1992 BLUFF EROSION STUDY UPDATE

Private Lots
North Cypress Street to Bluff Drive
Pismo Beach, California

Prepared for:
CITY OF PISMO BEACH

Prepared by:
FUGRO WEST, INC.

April 24, 2002



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April 24, 2002
Project No. 01-52-1541

City of Pismo Beach
Planning Division
760 Mattie Road
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Attention: Ms. Carolyn Johnson

Subject: **1992 Bluff Erosion Study Update**
Private Lots, North Cypress Street to Bluff Drive, Pismo Beach , California

Dear Ms. Johnson:

Fugro, in association with Moffatt & Nichol Engineers and Crawford Multari Clark & Associates, is pleased to submit this update to the 1992 Bluff Erosion Study update to the Earth Systems Consultants (1992) report. The purpose of this study is to characterize the general coastal and geotechnical processes that influence bluff erosion along private lots that bound the seacliff in Pismo Beach, and to discuss preliminary engineering concepts that could be used to provide bluff p rotection along the seacliff. This report was prepared according to our proposal dated August 22, 2001, and authorized by the City of Pismo Beach Purchase Order No. 1221.

Selected data collected during this study was obtained digitally and is being submit ted to the City with data to be input into the City' s Geographic Information System (GIS). GIS data submitted with this study includes historical aerial photos, oblique aerial photos of the study area, geology, and existing bluff top lines, access, vacant lots, and estimated setbacks.

Bluff erosion is active along the Pismo bluffs, has impacted bluff top developments in the past, and will need to be addressed in future development, maintenance, and redevelopment of the private lots along the seacliff.

Please contact the undersigned if you have questions or we can be of additional service.

Sincerely,

FUGRO WEST, INC.

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Copies: 2 – Addressee (1 unbound, 1 - *.pdf)

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GENERAL CONDITIONS

Fugro prepared the conclusions, recommendations, and professional opinions of this report in accordance with the generally accepted geotechnical principles and practices at this time and location. This warranty is in lieu of all other warranties, either expressed or implied. This report was prepared as a planning document for the exclusive use of the City of Pismo Beach and their authorized agents only. It is not intended to address issues or conditions pertinent to other parties, for lot-specific development or for other uses.

Our characterization of the coastal conditions is based on review of existing information and observations performed at specific locations, and the interpolation and extrapolation of data between points of observation. The coastal conditions described will vary from that described in this report and will change with time.

1. PROJECT DESCRIPTION

This project generally consists of a technical evaluation of bluff erosion relative to the new development, redevelopment and protection of existing structures on approximately 105 private lots that bound the seacliff between Harloe Avenue and The Bluffs Drive in Pismo Beach, California. The study area consists of approximately 5 miles of coastline. The coast is bound by relatively steep bluffs that range in height from approximately 20 feet to 110 feet. Approximately 3-½ miles of the coastline within the study area is privately owned, with the remainder owned by the City. The 105 lots include open space easements along the bluff top, existing single homes, hotels, several vacant lots, and several lots that are currently being developed. The limits of the study area relative to local streets and nearby landmarks are shown on Plate 1 – Vicinity Map.

2. WORK PERFORMED

2.1 PURPOSE

This study was performed as an update to the Earth Systems Consultants (ESC) 1992 Bluff Erosion Study prepared for the City. The ESC (1992) Bluff Erosion Study[1] was focused on evaluating bluff erosion relative to public land, facilities and projects of the City. This report will serve as a technical document for the City's update to the City's 1983 Local Coastal Land Use program, which will establish the policies and standards for reviewing private development. This study evaluates coastal erosion processes along the bluffs, and will be used by the City to help develop the criteria and requirements for development, redevelopment and protection of existing development along the coastal bluffs.

This study is not intended to predict specific rates of retreat for any single property. The bluff retreat rates presented, and the retreat lines shown on the plates included in this report, are an estimation of an average for the coast. It is not appropriate to rely on these lines for establishing the location of specific structures. Each property, and each project contemplated for a property, must be carefully analyzed for retreat characteristics and stability. The City, individual property owners and the Coastal Commission should not rely on this report or the accompanying plates for the lot-specific development of projects. The appropriate use of this report is for the City's planning of strategies and restrictions that will benefit coastal resources and landowners citywide.

2.2 BLUFF EROSION EVALUATION

The bluff erosion evaluation was completed by geotechnical, coastal, and planning professionals from Fugro, Moffatt & Nichol Engineers, and Crawford Multari Clark Associates, respectively. A summary of the work completed by these firms follows:

[1] Earth Systems Consultants (1992), *Bluff Erosion Study, City of Pismo Beach, California,* July 31

Fugro performed field geologic mapping of the bluff area, reviewed existing geologic reports for selected lots that were provided by the city, reviewed historical aerial phot ograph pairs for the site vicinity, and performed an aerial reconnaissance of the site to obtain oblique aerial photographs of the bluffs. This data was then used to document the existing coastal conditions such as presence of shoreline protection systems , existing building setbacks, and estimate historical bluff retreat rates.

Moffatt & Nichol Engineers performed a limited coastal study of the project area to characterize the general wave exposure and coastal processes that affect bluff erosion in the project area. This data included preliminary estimates of significant wave height, exposure, and frequency, and was used to develop engineering concepts for bluff protection.

Crawford Multari & Clark Associates served as liaison between the project team and the Coastal Commission. CMCA consulted with the Coastal Commission and City in an attempt to clarify Coastal Commission permit policies, procedures, jurisdictional limits, and definitions for development. CMCA then reviewed the engineering concepts prese nted in this report relative to City and Coastal Commission permit and land use requirements.

2.3 SCOPE OF WORK

As a basis for providing the preliminary geotechnical recommendations presented in this report, we have performed the following scope of work:

- Reviewing selected published geologic maps, previous consultant reports for various properties, aerial photographs, and previously obtained geotechnical information relative to characterizing the geologic conditions at the site;
- Identifying existing vacant pr ivate lots along the bluffs and associated linkages to vertical and lateral public access;
- Mapping of the geology and existing coastline conditions based on:
  - Data review and site reconnaissance;
  - Performing an oblique aerial survey of the bluffs on November 23, 2001;
  - Geologic mapping of predominant geologic structure along the coastline; and
  - Inputting the data obtained into a geographic information system (GIS) database.
- Moffatt & Nichol Engineers performed a limited coastal engineering study of the bluffs, and met with the City and Fugro on December 14, 2001;
- Crawford Multari & Clark Associates and Fugro performed a teleconference with the Coastal Commission on December 18, 2001. CMCA and the City' s Community Development Director subsequently met with the C oastal Commission at their office in Santa Cruz on January 23, 2002 and April 5, 2002, respectively, to go over the approach to

the Pismo bluff study and policies relating to development with the Coastal Commission's Beach Erosion and Response document as the essential element of discussions.

- Summarizing the data obtained in a GIS database for submittal with this report; and
- Preparing this written report, with associated graphics, presenting our opinions and recommendations regarding:
  - Existing geologic and seismic conditions along the bluffs;
  - Estimated bluff retreat, 100 year setback, and bluff profile* for the private bluff top lots as summarized in table and GIS format;
  - Coastal processes and considerations for coastal improvements;
  - Bluff protection measures for development, redevelopment and existing structures; and
  - Surface and subsurface drainage.

* Topography of the study area was not available from the City for purpose of estimating the height of the bluffs, and the seacliff profile as we had planned. Instead, a set of oblique aerial photos was obtained from an air plane using a digital camera to help document the existing seacliff profile and conditions.

3. SUMMARY OF FINDINGS

- The Pismo Bluffs are an erosional coastline that has formed by progressive retreat of soft rocks near the shoreline and instability and erosion of the overlying soil deposits. There are approximately 105 privately owned lots along the bluff top that are residential, commercial or open-space. Only 13 lots are currently vacant. The main factors affecting bluff erosion are wave attack at the base of the seacliff, gradual erosion and flattening of the terrace deposits above cliff, and the geologic makeup of the seacliffs. Beach formation is limited along the bluffs with the sand on beaches upcoast of South Point being mostly supplied by local erosion of the shoreline and the bluffs themselves. Where present, the beaches are typically narrow and steep.
- Average annual rates of retreat can be misleading in characterizing the threat to existing homes and bluff top development. Reliable estimates of retreat are difficult to obtain because the historical record and the quality of the information is limited relative to on-going coastal processes. Historical aerial photos along the bluffs cover the last approximately 50 years; however, current policies typically require an estimate of 75 to 100 years of retreat in to the future. Retreat typically occurs episodically with several feet to several tens of feet of the bluff top being eroded off during a single season or storm event, while the bluff top in adjacent areas remains virtually unchanged. Episodes such as

sea cave collapse and point erosion, appear to produce higher rates of retreat locally; but then appear to decrease as years pass without further instability at that same location. The apparently higher and dormant rates of retreat are only symptomatic of the episodic nature of bluff erosion. Rates of retreat therefore have limitations associated with their use in providing a technical basis for land use planning and hazard analyses.

- The overall bluff retreat rate is approximately 4 inches per year over the study area. Retreat rates of only 2 inches per year were observed where the bluffs are comprised of relatively resistant volcanic tuff bedrock or are south facing. Retreat rates of 6 to 12 inches per year where noted in areas where there is only a limited bedrock exposure at the base of the seacliff, there has been a seacave collapse, or where points are being eroded off the shoreline. The bluff retreat rates do not consider increasing wave energy, rising sea levels, or tectonic movements along the coast line.
- The projected bluff top for 100 years of retreat along the bluff is shown on Plate 9. From the projected bluff top, we estimate that there are approximately 66 homes and buildings within the projected 100-year setback, and of those 22 are within a projected 25-year setback. Although these estimates do not specifically quantify the actual hazard of bluff retreat; the projections are an indication that bluff retreat in Pismo Beach will continue impact to existing homes, property and coastal access, possibly to a greater extent than it has in the past.
- While some areas along the bluff top are relatively stable and slow to erode, bluff protection such as control of drainage, structural shoreline protection (seawalls), and underpinning of existing structures are immediately needed to protect existing structures and property. The need, permitting and maintenance of bluff protection are growing issues that the City will face. Plates 9 and 10, and Table 1 summarize the existing bluff conditions, zones of similar coastal conditions, and the likely areas where future bluff protection is likely to be requested from property owners.

3.1 ZONES OF DIFFERING BLUFF CONDITIONS AND RATES OF RETREAT

The bluff conditions are characterized based on the estimated average rate of historical retreat, presence of existing bluff protection systems, building setbacks from the existing top of bluff, and coastal access points. Plate 9 summarizes the estimated top of bluff as of December 15, 2001, the corresponding 100-year setback line from the top of bluff, access points, various bluff protection systems, and significant geologic features along the bluffs. Existing improvements were noted from site visits and an aerial survey of the site. A composite of digital photos obtained during a chartered flight along the coastline on November 23, 2001 is presented on Plate 10. A lot-by-lot inventory of the data presented on Plates 9 and 10 is presented in Table 2. Table 1 presents the following fifteen coastal zones where the bluff conditions are considered to be similar.

Table 1: Coastal Zones

Zone	Existing Condition and Likely Future Bluff Protection	Avg. Bluff Retreat (inches/year)
1. The Bluffs Drive Plates 9.1 and 10.1	• Existing development is partially developed 21 house lots on the landward side of the roadway. • Coastal access trails and bluff top setbacks are provided along the seaward side of the roadway. • There are relatively large landslides on the bluff and hillside near the northerly end of The Bluff Drive, but do not appear to affect the existing development. • Future bluff protection is likely to consist of maintaining existing bluff top setbacks thro ugh control of drainage and erosion.	4
2. 311 to 435 Indio Drive (North) Plates 9.1 and 10.1	• Existing development is 15 bluff top houses and 1 vacant lot, with one lot currently under construction. Most development and streets layout show up on 1962 aerial photographs. • The terrace deposits at the top of the cliff are relatively thin, and there are few seawalls. Bluff erosion is most influenced by gradual undercutting of relatively flat -lying to slightly favorable dipping shale beds in the Monterey Forma tion. • There is essentially no sand beach development. • Construction of Indio Drive appears to have slowed the rate of bluff top retreat by intercepting surface drainage that previously ran towards the cliff. • Future bluff protection is likely to consist of n otch fills and limited seawalls to protect existing homes with limited setbacks. Underpinning of existing homes with deep foundations is likely to be needed to protect against instability of the cliff face.	4

Zone	Existing Condition and Likely Future Bluff Protection	Avg. Bluff Retreat (inches/year)
3. 99 to 307 Indio Drive (South) Plates 9.2 and 10.1	• Extension of development in Zone 2. Existing development is 17 bluff top houses, with 1 lot currently being redeveloped. • The terrace deposits thicken from Zone 2, and compose the majority of the bluff in some areas. Bluff erosion is most influenced by erosion of the terrace that appears more silty in this area, and undercutting of slightly adverse bedding of the shale bedrock at the shore line (Miguelito Member of the Pismo Formation). • Sand beaches are narrow and steep. • Building setbacks are commonly minimal and many were initially constructed near the top of bluff. • Construction of Indio Drive appears to have slowed the rate of bluff top retreat from 7 inches per year by intercepting surface drainage that previously ran towards the seacliff. • Shoreline protection consisting of seawalls, shotcrete, and rock revetment are common. • Relatively high rates of erosion (8 inches per year) are observed near Florin on lots without seawalls, that are bound by existing shoreline protection, and where the bedrock exposure at the base of the seacliff is minimal or near the shoreline. • Future bluff protection is likely to consist of replacement of existing seawalls and construction of new seawalls on unprotected lots. Underpinning of existing homes with deep foundations is likely to be needed to protect against instability of the terrace.	4 typical (8 near Florin)
4. Sea Ridge to Ebb Tide Plate 9.2, 10.1 and 10.2	• Existing development is 5 relatively recent residential housing tracts and subdivisions, with one tract vacant, and one tract under construction. • Setbacks are relatively large with coastal parks and access provided between the building and top of bluff. Shoreline bedrock is mostly shale of the Pismo Formation – Miguelito member. • The sand beach is nearly continuous and narrow. • Bluff top retreat appears to be mostly dependent on gradual erosion and flattening of the terrace deposits that comprise at least half the seacliff. Deep rills, gullies and headward erosion are common along the top of bluff. Erosion of the shoreline appears relatively uniform and moderate. • Bluff protection appears to consist of landscaping and drainage control beyond the top of the bluff. • Future bluff protection is likely to consist of maintaining existing bluff top setbacks through control of drainage and erosion.	4

Zone	Existing Condition and Likely Future Bluff Protection	Avg. Bluff Retreat (inches/year)
5. The Cliffs to Spyglass Inn Plates 9.2, 9.3 and 10.2	• Development is mostly relatively recent hotel and residential development, and includes the Spyglass Inn. • The terrace deposits compose at least the half the seacliff . The shoreline is mostly composed of shale of the Monterey Formation. The shale is locally covered by a thin layer of bituminous sandstone of the Pismo Formation. • Intermittent sand beaches are narrow and steep. • The shale is tightly folded and strikes o ffshore or is adverse. The shale forms an irregular coastline comprised of headlands, reentrants, and seacaves. Bluff top erosion is commonly episodic occurring as slippage along bedding planes, landslides or sea cave collapse. • Bluff protection is mainly stone revetment and sea cave fill that has been placed in response to sudden retreat during significant storm events. • Future bluff protection is likely to consist of revetment placed at reentrants or collapsed seacaves, cave fills, underpinning of existing structures with deep foundations to protect against instability of the terrace, maintaining existing setbacks by controlling surface drainage, and possible seawalls.	4
6. Spyglass Drive Plates 9.3 and 10.2	• Existing development consists of 15 bluff -top houses. • The terrace deposits compose at least the upper 2/3 of the bluff face. The shoreline is mostly Monterey shale that strikes offshore, and is covered by black bituminous sandstone at the southerly end of the beach. • Bluff top retreat appears to be dependent on both gradual erosion and flattening of the terrace, and erosion of the shale and sandstone near shoreline. Shoreline erosion appears to have resulted in slumping and landsliding of the bluff face that can extend 10 to 20 feet into the slope. It is our experience that further bluff retreat can occur rapidly once the thin veneer of bituminous sandstone is eroded away. • The stability of the bluff slope under static and seismic loads is likely an important factor influencing the foundation support for these residences. • A narrow sand beach is developed along the seacliff. • Bluff protection consists of seawalls and stone revetment. Some residences are supported on deep foundations. • Future bluff protection is likely to consist of seawall replacements and construction of new seawalls on unprotected lots. Underpinning of existing homes with deep foundations is likely to be needed to protect against instability of the terrace.	4

Zone	Existing Condition and Likely Future Bluff Protection	Avg. Bluff Retreat (inches/year)
7. Seacliff Drive Plates 9.3 and 10.2	• Existing development consists of 6 ex isting bluff top homes located on either side of a small park. • Sand beaches are poorly developed or not present near the houses. • The terrace deposits are near vertical and extend down to near the shoreline on the southerly lots. Shoreline erosion appears to be controlled mostly by wave erosion to the base of seacliff. • The stability of the bluff slope under static and seismic loads is likely an important factor influencing the foundation support for the residences. • Bluff protection consists of stone revetm ent along the northwest facing shoreline below the northerly lots, and a seawall. • Future bluff protection is likely to consist of seawall replacements and construction of new seawalls on unprotected lots. Underpinning of existing homes with deep foundatio ns is likely to be needed to protect against instability of the terrace.	4
8. Park Place Plates 9.3 and 10.2	• Existing development consists of 1 house near the bluff top and 1 deep lot with the house setback. • The bluff consists of a shallow thickness of te rrace deposits overlying favorably bedded Monterey shale that dips into the bluff. • There is no beach below the cliff. • Future bluff protection is likely to consist of maintaining existing setbacks by controlling surface drainage, and possible notch fills or localized shotcrete applications to the seacliff.	2
9. Shoreline Drive to northerly terminus of Ocean Boulevard Plates 9.3 and 10.2	• Existing development consists of 13 bluff top homes, 3 vacant lots, and 1 lot occupied by a recreational building that su pports a condominium complex. • The terrace deposits compose at least ¾ of the seacliff and overlies Monterey shale. • There is a narrow sand beach along the southern half of this zone. • Bluff protections consisting of various seawalls cover most of the bluff in this area. • Future bluff protection is likely to consist of seawall replacements and construction of new seawalls on unprotected lots. Underpinning of existing structures with deep foundations may be needed for structures with relatively small setbacks.	4

Zone	Existing Condition and Likely Future Bluff Protection	Avg. Bluff Retreat (inches/year)
10. 1243 and 1400 Ocean Boulevard Plates 9.4 and 10.3	• Existing development consists of 2 bluff top homes on the northwest facing bluff of South Point. • The seacliff is composed of highly deformed soft shale of the Monterey Formation and resistant slabs of Obispo tuff that are in fault contact at this location. • There is no beach below the cliff. • Lots are protected by seawalls constructed between slabs of tuff. • Future bluff protection is likely to consist of maintaining or replacing the existing seawalls, and possible underpinning of structures to protect against instability of the seacliff.	4
11. South Point (Ocean Boulevard, Boeker, Windward) Plates 9.4 and 10.3	• Existing development consists of 10 bluff top homes, with one lot currently under construction. • The seacliff is mostly composed of resistant Obispo tuff that dips into the bluff. Erosion has commonly resulted in a notch to form in the tuff at the shoreline. Bluff top erosion is slow, and is likely dependent on block and wedge failures in the r ock that develop when the rock structure is undercut by the notch. • Beaches have not developed at the base of the seacliff. There are numerous sea stacks and outcrops near the shoreline that help to break waves before they reach the shore. • Future bluff protection is likely to consist of notch fills and localized shotcrete or small seawalls to strengthen weak or adverse structure in the rock, and cobble management,.	2
12. Price Street Plates 9.5 and 10.3	• Existing development consists of the Shore Cliff Lo dge hotel. A public access stairway is provided. • The seacliff is composed of resistant Obispo tuff. Seacaves have formed along the base of the seacliff. Bluff top erosion is slow and is likely dependent on the formation of seacaves and their subsequent collapse. The shoreline is irregular with sea stacks that help to break waves before they reach the shore. • Shoreline protection consisting of a seawall is provided at the base of the public stairway. • Future bluff protection is likely to consist of seacave or notch fill, revetment placed at reentrants or seacave openings, and seawalls to protect stairway access.	2

Zone	Existing Condition and Likely Future Bluff Protection	Avg. Bluff Retreat (inches/year)
14. 2555 Price Street to Wilmar Avenue Plates 9.5 and 10.4	• Existing development consists of 5 hotel complexes, 1 bluff top home, and 2 vacant lots. Most hotels have public access stairways. • The seacliff is composed of terrace deposits that compose approximately ½ of the seacliff overlying siliceous Obispo tuff. Many seacaves have developed along joints sets in the tuff. Bluff top retreat appears to be mostly dependent on gradual erosion and flattening of the terrace deposits, and the formation and subsequent collapse of seacaves. • The southern limit of this zone is the northerly wet sand beach of Pismo State Beach. • Shoreline protection is mostly stone revetment placed at reentrant features that likely formed in response to seacave collapse. • Future bluff protection is likely to consist of seacave or notch fill, reinforced shotcrete to stabilize adverse joints in the rock, revetment placed at reentrants or seacave openings, seawalls to protect stairway access, underpinning of existing structures with deep foundations, and seawalls to protect deep foundation already exposed in the seacliff.	4
15. Wilmar Avenue to Harloe Avenue. Plates 9.6 and 10.4	• Existing development consists of 2 hotel complexes, 4 bluff top homes, and a vacant lot. • The seacliff is mostly composed of terrace deposits that locally overly a thin exposure of Pismo Formation sandstone. Bluff top erosion appears to be mostly dependent on gradual erosion and flattening of the terrace deposits, and episodic erosion of the basal terrace deposits due to wave attack during severe storm events. • The base of the seacliff is bound by Pismo Beach. The high tide does not always reach the base of the seacliff. • The beach provides shoreline protection. Portions of the bluff are covered with shotcrete near Harloe Avenue. • Future bluff protection is expected to consist of beach nourishment, possible small revetment, and underpinning existing structures with deep foundations to protect against instability of the terrace.	4

The coastal zones and conditions should be considered preliminary and subject to change. Bluff conditions are part of the dynamic coastal environment. The limits of these zones a nd subsequent need for bluff protection are likely to change with the coastline. Coastal zones, bluff conditions, and the needs for bluff protection should be reviewed on an ongoing basis.

