DANA POINT GENERAL PLAN

COASTAL EROSION TECHNICAL REPORT

July 11, 1990

ZEISER

GEOTECHNICAL, INC.

DANA POINT GENERAL PLAN

COASTAL EROSION TECHNICAL REPORT

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PN 89312-2

Prepared For:

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July 11, 1990 PN 89312-2

Mr. John Bridges
COTTON/BELAND/ASSOCIATES, INC.
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Subject: City of Dana Point General Plan, Coastal Erosion Technical Report.

In accordance with your request and authorization, Zeiser Geotechnical, Inc. has completed an investigation of geotechnical conditions and historical erosion for the City of Dana Point coastal zone. This zone encompasses approximately 6.7-miles of coastline extending from Three Arch Bay in the north to the City of San Clemente boundary in the south.

The primary objectives of our investigation have been threefold: A) to assess the natural static factors and dynamic processes and urbanization factors impacting the City of Dana Point coastal zone; B) to assess the magnitude and frequency of historical coastal erosion affecting this section of coastline, and C) to provide feasible long-term and short-term planning options and coastal erosion mitigative alternatives for City planners and individual property owners alike, including assessment of the policies of existing Local Coastal Programs. The findings, conclusions and recommendations of this report address each of these objectives.

We appreciate the opportunity to provide you with geotechnical services for this project. Should you have any questions concerning the content of our report, please contact our office.

Sincerely,

ZEISER GEOTECHNICAL, INC.

Eric D. Hendrix
Senior Engineering Geologist
C.E.G. 1531
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COASTAL EROSION TECHNICAL REPORT

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Zeiser Geotechnical, Inc. has completed an investigation of historical erosion and a technical assessment of existing natural and artificial conditions within the entire coastal zone of the City of Dana Point, extending from Three Arch Bay in the north to Poche Beach and the City of San Clemente boundary in the south. Our investigation has been conducted with the intent of preparing a planning guidelines document suitable for use by both City planning agencies (Community Development Department) and homeowners' associations alike. The report summarizes both technical data on coastal geology and oceanographic processes, as well as our recommendations for coastal development policies and coastal erosion mitigation measures. Policy recommendations include amendments to policies of County and State-approved existing Local Coastal Programs, where appropriate.

The historical coastal research involved in this investigation has benefitted immeasurably from both the practical experience and data resources of Gerald G. Kuhn, Coastal Consultant and former Research Associate, Marine Geology Laboratory of Scripps Institution of Oceanography at La Jolla, California. Zeiser Geotechnical, Inc. acknowledges his significant contributions to this investigation.

Key historical erosion and coastal process findings of the current investigation include the following:

- o Coastal erosion and coastal bluff failure has been highly episodic, and temporally linked to large storms, particularly the storm periods of 1884 to 1893, 1916, 1938 to 1941, 1958, 1968, 1978, 1980 and 1983.

- o Available historical records (government survey maps and photographs) document subaerial coastal bluff and sea cliff erosion processes as dominant over marine erosion processes. Marine erosion has been locally severe along the southern Capistrano Beach area, south of Estrella Stairs (50 to 60 feet of shoreline retreat, 1980, 1983 storm), and at Niguel Shores (Dana Strand beach) immediately south of Ritz Carlton headland. Records of subaerial erosion for Capistrano Bluffs document bluff-top retreat on the order of 20 to 30 feet during one major storm period (1938 storms). Between 90 and 100 feet of retreat has been documented for the western and southwestern faces of the Dana Point headlands area, produced during the 1884-1891 storm period and 1916 storm. Up to 150 feet of subaerial erosion and retreat of bluff-top terrace sands occurred along Niguel Shores during the 1938 to 1941 storm period, while up to

50 feet of bluff-top retreat occurred in the eastern Monarch Bay area during the same period. These large-magnitude, short-term coastal erosion episodes suggest that existing Coastal Act 25-foot bluff-top structural setbacks are not adequate to protect blufftop property within the City limits from the threat of erosion over a 50-year design life period.

- Periodic coastal bluff failures have also occurred during non-storm years a long Capistrano Bluffs/Doheny Palisades, and locally in Monarch Bay and Niguel Shores, due to poor surface drainage control and landscape overwatering by bluff-top property owners, yielding bluff-top erosion of terrace sands and blockfall landslides triggered by excessive groundwater accumulations.

- Salt Creek Beach and Doheny Beach State Park comprise the most historically stable sections of the Dana Point coastal zone. The former is stable due to the predominantly cross-shore sediment transport mode within its' pocket beach, while the latter is relatively stable due to the periodic replenishment of sediment from San Juan Creek outfall, and the southward deflection of effective longshore sand transport by the Dana Point headland and Dana Harbor breakwaters.

