unit 1 spent fuel pool, should be considered as part of any reevaluation of seismic margins of the DCNPP.

5. Vibratory ground motions at the DCNPP site based on realistic source fault characterizations

The three likely controlling seismic source structures for generation of earthquakes potentially yielding maximum vibratory ground motions at the DCNPP site are, in order of decreasing threat to the seismic margins of the facility, 1.) A M6.75>7.0 reverse mechanism earthquake occurring on the San Luis Range thrust c.1.0 km beneath the DCNPP, 2.) a maximum near-field 6.75≥7.0 strike slip earthquake on the overall Shoreline fault, occurring within c. 0.5 km of the DCNPP (not including a M>7.0 earthquake on this fault acting as a splay carrying in fault rupture from the San Simeon-Hosgri fault), and 3.) a M≥7.5 strike slip earthquake originating along the San Simeon-Hosgri fault, occurring within 4.5 km of the DCNPP.

The attached plot shows response spectra from a range of earthquakes originating from these three potential sources, calculated using standard NGA attenuation relationships, compared with response spectra from the four earthquake sources identified in PG&E's Shoreline Fault Final Report and in other PG&E submissions to the NRC. Note that the only source on the PG&E plot that is part of their "Southwest Boundary Zone" is the San Luis Bay fault which is not

recognized as being closer than 8 km to the DCNPP. This fault, however, appears to be only a fairly minor hanging-wall splay of the underlying San Luis Range thrust, which continues beneath the DCNPP site and is exposed in Estero Bay as PG&E's "N40W" fault.

The maximum pga among the PG&E response spectra is 1.53 g, "ergodic" for a M6.5 earthquake on the San Luis Bay fault or 1.4g "single sigma" for a M6.5 earthquake on the Los Osos fault. Pga values for M6.5 earthquakes on the Shoreline fault are slightly lower. Contrasting with this, the maximum spectral pga for a M7.0 earthquake on the San Luis Range fault directly beneath the DCNPP, is 2.35g. This site pga value may well exceed the vibratory ground motion for which seismic margins of critical facilities in the DCNPP have been designed or analysed.

6. Soil Structure Interaction (SSI)

The results reported in PG&E's 1988 LTSP Final Report may not accurately predict the effects of SSI because of at least two considerations

1.) The input of vibratory ground motion may be unrealistically low, as suggested in comment (5) above, and

2.) The DCNPP foundation configuration represented in the LTSP SSI illustrations is clearly oversimplified and likely is unconservative for a realistic SSI analysis. In particular there is much more, and deeper, open space beneath the Turbine-Generator and Auxiliary buildings in their actual foundations than is shown on PG&E's SSI model drawings, as is illustrated on the attached map and cross sections.

7. Raw water storage reservoirs, seich hazard

As part of PG&E's presentation for this CEC Workshop, they show slides entitled "Spent Fuel Pool Supplemental Water Sources" and "DCPP Design Overview". Each of these slides presents information concerning the DCNPP emergency cooling systems, and each identifies the two 2.5

million gallon raw water storage reservoirs at the site as supplemental or backup sources of emergency cooling water. Regarding this we note that the two reservoirs are broad, relatively shallow basins located on the planed off top of a topographic knob near the base of the ridge behind the DCNPP (shown on Image 4 of the presentation by Barbara Byron). The effect of earthquake-induced seiches that were widespread in the San Francisco Bay area as effects of the 1989 M6.9 Loma Prieta earthquake was that swimming pools and other open-water basins lost much of their water as it sloshed out of the basin. This occurred not only in close proximity to the earthquake epicenter in the Santa Cruz Mountains west of San Jose, but at points at least as far distant as Walnut Creek, nearly 100 km from the epicenter. The likely occurrence of similar seich-induced loss of water from the two open raw water storage basins identified as sources of 5 million gallons of cooling water by PG&E would appear to cast some doubt on the validity of this aspect of its emergency planning.

Note also that Byron's Image 4 aerial photo of the DCNPP included with her 2011 CEC IERP Nuclear Workshop presentation clearly shows the proximity of the Dry Cask Spent Fuel storage pad to the two raw water reservoir basins. The close proximity of the two facilities suggests that a seich surge from the basins, in addition to reducing the amount of stored water available for emergency cooling in the plant, could temporarily but violently flood the spent fuel Dry Cask pad. We are not aware of whether this has been considered in connection with a hazards evaluation of this facility. We would also note that the oblique aerial photo referenced above appears to show the Dry Cask pad being located more or less directly under the power line from Unit 1 to the substation in Diablo Canyon, seemingly another potentially hazardous situation.

3. List of Illustrations to Accompany Comments for CEC IEPR Seismic Safety Workshop July 26, 2011

Comment 2-1

2-1-(1.) Digital terrain image of south central coastal California showing late Quaternary faults and areas of down-dip thrust fault ramps and zones of complex compressional faulting.

2-1-(2.) Earthquake epicenters for the period 1934-2002 on digital terrain base, south central coastal California

2-1-(3.) Earthquake focal mechanisms for events during the period October 1987 through January 1997, also estimated epicenters of M>5.0 historic earthquakes, south central coastal California.

Comments 2-2, 2-3

2-3-(1.) Map showing the onshore and offshore terrain and fault traces, Estero Bay – Irish Hills/Los Osos Valley, and San Luis Obispo Bay region.

2-3-(2.) Geologic cross section through the Irish Hills and adjacent Los Osos Valley and offshore area.

2-3-(3.) Cross section showing earthquake hypocenters and faults, Irish Hills/Los Osos Valley and adjacent offshore area.

2-3-(4.) Diagrammatic cross section showing tectonics of uplift and scarp formation Irish Hills and adjacent offshore area.

2-3-(5.) Maps by CDMG (1998) and Nitchman and Slemmons (1994) showing (a) probabilistic extent of strong ground motion from the San Luis Range, Los Osos, and Hosgri faults (CDMG 1998), and the principal structural features in and adjacent to the northwest San Luis Range (Nitchman and Slemmons, 1994)

Comment 2-4

2-4-(1.) Geologic Map, Onshore and Offshore, of Diablo Cove Fault Area

2-4-(2.) Photograph showing fault features in walls of DCNPP Unit 1 Power Block (Turbine-Generator Building) and Containment Foundation Excavation

2-4-(3.) Aerial photo showing trace of Diablo Cove fault zone relative to DCNPP.

Comment 2-5

2-5-(1.) Comparison of PG&E Response Spectra Family (LTSP Hosgri; Minimum Length Ranges of Segmented Shoreline Fault) vs Response Spectra Family Including LTSP Hosgri, and Ranges of Potential Earthquake Magnitudes for the Hosgri, Shoreline, and San Luis Range Faults, All Plotted Using NGA Attenuation Relationships.

Comment 2-6

2-6-(1.) Foundation configuration of power block structures (LTSP, 1988), as annotated to show major terrain and foundation excavation features.

2-6-(2.) DCNPP foundation profile A-A' from LTSP, 1988, annotated to show actual foundation excavation profile based on 1973 FSAR, and 1978 ASLB Testimony.

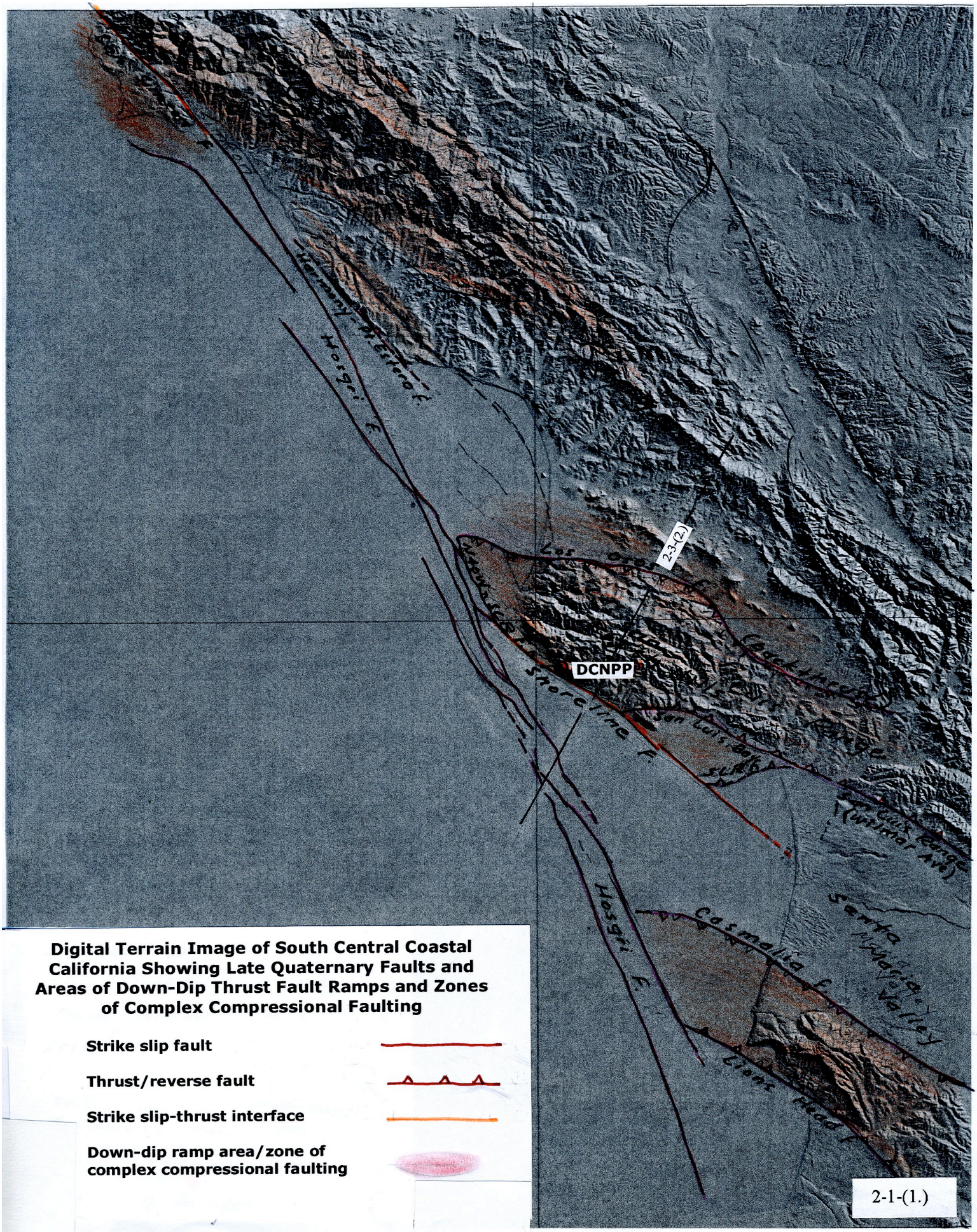
2-6-(3.) DCNPP foundation profile B-B' along major axis of Turbine-Generator Building, based on 1973 FSAR and 1978 ASLB Testimony.