Table 2: Lot by Lot Data Summary

Address	APN	Existing Development	Estimated Setback From Bluff Edge (feet)	Field Check	Bluff Height (feet)	Vertical Access (none/improved/unimproved)	Top of Bluff Lateral Access (none/improved/unimproved)	Existing Bluff Protection	Estimated Bluff Retreat (inches/year)
0 The Bluffs Drive	010-562-024	Trail/Open Space	100			None	Improved	None	
435 Indio Dr.	010-175-001	Single Family	0	yes		None	None	None	4
431 Indio Dr.	010-175-002	Single Family	25			None	None	None	4
427 Indio Dr.	010-175-003	Single Family	0	yes		None	None	Terrace Wall	4
423 Indio Dr.	010-175-004	Single Family	0	yes		None	None	Terrace Wall	4
419 Indio Dr.	010-175-005	Vacant	Construction			None	None	None	4
417 Indio Dr.	010-175-006	Single Family	20			None	None	None	4
413 Indio Dr.	010-175-007	Single Family	15			None	None	None	4
409 Indio Dr.	010-175-009	Single Family	15			None	None	None	4
405 Indio Dr.	010-175-010	Single Family	15			None	None	Terrace Wall	4
401 Indio Dr.	010-175-011	Single Family	15	yes		None	None	None	4
333 Indio Dr.	010-192-012	Single Family	20			None	None	None	4
329 Indio Dr.	010-192-011	Single Family	20			Improved	None	Shotcrete Wall	4
325 Indio Dr.	010-192-003	Single Family	20			None	None	None	4
323 Indio Dr.	010-192-004	Single Family	17			None	None	None	4
319 Indio Dr.	010-192-005	Vacant	Vacant			None	None	None	4
315 Indio Dr.	010-192-006	Single Family	10			Improved	None	None	4
311 Indio Dr.	010-192-007	Single Family	65			None	None	Terrace Wall	4
307 Indio Dr.	010-192-008	Single Family	0	yes		None	None	None	4
303 Indio Dr.	010-192-009	Single Family	20			None	None	None	4
229 Indio Dr.	010-204-001	Single Family	0	yes		None	None	Concrete Wall	4
223 Indio Dr.	010-204-002	Single Family	0	yes		None	None	Concrete Wall	4
219 Indio Dr.	010-204-003	Single Family	0	yes		Improved	None	Terrace Wall	4
215 Indio Dr.	010-204-004	Single Family	0	yes		None	None	None	4
211 Indio Dr.	010-204-005	Single Family	10			None	None	None	4
203 Indio Dr.	010-204-006	Single Family	15	yes		None	None	None	4
201 Indio Dr.	010-204-007	Single Family	20			None	None	Rip-rap	4
125 Indio Dr.	010-205-001	Single Family	15	yes		None	None	None	8
121 Indio Dr.	010-205-002	Single Family	13	yes		Improved	None	Shotcrete Wall	8
117 Indio Dr.	010-205-003	Vacant	Vacant			None	None	None	8
113 Indio Dr.	010-205-004	Single Family	13			None	None	Concrete Wall	4
109 Indio Dr.	010-205-005	Single Family	21			None	None	Shotcrete Wall	4
107 Indio Dr.	010-205-006	Single Family	25			Improved	None	Shotcrete Wall	4
101 Indio Dr.	010-205-007	Single Family	6	yes		None	None	Shotcrete Wall	4
99 Indio Dr.	010-141-043	Single Family	5			Improved	None	None	4
0 Seabridge Court	010-141-028	Park	100			None	Improved	None	
0 Beachcomber Dr.	010-141-051	Park	100			None	Improved	None	
0 Shell Beach Rd. (North)	010-152-018	Park	100			None	Improved	None	
0 Shell Beach Rd. (South)	010-152-018	Vacant	Vacant			Unimproved	Unimproved	None	4
0 Silver Shoals Dr.	010-142-025	Park	100			None	Improved	None	
0 Shell Beach Rd.	010-152-007	Vacant/Residential	100			Unimproved	Unimproved	None	4
2801 Shell Beach Rd.	010-152-008	Residential	60			None	None	None	4
0 Ebb Tide Way	010-143-015	Park	100			None	Improved	None	
2770 Shell Beach Rd.	010-152-028	Vacant/Residential	NA			None	Unimproved	None	4
2757 Shell Beach Rd.	010-041-044	Hotel	105	yes		Improved	Improved	None	4

Table 2: Lot by Lot Data Summary

Address	APN	Existing Development	Estimated Setback From Bluff Edge (feet)	Field Check	Bluff Height (feet)	Vertical Access (none/improved/unimproved)	Top of Bluff Lateral Access (none/improved/unimproved)	Existing Bluff Protection	Estimated Bluff Retreat (inches/year)
2727 Shell Beach Rd.	010-041-018&028	Hotel construction	NA			None	None	None	4
2703 Spyglass Dr.	010-041-035	Hotel	55	yes		None	Improved	None	4
2695 Spyglass Dr.	010-042-001								
2689 Spyglass Dr.	010-042-002								
2685 Spyglass Dr.	010-042-003								
2679 Spyglass Dr.	010-042-004								
2669 Spyglass Dr.	010-042-005	Single Family	30			None	None	None	4
2659 Spyglass Dr.	010-042-006	Single Family	35			None	None	None	4
2631 Spryglass Dr.	010-042-007								
2611 Spyglass Dr.	010-042-008	Single Family	30	yes		None	None	Concrete Wall	4
2595 Spyglass Dr.	010-042-009								
2585 Spyglass Dr.	010-042-010								
2579 Spyglass Dr.	010-042-011	Single Family	21			None	None	Concrete Wall	4
2569 Spyglass Dr.	010-042-012								
2559 Spyglass Dr.	010-042-013	Single Family	18			None	None	Concrete Wall	4
2549 Spyglass Dr.	010-042-014	Single Family	23			None	None	None	4
Solano Road	010-050-001	City Park	--	--	--	--	--	--	--
Seacliff Drive	010-050-002	City Park	--	--	--	--	--	--	--
188 Seacliff Dr.	010-505-014	Single Family	20	yes		None	None	None	4
194 Seacliff Dr.	010-505-015	Single Family	12	yes		None	None	None	4
200 Seacliff Dr.	010-505-016	Single Family	2	yes		None	None	None	4
0 Seacliff Drive	010-505-017	City Park	--	--	--	--	--	--	--
195 Naomi Dr.	010-504-009	Single Family	0	yes		None	None	Shotcrete Wall	4
185 Naomi Dr.	010-501-008	Single Family	12			None	None	Shotcrete Wall	4
181 Naomi Dr.	010-501-007	Single Family	15			None	None	Concrete Wall	4
129 Park Pl.	010-221-045	Easement?	--			None	None	None	2
129 Park Pl.	010-221-043	Residential	120	yes		None	None	None	2
___ Park Pl.	010-221-051	Single Family	12	yes		None	None	None	2
2251 Shell Beach Road	010-221-053	Condominium	2	yes		None	None	Concrete Wall	4
2181 Shoreline Dr.	010-052-022	Single Family	27	yes		None	None	Concrete Wall	4
2171 Shoreline Dr.	010-052-021	Single Family	27			None	None	Concrete Wall	4
2161 Shoreline Dr.	010-052-020	Single Family	30			None	None	Concrete Wall	4
Shoreline Dr.	010-052-019	Vacant	Vacant	yes		None	None	None	4
2141 Shoreline Dr.	010-052-018	Single Family	35			None	None	Concrete Wall	4
2131 Shoreline Dr.	010-052-037	Single Family	32	yes		None	None	None	4
2121 Shoreline Dr.	010-052-039	Single Family	24	yes		None	None	None	4
2111 Shoreline Dr.	101-052-041	Vacant	Vacant			None	None	None	4
2101 Shoreline Dr.	010-052-040	Single Family	32			None	None	Soldier Pile Wall	4
2091 Shoreline Dr.	010-052-013	Single Family	0	yes		None	None	Concrete Wall	4
Shoreline Dr.	010-052-012	Vacant	Vacant			None	None	None	4
2054 Ocean Blvd.	010-221-049	Single Family	18	yes		None	None	Concrete Wall	4
0 Ocean Boulevard	010-231-001343	City Park	--	--	--	--	--	--	--
O Ocean Boulevard	010-301-001	City Park	--	--	--	--	--	--	--
1 Ocean Blvd.	010-302-001	Vacant/Beach	Vacant	yes		None	None	None	4
1400 Ocean Blvd.	010-302-002	Single Family	4	yes		None	None	Concrete Wall	4

Table 2: Lot by Lot Data Summary

Address	APN	Existing Development	Estimated Setback From Bluff Edge (feet)	Field Check	Bluff Height (feet)	Vertical Access (none/improved/unimproved)	Top of Bluff Lateral Access (none/improved/unimproved)	Existing Bluff Protection	Estimated Bluff Retreat (inches/year)
1243 Ocean Blvd.	010-302-013	Single Family	8	yes		None	None	Concrete Wall	4
1201 Ocean Blvd.	010-302-012	Single Family	0	yes		None	None	None	2
1189 Ocean Blvd.	010-302-016	Single Family	17	yes		None	None	None	2
1115 Ocean Blvd.	010-302-021	Single Family	17	yes		None	None	None	2
1101 Ocean Blvd.	010-302-020	Single Family	22	yes		None	None	None	2
1051 Ocean Blvd.	010-302-026	Single Family	22	yes		None	None	None	2
1029 Ocean Blvd.	010-302-027	Single Family	7	yes		None	None	None	2
979 Ocean Blvd.	010-302-028	(Guest House)	8	yes		None	None	None	2
366 Boeker St.	010-311-009	In Construction	30	yes		None	None	None	2
367 Boeker St.	010-312-009	Single Family	8	yes		None	None	None	2
398 Windward Av.	010-371-021	Single Family	9	yes		None	None	None	2
401 Ocean Boulevard	010-355-002	City Park	--	--	--	--	--	--	--
Cliff Avenue	005-250-007	Future City Park	--	--	--	--	--	--	--
Price St.	005-250-010	Open Space	0	yes		None	None	Rip-rap	2
2651 Price St.	005-250-009	Hotel	18	yes		None	Improved	Concrete Wall	2
Price St.	005-250-006	Hotel tennis courts	--	--	--	--	--	--	--
2555 Price St.	005-261-001	Hotel	0	yes		Improved	Improved	Rip-rap	4
Price St.	005-262-001	Open Space?	--	--	--	--	--	--	--
2911 Price St.	005-263-071	Hotel	33			None	None	None	4
2351 Price St.	005-261-006	Hotel	50			Improved	None	None	4
2241 Price St.	005-261-005	Hotel	62	yes		None	Improved	None	4
Ocean Wy.	005-171-010	Vacant	Vacant			Improved	None	None	4
301 Wilmar Ave.	005-052-010	Single Family	22	yes		None	None	None	4
300 Wilmar Ave.	005-053-028	Vacant	Vacant			None	None	None	4
311 Harbor View St.	005-053-026	Single Family	26			None	None	None	4
300 Harbor View St.	005-054-011	Single Family	25			None	None	None	4
1621 Price Street	005-055-009								
1601 Price Street	005-055-008								
295 Harloe St.	005-112-011	Single Family	0			None	None	Terrace Wall	3
251 Harloe St.	005-112-010	Single Family	0			None	None	Terrace Wall	3

4. BLUFF TOP DEVELOPMENT CONSIDERATIONS

The following bluff top development considerations are based on our understanding of Coastal Commission guidelines from our meetings and discussions with their personnel, review of the BEAR guidance document [2], and our evaluation and review of the conditions along the bluffs.

4.1 NEW DEVELOPMENT – development on a vacant parcel

New development along the bluff top can accommodate on-going bluff top retreat by recognizing the potential for coastal erosion, and setting structures back adequately from the seacliff to reduce the potential for buildings and improvements to be impacted by bluff retreat.

Currently there are only 12 privately owned vacant lots that could be developed along the bluff top, one is now in construction and 3 to 5 of the vacant lots have entitlements to develop. The locations of the vacant lots are shown on Plate 9. City codes currently require that structures be setback a minimum of 25 feet from the top of the bluff, or the equivalent distance for 100 years of retreat. An additional buffer (factor of safety) could be added to the 100-year retreat estimate to accommodate processing time with the Coastal Commission and reduce the potential additional armoring to the coastal bluffs to be needed during the life of the structure.

To accommodate this goal, geologic reports prepared for new development should recommend a setback from the top of the bluff by estimating the bluff erosion rate and utilizing a safety factor to estimate an appropriate setback between site improvements and the top of bluff. The geologic reports should consider slope stability, seismic loading, drainage, and any other factors that influence the stability of the seacliff and could require a greater setback. From a geotechnical viewpoint, variances from the front yard setback would be preferred over those from the bluff setback. In addition to the setback, site grading and drainage should be designed to reduce the potential for water to run over the seacliff, and to control areas of concentrated drainage or runoff. Shoreline protection systems typically are not permitted to protect vacant lots or new development.

4.2 REDEVELOPMENT– additions to existing development

Redevelopment or rebuilding on existing lots will generally be subject to the same requirements as for new development. If setbacks are not available to satisfy current code and permit requirements then the setbacks will likely be maximized by locating structures closer to the roadway and away from the bluff top. Building envelopes may need to be reduced to provide a reasonable setback from the top of bluff. Variances from the front yard setback would be preferred over variance from the minimum bluff top setback.

[2] California Coastal Commission (1999), *Beach Erosion and Response Guidance Document*, December.

Accessory structures located within the bluff retreat setback should be permitted only with the understanding that they will need to be removed when they become threatened by bluff retreat. No structure should be approved within the setback that cannot be readily moved back from the seacliff or removed from the property. Protection of such accessory structures should not be the reason for any structural protection of the shoreline.

4.3 PROTECTION OF EXISTING STRUCTURES

Protection of existing lots is an immediate need, and is likely to be an on-going coastal issue for the City. Protection of existing structures is needed when structures become threatened by bluff top retreat. Structural shoreline protection systems (seawalls), stone revetment, and underpinning existing structure with deep foundations have commonly been used to protect existing structures from bluff erosion in Pismo Beach, see Plates 11, 12 and 13.

Plate 10 summarizes the estimated 100-year setback from the existing top of bluff. There are approximately 66 lots with homes located within the estimated 100-year retreat setback, and of those 22 have homes located within the estimated 25-year retreat.

4.4 SLOPE STABILITY

The stability of the seacliff should be considered in geotechnical studies that recommend bluff top setbacks. Instability of the seacliff and overlying terrace can compromise foundation support for buildings and bluff top improvements. Many of the seacliffs are steep or near vertical and could be subject to slope instability due to ongoing erosion, daylighting groundwater on the slope face, prolonged periods of rainfall, or seismic events. Current practice in San Luis Obispo County is to consider a slope stable when geotechnical testing and analyses indicate that the slope has a minimum factor of safety of 1.5 under static loading conditions, and at least 1.1 under earthquake loading conditions when considering a pseudostatic coefficient of 0.15. Structural discontinuities such as joints, faulting, and bedding planes in the rock can also influence slope stability and should be considered in these analyses. Slope stability is likely to be of particular importance to the foundation support of a structure whenever a building is located within a 1:1 line projected upward from the base of the seacliff.

4.5 PUBLIC ACCESS

It is important that sufficient public access to beaches be provided. Lateral access is walkways, parks, and trails along the bluff top. Vertical access is stairways or trails that connect the bluff top to the beach. Apart from safety issues, unimproved trails and pedestrians scrambling down bluff faces can cause significant erosion. Paved walks and structural stairways can be designed to help protect public access points from bluff top and shoreline erosion.

Public access is available at various points along the study area; however, unimproved vertical and lateral access was observed at the site. Improved and unimproved access points are shown on Plate 9. Unimproved lateral access is common on vacant lots where foot trails have

developed to connect improved walkways on adjace nt lots. Unimproved vertical access is common on vacant lots and at City parks particularly at preferred surfing locations.

It is likely that unimproved access will continue. In consideration of managing the bluffs as a City-wide resource, an effort should be made to identify unimproved vertical and lateral access and to improve these access points with stairways or fixed paths to minimize erosion to the seacliff. Maintenance and bluff protection should be provided to maintain access and to reduce the potential bluff erosion, similar to any other bluff top structure.

5. BLUFF PROTECTION

Bluff protection can be provided as part of site development, as routine maintenance of existing property, as an emergency response, or to protect existing structures or bluf f top improvements that have gradually become threatened by ongoing retreat of the bluff top. The threats to public and private property at Pismo Beach can be addressed through a range of techniques. Managed retreat may be necessary in some areas. Commo nly a combination of bluff, site, and shoreline protection measures are necessary to properly manage bluff top development.

In general, the appropriate approach is to do the least amount necessary to the bluff and shoreline in order to achieve the object ive of the project. "Softer" solutions, such as setbacks and landscaping will always be preferred over structural protection the bluff and shoreline.