- Storm drain outfall at Dana Harbor Drive park accelerates bluff erosion and delivers contaminated waters to Dana Harbor proper, eventually contaminating Harbor sediment and preventing its use of dredge fill in beach nourishment programs downcoast.

Key mitigation alternatives, planning options and policy recommendations for the Dana Point coastal zone include the following:

- Re-zoning and upgrading of several existing residential, commercial or open-space land-use areas to Open-Space/Conservation status, thus ensuring minimal development options and reducing risk of subsequent property loss.

- Existing recreational land-use designations for shoreline areas are considered appropriate, providing compliance with Coastal Act public access requirements. However, the designated "other permitted uses" of these recreational districts as allowed in existing LCP's should be restricted to prevent construction of facilities on coastal stretches with high predicted storm wave run-up elevations.

- Existing 25-foot bluff-top structural setbacks mandated by the Coastal Act are inadequate, and should be increased in several areas (see Plates 1, 2 and 3), up to as much as 100 feet from "state-defined" existing bluff edges.

- A dewatering-well system, including monitoring wells, should be considered for implementation along the high and very high hazard severity zones (see Plate 4) along the Capistrano Bluffs/Doheny Palisades subunit, to minimize the accumulation of homeowner-irrigation groundwaters, and reduce blockfall landsliding hazards. Federal subsidies may be available for dewatering through the Environmental Protection Agency, if the dewatering system is established as part of a local Wastewater Reclamation Program.

- A periodic sand nourishment program is recommended for the beach immediately downcoast from Doheny Beach State Park, to replenish, widen and stabilize the Capistrano Beach area. Dana Harbor dredge sediment is currently considered too contaminated by storm drain outfall for use in nourishment programs; improvement of the quality of these dredge materials would make them the ideal periodic source for beach nourishment. Strategic placement of sandfills should account for the southward deflection of effective longshore currents by the Dana Harbor breakwaters.

- Deepened caisson footings into bedrock are recommended for stabilization of bluff-top structures <u>only</u> in those areas where toe-of-bluff talus accumulations are significantly high enough to produce a natural setback plane above the level of practical caisson embedment (see Figure 10 for example).

- Sea walls are self-cannibalizing by nature, and tend to produce dangerous increases in wave run-up elevations; they should be employed as a last resort protective devices for beaches in the Doheny Beach/Capistrano Beach subunit. All beach protective devices should be designed considering breaker heights recorded during the 1939 storm period, and should account for progressive sea level increases and elevated perigean spring tide conditions in their long-term design life.

- Coastal protection should account for the possible superposition of elevated storm surges and predictable perigean/proxigean spring tides (Appendix E).

- Geologic Hazard Abatement Districts should be established for several areas, including Capistrano Beach, Capistrano Bluffs, Niguel Shores/Breakers Isle development and Monarch Bay community, to establish planned local cooperation in preventing coastal hazards and to provide state and local subsidies for mitigative measures.

- The Capistrano Bluffs/Doheny Palisades subunit should be considered the first item of business for City Planners with regard to coastal hazards mitigation; southern Capistrano Beach is ranked second in severity level (see Plate 4).

- Despite the implications of quantifiable, post-1884 coastal erosion data, there is considerable evidence that the storms of the first half of the 19th century (through 1862), for which there is only qualitative data, may have produced considerable coastal damage. These storms were generally associated with the El Nino-Southern Oscillation Event (ENSO), and moved upcoast from the southeast. It is conceivable that design breaker heights and rainfall intensity from these storms exceeded the recorded conditions of subsequent storms, and therefore design parameters for coastal protective devices should incorporate factors of safety to account for the exeedance limits of these earlier storms.

- Coastal Development Permits should not be issued for any blufftop development site unless a detailed site-specific geotechnical investigation has been conducted, to include a minimum of one bucket-auger boring downhole-logged by a State-licensed engineering geologist.

SECTION I

INTRODUCTION

A. Objectives

Zeiser Geotechnical, Inc.'s investigation of coastal erosion within the recently-incorporated Dana Point city limits has involved geotechnical review, inspections and analysis during preparation of preliminary planning recommendations regarding the prevention, control and correction of beach and shoreline erosion, including analysis of the potential for and mitigation of seacliff erosion. Technical analysis has included the evaluation of both static and dynamic factors affecting shoreline, beach and cliff erosion, as well as the available historical record of shoreline erosion.