2-6-(4.) Map showing geology and pregrading (1966) terrain at DCNPP site.

2-6-(5.) Geologic Map of Units 1 and 2 Construction Excavations from 1973 FSAR and 1978 ASLB Testimony.

Comment 2-7

2-7-(1.) Oblique aerial photo of DCNPP complex showing raw water storage reservoirs and adjacent Dry Cask storage pad (Image 4 in CEC IEPR presentation by Barbara Byron).



Digital Terrain Image of South Central Coastal California Showing Late Quaternary Faults and Areas of Down-Dip Thrust Fault Ramps and Zones of Complex Compressional Faulting

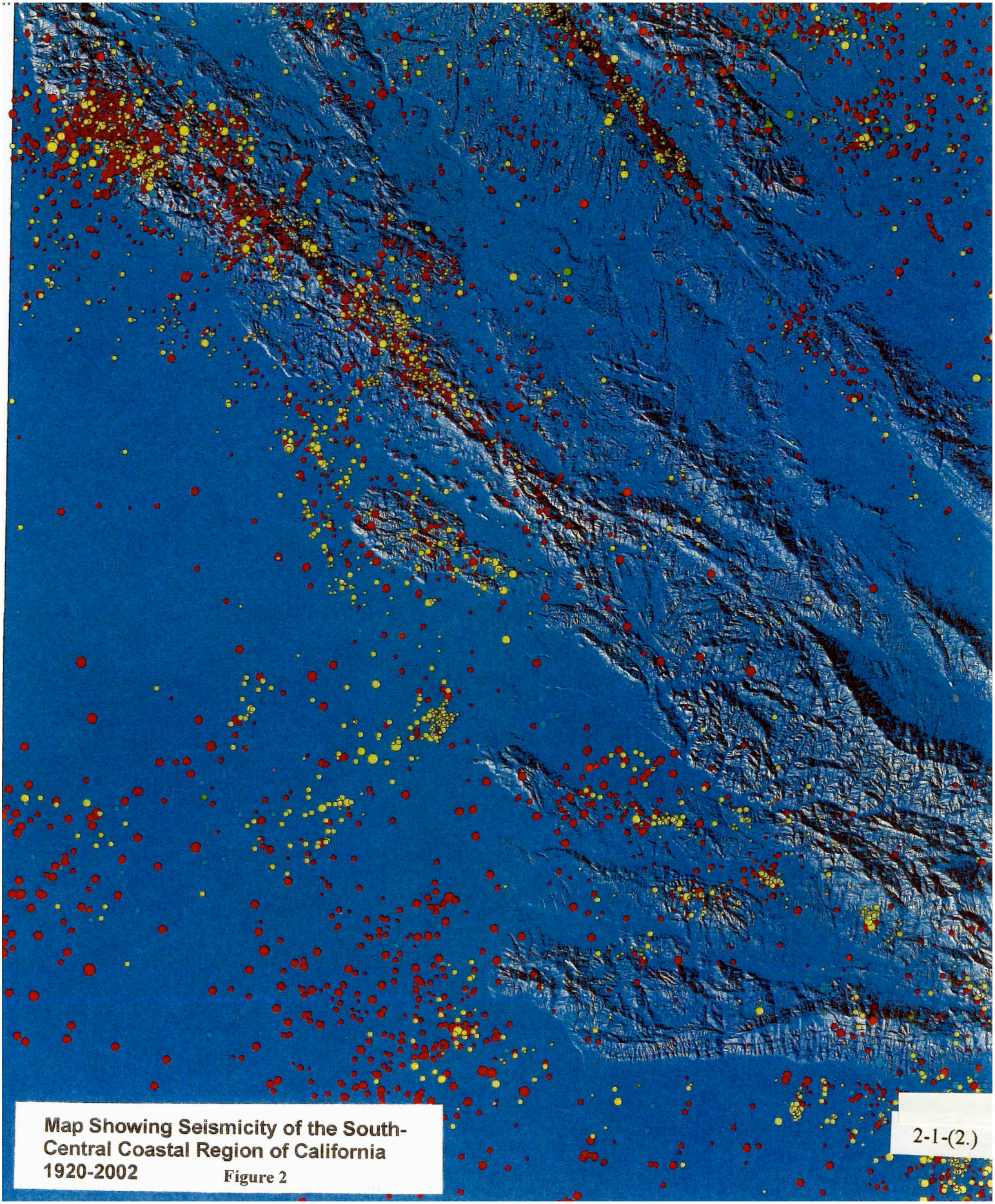
Strike slip fault

Thrust/reverse fault

Strike slip-thrust interface

Down-dip ramp area/zone of complex compressional faulting

2-1-(1.)



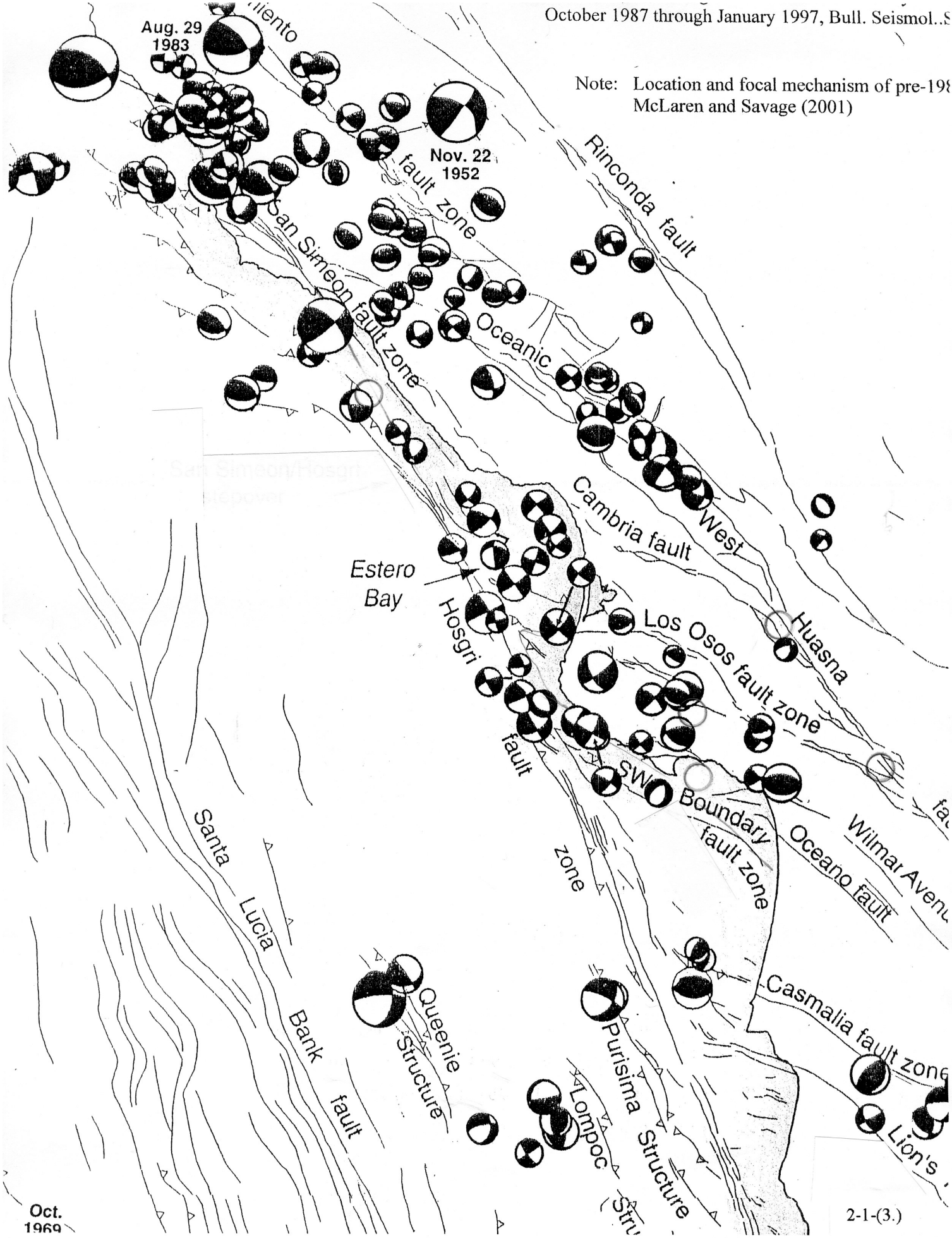
Map Showing Seismicity of the South-Central Coastal Region of California 1920-2002