5.1 DO-NOTHING

Bluff erosion is an ongoing dynamic process that will continue to impact the Pismo Bluffs. Bl uff erosion is typically characterized using an estimated annual historic rate of retreat; however, bluff retreat commonly occurs in episodic events where several to several tens of feet of the bluff top are eroded from a specific area during a single seas on or storm event. Ongoing retreat is likely to continue to encroach upon existing structures located above the seacliff, undermine coastal stairways and seawalls, and erode adjacent lands reducing building setbacks.

Estimated historical rates of bluff to p retreat are typically 4 inches per year along the 5 -mile coastline, 2 -inches per year where there is resistant bedrock that protects the shoreline along South Point and near the Shore Cliff lodge, and on south facing shorelines, and 8 inches per year where terrace deposits are exposed near the shoreline along portions of Indio Drive. Changing sea levels due to changes in the global environment, increased wave energy, tectonic movements, and seismic events can change bluff and oceanic conditions and could either increase or reduce the bluff erosion relative to historical rates of retreat.

5.2 BLUFF TOP SETBACK

Newly or redeveloped lots along the bluff top can accommodate on -going bluff top retreat by recognizing the potential for coastal erosion, and setting s tructures back from the bluff top to reduce the potential for buildings and improvements to be impacted by bluff retreat.

Setbacks are typically provided between structures and the bluff top to allow for ongoing erosion of the seacliff over some period of time as discussed previously in this report.

Setbacks should consider the stability of the existing bluff face, impacts of development on site drainage, and the episodic nature of retreat in addition to the average rate of bluff top retreat. Eventually it can be expected that the shoreline will retreat to the structure; commonly whether bluff protection is provided or not. Current setback requirements are discussed in Section 4.1.1 of this report. In some instances, buildings can be remodeled or reloc ated farther away from the bluff. Accessory structures can be relocated and should not serve as a justification for shoreline protection.

5.3 SURFACE DRAINAGE AND GRADING

Plate 11 summarizes common methods for protecting the bluff top from ongoing erosion due to uncontrolled surface drainage. The terrace deposits are commonly exposed on the seacliffs and are highly erodable. Surface drainage and concentrated flows of runoff should not be allowed to pond near the bluff top or run uncontrolled over the slope. Roof gutters with downspouts, drainage mats, impervious blankets, and underdrains are common improvements that are used to collect surface drainage.

Collected drainage water should be transmitted to solid pipes that connect to onsite or street drainage systems and discharge the water to base of the seacliff. Cantilevered drain pipes are extended out from near the top of bluff to reduce the potential for disturbance to the bluff face during construction. The cantilever pipes should extend out beyond the s horeline so that water discharged from the pipes does not fall directly on the seacliff. Alternatively, collector pipes can be anchored to the bluff face, and outlet on the rocky shoreline or with suitable energy dissipation devices. Wave exposure shoul d be considered when selecting anchorage systems and outlet locations.

Grading on the bluff face is typically not recommended. However, grading may be warranted to repair severely eroded areas or gullies where uncontrolled surface drainage has run over the slope. Plate 10 shows a detail for reconstructing using geosynthetic reinforcements to form a slope that can be landscaped. Conventionally graded slopes without reinforcement can typically be constructed to inclinations of 2h:1v (horizontal to vertical). However, the natural bluff face is commonly steeper than 2h:1v. Geosynthetic reinforcement consists of layers of fabric, wire mats, or plastic grids that are rolled out and placed within the fill to help support the fill and can allow slopes to be con structed to inclinations near-vertical. Access for the construction equipment can be the controlling factor that determines the limits of the repair along the bluff face.

5.4 LANDSCAPING

A common cause of excessive soil moisture, which can lead to slope and b luff failure, is the misuse and/or mismanagement of irrigation water. Problems associated with irrigation are caused by a variety of factors including: over -irrigation (watering beyond the needs of the

plants); broken or missing irrigation components; inadequate or inappropriate irrigation equipment; inadequate vegetative cover; and inappropriate plant material.

An effective method for stabilizing slope and upper bluff areas is to establish a vegetative cover with deep rooted plant materials. Vegetation provides erosion control through the creation of a network of roots. In addition, the surface of the soil is protected from the scarification effect of rain. Vegetative cover should have the capacity to survive (once established) without supplemental irrigation. Native and/or naturalized plant material is recommended for all new planting. It is not recommended, however, to clear mature stands of existing vegetation. The act of clearing vegetation may have a destabilizing impact to the soil on or above the bluff, and make the soil more prone to erosion. In addition, open unprotected soil will persist through the time required to re-establish new vegetation.

5.5 BEACH REPLENISHMENT AND RETENTION

A wide beach provides bluff protection under severe storm wave conditions, in addition to recreational opportunities. It would probably not be practical to attempt to establish a wide sandy beach along the base of the Pismo Bluffs study area as a whole, because the wave energy is both high and directed strongly south over much of the study area (north of Pismo State Beach). These wave characteristics would tend to transport the nourishment sand rapidly toward Pismo State Beach; the natural erosional state of the study area simply does not include a wide sandy beach.

We estimate that ongoing erosion of the seacliffs only contributes approximately 10,000 to 15,000 cubic yards of sediment to the shoreline each year, of which less than half, or approximately 5,000 cubic yards, is likely sand sized or larger grain sizes that will actually be deposited on the beaches. By comparison, approximately 160,000 cubic yards of coarse sediment per year is delivered from the Santa Maria River to the wide beaches to the south.

The coastline in the study area is relatively jagged, with numerous sea stacks and hard rocky headlands flanking softer, more retreated geologic units. Pocket beaches are common in the more retreated areas. It may be feasible to carry out beach replenishment at some of the pocket beaches, but it is not likely that the sediment would be naturally transported to feed other beaches along the bluffs. Beach replenishment can be implemented through obtaining opportunistic (disposal material which becomes available, e.g., from local construction projects) and planned (at market cost) beachfill material. More analysis would be needed to fully assess the feasibility of this approach at Pismo Beach.

5.6 SHORELINE COBBLE MANAGEMENT

In some high-energy wave environments, the erosional impact of waves against the toe of the bluff can be increased by the scouring effect of beach cobbles, or undersized concrete rubble or revetment stone. Conversely, in lower energy wave environments, cobbles and properly placed stone can act to armor the bluff. Cobble management – that is, removing cobbles from

high-energy environments and placing them in nearby low -energy locations – can reduce the problem of cobble scour.

5.7 STRUCTURAL SHORELINE PROTECTION

Structural shore protection alternatives include seawalls, revetment, and seacave and basal notch fill. Plate 12 summarizes common types of structural shoreline protection. Structural shoreline protection can sometimes be used to stabilize the toe of a bluff and reduce the threat of bluff-top property damage. Identification of shore protection needs – including the maintenance needs of existing structures – should be a proactive, not a reactive, effort. Current Coastal Commission policies would allow structural shoreline protection only in cases where existing structure or critical properties are in imminent danger due to bluff erosion. The threats to existing structures and bluff top improvements should be identified and addressed as soon as possible to allow adequate time for permit review, processing and design before the condition escalates to an emergency measure (which cannot always be avoided).

When structural measures are considered, a full range of reasonable alternatives should be studied before final selection and approval. This review would be required as part of the permitting process; permits for shoreline protection structures can be difficult and time -consuming, and in some cases impossible, to obtain. A discussion of the affects of structural shoreline protection is presented in Section 5.10 of this report. The design and permitting of structural shoreline protection will consider potential impacts to adjacent property and overall coastal erosion in addition to protecting the subject property.

Structural shoreline protection should be designed and managed on as wide a reach of coastline as possible. The coastal zones discussed in Section 3.1of this report can be used to identify the coastal areas that are likely to be impacted by shoreline protection structures within that area.

5.7.1 Seawalls

Seawalls are best suited to areas where the shoreline is rocky, and there is no significant beach development at the foot of the cliff. These areas are generally in areas where there are already existing seawalls along the bluffs. There are many types of seawalls available, each with advantages, drawbacks and varying degrees of effectiveness. A cast-in-place pile-supported or gravity concrete wall may be a suitable solution for the many of the bluff locations where seawalls are needed. In locations with an existing patchwork of seawalls, a concrete façade can be applied to unify and improve the overall appearance. This would also have the benefit of reinforcing the weak point at the join between two adjacent seawalls.

Where possible, sea walls should be directly founded in bedrock to reduce or eliminate undermining which is one of the prime vulnerabilities of this type of structure. If the bedrock is deeply buried, a sheetpile wall may be a suitable alternative. However, given that the beaches are likely to be relatively thin along the bluffs, driven sheet pile walls are likely not a practical means of constructing a seawall within the study area.

It is often stated that seawalls exacerbate beach erosion by reflecting the wave energy tha t would otherwise dissipate on the unprotected beach or bluff. This process would narrow the beach further, in addition to the effects of the processes described above. A review of recent field measurements by Everts Coastal (1996) [3] suggests that this effect is less clear -cut than has previously been believed. Greater seasonal changes, and faster loss of sand during storms, have been observed. However, the field evidence that overall erosion rates are greater in front of and close to a seawall is inconcl usive. Because the shoreline along the Pismo Bluffs is relatively resistant and erodes slowly, seawalls appear suitable for some areas and should not adversely impact beach development or access within a reasonable design life (50 - to 100 years or more). Blankets of riprap, stone or artificial barriers can be placed seaward of a seawall to help lessen erosion at the toe of the wall, dissipate wave energy, and limit the height of the wall.

5.7.2 Revetment

Revetment has commonly been placed along the base of ree ntrants or near the mouths of collapsed seacaves to protect against accelerated erosion that has occurred in these areas. Revetment constructed of large stones can be an effective means of protecting the base of bluffs from wave induced scour by effectiv ely dissipating wave energy within voids between stones, rather than reflecting wave energy as occurs with solid walls. This may decrease the impact to beaches and to adjacent property (edge effects). In addition, the cost of constructing and maintaining revetment is significantly lower than seawalls.

However, revetment may be considered aesthetically unpleasing to some people, and encroach onto already narrow beaches. Revetment can also pose a hazard to beach users who fall or injure themselves climbing on the structure. Rock revetment may be appropriate in areas where they do not impede public use of the beach, for example, in rocky reentrant areas.

5.7.3 Colored Shotcrete Fill of Seacaves and Basal Notches

Shotcrete material can be injected into seacaves, us ed to stabilize intensely fractured or eroding rock masses, and as basal notch fill at the bluff toe to fill the void and help support unstable rock structure above. The fill may also support the overlying bluff and improve protection against lower bluff failure. Shotcrete is best suited for rocky shoreline that is relatively resistant but may have localized geologic structure, basal notches or open joints that are resulting in accelerated erosion of the seacliff. Shotcrete can be used to stabilize the ar eas and minimize the impact to the seacliff that may result from the construction of more robust seawalls. Shotcrete can be reinforced and anchored to the bedrock if necessary, and colored and sculpted to match the bluff face.

[3] Everts Coastal (1996), *Supplemental Analysis: Environmental Effects of the Proposed Del Playa Seawall*, Prepared for Santa Barbara County Planning and Development

Shotcrete has commonly been used along portions of the shoreline, sometimes in lieu of properly designed seawalls or to stabilize the terrace from headward erosion. Other alternatives, such as erosion control matting with suitable vegetation can be better suited for protection against surficial erosion of the terrace soils than shotcrete.

5.8 COORDINATION OF SHORELINE PROTECTION

Structural shoreline measures should be implemented in a coordinated fashion, both to minimize outflanking and potential end effects, and for aesthetic purposes. A patchwork of individual seawalls and revetment can be much more visually obtrusive than a continuous system, for example a continuous concrete seawall colored and textured to match the appearance of the surrounding rock. Standardized stability, functional and aesthetic requirements should be specified for shore protection throughout the study area.

5.9 UNDERPINNING OF EXISTING STRUCTURES

Plate 13 summarizes concepts for underpinning existing structures that are threatened by bluff retreat and instability. Underpinning typically consists of placing a new deep foundation and/or retaining wall system beneath or in front of the structure that needs protection, and designing this system to retain the soils behind the bluff in the event that the bluff is eroded away in front of the structure. These concepts have been used on previous private and commercial projects along the bluffs. Drilled shaft foundations associated with the underpinning have become exposed in the seacliff at some locations. Deep foundations have typically consisted of cast-in-place drilled shafts that are embedded into the underlying bedrock or below the beach. Tiebacks can be drilled and grouted into sound material beneath the structure to provide lateral support for the relatively slender deep foundation elements or retaining walls.

5.10 IMPACTS OF STRUCTURAL SHORELINE PROTECTION

Structural shore protection alternatives include seawalls, revetment, and seacave and basal notch fill. When structural measures are considered, a full range of reasonable alternatives are typically studied before final selection and approval. This review will be required as part of the permitting process; permits for shoreline protection structures can be difficult and time-consuming, and in some cases impossible, to obtain. The main issues that should be considered in the design and permitting of structural shoreline protection are:

- Whether or not structural shoreline protection is the only practical means to protect the existing structure or property from imminent danger or destruction.
- Structural shoreline protection does not protect the beach seaward of the structure location, nor if properly designed does the structure prevent a beach from forming. On an eroding coastline such as Pismo Beach, if shoreline protection is constructed onshore of an eroding beach, the beach will continue to erode until the structure is reached.
- Where bluff erosion provides a significant contribution to the local sediment supply, shoreline protection that slows or halts that erosion will decrease the sediment supply. This

may in turn cause the beaches to narrow further, both at the protection structure and down-coast of the structure. Coastal bluff retreat and erosion along the wave platform appear to be the main source of sediment to the narrow beaches along the bluffs. Mitigation for this loss of beach sand should normally include compensation for the quantity of sand that would have been supplied from the bluff had it not been protected. Impacts of this loss of sand at and south of Pismo State Beach are expected to be small to negligible: the primary source of sediment in this area is the Santa Maria River.

- Seawalls and revetment can further narrow an already existing beach by encroachment. This is a much smaller effect for seawalls, which can be constructed to be very narrow (up to a few feet wide). Unengineered revetment – piles of rock placed haphazardly on the beach at the toe of an eroding bluff – encroach more than do engineered and carefully constructed revetment, in which the stones are carefully placed to attain a stable slope and reduced footprint.
- Structural shoreline protection does not prevent erosion of adjacent land, or of the beach in front of the protection structure. Along an eroding sea cliff, the bluff adjacent to the structure may retreat landward of the structure, possibly resulting in erosion of the bluff behind the structure (outflanking). Outflanking can lead to failure of the shoreline protection, and so to failure of the bluff. In addition, once the beach o n either side of the structure has retreated landward of the structure, the beach in front of the structure may disappear, limiting public access to the remaining beaches.
- Further end effects are possible, particularly after adjacent areas have retreated l andward of a protection structure.
    - First, wave-structure interactions may enhance the erosion rate adjacent to unprotected seacliffs. This impact would be caused mostly by wave reflections from the edge of the structure. There is no clear consensus concer ning when, where, and how much, of an impact this process will cause (Everts 1996) 4. End effects can be difficult to distinguish from the natural level of bluff retreat at adjoining land.
    - Second, an accumulation of sand could form against the upcoast e nds of the structure, and/or erosion downcoast of the structure could be enhanced once the structure projects significantly seaward of the non -armored bluff line. In other words, the armored part of the bluff could act as a groin. For this second type of impact to be significant, the structure would have to extend many tens of feet

[4] Everts Coastal (1996), *Supplemental Analysis: Environmental Effects of the Proposed Del Playa Seawall*, Prepared for Santa Barbara County Planning and Development

beyond the receding bluff – at which point outflanking would likely have occurred.

6. METHODOLOGY

6.1 BLUFF RETREAT

Bluff retreat was primarily estimated from review of historical aerial photographs, review of previous reports, and site reconnaissance. The bluff retreat was typically estimated by comparing the estimated top of bluff between December 15, 2001 aerial photograph pairs provided by the City to historical aerial photograph pairs obtained for selected years ranging back to 1949. The bluff top observed in aerial photographs was compared to other years by measuring from various geographic features that could be identified between photos such as houses, streets, pipelines, ridgelines, predominant drainage paths, and geologic contacts.

Bluff retreat rates are expressed as a historical average rate of retreat within the limits of the photos reviewed (a maximum 52-year period) for the "unprotected" bluff; however, the reported retreat rates are most likely influenced by changes in landuse from agricultural to residential and commercial, seawalls, drainage improvements, and bluff stabilization measures. Overall the retreat rates appear to have decreased in most areas within the 52-year historical record.

Bluff erosion was observed to vary considerably over relatively short distances. To provide reasonable estimates of bluff retreat, Fugro has attempted to estimate average uniform retreat rates for various areas along the bluffs (see Tables 1 and 2 in Section 3 of this report). The rate of retreat and coastal erosion is an episodic process where several feet to several tens of feet of coastline may erode away during a single storm event or season while the bluff top at an adjacent location remains virtually unchanged. The average rates of retreat attempt to characterize an overall rate of retreat that occurs as an accumulation of many ongoing episodic events (such as landslides, headward erosion, and seacave collapses).

6.2 GEOGRAPHIC INFORMATION SYSTEMS

Data obtained from this study was input in a geographic information system (GIS) database. GIS data can be used to reference any form of data spatially so that the data can be recalled in response to various queries. Once the data is spatially located, the data can be accessed to generate maps or tables to present data in other formats or for other uses. The GIS data obtained for this study included:

- An inventory of existing private vacant lots and linkages to existing vertical access (stairways or trails connecting the bluff top to the beach) and lateral access (walkway or trails along the top of the bluffs);

- Geology as modified from the Hall (1973) [5] regional geologic map based on our local data;
- Estimated bluff retreat and 100-year setback by lot number and street address;
- Oblique aerial photos obtained taken from a chartered plane using a digital camera; and
- Historical aerial photographs from 1971 and 1949.

The GIS data was used in conjunction with December 15, 2000 digital aerial photographs, streets, and lot lines provided by the City to generate the geologic map on Plate 6 and the bluff location and setbacks maps shown on Plate 9 in this report. The data is submitted to the City with this report.

7. EROSIONAL PROCESSES

Coastal bluffs are typically subject to three types of erosive natural processes:

- Sea wave erosion at the toe of the bluff that is dependent on the size and frequency of sea waves and the resistance of the shoreline and geologic materials exposed on the seacliff;
- Slope failure of the bluff that is dependent on the strength, geologic structure, and moisture conditions of the soil and rock that form the seacliff under both static and seismic loading conditions; and
- Surface erosion and gradual flattening of the cliff face.

Because there is only a narrow width or no sand fronting the bluffs, the bluffs are exposed to direct wave activity during winter storms. Even in places where a narrow beach is present, it provides little protection. Waves breaking directly onto the face of the bluff cause the most erosion at the bluff toe; this is sometimes exacerbated by scouring from cobbles. The angle of the bluff face near the toe can steepen, often to an overhanging situation, and seacaves and basal notches are well developed in many areas along the bluffs. When the angle at the base of the cliff face is such that the upper portions no longer have sufficient support from underneath, the upper portion collapses.

Erosion of the bluff typically occurs in a stepwise fashion. The greatest erosional force is experienced during storms, and little or no erosion may occur during periods of low storm activity. In addition, if the bluff is composed of jointed or fractured rock, failure of the bluff will tend to occur along existing planes of weakness, joints, bedding planes, or faults in the rock. More generally, the erosion rate is a function of the composition of the bluff as well as of the wave forces.

[5] Hall (1973). *Geology of the Arroyo Grande 15' Quadrangle*, San Luis Obispo County, California, U.S. Geological Survey, Scale: 1:48,000.