Our preliminary objective has been to prepare this report, summarizing our findings, conclusions and recommendations in both text and graphical format, in compliance with Section 65302 of the California Government Code. The report has been prepared for primary use as a planning guidelines document by appropriate City of Dana Point agencies, particularly the Department of Community Development and Planning Commission, as well as local homeowners' associations, development districts or other private sector groups. The report is intended to function as an appendix to the Technical Reports of the City General Plan Conservation/Open Space, Land Use/Local Coastal Plan and Safety Elements. Recommendations and technical data from this report, summarized in Section III, should also be disseminated throughout and reformatted within the content of the City Master Environmental Assessment (MEA) and Environmental Impact Report (EIR). In light of the intended function of this report as a planning guidelines document, the Summary of Planning Options and Mitigative Alternatives (Section II) includes assessment of both existing and historical geotechnical conditions, as well as existing planning documents and maps, including the California Coastal Plan and Amendments, City of Dana Point Specific Plan and Land Use Regulations Maps, Dana Point Local Coastal Program, South Laguna Specific Plan and Local Coastal Program, Capistrano Beach Specific Plan and Local Coastal Program, and Laguna Niguel Planned Community Development Plan and Feature Plan. These latter planning documents were prepared by the Orange County Environmental Management Agency in association with private urban planning consultants (see Appendix A, References), and have been adopted by the Orange County Board of Supervisors.

B. Scope of Work and Analytical Procedures

Our analysis and assessment of historical shoreline erosion in general has followed the outline and recommendations of Fulton's (1981) Manual for Researching Historical Coastal Erosion (California Sea Grant Publication).

The current investigation has involved the following specific operations:

- Compilation and analysis of available historical data (government agency topographic survey maps; vertical and oblique low-altitude airphotos; meteorologic and oceanographic data, etc.).
- Compilation and review of available unpublished private consultant reports prepared for and approved by OCEMA.
- Compilation and review of published geologic maps and reports.
- Field reconnaissance and surveys with geologic mapping of selected areas within the city Coastal Development District, as defined on the adopted Land Use Regulations Maps.
- Preparation of this report and accompanying maps, tables and illustrations.
- Interface with City of Dana Point planning officials within the community Development Department, and members of various homeowner's associations, to obtain a comprehensive understanding of both public and private sector development needs.

Analytical procedures involved evaluations of two distinct but equally critical data sets: (1) historical coastal erosion records, and (2) present-day static and dynamic coastal geotechnical processes and their relationships to urbanization within the Dana Point coastal zone.

The first data set, concerning historical coastal erosion, was analyzed by determining shoreline movement using available historical topographic maps prepared by both the U.S. Coast and Geodetic Survey (now National Ocean Survey/NOS, within National Oceanic and Atmospheric Administration/NOAA) and U.S. Geological Survey, plus historical aerial photographs of the Dana Point coastal zone flown by many different agencies between 1924 and 1983. Five separate historical topographic survey maps of the Dana Point coastline were examined, prepared in 1885, 1934, 1948, 1968, and 1975 with 1981 photo-revision. These maps were photographically enlarged as transparent reproductions at a normalized scale of 1:10,000 for coastline comparisons. These comparisons involved delineation of Mean High Water Line (MHW), beach or toe of seacliff, and coastal blufftop positions. Because shorelines in these maps were surveyed several years apart, their usefulness is limited to establishing net shoreline changes and long-term change rates; these maps are further limited in application to coastal reaches were net changes in shoreline position exceed recognized uncertainly or confidence limits, as determined by map type or scale. Reasonable uncertainty limits are recognized by coastal specialists to vary between 30 and

60 feet, and can include original survey errors, image processing or photogrammetric errors or mean high water line location errors (Goldsmith et al, 1978; Leatherman, 1983; US Army Corps of Engineers, 1987B). Survey accuracy levels for the 1885 and 1934 US Coast and Geodetic survey "T" series maps, used in the present investigation, (Appendix A) are generally recognized as the best available of all historical coastal maps. The 106-year time span covered by available maps is 40% greater than the span covered by airphotos; these maps represent the longest semi-quantifiable shoreline movement data set available for southern California.

Historical vertical aerial photographs were analyzed with standard stereoscopic and zoom transferscope methods, in order to quantitatively assess shoreline position changes between time periods represented by the historical maps. Supplemental low-altitude oblique aerial photographs were utilized to document zones historically subject to erosion and/or bluff failure between 1924 and 1983.

The second data set, static and dynamic coastal processes and their relationship to coastal urbanization, were analyzed via geologic mapping, review of private consultant and governmental regulatory agency reports, and published geologic maps and reports. these technical data are summarized within Section III (below), and the results compiled and illustrated in Table 1 and Plates 1 through 5 (In Pocket).

C. Technical Report Format

In order to provide a final product which functions effectively as both a planning document for use by lead agencies and laymen alike, and as a preliminary technical guideline for future site-specific geotechnical investigations within the City of Dana Point Coastal Development District, the content of this report has been subdivided into a section summarizing Policy Options and Mitigation Alternatives (Section II, below), and a section summarizing technical data for the coastal zone, including geologic framework, littoral processes, historical coastal erosion and historical meteorologic data (Section III, below) where appropriate, both the Policy and Technical Data summarizes discuss issues within six distinct geographic subdivisions of the City of Dana Point coastal zone; this subdivision scheme facilitates the communication of planning issues impacting specific stretches of coastline.