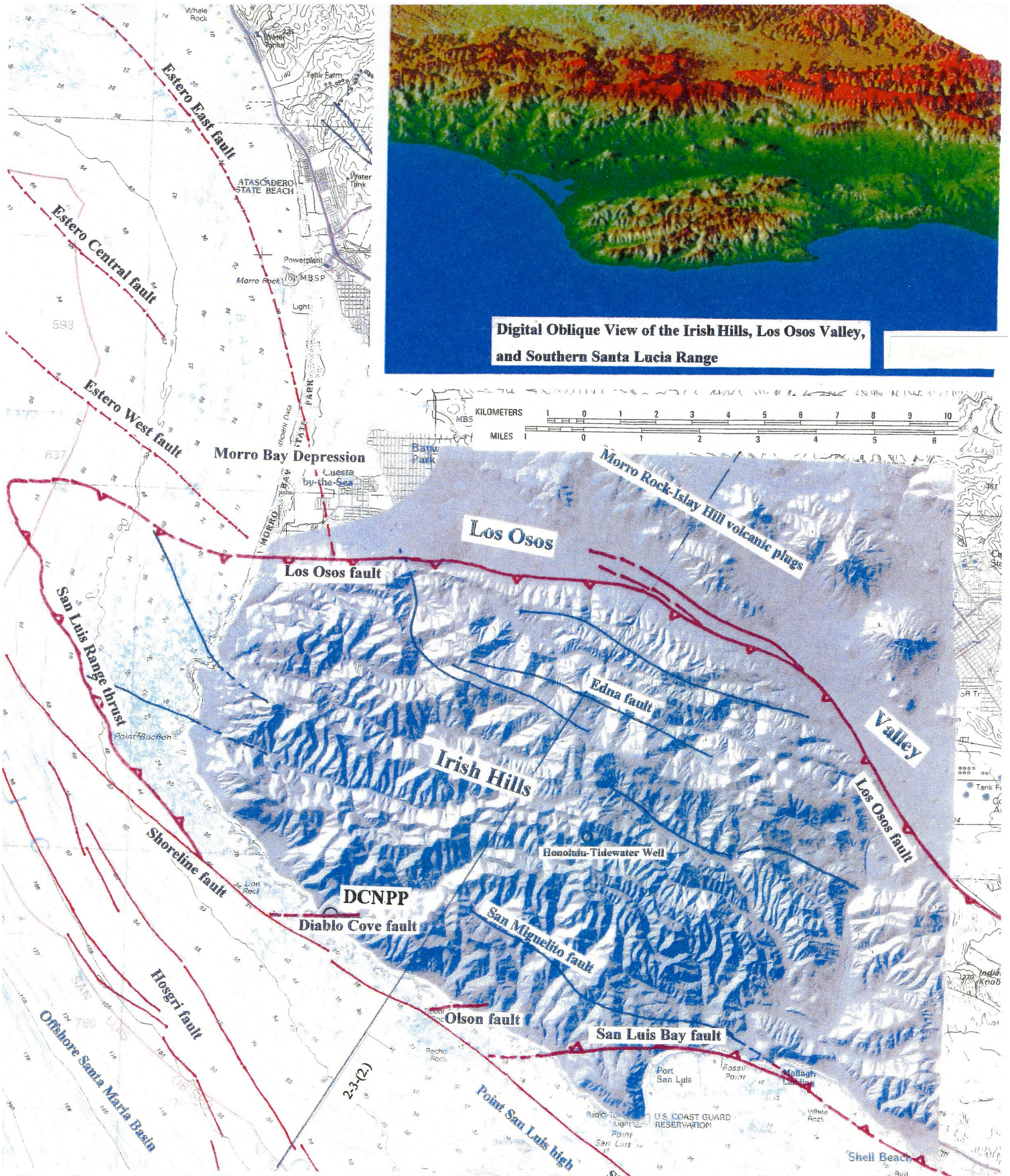
Figure 2

2-1-(2.)

October 1987 through January 1997, Bull. Seismol..S

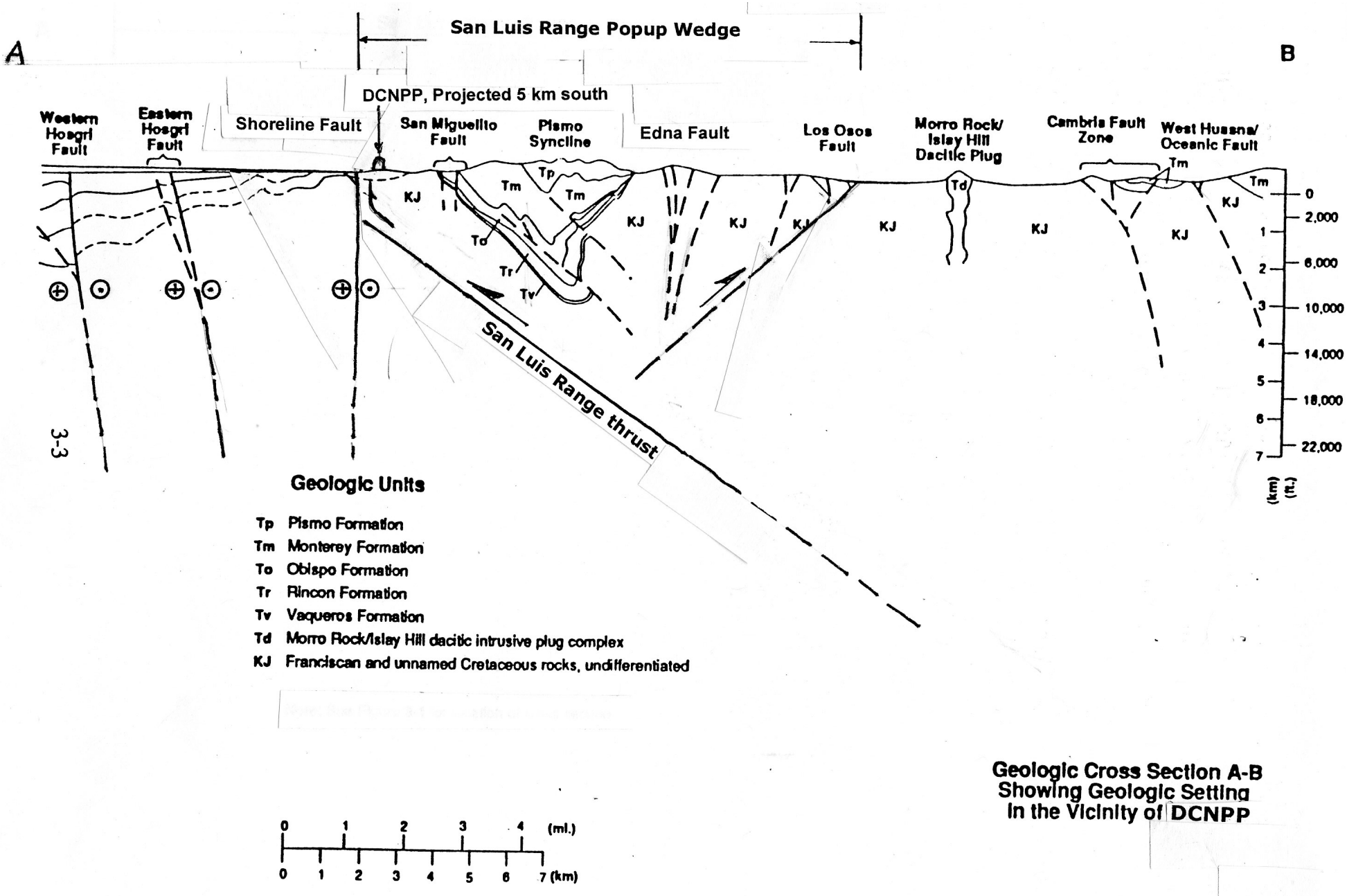
Note: Location and focal mechanism of pre-198
McLaren and Savage (2001)