8. COASTAL PROCESSES

8.1 COASTAL SETTING

The study area includes the five-mile stretch of coastline from Harloe Avenue, just north of the Pismo Beach Pier, through unincorporated Shell Beach, north to the Pismo Beach city limits. The coastline trends from northwest to southeast through this area. For simplicity, when referring to relative locations along the coast, upcoast is herein referred to as north and downcoast as south. Upcoast (to the north and west) of Pismo State Beach, the coastline within the study area is actively eroding and retreating. The coastline displays the typical erosional features of sea cliffs, seacaves, and sea stacks throughout the study area. As is also typical for erosional coastlines, there has been little or no long-term sand deposition, so that beaches are narrow or absent. The absence of beaches appears to be the natural state of the coastline, rather than a direct result of human activities.

8.2 WAVE SETTING

Waves approach the study area from a directional window oriented to the south through the west. Plate 2 shows the directional window for the southernmost limit of the study area. Moving upcoast through the study area, the shoreline along Indio and The Bluffs Drive becomes progressively more sheltered from northwesterly winds and swells by Point San Luis.

8.2.1 Significant Wave Height

Large waves in this general area of the California coast are usually due to a combination of swell generated by winter storms in the North Pacific and locally generated seas. The study area is protected from northwesterly swells by the coastline near Point San Luis, with the largest waves typically approaching from the west. The wave exposure of the study area is similar to that at the Diablo Canyon Buoy (Coastal DIP 2001); the location of this buoy is shown in Plate 2. Plate 3 shows the probable wave height distribution for the Diablo Canyon Buoy. Plate 4 shows the significant wave height statistics measured by the Diablo Canyon buoy since June 1983 for the summer months (May though October) and the winter months (November through April) since June 1983.

The "significant wave height" is defined as the average height of the highest one-third of waves measured in a given period. The maximum observed wave between June 1983 and November 2001 had a significant wave height of 21 feet, on January 11, 2001. However, such large waves as this break offshore, and the amount of energy that reaches a beach or bluff is limited by the nearshore water depth and slope.

8.2.2 Wave Distribution

Plate 4 gives the wave direction distribution for the winter months; the most common directions are from due west or slightly north of west. The highest winter waves come from almost due west (270º). In contrast, during the summer months there is a small secondary peak

resulting from Southern Hemisphere storm swell. The wave heights asso ciated with this secondary peak are relatively small, however, typically 5 feet.

The southernmost limit of the study area is only slightly more sheltered than Diablo Canyon, and similar wave heights are expected. Moving upcoast through the study area, the shoreline becomes progressively more sheltered from northwest storms; however, the coastline is still exposed to swell from the west to southwest. Only at the far northern end of the study area, past Palisades Park, does the additional sheltering of the coastline by Point San Luis become significant.

Over the past 50 years, Northern Hemisphere cyclones have become more intense and have tended to move towards the south (Graham and Diaz 2001). [6] For example, Graham and Diaz report that in the study area the hindcast 99th percentile significant wave height has increased by 20% in that time. The combination of higher and more southerly winds, if it continues, can be expected to increase the rate of bluff erosion.

8.3 WATER LEVELS

Water levels in the Pismo Beach region can be represented by those measured at Port San Luis. Characteristics from the Port San Luis gage are as follows.

Table 3: Water Levels (NOS 2001)

Datum	Height (feet, MLLW)
Extreme High (observed 1/73)	7.77
MHHW	5.39
MHW	4.68
MSL	2.83
MLW	1.04
MLLW	0.00
Extreme Low (observed 1/51)	-2.20

Bluffs are more vulnerable to storm -wave induced erosion during high tides, because, as mentioned previously in this report, the maximum amount of wave energy that reaches a bluff is strongly related to the depth of water at the toe of the bluff.

[6] Graham, N.E. and H.F. Diaz (2001), "Evidence for Intensification of North Pacific Winter Cyclones since 1948", *Bulletin of the American Meteorological Society*, 82, pp. 1869 – 1893.

Storm surge is relatively small, although not insignificant, when compared with tidal fluctuations. For example, the winter storm of January 17 and 18, 1988 produced the all time record low barometric pressure (Chambers Group).[7] Water levels measured by NOS (2001) at the San Luis Obispo gage during this event were at most 1.5 feet above predicted astronomical levels.

A statistical analysis of recorded water surface elevations at Los Angeles Harbor (the reference station for Port San Luis) gives the following statistics for extreme high water elevations, based on measurements from 1924 through 1988. The corrected values for Port San Luis are also given.

Table 4: Extreme Water Level Statistics at Los Angeles Outer Harbor (1924 – 1988) and Corrected for Port San Luis

Recurrence Interval (years)	Height (feet, MLLW) Los Angeles	Height (feet, MLLW) Port San Luis
5	7.60	7.45
10	7.70	7.55
25	7.83	7.67
50	7.92	7.76
100	8.00	7.84

In addition to the short-term fluctuation in the sea surface, long-term sea level rise should also be considered. Predictions of future sea level rise are uncertain, depending on the influence of global warming. The state of the art predictions generally range from 0.5 feet to 1.2 feet by the year 2050 (Titus and Narayanan 1995[8], Woodworth 1995[9], Douglas 1992[10]). A sea level rise of 0.02 feet per year is a reasonable estimate.

[7] Chambers Group, Inc. (1992), Final Environmental Impact Report / Environmental Assessment for the BEACON Beach Nourishment Demonstration Project. Prepared for BEACON.

[8] Titus, J.G. and V.K. Narayanan (1995), *The Probability of Sea Level Rise*, U.S. EPA 230-R-95-008.

[9] Woodworth, P.L. (1990), "A Search for Accelerations in Records of European Mean Sea Level", International Journal of Climatology **10**, pp. 129-143

[10] Douglas, B.C. (1992), "Global Sea Level Acceleration", J. Geophys. Res. **97**(C8), pp. 699-706

8.4 SEDIMENT TRANSPORT

The sand in the beaches south of Shell Beach, including Pismo State Beach, is believed to originate in the Santa Maria River. Pismo Beach lies at the far northern end of the Santa Maria Littoral Cell. Fossil Point, just west of Mallagh Landing, is a complete littoral barrier that prevents sediment from San Luis Obispo Creek from reaching the study area (Everts 2001)[11].

The largest source of sand to the Santa Maria Littoral Cell is the Santa Maria River, near the south of the littoral cell and about 20 miles south of Pismo Beach. Approximately 500,000 cubic yards of sand per year were delivered to the river mouth before the construction of Twitchell Dam upstream of the Santa Maria River in 1958 (Kroll 1974 [12], Knudsen et al. 1992[13], Moffatt & Nichol Engineers 2001[14]). The volume of sand that is delivered to the river mouth has since dropped to approximately 160,000 cubic yards per year. These volumes are larger than those assumed in the widely quoted sediment budget originally prepared in 1966 for this littoral cell (Bowen and Inman 1966[15], U.S. Army Corps of Engineers 1986[16]) and fully account for the sediment observed in the cell. The 1969 floods demonstrated that the Santa Maria River sources more sediment than was previously believed; it is not necessary to assume an offshore source of sand, as was done in the earlier study.

There is essentially no net transport of sediment north of Pismo State Beach. Wave refraction around Point San Luis causes waves to strike Pismo State Beach directly onshore, and the headlands at Shell Beach are a partial or complete barrier to the transport of sand (Everts 2001)[17]. Therefore, the beaches at and to the north of Shell Beach are much narrower than those

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[11] Everts, Dr. Craig, Everts Coastal (2001), personal communication, November 20.

[12] Kroll, C.G. (1974), *Estimate of Sediment Discharges, Santa Ana River at Santa Ana and Santa Maria River at Guadalupe California*, U.S. Geologic Survey.

[13] Knudsen, K., B. Hecht, D.O. Homes and I. Flaschka (1992), *Hydrologic and Geomorphic Factors affecting Management of the Lower Sisquoc River Alluvial Corridor, Santa Barbara County, California*, Prepared by Balance Hydrologics, Inc. for SP Milling Company

[14] Moffatt & Nichol Engineers (2001). *Santa Maria River and Estuary Enhancement Plan, Phase 1 Final Engineering Report*, prepared for The Dunes Center, November 1.

[15] Bowen, A.J. and D.L. Inman (1966), *Budget of Littoral Sands in the Vicinity of Point Arguello, California*, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Memo #19.

[16] U.S. Army Corps of Engineers (1986), *Southern California Coastal Processes Data Summary*, Ref. No. CCTSWS 86-1

[17] Everts, Dr. Craig, Everts Coastal (2001), personal communication, November 20.

to the south. The larger beaches in the study area north of Pismo State Beach are believed to be composed of sand locally generated from shoreline and bluff erosion .

The rate of bluff erosion may have been affected by human activities. Seawalls have been constructed at Pismo Beach to reduce bluff erosion; this may have caused further narrowing of the beached by restricting this supply of sand. Conversely, some act ivities may have increased the rate of bluff erosion. For example, poorly planned drainage can cause surface water to run over the face of a sea cliff, causing surface erosion; excessive irrigation at the top of a bluff can cause the soil to become satura ted, leading to slope failure. Aerial photos from 1949 show that much of the bluff top in the Shell Beach area was used for agriculture, with the fields graded right up to the top of the seacliff.

Before Twitchell Dam trapped much of the sediment supply t o the Santa Maria River, the Pismo-Nipomo Dunes south of Pismo Beach were accreting at a long -term rate of more than 2 feet per year. Since the construction of Twitchell Dam, the shoreline in this region has been relatively static, while the shoreline nea r Guadalupe, in the southern half of the littoral cell, has retreated at up to 2 feet per year (Moffatt & Nichol Engineers 2001) [18]. Shoreline retreat in the southern part of the littoral cell will likely continue, and extend north towards Pismo Beach. In the long term (several decades), Pismo State Beach is likely to retreat. At present, however, the lack of sand fronting the bluffs at Pismo Beach appears to result primarily from the local geology and sand supply, rather than from large -scale human activ ities.

9. GEOLOGIC CONDITIONS

9.1 GEOLOGIC SETTING

Pismo Beach is located in the Coast Ranges geologic and geomorphic province. The Coast Ranges province consists of north-northwest-trending Jurassic- to recent-age sedimentary, volcanic, and igneous rocks extend ing from the Transverse Ranges to the south into northern California. The rocks are faulted and folded as a result of both local and regional tectonic movements. The regional geology as mapped by Hall (1973) [19] is illustrated on Plate 5. The local geologic conditions along the coastline of Pismo Beach, as modified from Hall' s map, are shown on Plate 6.

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[18] Moffatt & Nichol Engineers (2001). *Santa Maria River and Estuary Enhancement Plan, Phase 1 Final Engineering Report*, prepared for The Dunes Center, November 1.

[19] Hall (1973). *Geology of the Arroyo Grande 15' Quadrangle*, San Luis Obispo County, California, U.S. Geol ogical Survey, Scale: 1:48,000.

The terrain in the project area is dominated by the Pismo bluffs that range in height from approximately 20 to 110 feet in height. The bluffs are bound by an adjacent coastal plain that is occupied by the City of Pismo Beach, and furthered by the foothills of the San Luis Range. The base of the San Luis Range borders the northeastern boundary of the city beyond Highway 101. The bluffs are comprised of a v ariable thickness of marine terrace deposits that overly various Miocene-age sedimentary and volcanic rocks.

9.2 STRATIGRAPHY

Exposed in the bluffs and on the adjacent foothills are terrace deposits (Qt), Pismo Formation (Tmp), Monterey Formation (Tmm), Obisp o Tuff (Tmo) and Rincon Formation (Tmr). The locations of these units are shown on the geologic maps on Plates 5 and 6. The bluff face is locally displaced by landslide deposits (Qls) or covered by artificial fill materials (Af) that are not always shown on the maps.

9.2.1 Terrace Deposits (Qt)

The terrace deposits consist predominantly of sand and gravel bound in a clay matrix. The terrace is deposited over the Monterey Formation, Pismo Formation, and Obispo Formation where exposed in the seacliff. The terra ce deposits are relatively cohesive in a dry state and stand vertically to several tens of feet in height at various locations along the bluffs. The marine terrace deposits along the bluff exhibit a relatively low resistance to erosion however, and are likely to become unstable when erosion undercuts the base of the slope or surface water is allowed to run over the top of the bluff. Erosion of underlying bedrock by storm wave action, uncontrolled or concentrated surface water runoff, and subsurface ground water seepage that daylights on the seacliff have resulted in erosion at the toe and headward areas of the terrace. Subsequently, the terrace deposit slope steepens and soil instability or landsliding occurs.

9.2.2 Pismo Formation (Tmpe, Tmpm, Tmps)

The Edna (Tmpe), Miguelito (Tmpm) and Squire (Tmps) members of the Pismo Formation (Tmp) are exposed at various locations along the seacliff (Plate 6). The Edna member consists of basal conglomerate and bituminous sandstone. The Miguelito member consists of claystone and shale. Between Spyglass Drive and the Florin cul -de-sac on Indio Drive, the Edna member of the Pismo Formation has eroded to a relatively thin remnant of bituminous sandstone and shale that unconformably overlies the Monterey Formation at va rious locations (Plate 6.1).

It appears that the Edna Member was deposited in a preexisting topographic depression on the surface of the Monterey Formation. A basal conglomerate is encountered above the Monterey Formation at Florin and near Silver Shoal s. The basal conglomerate is overlain by bituminous sandstone also of the Edna Member. At the southerly end of Spyglass Drive, the bituminous sandstone outcrops as a black relatively rounded mass of tar -sand type material. There is also an outcrop of Pismo Formation sandstone at the point of a headland at Ocean Park.

The bituminous units of the Edna sandstone are generally well cemented and resistant to weathering, but have some well-developed jointing. The jointing and bitumen content of the sandstone appear to be limiting factors on the overall strength and erosion resistance of the formation. A prominent joint set orientation is roughly parallel with the bluff face, and appears to control the overall orientation of the base of the bluff.

The Squire member of the Pismo Formation is exposed on the seacliff southerly of the Wilmar Avenue Fault north of Harloe Avenue. The Squire member is a white moderately weathered sandstone with limited outcrops.

9.2.3 Monterey Shale (Tm)

The Monterey Formation generally consists of interbedded dolomitic to cherty shale strata. The shale of the Monterey Formation is exposed on the majority of the bluff north from Florin to the near the northerly City limit where the shale is in fault contact with Obispo tuff (Plate 6.1 and 6.2). Southerly of Florin, the Monterey Formation crops out intermitmently from beneath a relatively thin veneer of Pismo Formation bituminous sandstone, conglomerate, and claystone. The shale crops out more commonly from beneath the Pismo Formation between Spyglass Park and the northerly end of South Point. At South Point (the southerly limit of Ocean Park) the Monterey Formation is in fault contact with the Obispo tuff. The contact between the Monterey shale and Obispo tuff is an area of significant retreat that may be associated with softer rocks and folding near the fault zone. The contact between the shale and the tuff is the likely extension of the Pismo fault mapped by Hall (1973) [20], and inferred by Lettis et al. (1994) [21] as being further to the south.

The shale strata are locally severely tectonically deformed, resulting in tight folding, jointing, and minor faulting. Seacaves appear to be developed in areas where deformation is more intense. Although the bedding planes within the Monterey Formation are commonly weak and known to influence the stability of slopes, the bedding planes within the shale seldom dip adversely out of the bluff face, and then only at relatively shallow angles. Slight adverse bedding orientations and a shallow bedrock exposure at the base of the seacliff appear to influence the bluff retreat near Florin. Otherwise, the Monterey Formation appears moderately resistant to erosion. The erosion and shape of the bluff is most commonly oriented along joint sets perpendicular to the bedding orientation, and local near-vertical bedding that strikes into the seacliff.

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[20] Hall (1973). *Geology of the Arroyo Grande 15' Quadrangle*, San Luis Obispo County, California, U.S. Geological Survey, Scale: 1:48,000.

[21] Lettis, W.R. et al. (1994). "Quaternary Deformation of the San Luis Range, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 111 –132.

9.2.4 Obispo Formation (Tmot, Tmor, Tmof)

Obispo Formation is the predominant rock that forms the steep cliffs along South Point, Dinosaur Caves, the Shore Cliff Lodge, and the white cliffs between the Shore Cliff Lodge and Wilmar Avenue (Plates 6.2 and 6.3). The tuff is relatively resistant and forms irregular shore lines, seacaves, and overhangs along South Point and Dinosaur Caves. The tuff is well bedded near Margo Dodd Park and Dinosaur caves with relatively steep bedding and joint sets that dip into the seacliff to form dramatic overhangs of nearly 30 feet.

White fine-grained tuff is exposed on the majority of seacliff southerly of the point at Shore Cliff Lodge and north of Harloe Avenue (Plate 6.3). The white tuff is only moderately resistant. Seacaves are common along wide-spaced but predominant joint sets in the tuff. The erosion of the seacaves along these joints and the subsequent collapse of the sea caves are significant factors influencing the rate of seacliff retreat in this area.

9.2.5 Rincon Formation (Tr)

Rincon Formation consists of dark brown to black siltstone and claystone. The Rincon Formation is exposed on the Seacliff where the Wilmar Avenue fault is exposed (Plate 6.3). The exposure of the Rincon Formation is relatively limited at the fault location. The Rincon Formation is bound by the Squire Member of the Pismo Formation southerly of the fault.

9.3 STRUCTURE AND FAULTING

The predominant geologic structure in Pismo Beach is the Pismo syncline (Hall 1973) [22]. The axis of the syncline is mapped along the Avila Valley north of the city. The city is located on the westerly limb of the broad open fold of the Pismo syncline. Compression along the syncline has resulted in a series of low to high angle reverse and thrust faults that intersect the bluffs at various locations. These faults are mapped by Hall (1973) [23] and Lettis et al. (1994)[24] and are shown on Plate 5.

The San Luis Range is traversed by a series of west- to northwest-trending faults and folds. The following provides a summary of the predominant mapped faults in the project area.

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[22] Hall (1973). *Geology of the Arroyo Grande 15' Quadrangle*, San Luis Obispo County, California, U.S. Geological Survey, Scale: 1:48,000.

[23] Hall (1973). *Geology of the Arroyo Grande 15' Quadrangle*, San Luis Obispo County, California, U.S. Geological Survey, Scale: 1:48,000.

[24] Lettis, W.R. et al. (1994). "Quaternary Deformation of the San Luis Range, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 111–132.

The San Luis Range fault includes a series of faults such as the San Luis Bay, Wilmar Avenue, San Miguelito, Olson trace, Santa Maria River, and Oceano faults in the CDMG (1996) fault database. The northern end of the Wilmar Avenue fault and the southern end of the San Miguelito fault intersect the seacliff as shown on Plates 5 and 6.3. The San Luis Range is generally mapped as a zone of faulting that is generally parallel to Highway 101 through Pismo Beach. The resulting zone of faulting included in the CDMG database is similar in seismic source potential to a blind thrust fault system mapped in the area by Namson and Davis (1990) [25].

The San Miguelito fault is not considered to be active by CDMG (Jennings 1994) [26]. It is a roughly 5.5-mile long west- to northwest-trending zone of normal faulting with primarily high-angle dip-slip movement. The fault intersects the coastline near the northern end of the study area as show on Plate 5. According to Lettis et al. (1994) [27], late Quaternary marine terraces that cross the northwestern and southeastern projections of the San Miguelito fault zone do not show signs of deformation. It is likely that the San Miguelito fault zone has not had any movement during the late Quaternary. As discussed above, CDMG (1996) includes the San Miguelito fault within the San Luis Range fault zone in their fault database.