Graphical elements, particularly Plates 1 through 3 (400-Scale Coastal Geotechnical Maps, In Pocket), have been prepared to illustrate geotechnical constraints and potential mitigation alternatives in a "user-friendly" format which effectively communicates constraints to public and private sectors alike. Plates 1 through 3 summarize the general coastal geology, County subdivisions and tract numbers, geotechnical constraints and potential mitigation alternatives (Section II) in visual format. Plate 4 comprises the 1000-Scale Geotechnical Constraints Severity Map, which depicts coastal hazard severity levels utilizing a color-code rating scheme, with consideration to both geotechnical hazards and land use scenarios. Significant historical slope failures and specific zones of beach erosion and/or seacliff retreat are illustrated on this map, as a qualitative measure of historical coastal instability. Table 1 provides a matrix of salient geotechnical conditions, utilized in part to develop the color-coded rating scheme of Plate 4, for each of the six geographic subdivisions of the coastal zone. Selected historical coastal erosion events are additionally depicted on Plate 5, where they are superimposed on a historical rainfall curve in order to emphasize the uneven temporal distribution of coastal erosion as a function of episodic meteorologic events, and as relates to the historical urbanization period of the southern Orange County coastal zone. The remaining illustrations are intended to depict static conditions and dynamic coastal processes as a supplement to the discussions in the Technical Data Section. Appendix B presents a glossary of geologic and coastal process terms utilized in this report; Appendix D presents a recommended list of emergency preparedness guidelines which may be adopted for the coastal zone by City planners.

SECTION II

SUMMARY OF POLICY OPTIONS AND MITIGATIVE ALTERNATIVES

A. Dana Point Coastal Zone and Geographic Subunits

The coastal zone within the incorporated Dana Point city limits includes approximately 6.7 miles of shoreline (35,380 linear feet), roughly 68 percent of which is currently under private ownership, 18 percent (Doheny Beach Park) which is owned by the State, and the remainder which is under County ownership (US Army Corps of Engineers, 1985b). This coastal zone extends from Three Arch Bay Beach at its northern boundary with the City of Laguna Beach, to Poche Beach at its southern boundary with the City of San Clemente (Figure 1, Site Index Map).

For the purpose of the present investigation, the coastal zone has been subdivided into six geographic subdivisions or "subunits", as illustrated in Table 1 and Plates 1 through 4 (In Pocket). These six coastal subunits were arbitrarily selected on the basis of unique geologic conditions, topography and/or coastal process within their boundaries; they are therefore generally independent from either existing zoning or land use element designations of Specific Plans or Local Coastal Plans (see References, Appendix A). The six subunits include, from south to north: 1) Capistrano Beach/Doheny Beach subunit, extending from Poche Beach to the easternmost breakwater of Dana Point Harbor, and including the San Juan Creek outfall as well as all land seaward of the Atchison, Topeka and Santa Fe railroad easement; this subunit includes Capistrano Beach private community, Capistrano Beach Park and Doheny Beach State Park; 2) Capistrano Bluffs/Palisades Subunit, extending from the terminus of Camino Capistrano Street to the San Juan Creek Floodplain boundary, and including all coastal bluff face and blufftop area northeast of Pacific Coast Highway (Dana Bluffs, Doheny Palisades, etc.); 3) Dana Cove and Harbor subunit, extending between the eastern and western harbor breakwaters, and including the coastal bluffs and park areas along Dana Point Harbor Drive and Cove Road, including the Lantern Bay Project Area but excluding the harbor facility itself; 4) Dana Point Headlands subunit, extending from the western harbor breakwater northward to the southern end of Niguel Shores Beach; 5) Niguel Shores subunit, including both the beach and adjacent coastal bluffs of Niguel Shores ("Dana Strand Beach"), Breakers Isle, Ritz Carlton headland, Salt Creek Beach ("Ritz Cove") and Salt Creek outfall; 6) Monarch Bay subunit, including the narrow beach and sea cliffs north of Salt Creek outfall, northward to the boundary with Three Arch Bay Beach.