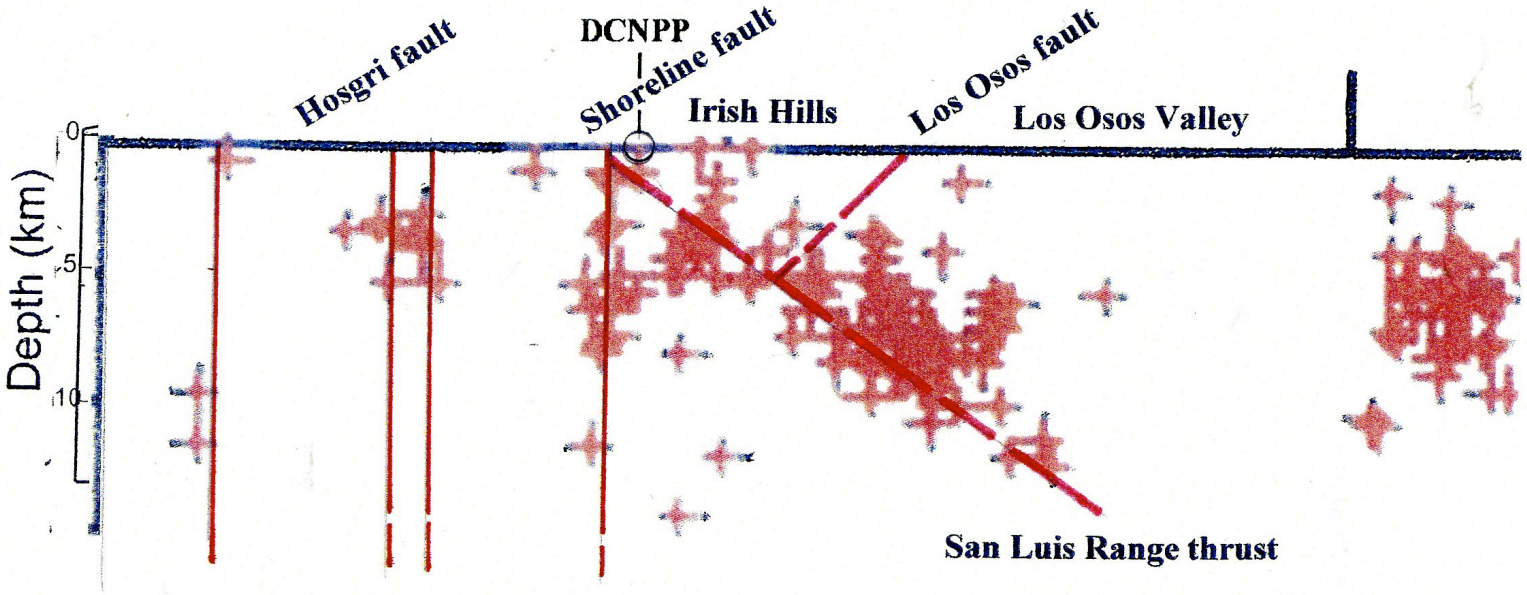


Map Showing the Onshore and Offshore Terrain and Fault Traces, Estero Bay-Irish Hills/Los Osos Valley, and San Luis Obispo Bay Region

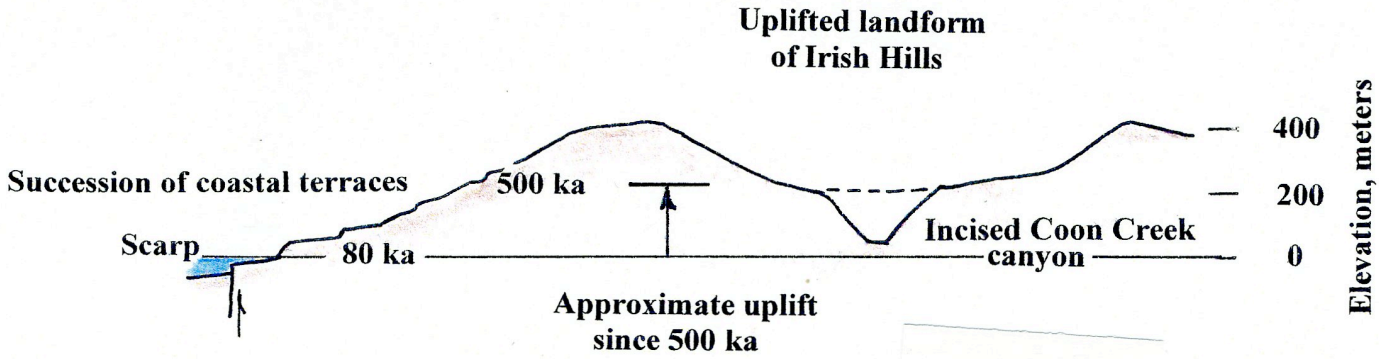
2-3-(1.)

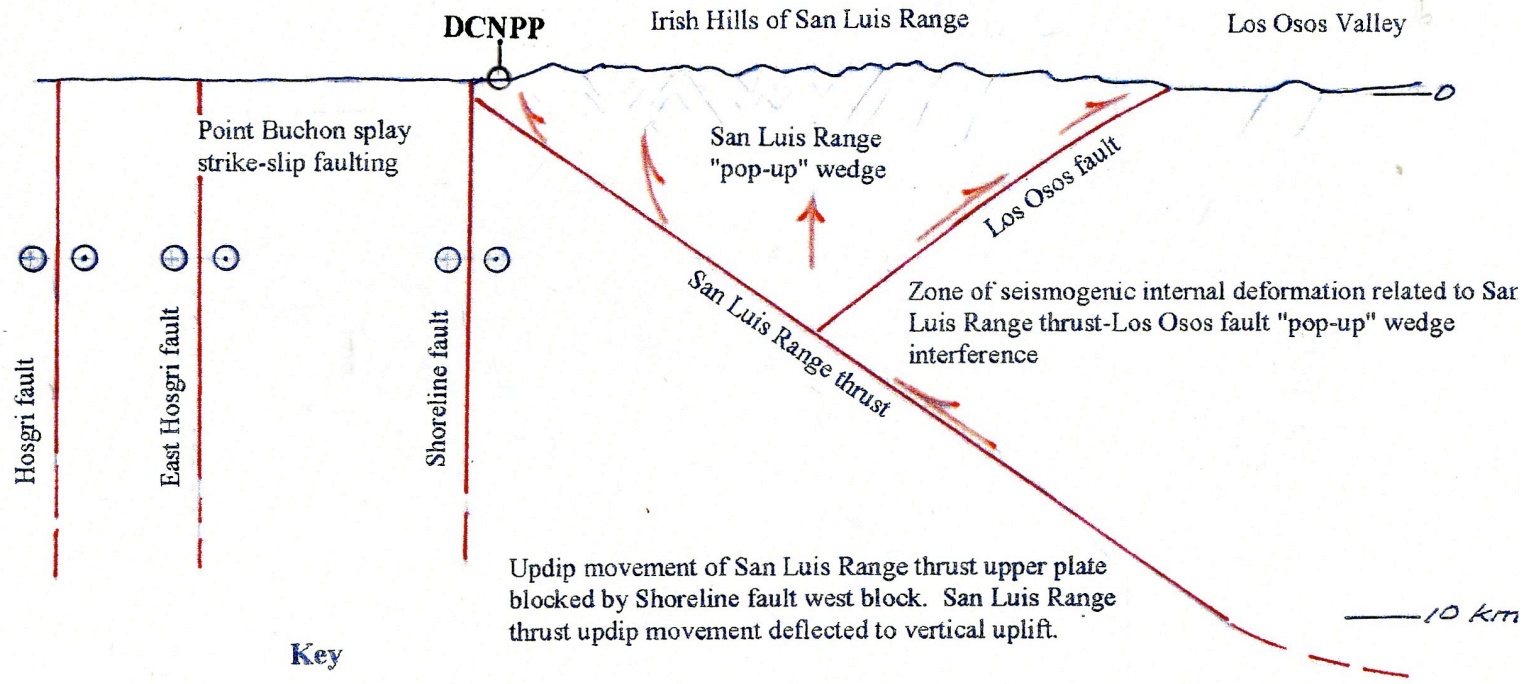


Geologic Cross Section A-B Showing Geologic Setting in the Vicinity of DCNPP

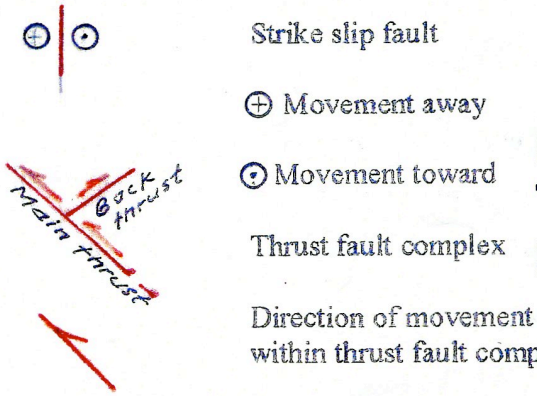


Cross Section Showing Earthquake Hypocenters and Faults, Irish Hills/Los Osos Valley and Adjacent Offshore Area