The Pismo Fault is not considered to be active by CDMG (Jennings 1994) [28]. It is a relatively short fault mostly exposed in the Obispo Formation trending northwest across South Point/Old Shell Beach and Highway 101 as shown on Plates 5 and 6.2. According to Lettis et al. (1994)[29], late Quaternary marine terraces that cross the southeastern projection of the Pismo fault zone do not show signs of deformation. The Pismo Fault does appear to form the contact between Monterey Shale and the Obispo Tuff near the southerly end of Ocean Park.

The Wilmar Avenue Fault strikes west-northwest and extends westward from Arroyo Grande Creek about 4 miles to Pismo Beach, where the fault is exposed in the seacliff. Jennings

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[25] Namson, J.S., and Davis, T.L. (1990), "Late Cenozoic fold and thrust belt of the southern Coast Ranges and Santa Maria basin, California", *American Association of Petroleum Geologists Bulletin*, v. 74, p. 467-492.

[26] Jennings, C.W. (1994), *Fault activity map of California and adjacent areas*, California Division of Mines and Geology, Geologic Map No. 6, Scale 1:750,000.

[27] Lettis, W.R. et al. (1994). "Quaternary Deformation of the San Luis Range, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 111 –132.

[28] Jennings, C.W. (1994), *Fault activity map of California and adjacent areas*, California Division of Mines and Geology, Geologic Map No. 6, Scale 1:750,000.

[29] Lettis, W.R. et al. (1994). "Quaternary Deformation of the San Luis Range, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 111 –132.

(1994)[30] considers the fault potentially active. The fault is known primarily from a seacliff exposure near Wilmar Avenue in the City of Pismo Beach, where it reportedly displaces the 120,000-year-old terrace a vertical distance of 6.4 meters (Lettis et al.1994)[31].

Nitchman and Slemmons (1994)[32] map the eastern segment of the Wilmar Avenue fault extends between Price Canyon and Arroyo Grande Creek. The eastern section of the fault is not exposed at the surface and is interpreted by Nitchman and Slemmons to be a blind reverse fault that has formed a surficial monocline. That interpretation is based partially upon geologic data obtained from the "Farmboy" quarry where there are steeply folded rocks on the north side of U.S. Highway 101 and essentially flat rocks of about the same age on the south side of the highway. As discussed above, CDMG includes the Wilmar Avenue fault within the San Luis Range fault zone.

The Los Osos fault is considered active by CDMG (Jennings 1994)[33] and segments of the fault are included in the Alquist-Priolo fault zone near San Luis Obispo. The onshore portion of the Los Osos fault zone is a series of discontinuous, subparallel and en echelon fault traces that extend from Morro Bay to Lopez Reservoir. Four fault segments have been identified for the Los Osos fault. The segments are: Estero Bay, Irish Hills, Lopez Reservoir, and Newsom Ridge (Lettis and Hall 1994)[34]. CDMG totals the fault segments to be approximately 30 miles in length. However, the different styles of faulting along the Edna-Los Osos fault zone do not necessarily support combining the individual fault segments as a single connected fault system.

Other active and potentially active faults in the project area include the offshore Hosgri fault, the West Huasna fault, the Rinconada fault, the Nacimiento fault, and the San Andreas fault.

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[30] Jennings, C.W. (1994), *Fault activity map of California and adjacent areas*, California Division of Mines and Geology, Geologic Map No. 6, Scale 1:750,000.

[31] Lettis, W.R. et al. (1994). "Quaternary Deformation of the San Luis Range, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 111 –132.

[32] Nitchman, S.P., and Slemmons, D.B. (1994), "The Wilmar Avenue fault: A late Quaternary reverse fault near Pismo Beach, California", *Seismotectonics of the Central California Coast Ranges*: Geological Society of America Special Paper 292, p. 103-110.

[33] Jennings, C.W. (1994), *Fault activity map of California and adjacent areas*, California Division of Mines and Geology, Geologic Map No. 6, Scale 1:750,000.

[34] Lettis, W.R. and Hall, N.T. (1994) "Los Osos Fault Zone, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 73-102.

9.4 SEISMICITY

Pismo Beach is within a seismically active region of central California that has experienced strong ground motion in response to earthquakes in the historical past. The City is located in relatively close proximity to numerous mapped faults of varying reported activity.

9.4.1 Historical Seismicity

The closest faults with reported historic seismic activity are the offshore and northern San Luis Obispo County faults within the Hosgri -San Simeon fault zone, the active Los Osos fault zone that is mapped along Los Osos Valley Road, the Oceano fault, and the San Andreas fault mapped along the boundary of eastern San Luis Obispo County. Earthquakes that have occurred in relatively close proximity to the site include the M5 San Luis Obispo earthquak e of 1830; the M5.0 San Simeon earthquake of 1853; a M5.0 earthquake near Lopez Canyon in 1917; a M5.1 earthquake near Avila in 1916; a M5 earthquake near Arroyo Grande in 1913, the M6.2 Bryson earthquake in 1952; a M5 earthquake offshore of Santa Maria in 1980, a M5.4 earthquake also near San Simeon in 1983; and the M6.7 Coalinga earthquake in 1983. The project area has also been subjected to ground motion from the 1812, 1857, 1906, 1934, 1952, 1966 and 1989 earthquakes along the San Andreas fault. Histo rical records report several of these earthquakes in close proximity to the site, and are discussed below:

1830 San Luis Obispo Earthquake. The 1830 earthquake is noted in the annual report from the Mission, and has an estimated magnitude of M5 (PG&E 1988)[35]. The location of the event is poorly constrained and cannot be attributed to a specific fault source, but the earthquake reportedly occurred somewhere near San Luis Obispo.

1916 Avila Beach Earthquake. This magnitude M5.1 event occurred offshore of Avi la Beach in San Luis Bay (PG&E 1988) [36]. The earthquake reportedly resulted in tumbling smokestacks of the Union Oil Refinery at Port San Luis, and a landslide that blocked the rai lroad tracks. However, the available descriptions of the shaking are somewhat limited. The earthquake was located near the mapped trace of the San Luis Bay fault (Lettis et al. 1994) [37].

1952 Bryson Earthquake. This magnitude M6.2 earthquake likely occurred on the Nacimiento fault, and was reportedly felt throughout most of the Cou nty. Higher intensities were

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[35] PG&E (Pacific Gas & Electric Company) (1988). *Final Report of the Diablo Canyon Long-Term Seismic Program*. U.S. Nuclear Regulatory Commission Docket Nos. 50 -275 and 50-323.

[36] PG&E (Pacific Gas & Electric Company) (1988). *Final Report of the Diablo Canyon Long-Term Seismic Program*. U.S. Nuclear Regulatory Commission Docket Nos. 50 -275 and 50-323.

[37] Lettis, W.R. et al. (1994). "Quaternary Deformation of the San Luis Range, San Luis Obispo County, California." *Seismotectonics of the Central California Coast Ranges*, Geologic Society of America Special Paper 292, 111 –132.

generally felt in the coastal valley areas that are underlain by alluvial soils. If this event is associated with the Nacimiento fault, then the fault is active, and not inactive as referred to in the CDMG (1996)[38] database and by Jennings (1994)[39].

9.4.2 Seismic Hazard Evaluation

The Pismo Bluffs are located in a seismically active region of central California relatively close to mapped active and potentially active faults. Peak horizontal ground accelerations for the site were estimated using probabilistic seismic hazard analyses. The intent of our evaluation was to characterize the seismic exposure of the site relative to the probability that earthquakes occurring on active and potentially active faults mapped within a 62-mile (100-kilometer) radius could generate strong ground motion at the site. The ground motions were estimated relative to an arbitrary location selected on Ocean Boulevard near South Point.

The probabilistic seismic hazards evaluation was completed using the Windows version of the computer program FRISKSP (Blake 2000)[40] and the CDMG (1996)[41] southern California fault database. The program FRISKSP is based on FRISK (McGuire 1978)[42] and has been modified for the probabilistic estimation of seismic hazards using three-dimensional earthquake sources.

The fault search routine in FRISKSP found 15 active and potentially active mapped faults and fault segments within the 100-kilometer radius of the site. A summary of the fault characteristics for twelve faults and fault segments that were considered to be the most capable of producing the high ground motion at the site is presented in Table 5 below.

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[38] California Division of Mines and Geology (1996), *California Fault Parameters*, DMG Open-File Report 96-08.

[39] Jennings, C.W. (1994), *Fault activity map of California and adjacent areas*, California Division of Mines and Geology, Geologic Map No. 6, Scale 1:750,000.

[40] Blake, T.F. (2000), "FRISKSP - A computer program for the probabilistic estimation of peak acceleration and uniform hazard spectra using 3-D faults as earthquake sources", Windows Version 4.0.

[41] California Division of Mines and Geology (1996), *California Fault Parameters*, DMG Open-File Report 96-08.

[42] McGuire, R.K. (1978), "FRISK - Computer program for seismic risk analysis using faults as earthquake sources." *Open File Report No. 78-1007*, United States Geological Survey (USGS), Reston, Virginia.

Table 5: Results of Fault Search

Fault or Fault Segment	Distance from Site (miles)	Maximum Moment Magnitude (M_w)	Fault Length (km)	Slip Rate (mm/yr)
San Luis Range (S. Margin)	<0.1	7.0	64	0.2 ± 0.1
Los Osos	4	6.8	44	0.5 ± 0.4
Hosgri	10	7.3	172	2.5 ± 1.0
Rinconada	14	7.3	189	1.0 ± 1.0
Casmalia (Orcutt Frontal Fault)	15	6.5	29	0.25 ± 0.2
Lions Head	20	6.6	41	.02 ± .02
San Juan	32	7.0	68	1.0 ± 1.0
Los Alamos (W. Baseline)	34	6.8	28	0.7 ± 0.7
San Andreas (Cholame)	42	6.9	62	34 ± 5
San Andreas (1857 Rupture)	42	7.8	345	34 ± 5
San Andreas (Parkfield Segment)	46	6.7	37	34 ± 5
North Channel Slope	50	7.1	60	2.0 ± 2.0

Note: All acceleration values are in units of g (9.81 m/s ^{2} or 32 ft/s^2). 1 kilometer (km) = approximately 0.6 miles.

The program FRISKSP was used to estimate peak horizontal ground accelerations associated with the following earthquake ground motions:

- Design-Basis Earthquake Ground Motion: An earthquake having a 10 percent chance of being exceeded in 50 years (Statistical Return Period ≈ 475 Years).
- Upper-Bound Earthquake Ground Motion: An earthquake having a 10 percent chance of being exceeded in 100 ye ars (Statistical Return Period ≈ 950 Years).

The probabilistic analyses were performed using the Boore et al. (1997) [43] attenuation relationship assuming randomly oriented components of peak acceleration as well as the NEHRP site class "D" designation. A si te class "D" designation includes stiff soil and indicates that material in the upper 30 meters (100 feet) of the site has an average shear wave velocity ranging between 180 and 360 meters per second. A summary of the probabilistic evaluation is presented in Table 6.

[43] Boore, D.M., Joyner, W.B., and Fumal, T.E. (1997). "Equations for Estimating Horizontal Response Spec tra and Peak Acceleration from Western North American Earthquakes: A Summary of Recent Work." *Seismological Research Letters*, Volume 68, Number 1, Seismological Society of America.

Table 6: Results of the Probabilistic Seismic Hazard Analysis

Ground Motion Parameter	Design-Basis Earthquake (10% in 50 Years)	Upper-Bound earthquake (10% in 100 Years)
Peak Horizontal Ground Acceleration	0.40	0.55

Note: All acceleration values in units of g (9.81 m/s^2 or 32 ft/s^2)

The results of the probabilistic analysis are also summarized on Plates 7 and 8. The analysis is presented as a plot of probability of exceedance versus peak ground acceleration for exposure periods of 50 and 100 years assuming all 15 fault sources identified by the fault search. The second plot shows the peak ground acceleration versus the average return period versus assuming all 15 fault sources, and versus the average return period of selected individual fault sources that have historically been most active or are relatively close to the site. Either of the plots can be used to estimate the data presented in Table 6.

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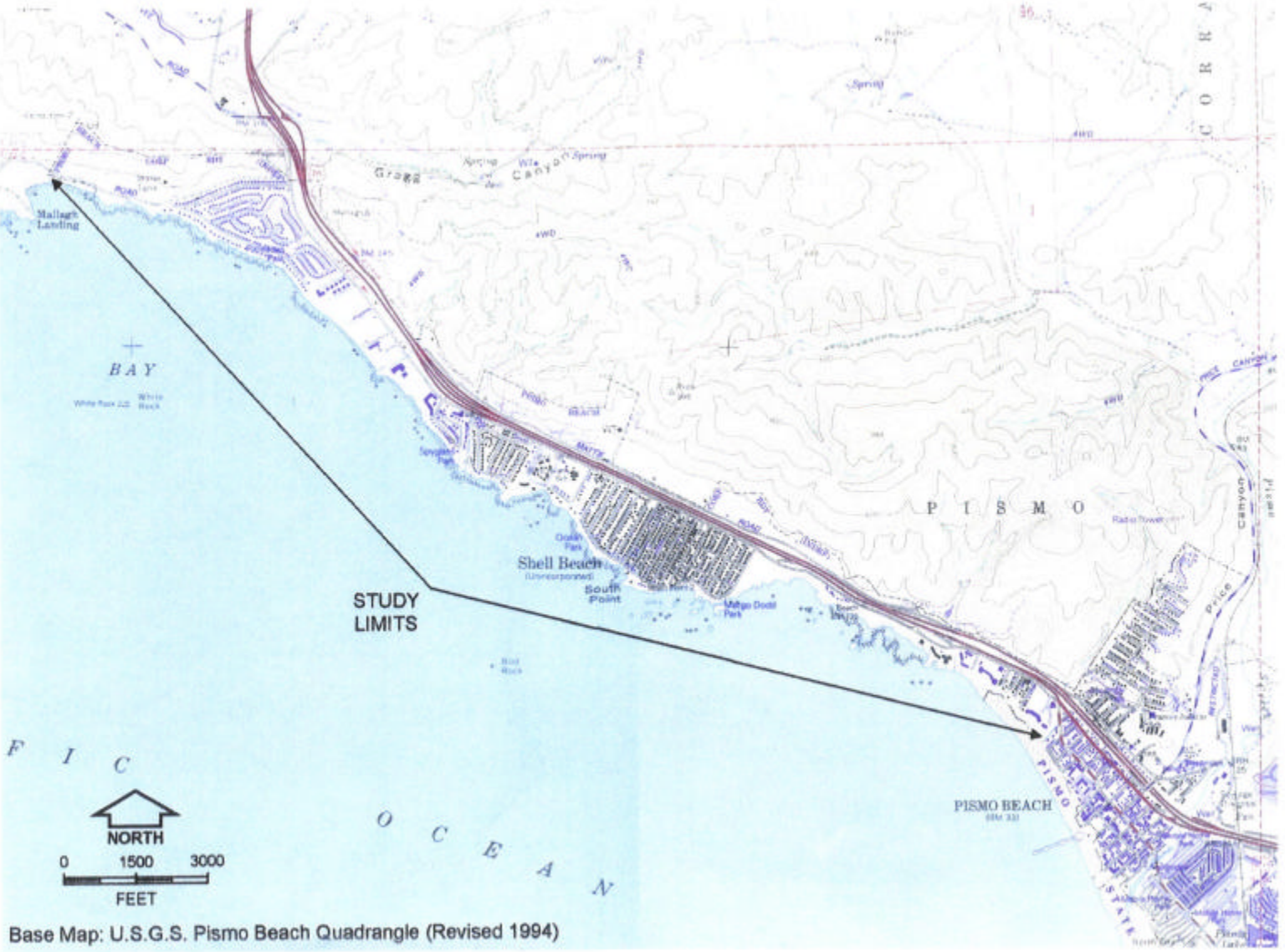
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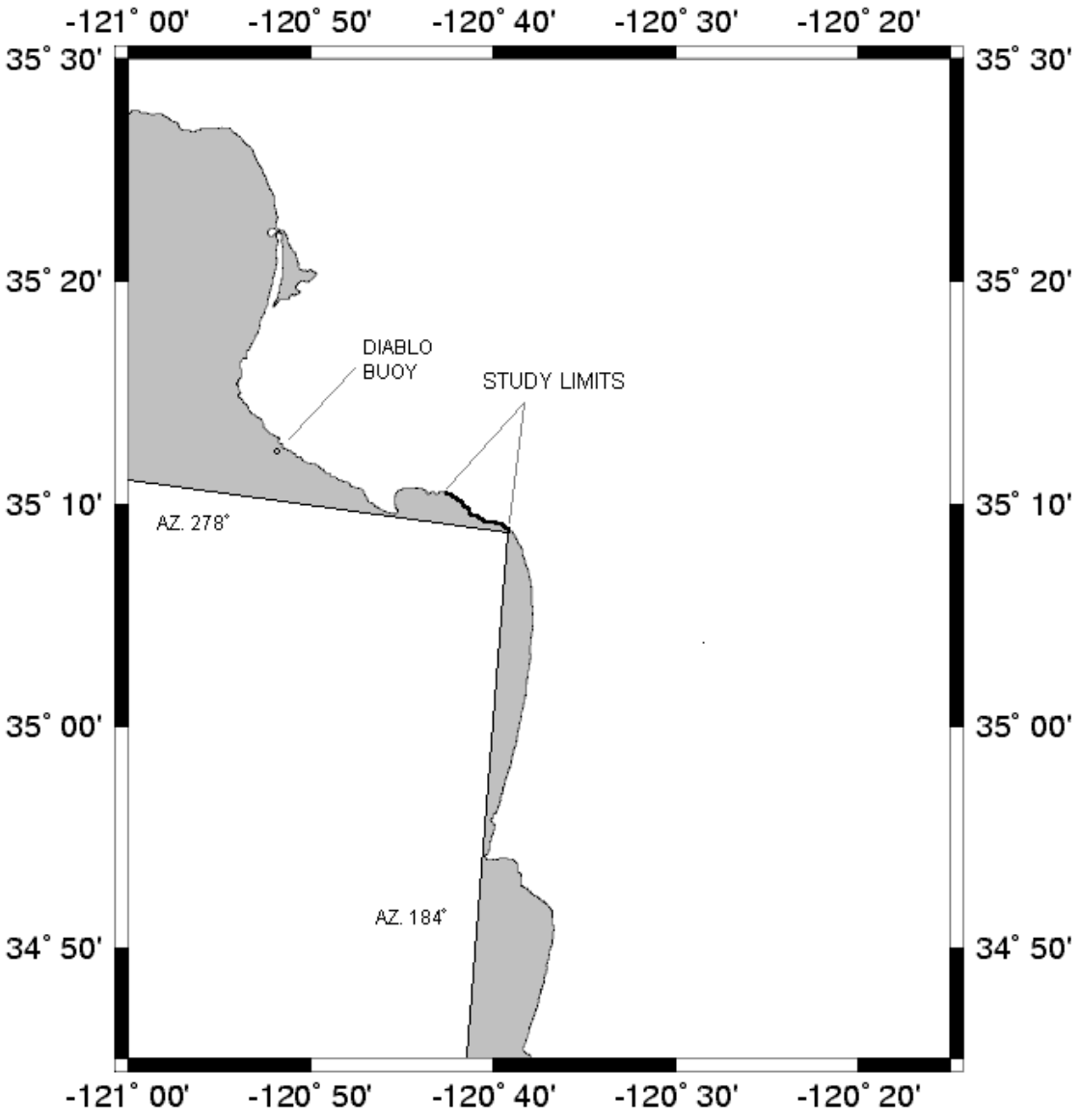
Base Map: U.S.G.S. Pismo Beach Quadrangle (Revised 1994)