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DATE. 6/29/90
FIG. NO. 1

SITE INDEX MAP
DANA POINT COASTAL ZONE

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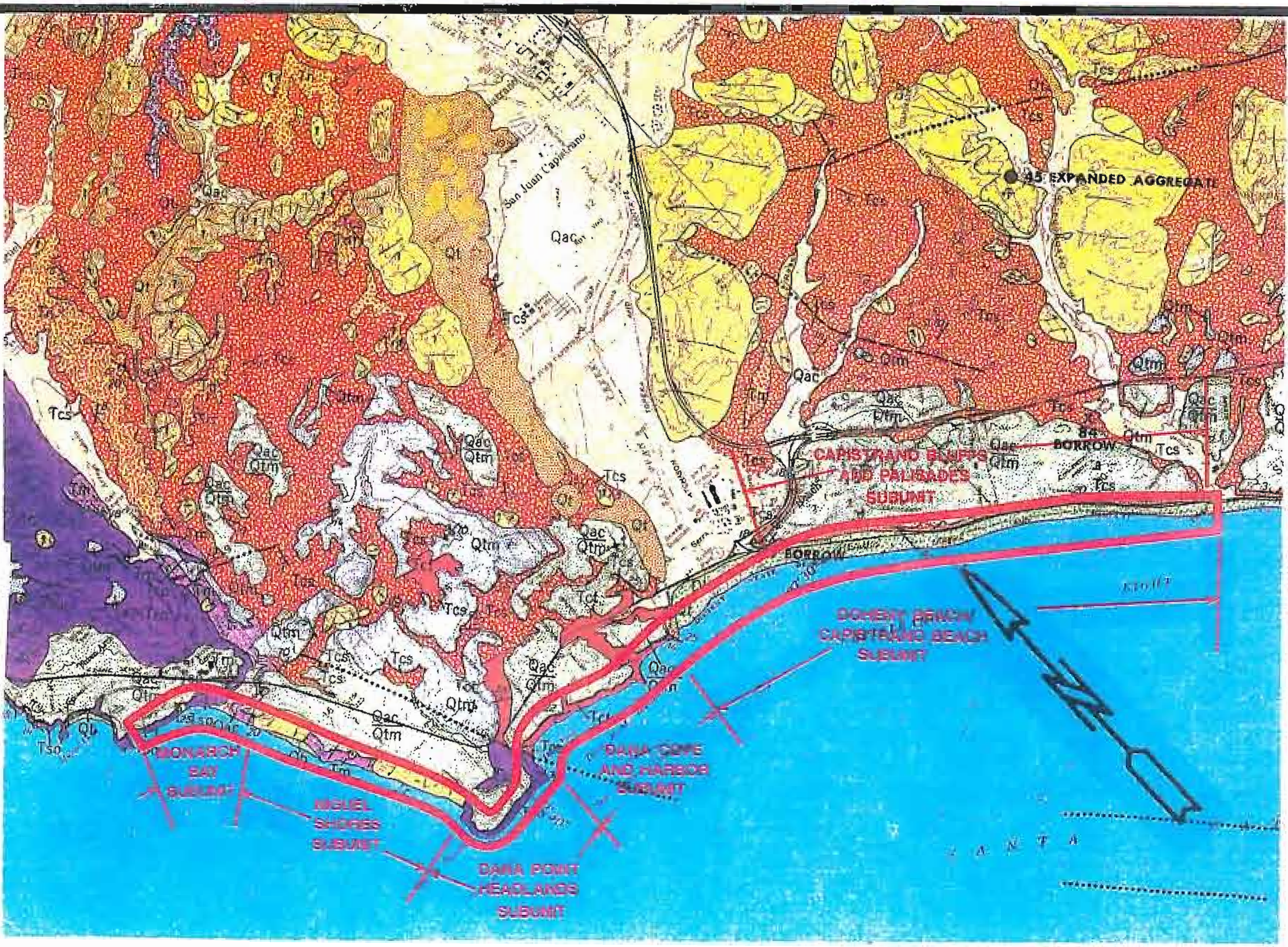

SCALE: 1"=4,000'
BASE MAP REFERENCE: CALIFORNIA DIVISION OF MINES & GEOLOGY BULLETIN 204.

▭ APPROXIMATE BOUNDARIES OF PROJECT STUDY AREA

Preliminary planning options, coastal protection measures and existing local coastal plan policies are discussed below for each of these six subunits. Technical data is discussed for each subunit separately, as well in Section III, where appropriate.

B. Coastal Act and Local Coastal Programs

The California Coastal Plan (1976, and revisions in 1977; 1980; Appendix A) was prepared by the State Coastal Commission, and defines general guidelines and 162 policies for land use planning and environmental protection as specified by the 1972 Coastal Initiative and 1976 Coastal Act (Division 20 of State Public Resources Code). The Coastal Act established the Coastal Resources Management Zone to include shoreline areas extending inland to the nearest prominent coastal drainage divide, or five miles from mean high tide line, whichever is less.