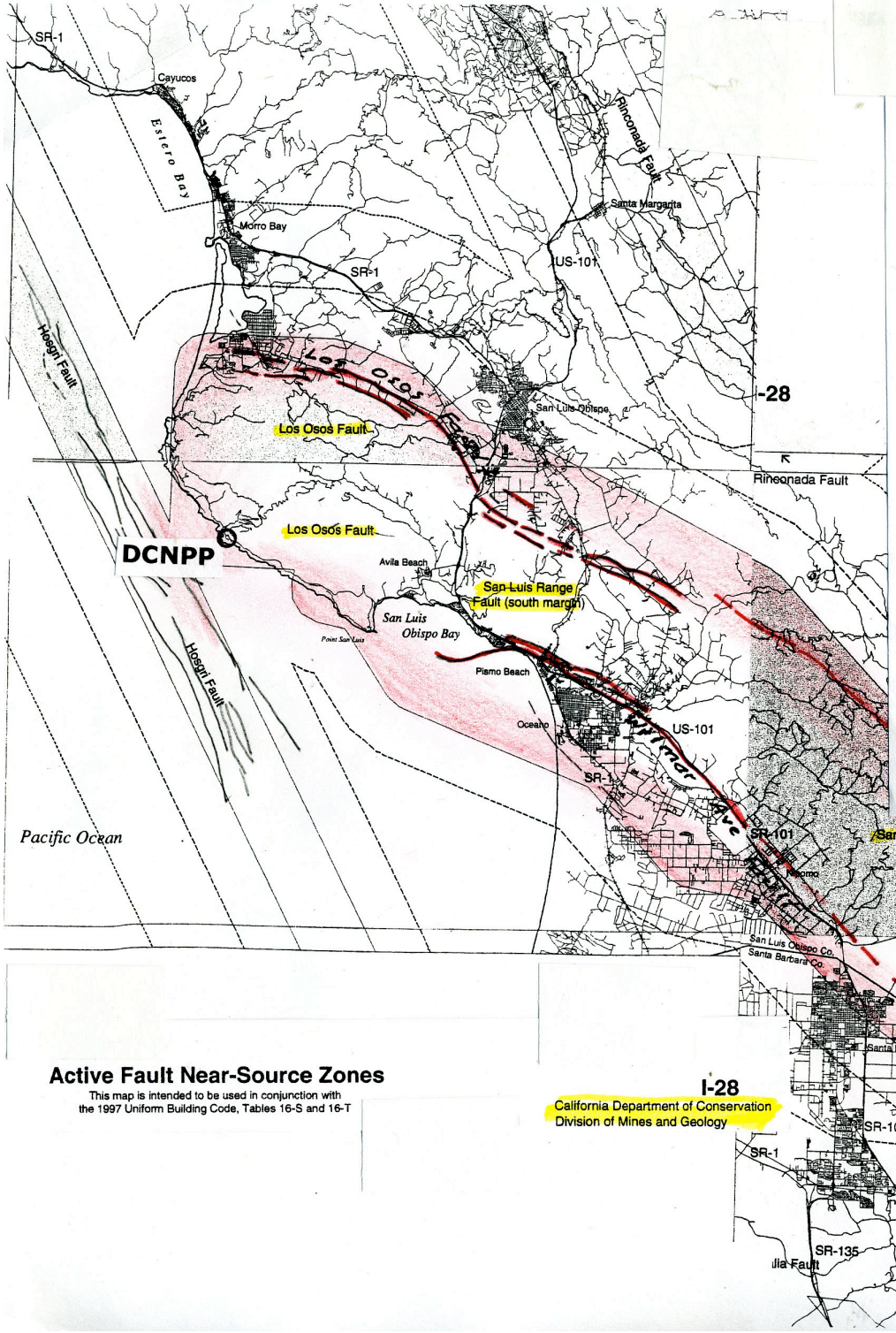




Key



Diagrammatic Cross Section Showing Tectonics of Uplift and Scarp Formation Irish Hills and Adjacent Offshore Area



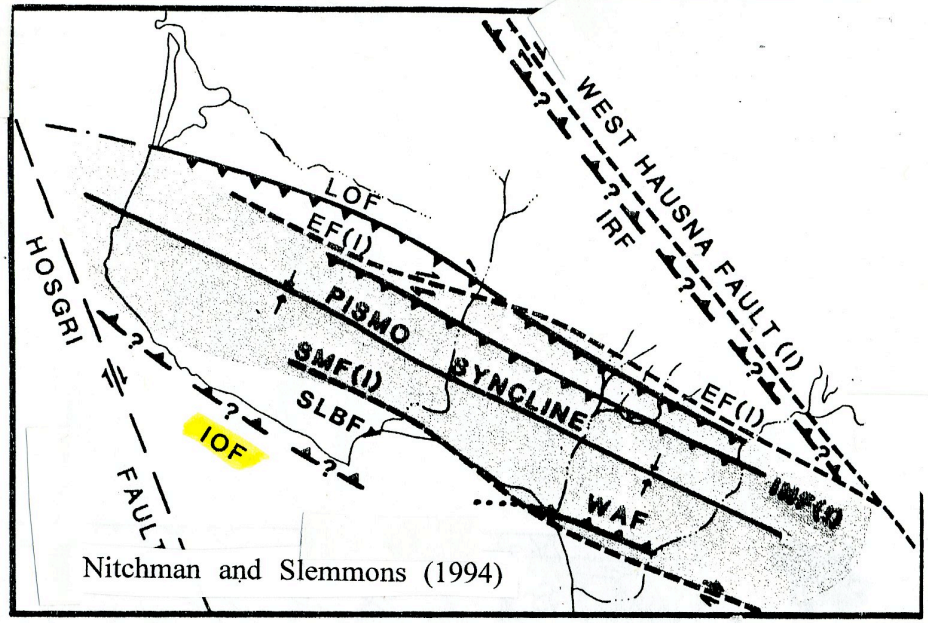
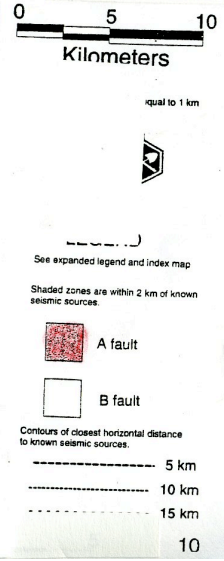
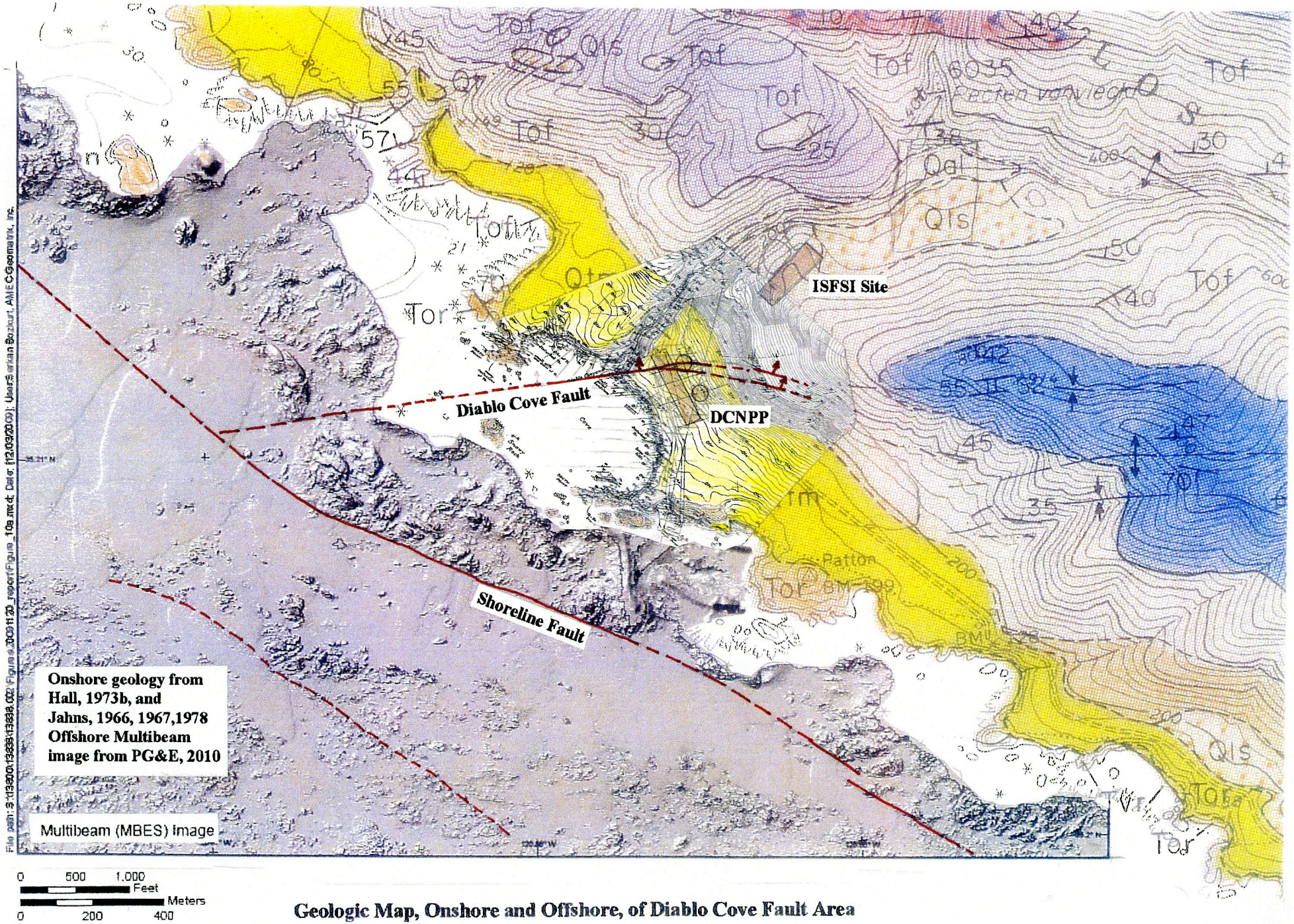
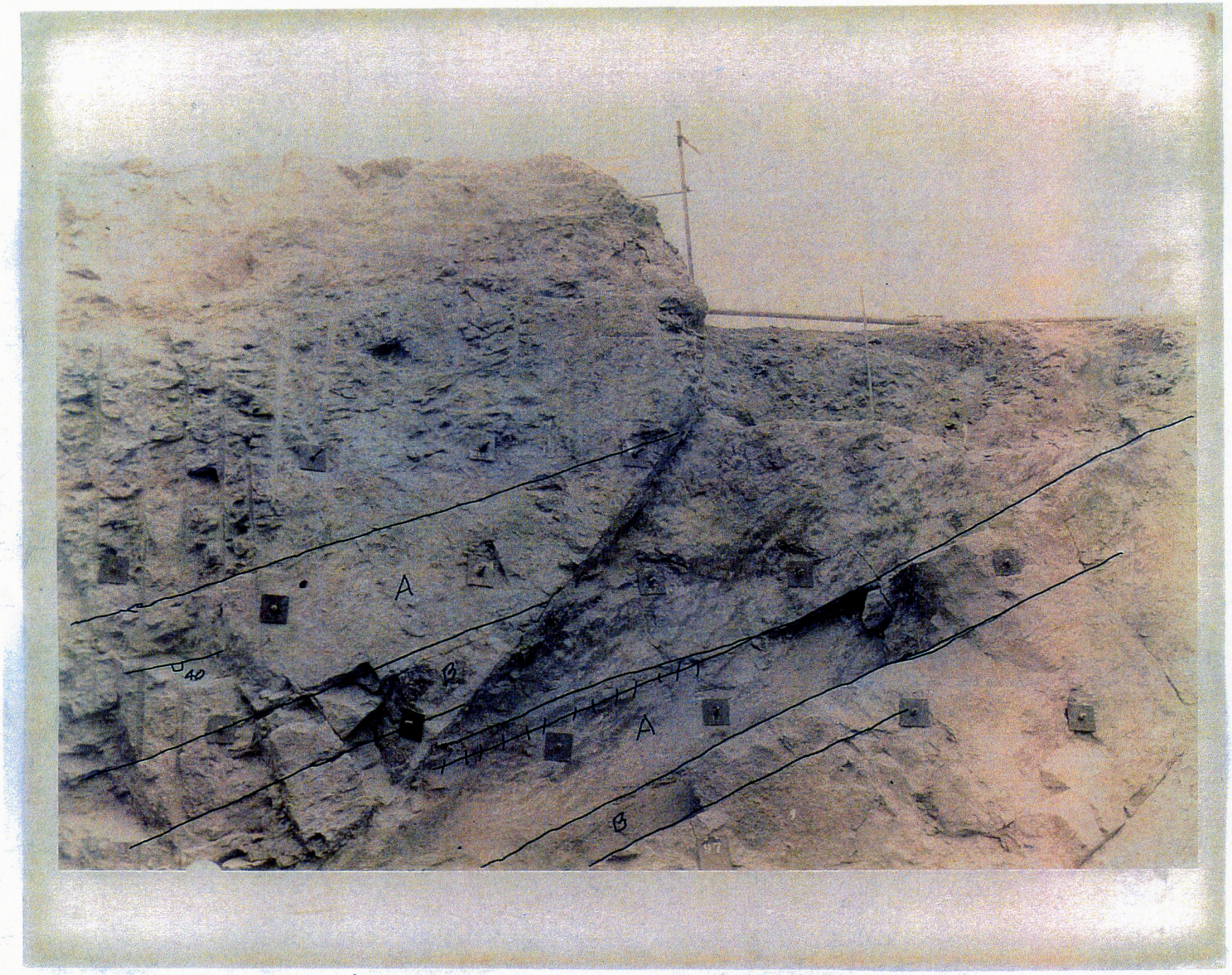