VICINITY MAP
1992 Bluff Erosion Study Update
Pismo Beach, California

PLATE 1

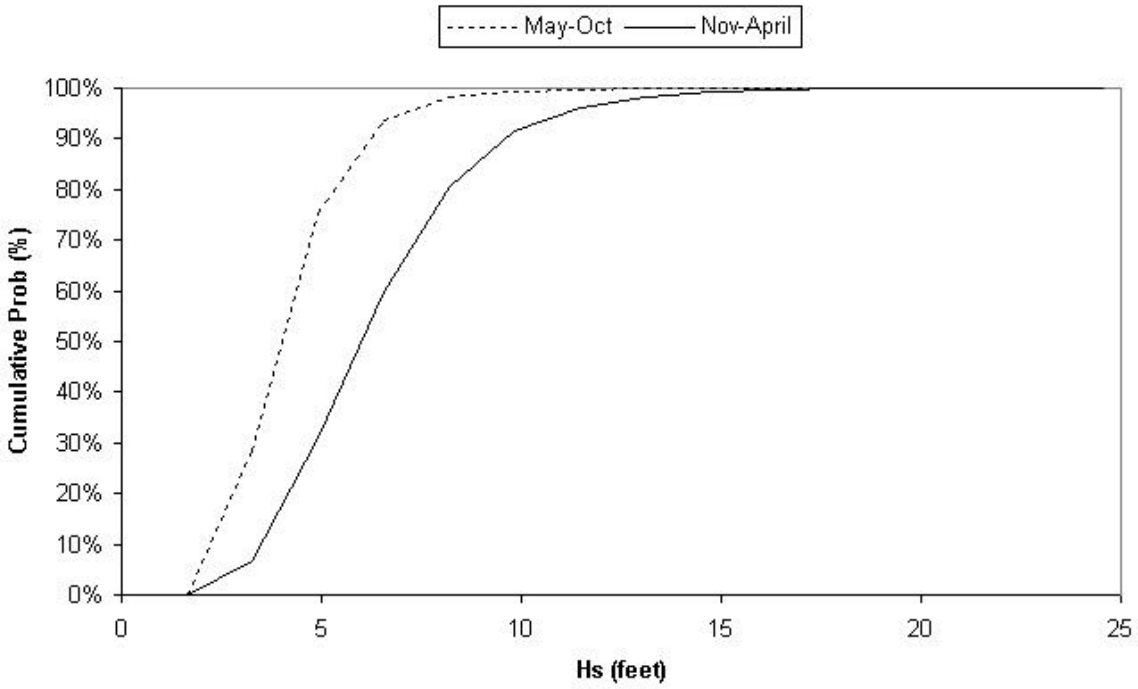
City of Pismo Beach
Project No. 01-52-1541

FUGRO



Base map: NOAA/NOS Medium Resolution Coastline Data
Prepared by Moffatt & Nichol Engineers

WAVE EXPOSURE
(FOR SOUTHERN LIMIT OF THE STUDY AREA)
1992 Bluff Erosion Study Update
Pismo Beach, California

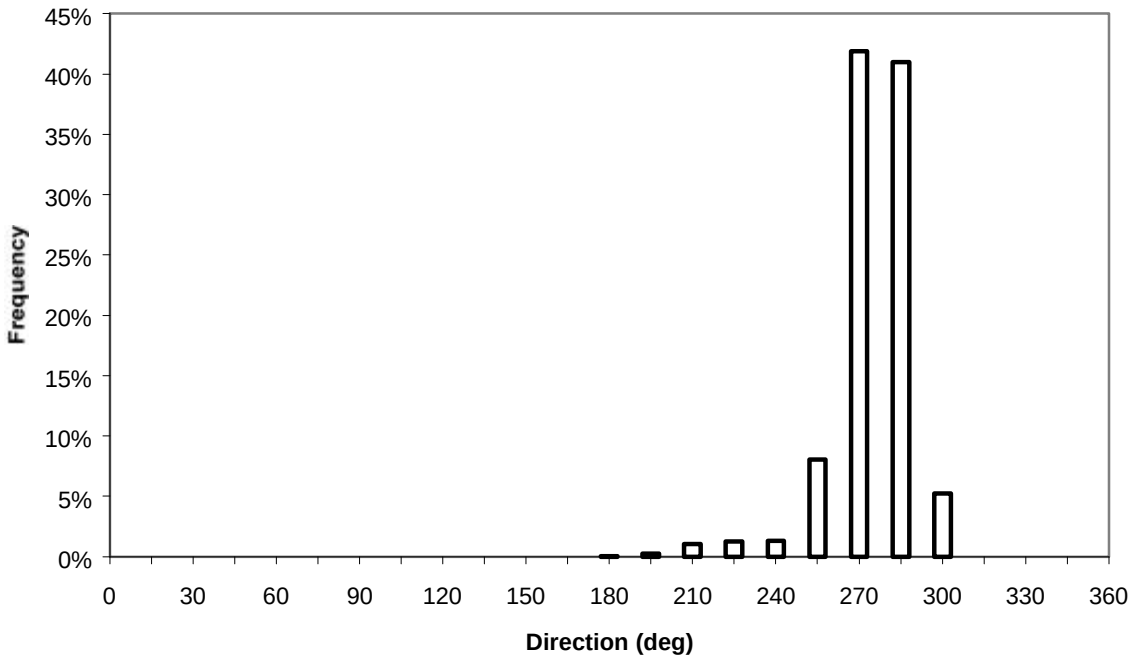


Prepared by Moffatt & Nichol Engineers

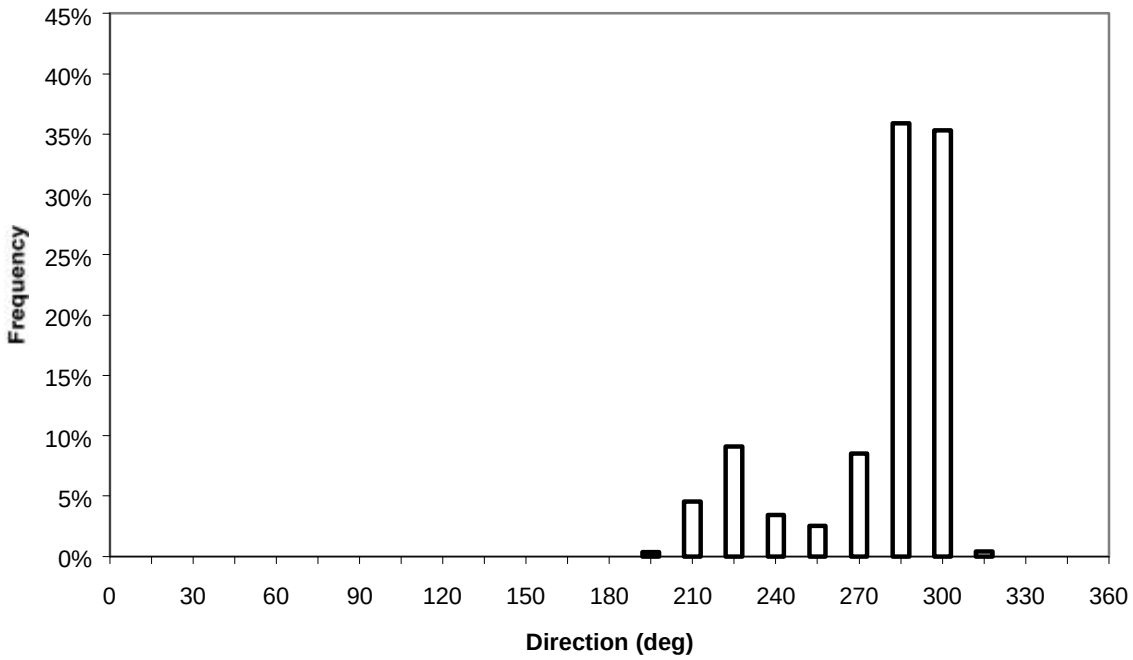
WAVE DIRECTION DISTRIBUTION
(FOR DIABLO CANYON BUOY-SUMMER AND WINTER)
1992 Bluff Erosion Study Update
Pismo Beach, California

PLATE 3

WINTER (NOVEMBER-APRIL)

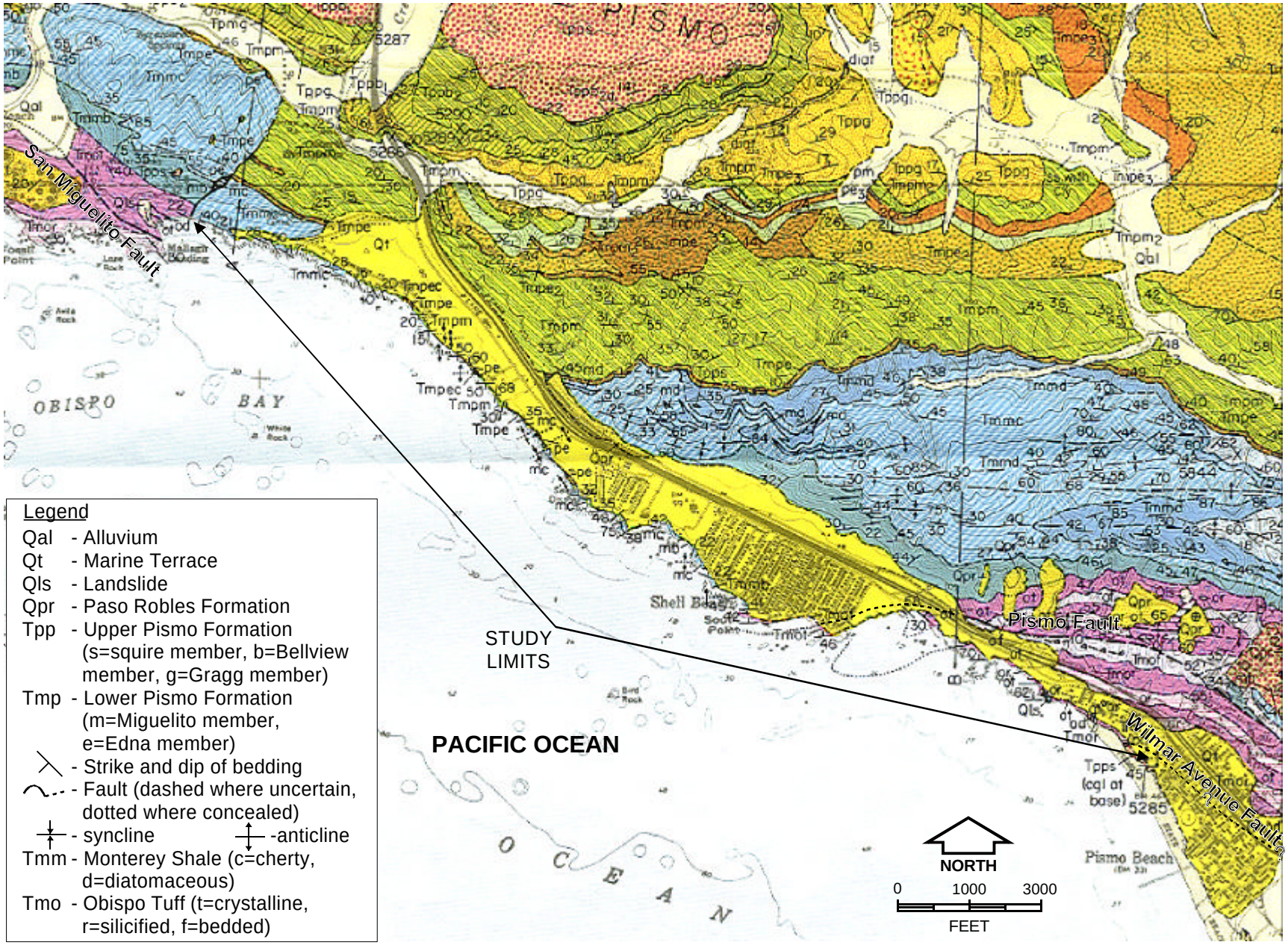


SUMMER (MAY-OCTOBER)



Prepared by Moffatt & Nichol Engineers

WAVE DIRECTION HISTOGRAM
(FOR DIABLO CANYON BUOY-SUMMER AND WINTER)
1992 Bluff Erosion Study Update
Pismo Beach, California

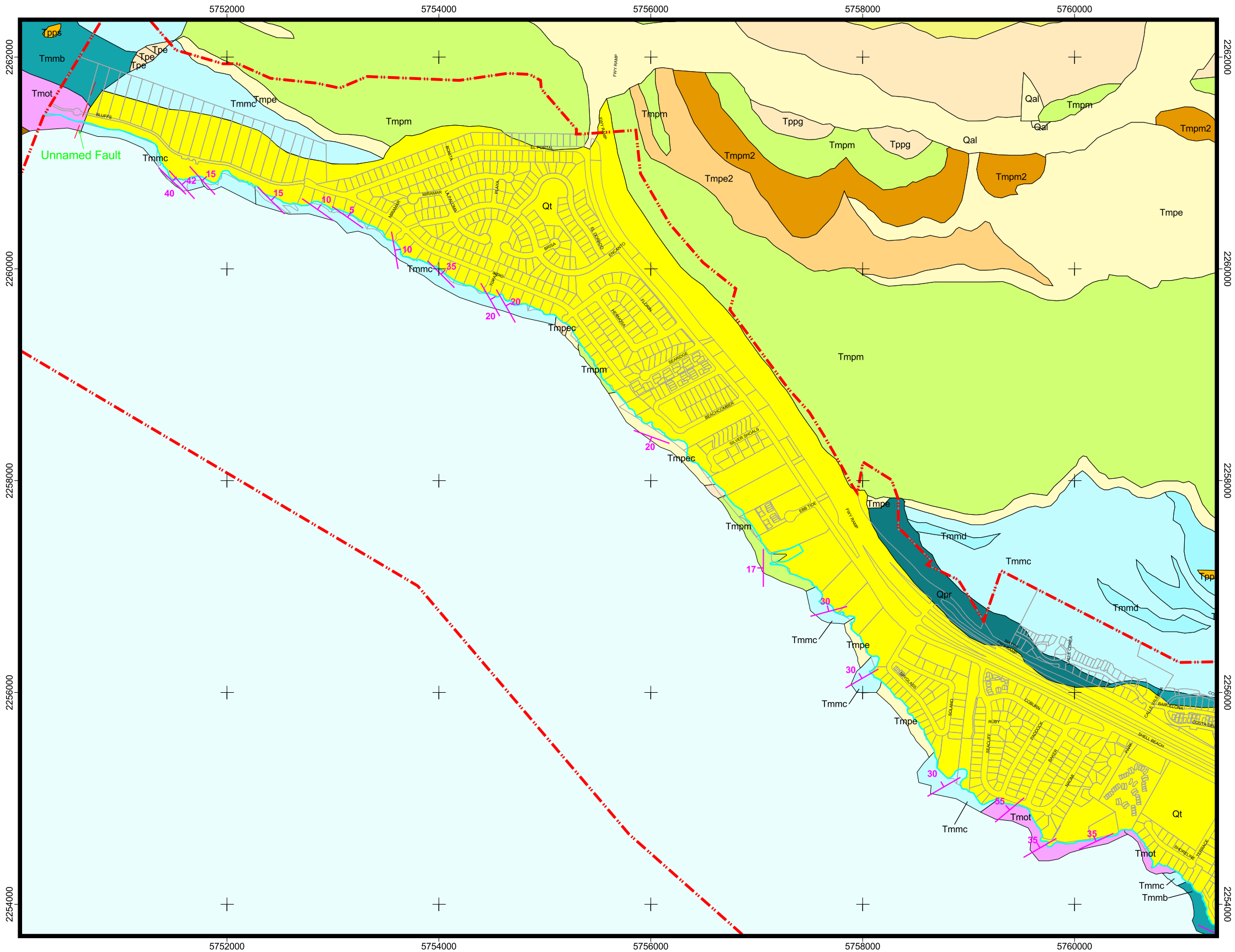


BASE MAP SOURCE: Geology Map of the Arroyo Grande 15' Quadrangle.

PLATE 5

REGIONAL GEOLOGIC MAP

1992 Bluff Erosion Study Update
Pismo Beach, California



LEGEND

- Parcel Boundaries
- Pismo Beach City Boundary
- Bluff Line
- Faults
- 20 Strike and Dip of Bedding

Qal -Alluvium
Qt -Marine Terrace
Qls -Landslide
Qpr -Paso Robles Formation
Tpp -Upper Pismo Formation (s=squire member, b=Bellview member, g=Gragg member)
Tmp -Lower Pismo Formation (m=Miguelito member, e=Edna member, c=conclomerate)
Tmm -Monterey Shale (c=cherty, d=diatomaceous)
Tmo -Obispo Tuff (t=crystalline, r=silicified, f=bedded)

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 1,000 feet

1000 0 1000 Feet

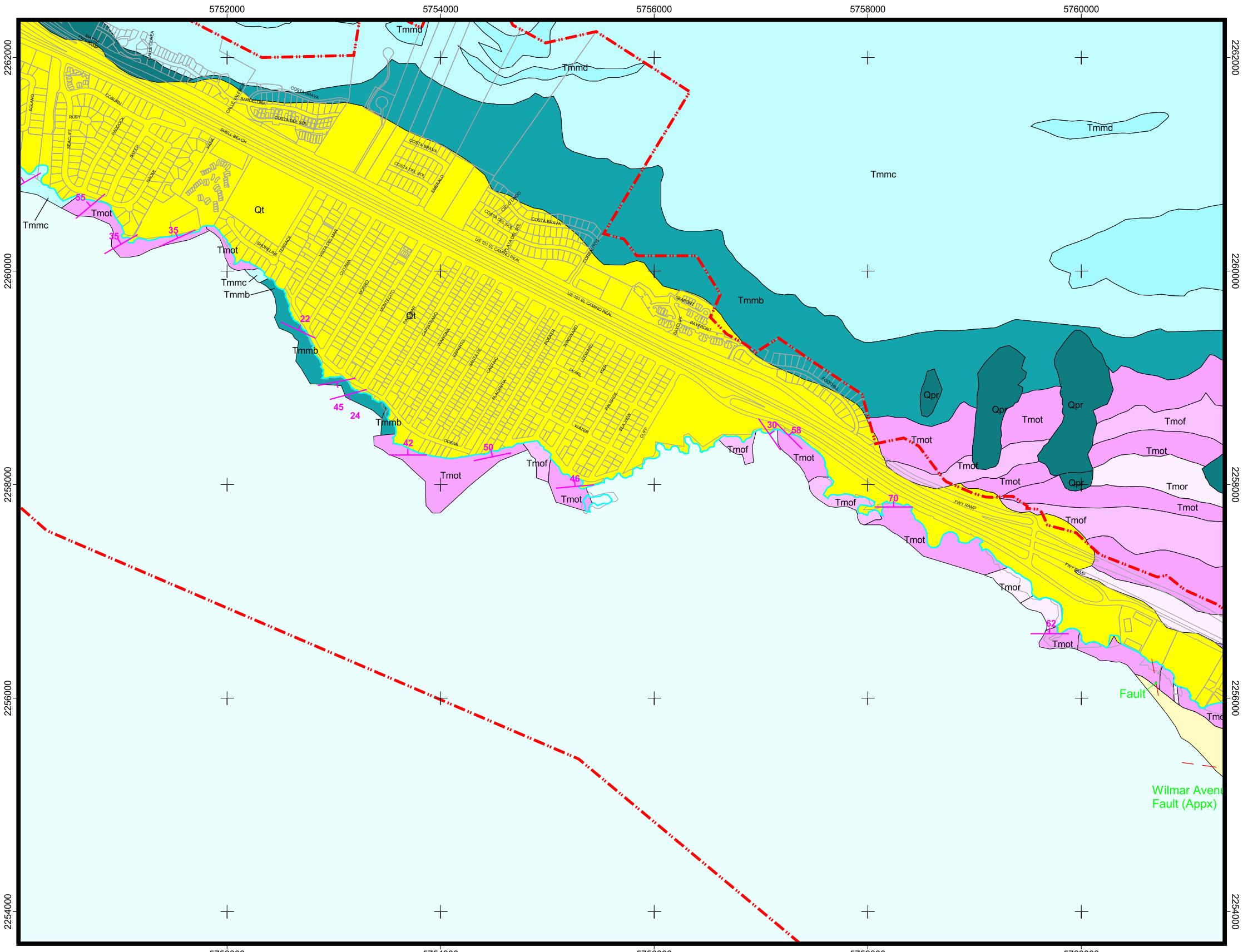
Geology

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 6.1

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LEGEND

- Parcel Boundaries
- Pismo Beach City Boundary
- Bluff Line
- Faults
- 20 Strike and Dip of Bedding