The Coast Act additionally establishes the following hierarchy or ranking of permitted uses for limited coastal lands, from highest-to-lowest land use priority: 1) environmentally-sensitive natural resource areas and biologic habitats, 2) agricultural development, 3) "coastal- dependent" development, 4) public recreation usage, 5) visitor-serving commercial 6) private residential, and 7) general commercial or industrial.

The policies established by the Coastal Act focus on the protection of coastal resources and the regulation of development in the Coastal Zone. The emphasis of the Coastal Act development policies is on encouraging well-planned and orderly development which is compatible with resource protection and conservation.

Coastal Act policies which should be considered and implemented during design and selection of coastal protection measures and planning alternatives within the Dana Point General Plan Land Use, Conservation/Open Space and Public Safety Elements include the following: 1) Sections 30230 and 30231 (maintenance/enhancement/restoration of marine waters, resources biologic habitats); 2) Section 30236 (protection of coastal watersheds and stream channels); 3) Section 30251 (protection of scenic and visual resources, and existing natural landforms) 4) Section 30253 (assurance of stability and minimizing risks relative to geologic and erosional factors, specifically natural landforms along seacliffs and coastal bluffs); 5) Sections 30210 through 30213 and 30500 (provision and maintenance of public access to beaches and coastal recreational areas, compliant with Article X if the State Constitution), 6) Section 30250 (location and stabilization of new residential developments) and 7) Section 30106 (requirements for coastal blufftop setbacks). Specific details of these policies with respect to planning options should be discussed within the General Plan Land Use Element.

The Coastal Act additionally requires each local government lying partially or wholly within the Coastal Zone to prepare a Local Coastal Program or Plan (LCP) for that part of the coastal zone lying within its jurisdiction. The LCP contains land use plans and local zoning ordinances which, subsequent to local approval, must be submitted to the State Coastal Commission for review and approval, and to ensure compliance with pertinent Coastal Act policies and sections (discussed above). Upon approval of the LCP by the State Commission, the responsibilities of review of coastal development applications and granting of Coastal Development Permits is transferred to the local government. However, the State Commission retains appeals and review authority for specific proposed developments, including areas between mean high tide line and the first public road inland, and zones 300 feet landward or seaward of any coastal blufftops.

Local Coastal programs and Land Use Regulations were previously prepared under the auspices of the Orange County Environmental Management Agency for four distinct districts of the South Coast Planning Unit, prior to incorporation of the City of Dana Point. These include LCP's and Specific Plans for Capistrano Beach (adopted 1988, County Board of Supervisors), Dana Point (adopted 1987), Laguna Niguel Planned Community (adopted 1987) and South Laguna (1983 Board of Supervisors approval; 1987 Coastal Commission approval with numerous amendments). These LCP's were prepared pursuant to State Government Code Section 65450; they incorporated and amended policies and implementation programs of the original County General Plan. Policies and Land Use Regulations of these LCP's were reviewed and amended during analysis of coastal conditions and provision of mitigative alternatives during the present study, in an effort to provide consistency, where appropriate, with existing public concerns and planning guidelines.

C. Summary of Recommendations

Shoreline erosion control and protection measures, for both beach and coastal bluff areas, are illustrated on the accompanying Coastal Geotechnical Maps (Plates 1 through 3, In Pocket) utilizing the GEMS (Geotechnical Mapping Symbols) method (Hannan, 1984). This approach is a simple illustrative method which represents geotechnical constraints and mitigation alternatives in a pictographic format which rapidly communicates ideas between the geotechnical engineering consultant, designer, urban planner and layman.

Several of these symbols are combined within areas featuring multiple geotechnical coastal constraints, to alert planners and homeowners of hazards, as well as their most logical long-term solutions. County EMA subdivisions/tracts are superimposed on these maps in order to provide an easy planning reference and method to obtain previous grading and/or construction permits, site plans and existing geotechnical reports for Dana Point coastal sites. These data are public record, available from County EMA Grading, Land Use and Environmental Planning departments. Summaries of the conditions forming the basis for these recommendations are also depicted on the maps.

TABLE 1
SEVERITY INDEX MATRIX FOR
GEOTECHNICAL CONSTRAINTS
DANA POINT COASTAL ZONE

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COASTAL GEOTECHNICAL CONSTRAINTS

GEOGRAPHIC SUBUNITS	MARINE DYNAMIC PROCESSES		SUB-AERIAL DYNAMIC PROCESSES			STATIC FACTORS		
	Sea Cliff Erosion/ Wave Attack	Beach Erosion	Sediment Budget	Seepage	Runoff and Blufface Erosion	Bedrock Structure	Erodible Lithology	Historical Failures
Monarch Bay	X		X		X	X (LOCAL)	X (LOCAL)	X (LOCAL)
Niguel Shores	X	X (LOCAL)			X	X (LOCAL)	X (LOCAL)	X
Dana Point Headlands	X		X		X	X (LOCAL)		X
Dana Cove & Harbor				X	X		X (LOCAL)	X (LOCAL)
Capistrano & Doheny Beaches		X (SEVERE)	X				X	X
Capistrano Bluffs/ Palisades			X	X	X	X	X	X