Figure 2. Generalized structural map of the San Luis Range. EF = Edna Fault; INF = Indian Knob fault; IOF = inferred offshore fault; IRF = inferred range front fault at base of Santa Lucia Mountains; LOF = Los Osos fault; SLBF = San Luis Bay fault; SMF = San Miguelito fault; WAF = Wilmar Avenue fault. Inactive faults denoted by (I). Shaded area denotes Tertiary marine strata within the fault-bounded Pismo syncline.





Geologic Map, Onshore and Offshore, of Diablo Cove Fault Area



Photograph Showing Fault Features in Walls of DCNPP Unit 1 Power Block (Turbine-Generator Building) and Containment Foundation Excavation

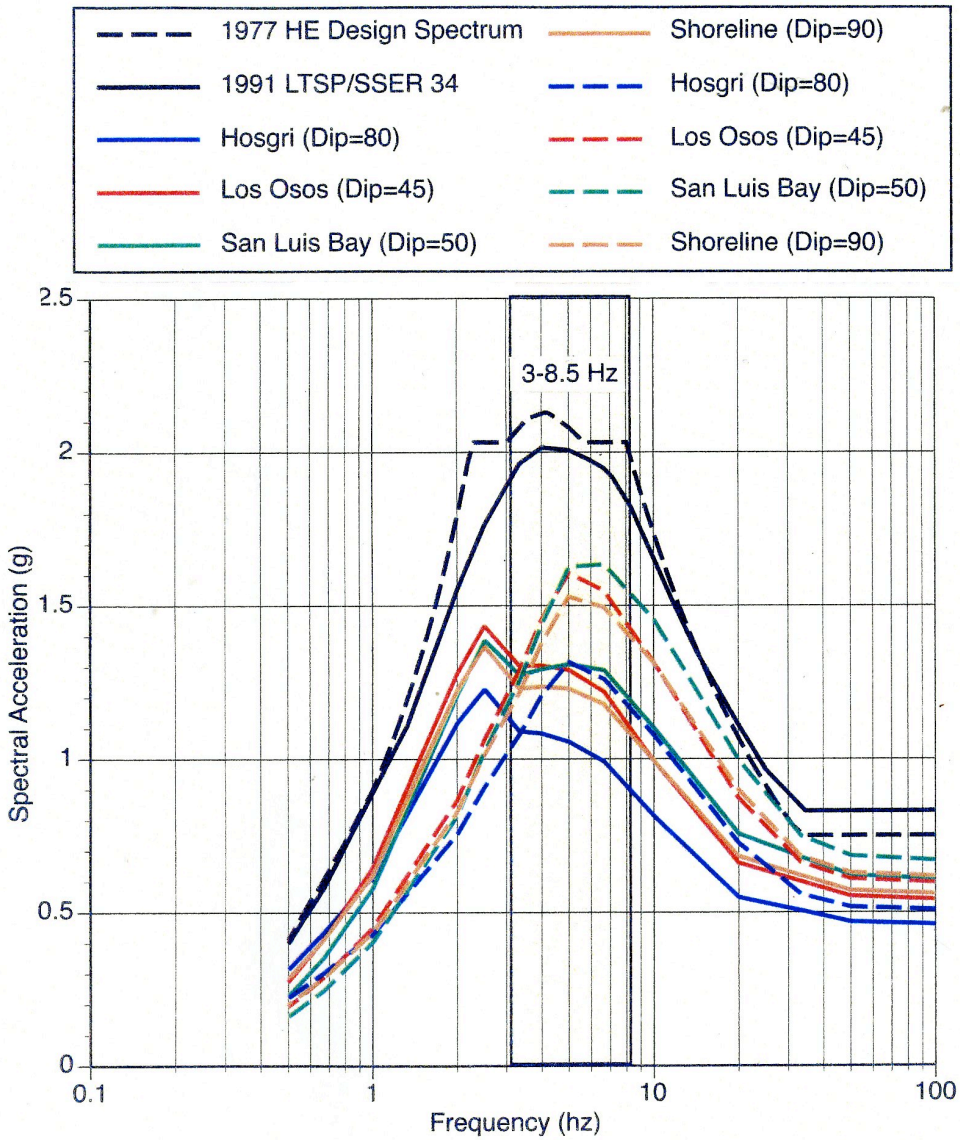
2-4-(2.)

2-4-(2.)

Aerial Photo Showing Trace of Diablo Cove Fault Zone Relative to DCNPP

2-4-(3.)

2-4-(3.)



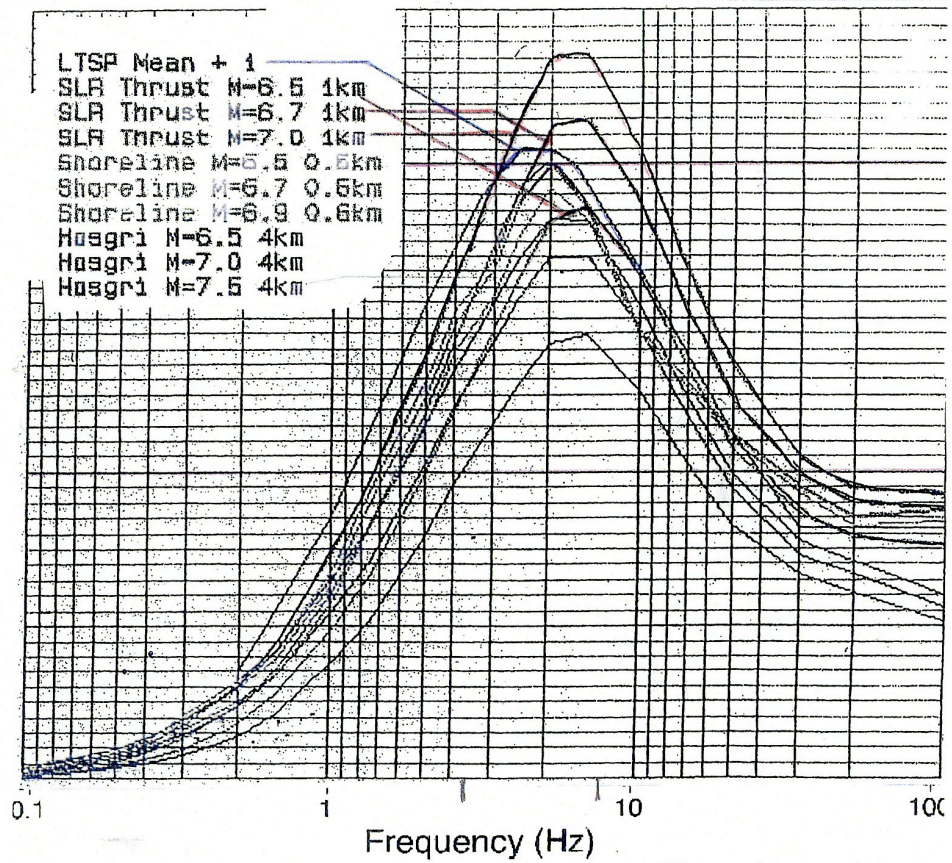


Figure 18

Figure 6-19. 84th percentile ground motion from the four nearby fault sources using the site-specific single-station sigma approach (solid lines) and the traditional ergodic approach (dashed lines). The 2.5 Hz peak in the site-specific spectrum reflects the DCPP site amplification.