Qal -Alluvium
Qt -Marine Terrace
Qls -Landslide
Qpr -Paso Robles Formation
Tpp -Upper Pismo Formation (s=squire member, b=Bellview member, g=Gragg member)
Tmp -Lower Pismo Formation (m=Miguelito member, e=Edna member, c=conclomerate)
Tmm -Monterey Shale (c=cherty, d=diatomaceous)
Tmo -Obispo Tuff (t=crystalline, r=silicified, f=bedded)

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 1,000 feet

1000 0 1000 Feet

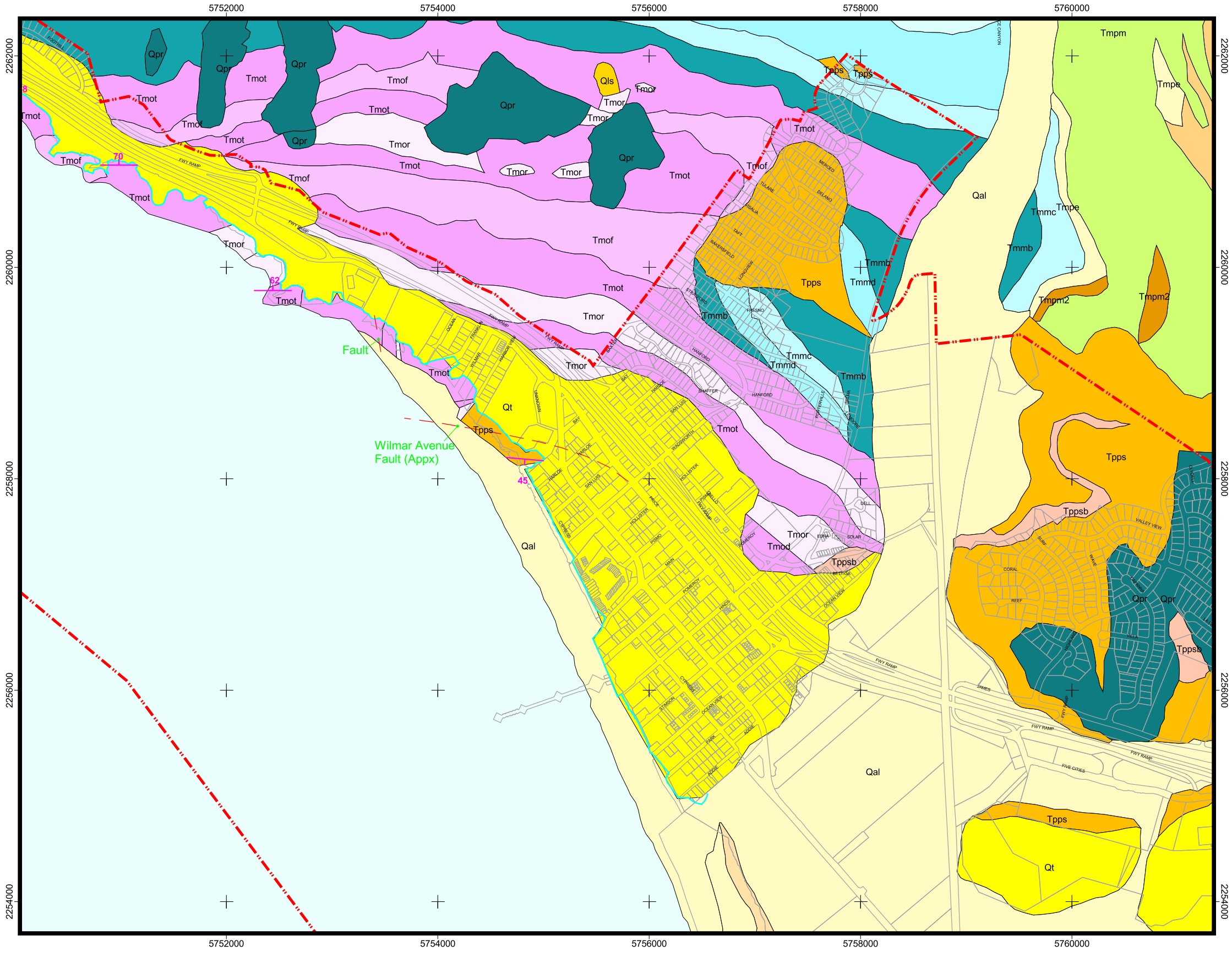
Geology

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 6.2

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LEGEND

- Parcel Boundaries
- Pismo Beach City Boundary
- Bluff Line
- Faults
- 20 Strike and Dip of Bedding

Qal	-Alluvium
Qt	-Marine Terrace
Qls	-Landslide
Qpr	-Paso Robles Formation
Tpp	-Upper Pismo Formation (s=squire member, b=Bellview member, g=Gragg member)
Tmp	-Lower Pismo Formation (m=Miguelito member, e=Edna member, c=conclomerate)
Tmm	-Monterey Shale (c=cherty, d=diatomaceous)
Tmo	-Obispo Tuff (t=crystalline, r=silicified, f=bedded)

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 1,000 feet

1000 0 1000 Feet

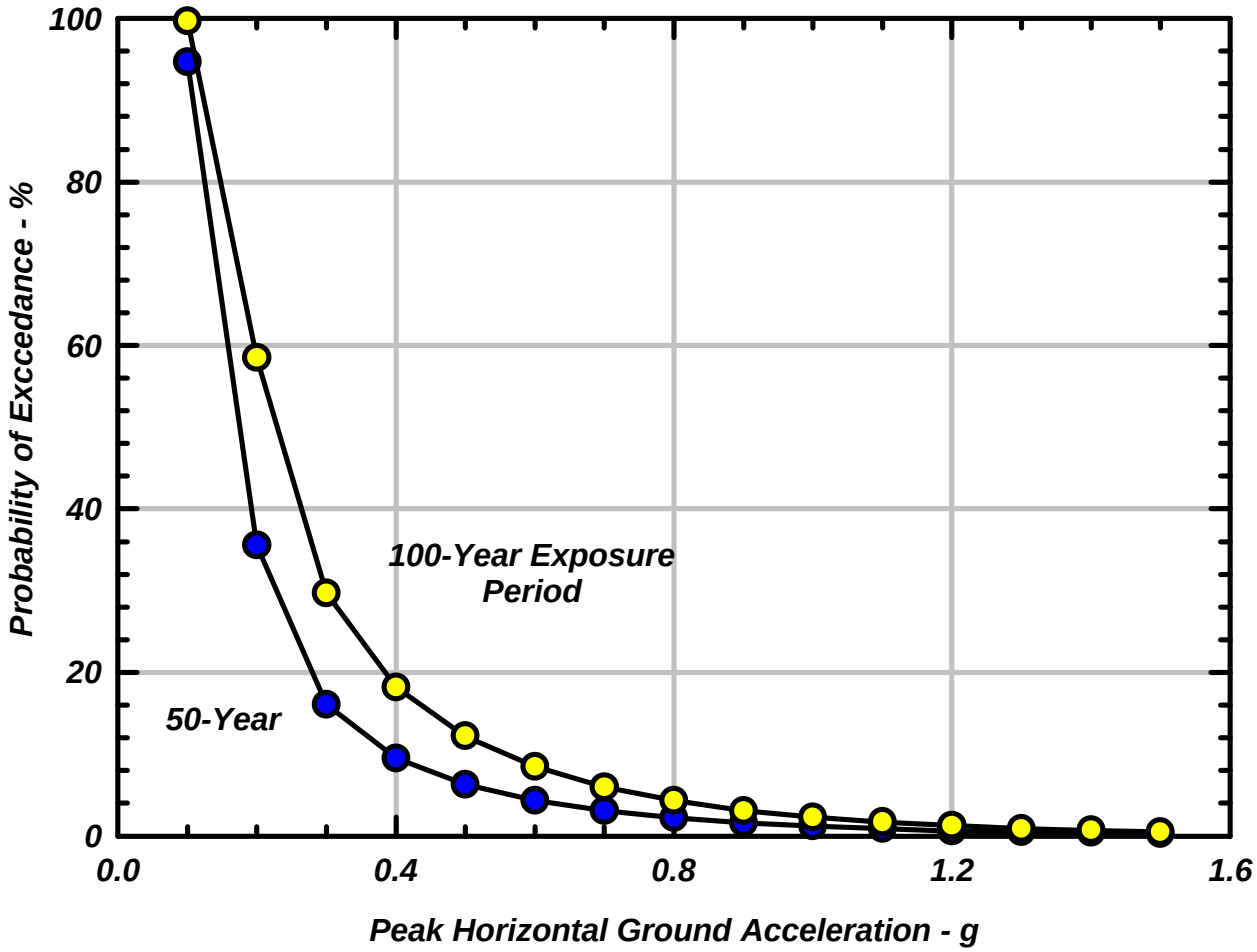
Geology

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 6.3

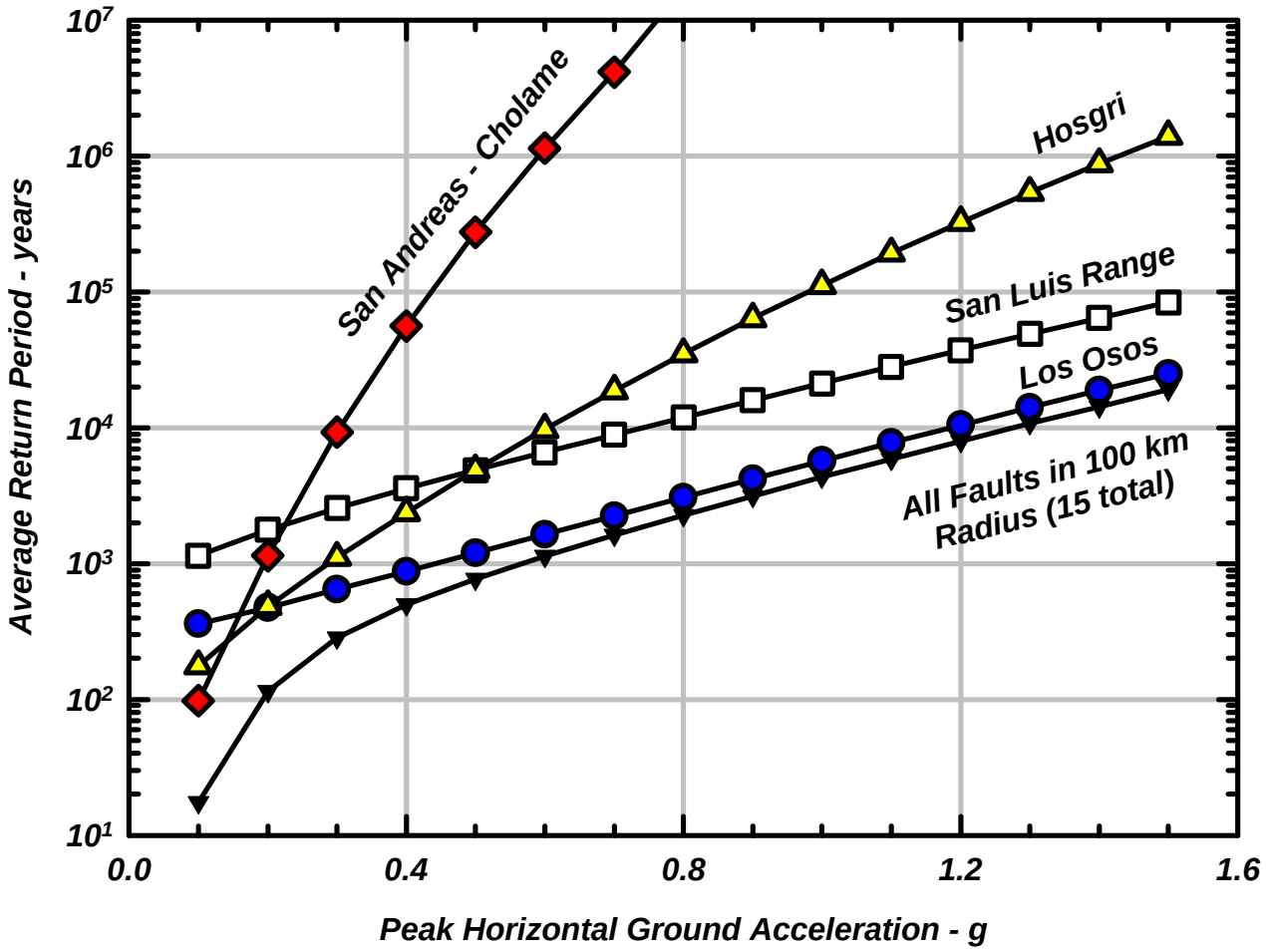
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Probability of Exceedance Versus Peak Horizontal Ground Acceleration

PROBABLITIC GROUND MOTION
1992 Bluff Erosion Study Update
Pismo Beach, California

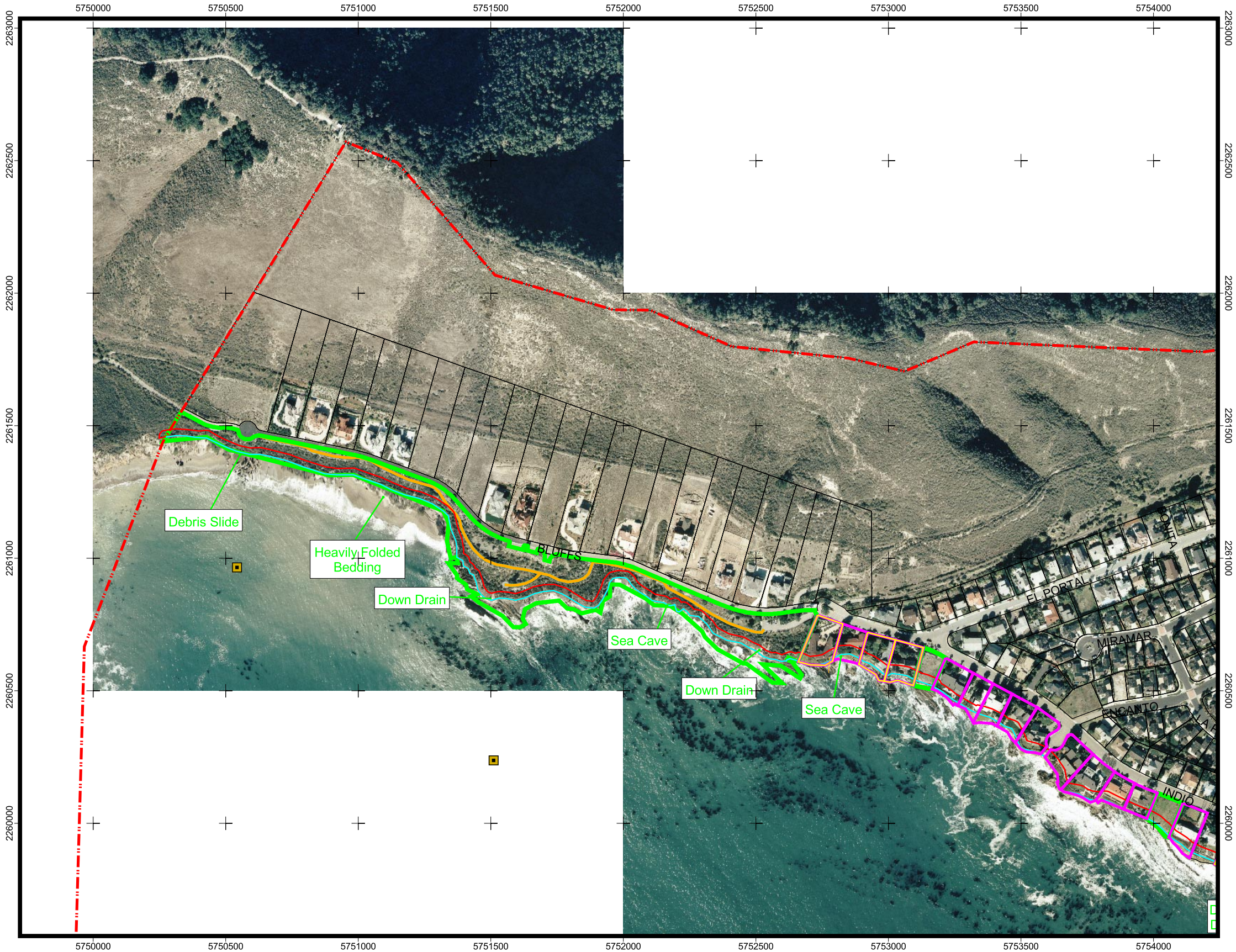
PLATE 7



Average Return Period Versus Peak Horizontal Ground Acceleration

AVERAGE RETURN PERIOD VS. GROUND MOTION
1992 Bluff Erosion Study Update
Pismo Beach, California

PLATE 8



LEGEND

- Existing Bluff Line
- Estimated 100 Year Bluff Line
- Improved Lateral Access
- Unimproved Lateral Access
- Improved Vertical Access
- Unimproved Vertical Access
- Pismo Beach City Boundary
- Parcels within 25 Year Line
- Parcels within 100 Year Line
- Vacant Parcels
- Parcel Boundaries
- Air Photo Location

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 400 feet

400 0 400 Feet

Bluffline Locations and Setbacks

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 9.1

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LEGEND

- Existing Bluff Line
- Estimated 100 Year Bluff Line
- Improved Lateral Access
- Unimproved Lateral Access
- Improved Vertical Access
- Unimproved Vertical Access
- Pismo Beach City Boundary
- Parcels within 25 Year Line
- Parcels within 100 Year Line
- Vacant Parcels
- Parcel Boundaries
- Air Photo Location