Additional justification for coastal protection recommendations can be obtained by reviewing the Technical Data Section (below), the geologic information included on Plates 1 through 3, the historic coastal erosion events summarized on Plates 4 and 5, and the geotechnical constraints matrix in Table 1. The color-coded constraints ranking system illustrated in Plate 4 is intended for use in conjunction with the Coastal Geotechnical Maps, and signals priority zones for planning program implementation. This "coastal strip" zoning scheme, as presented in Plates 1 through 4, has been employed in other coastal studies with relative effectiveness (State of California, 1977A; Griggs and Savoy, 1985); this zoning scheme and associated recommendations are intended as preliminary in nature only, to be used as a basis for long-term planning by the City of Dana Point, and to highlight local concerns for subsequent site-specific design by other consultants.

All existing Local Coastal Programs applicable to the Dana Point coastal zone contain policies requiring geologic reports in areas of known geologic hazards. All segments of all six subunits discussed herein possess significant known geologic hazards, and thus detailed geologic investigations of site-specific conditions should be required by the City of Dana Point prior to issuance of Coastal Development Permits. These geologic investigations should be required to include a minimum of one bucket auger boring for each blufftop development site, to be downhole logged by a State-licensed engineering geologist. As a further assurance of quality control for Coastal Zone development, the City should establish a private geotehcnical consulting firm to provide third-party-review of all geologic reports prepared within the Coastal Development District.

Any planning options discussed below which are officially implemented and adopted by the City should be applied with the recognition that standard building and grading codes and code enforcement do not necessarily keep pace with standards of prudent judgement applied by geotechnical professionals. As a rule of thumb, local grading codes tend to lag behind the current state of professional knowledge by five to ten years. Consequently, conformance to County grading codes or UBC (1988) by itself should not be accepted as adequate for mitigation of sensitive coastal hazards.

I. Capistrano Beach/Doheny Beach Submit

The historical record of beach erosion and property damage due to storm waves is significant within this subunit (Plates 4 and 5; US Army Corps of Engineers, 1959; 1985B; 1987A; 1987B; 1988C; R & M Consultants, 1982: Seymour et al, 1983; Moffatt and Nichol, 1985; Seymour, 1989), specifically the records of elevated storm wave heights during the 1939 through 1941, 1958, 1974, 1983 and 1988 storms, associated with the southerly El Nino Southern- Oscillation-Event (ENSO) (deep-water wave direction 180°-240°). It is strongly recommended that any new development or construction within the single-family-residential district of Capistrano Beach Private Community should be restricted to construction of coastal erosion protection devices, or modifications to existing structures which serve dual purposes as erosion-protection devices. Seaward construction or additions to existing structures are not encouraged. Permits should not be granted for removal of existing structures where the intent exists to develop new homes along Beach Road. As stated by a previous consultant, residential subdivisions and zoning should never have occurred along Capistrano Beach (R and M Consultants, 1982). The US Army Corps of Engineers' Beach Erosion Control Board noted in 1959 that marine erosion had the eventual potential to destroy the entire development area seaward of the Santa Fe railroad easement.