Comparison of PG&E Response Spectra Family (LTSP Hosgri; Minimum Length Ranges of Segmented Shoreline Fault) vs Response Spectra Family Including LTSP Hosgri, and Ranges of Potential Earthquake Magnitudes for the Hosgri, Shoreline, and San Luis Range Faults, All Plotted Using NGA Attenuation Relationships

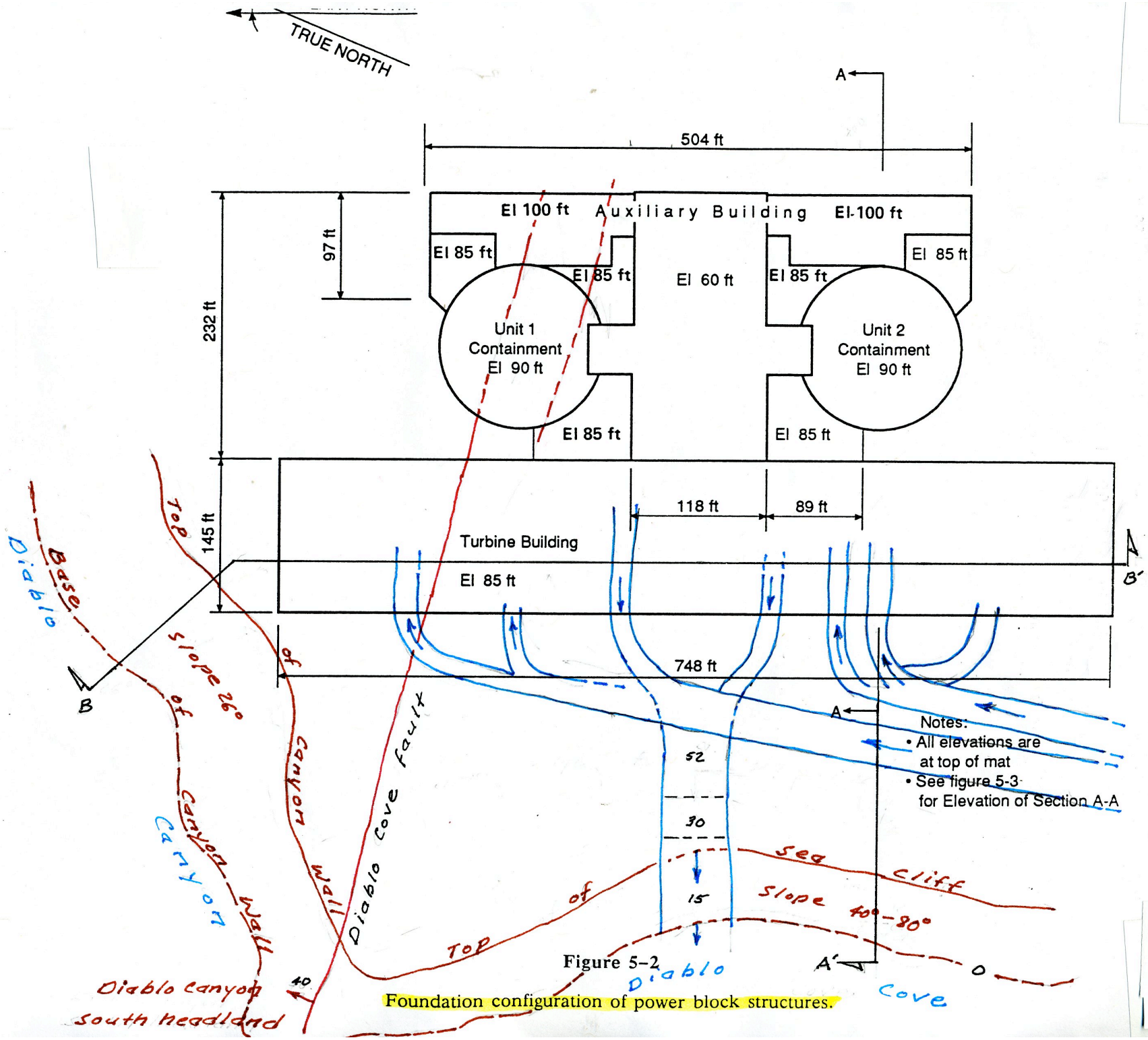
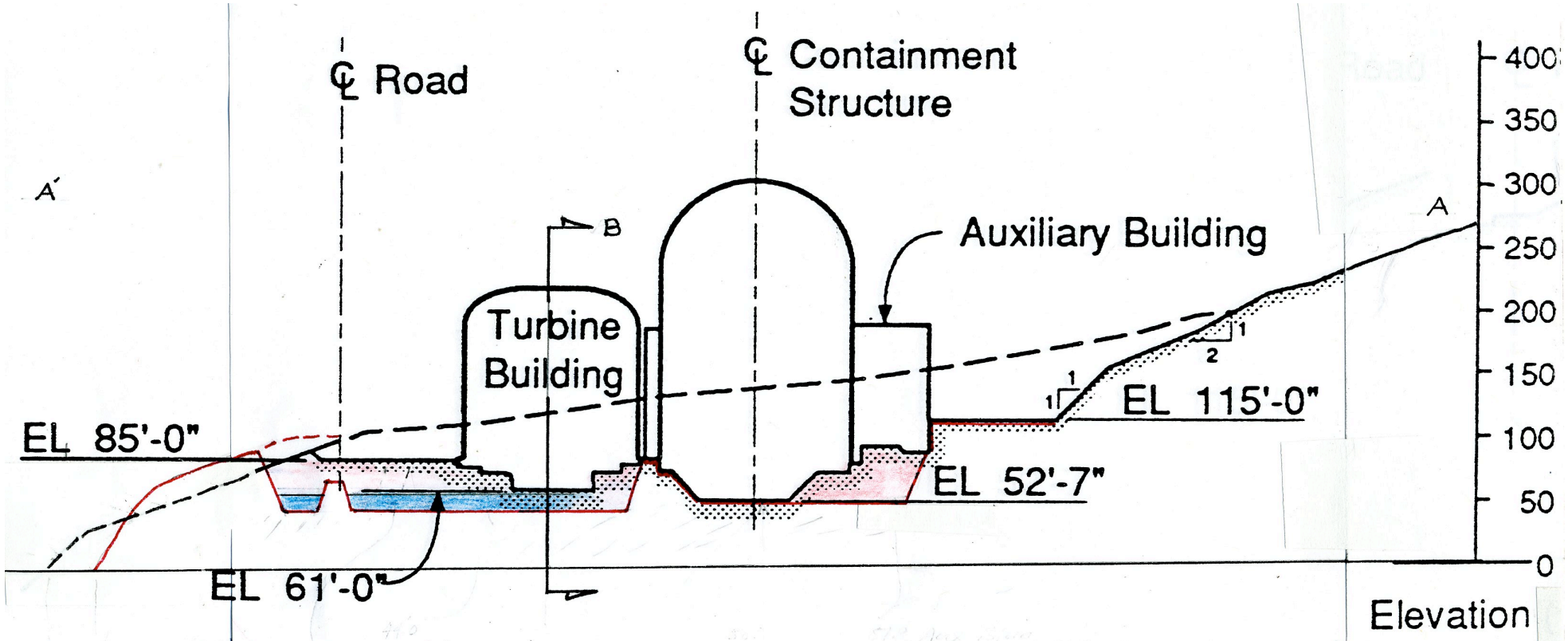


Figure 5–2

Foundation configuration of power block structures.