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 400 feet

400 0 400 Feet

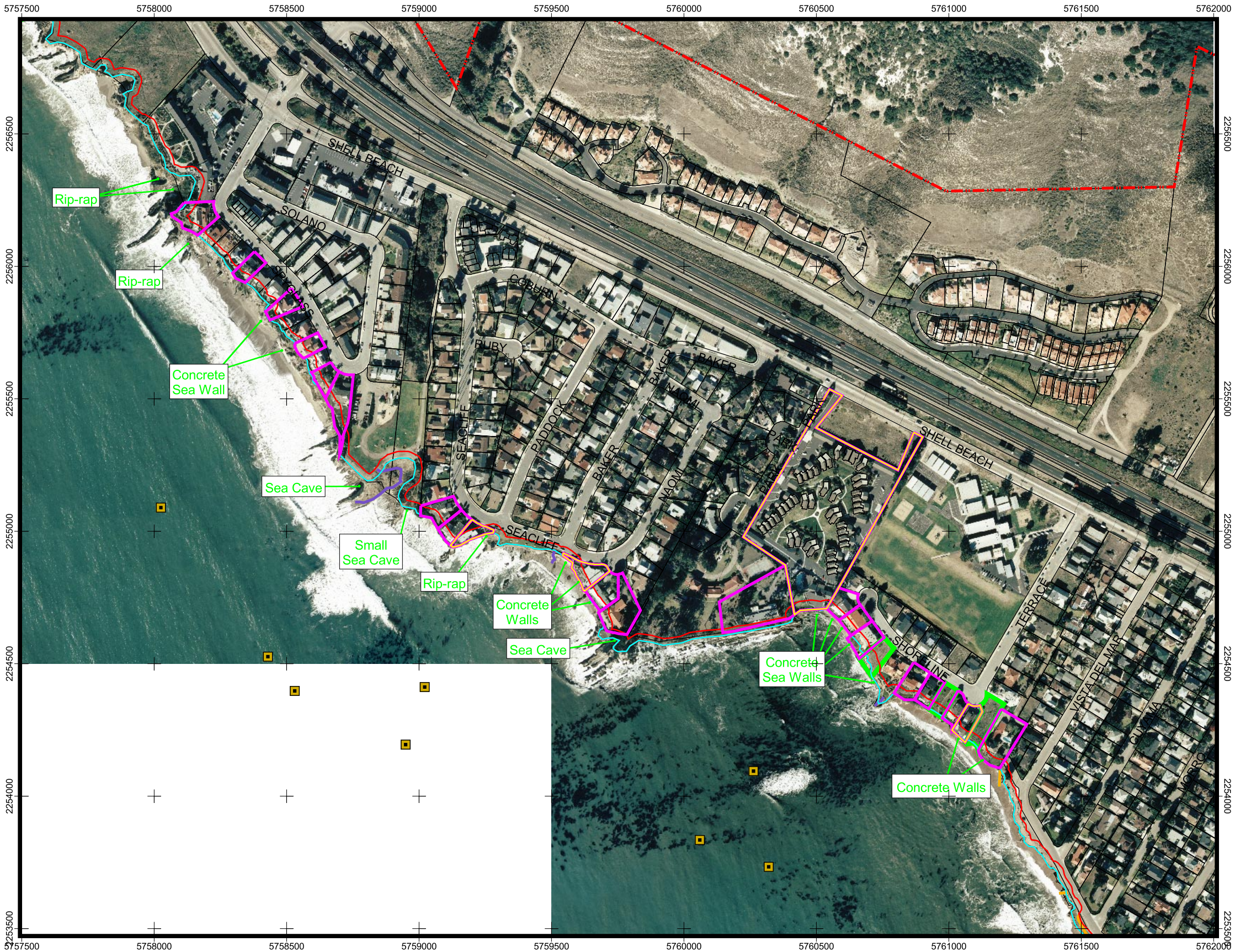
Bluffline Locations and Setbacks

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 9.2

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LEGEND

- Existing Bluff Line
- Estimated 100 Year Bluff Line
- Improved Lateral Access
- Unimproved Lateral Access
- Improved Vertical Access
- Unimproved Vertical Access
- Pismo Beach City Boundary
- Parcels within 25 Year Line
- Parcels within 100 Year Line
- Vacant Parcels
- Parcel Boundaries
- Air Photo Location

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 400 feet

400 0 400 Feet

Bluffline Locations and Setbacks

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 9.3

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LEGEND

- Existing Bluff Line
- Estimated 100 Year Bluff Line
- Improved Lateral Access
- Unimproved Lateral Access
- Improved Vertical Access
- Unimproved Vertical Access
- Pismo Beach City Boundary
- Parcels within 25 Year Line
- Parcels within 100 Year Line
- Vacant Parcels
- Parcel Boundaries
- Air Photo Location

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 400 feet

400 0 400 Feet

Bluffline Locations and Setbacks

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 9.4

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LEGEND

- Existing Bluff Line
- Estimated 100 Year Bluff Line
- Improved Lateral Access
- Unimproved Lateral Access
- Improved Vertical Access
- Unimproved Vertical Access
- Pismo Beach City Boundary
- Parcels within 25 Year Line
- Parcels within 100 Year Line
- Vacant Parcels
- Parcel Boundaries
- Air Photo Location

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 400 feet

400 0 400 Feet

Bluffline Locations and Setbacks

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 9.5

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LEGEND

- Existing Bluff Line
- Estimated 100 Year Bluff Line
- Improved Lateral Access
- Unimproved Lateral Access
- Improved Vertical Access
- Unimproved Vertical Access
- Pismo Beach City Boundary
- Parcels within 25 Year Line
- Parcels within 100 Year Line
- Vacant Parcels
- Parcel Boundaries
- Air Photo Location

Grid: California State Plane, Zone 5, NAD 27, Feet

N

SCALE: 1 inch = 400 feet

400 0 400 Feet

Bluffline Locations and Setbacks

1992 Pismo Bluff Study Update

Pismo Beach, California

Plate 9.6

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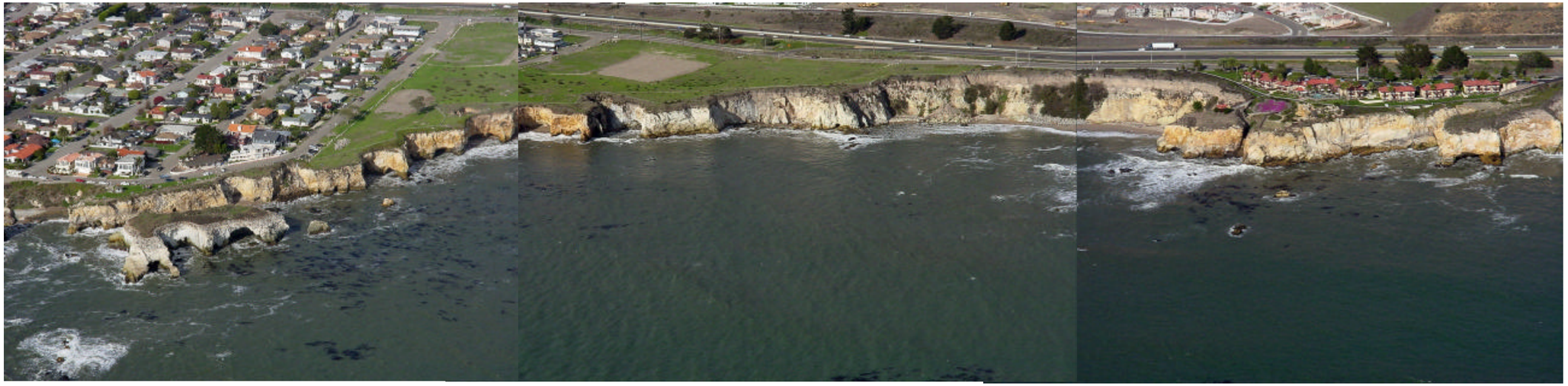
BLUFF PHOTOS
Afternoon of November 23, 2001
1992 Bluff Erosion Study Update
Pismo Beach, California





BLUFF PHOTOS
Afternoon of November 23, 2001
1992 Bluff Erosion Study Update
Pismo Beach, California





BLUFF PHOTOS
Afternoon of November 23, 2001
1992 Bluff Erosion Study Update
Pismo Beach, California



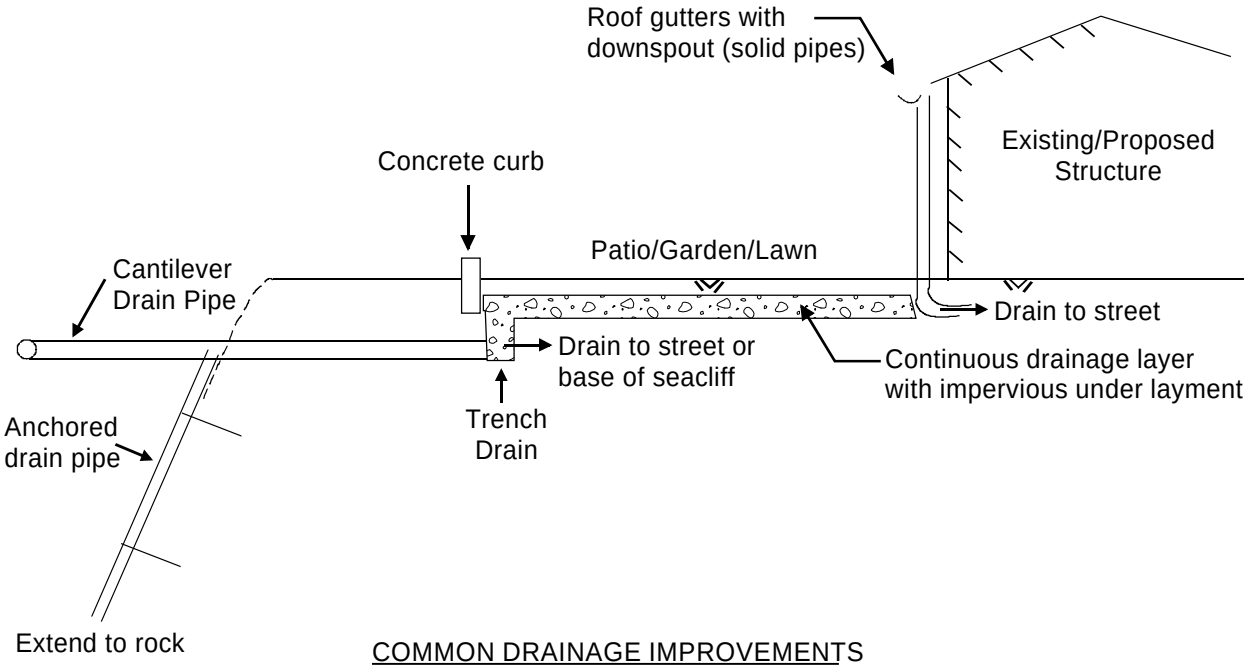
Shore Cliff Lodge
Zone 14
Whaler's Inn
Cottage Inn
Sea Crest



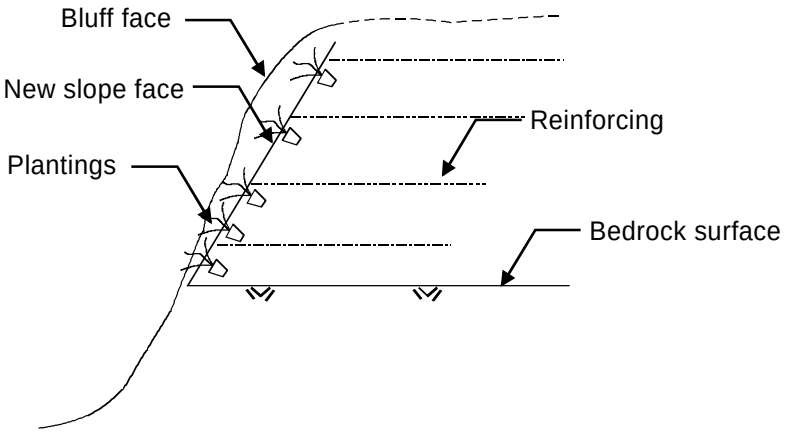
Zone 15
The Tides Motel and Cottages
Wilmar Avenue
Harloe Ave.

Cypress Street

BLUFF PHOTOS
Afternoon of November 23, 2001
1992 Bluff Erosion Study Update
Pismo Beach, California



COMMON DRAINAGE IMPROVEMENTS

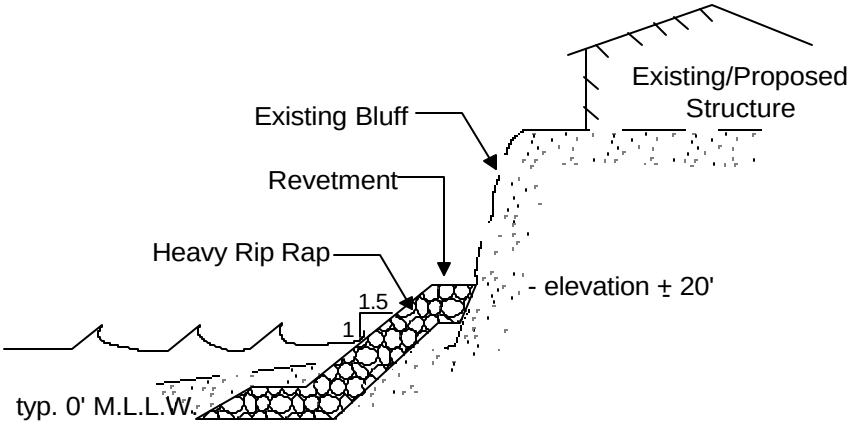


Note: Alternatively structural facings or support systems can be used.

GREEN WALL SYSTEM

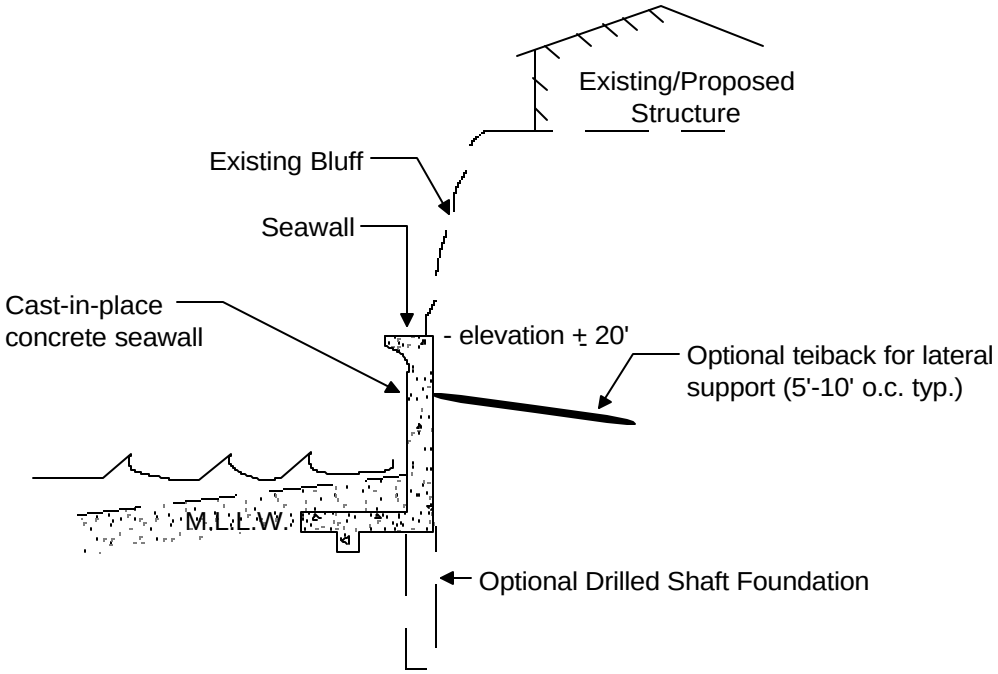
BLUFF TOP - PROTECTION SYSTEMS
1992 Bluff Erosion Study
Pismo Beach, California

PLATE 11



Note: Revetment can be concrete rubble or grouted

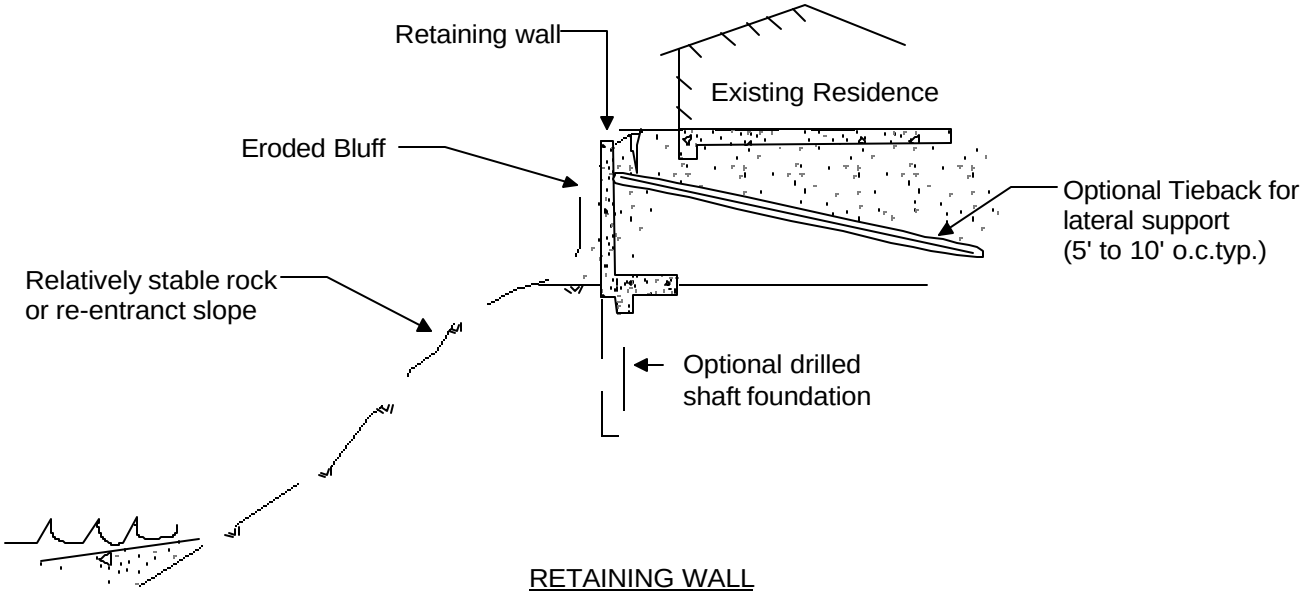
ROCK REVETMENT



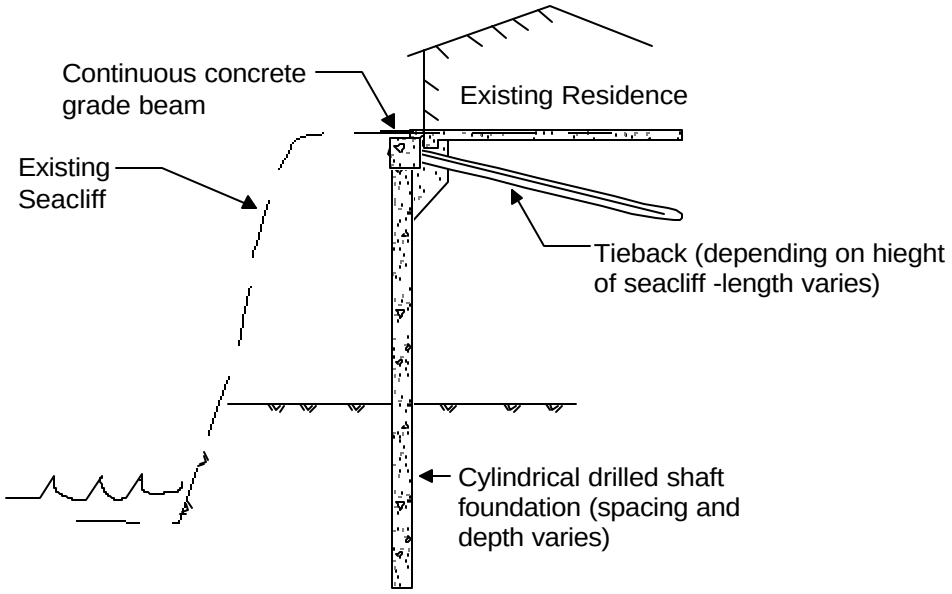
Note: Seawall can be steel sheet pile alternatively

SEAWALL

SHORE LINE - PROTECTION SYSTEMS
1992 Bluff Erosion Study
Pismo Beach, California



RETAINING WALL



UNDERPINNING OF EXISTING BUILDING

STRUCTURE PROTECTION SYSTEMS
1992 Bluff Erosion Study
Pismo Beach, California