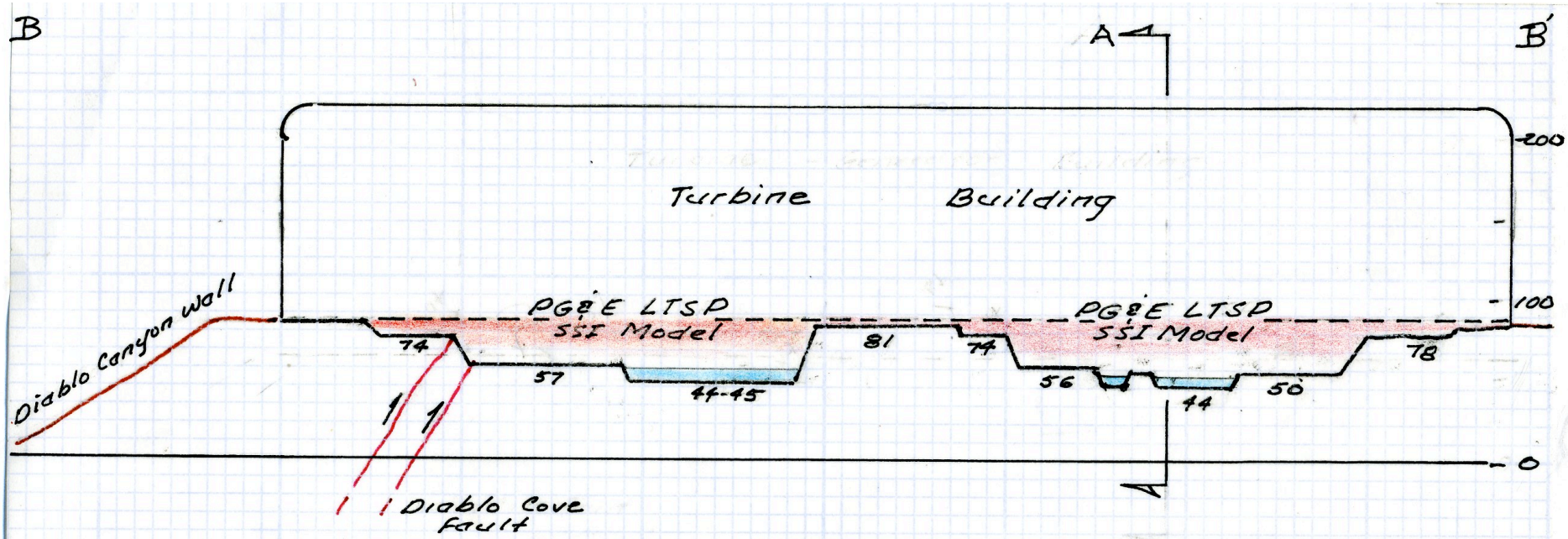
DCNPP Foundation Excavation profile

Printed line profile from 1988 LTSP SSI model

Red line = actual foundation excavation profile

Blue = circulating cooling sea water

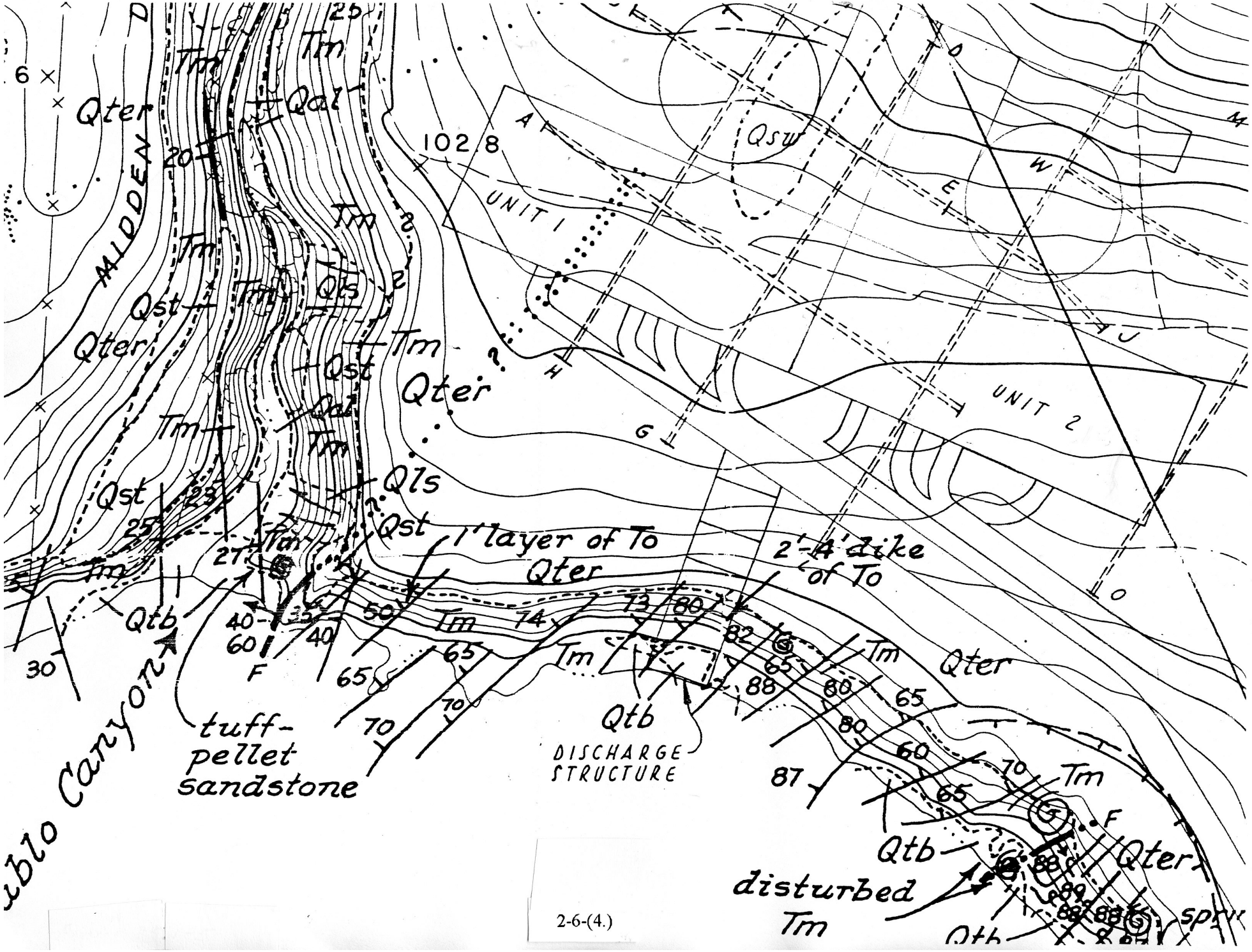
2-6-(2.)

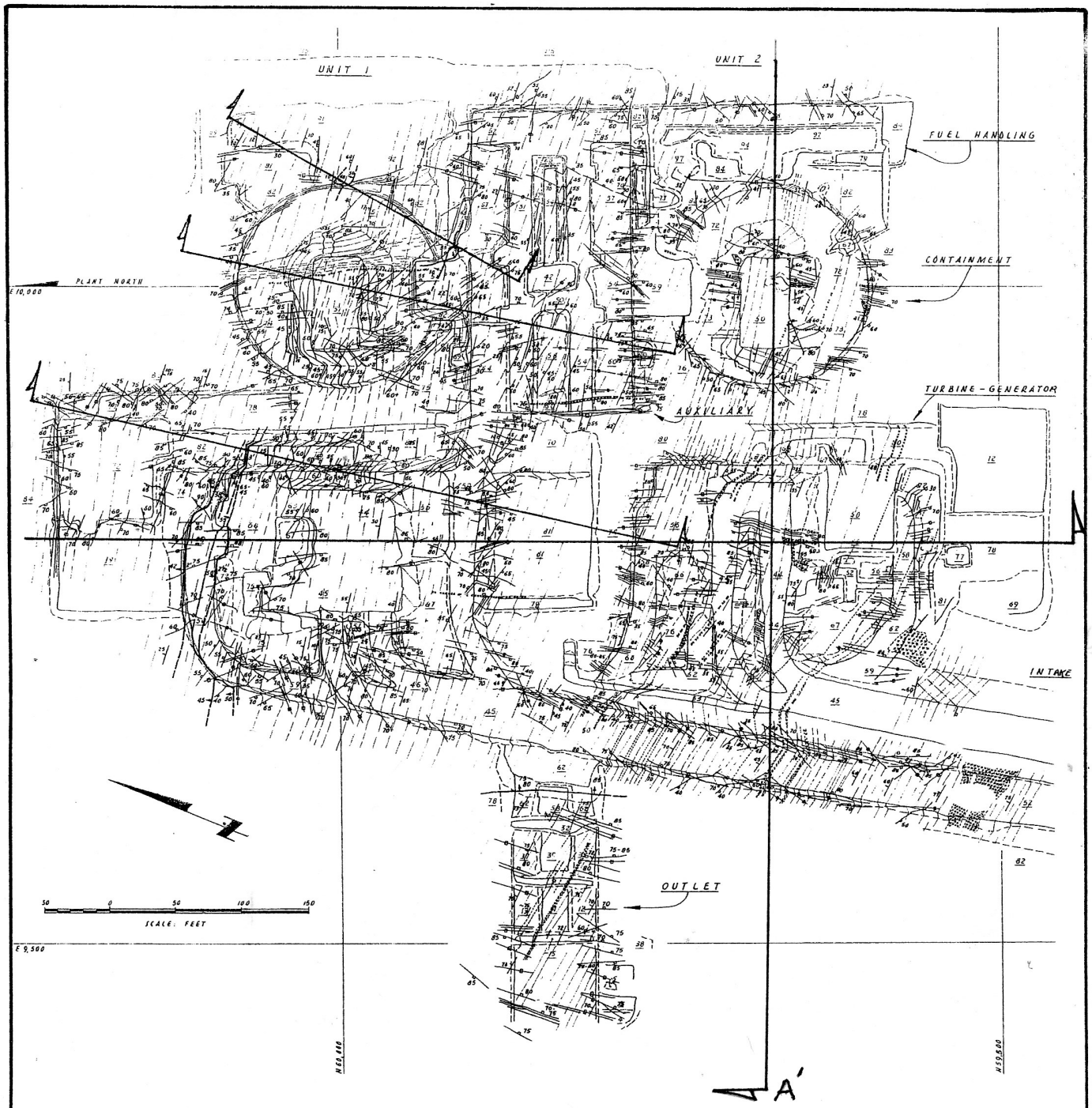


DCNPP Foundation Excavation profile

Horizontal dashed line = 1988 LTSP SSI model

Blue = circulating cooling sea water


Qter
Tm
Qal
Qls
Qst
Qtb
ALLDEN
UNIT 1
UNIT 2
Qsw
1'layer of To
2'-4' dike of To
tuff-pellet sandstone
DISCHARGE STRUCTURE
disturbed Tm
ublo Canyon



GEOLOGIC MAP OF UNITS 1 AND 2 CONSTRUCTION EXCAVATIONS

Diablo Canyon Nuclear Power Plant