Shoreline Sediment Budget

Sediment budget estimates for the northern proton of the Oceanside littoral cell prior to 1960 suggest that San Juan Creek deposited an annual mean of 132,000 cubic yards of coarse sediment in the Doheny Beach State Park area during non-flood years (Table 2) (US Army Corps of Engineers, 1959 Moffat and Nichol, 1985); sediment budget estimates calculated subsequent to extensive San Juan Creek flood control channelling indicates that annual sediment yields have dropped more than 50%, down to approximately 45,000 cubic yards per year. (Kroll and Porterfield, 1969; Taylor, 1983; Stow and Chang, 1987). This net decrease in sediment supply is related to both urbanization of the San Juan Creek as well as to the relative drought conditions affecting southern California since 1960. Shoreline position changes analyzed prior to construction of Dana Point Harbor (US Army Corps of Engineers, 1959) suggest an annual littoral drift sediment loss of 100,000 cubic yards from the southern half of the Doheny Beach/Capistrano Beach subunit, with the majority of the loss from Capistrano Beach. This observation was verified by the present study (Plates 4 and 5) and by others (R and M Consultants, 1982) suggesting that the natural effect of the west-protruding Dana Point Headland is to minimize the effects of southward longshore currents within the sheltered Dana Cove/northern Doheny Beach zone, thus reducing littoral transport of sand into the Capistrano Beach Park and private community beach areas. Shoreline observations subsequent to Dana Point Harbor construction in the early to mid 1960's illustrate continued net annual beach erosion south of a natural "inflection point" located approximately in line with Pines Park, on the order of 0.7 feet per year of shoreline retreat (Moffatt and Nichol, 1985; US Army Corps of Engineers, 1987B). This inflection point corresponds approximately with the northern limit of the red hazard severity zone in this subunit, depicted on Plate 4. Progressive annual beach accretion north of this inflection point since Harbor construction implies a further deflection of southward littoral sediment drift, due to the position of the Harbor breakwaters (Moffatt and Nichol, 1985). The difference between pre-Harbor (post-1949) net beach erosion at Doheny Beach State Park (US Army Corps of Engineers, 1959) and post-Harbor net beach accretion cannot be attributed to increases in sediment discharge from San Juan Creek, since A) flood sediment yield for the two periods are relatively similar (Section III C, below), and B) construction of flood control devices and channelization within San Juan Creek upstream of Doheny State Beach have tended to decrease rather than increase annual sediment discharges since Harbor construction (Simons, Li & Associates, 1984; US Army Corps of Engineers, 1985D). Construction of a 75 m groin at the mouth of San Juan Creek in 1964 would not have significantly reduced longshore transport to Capistrano Beach, either, given the relatively small size of this structure (US Army Corps of Engineers, 1986). Therefore, southward artificial deflection of littoral sediment transport effectiveness by Harbor breakwaters is judged to be a key factor in progressive Capistrano Beach erosion since the mid-1960's.

The rapid urbanization of the Capistrano bluffs and Dana Point inland areas since the 1960's has also decreased the sediment budget of the Doheny Beach/Capistrano Beach subunit, via the increase in paved surface areas and resultant reduction in erodible terrace area adjacent to the coastal zone. The construction of AT&SF railway, paved Pacific Coast Highway and the fences along Beach Road have additionally effectively removed the Capistrano Bluffs subunit area from contributing to the Capistrano Beach sediment budget. Given the results of recent statistical studies of sediment yields from coastal Orange County and Northern San Diego Country areas, which suggest that erosion of coastal bluffs and coastal terraces can contribute upwards of 250% more coarse sediment to littoral cells than do adjacent fluvial (river) system discharges (Osborne and others, 1989; US Army Corps of Engineers, 1985C), it seems reasonable that these urbanization factors have played a key role in hastening local beach erosion.

Shoreline Protection Measures

Structural underpinning of existing structures not currently on deep pile foundations (caisson-and-grade-beam systems) is recommended for the southernmost segment of Capistrano Beach. Driven piles are considered more feasible than cast-in-place concrete piles, due to the inherent groundwater and side-wall collapse problems associated with cast-in-place excavations on beaches. Available jet-probe sand thickness survey data indicate that bedrock elevations in this area (design storm scour elevations) are no deeper than 15 feet below existing beach grade (US Army Corps of Engineers, 1988B). Seawalls and sloped stone revetments are not recommended, given the natural wave refraction and erosion effects and self-cannibalization inherent to such structures as sand more preferentially erodes on their seaward flanks, creating steeper foreshores or beach profiles, increase in scour depth and resultant increase in surf zone breaker height (h_B), with eventual undermining of the protective device itself (Muir-Wood and Fleming, 1981; Moffatt and Nichol, 1985). Calculations of storm wave breaker heights for southern Capistrano Beach, assuming design storm wave conditions at least equal to those of 1939, 1958, or 1983 subtropical storm events (data from Marine Advisers, 1960B; Seymour et al; 1983; US Army Corps of Engineers, 1986), indicate that run-up elevations on beaches protected by seawalls or 1.5:1 sloped stone revetments are 2 to 3 times greater than existing residential elevations along Beach Road, with natural (unprotected) beach run-up elevations 50% higher than existing residential foundations (Moffatt and Nichol, 1985). These extreme runup conditions are a natural consequence of deeper scour elevations, steeper beach profiles and increased breaker heights associated with the progressively retreating shoreline. In light of this fact, seawalls and revetments are not recommended for design along Capistrano Beach south of the Pines Park area; for the beach area north of Pines Park, seawalls produce lower calculated run-up elevations, and are thus favored over revetments, although the latter are generally less costly to construct. Several homes along Capistrano Beach feature timber bulkheads on their seaward flanks (Figure 2A); such structures provide some stabilization of sand during smaller seasonal storm wave attack, but would not survive the large design wave conditions associated with storms such as the 1939, 1958 or 1983 events or elevated wave conditions such as those associated with perigean spring tides as in 1962 and 1974, (Appendix E) (Section IIIC, Subsection I, below) or combinations of both processes. Coastal engineers designing protective devices within northern Capistrano Beach and Doheny Beach areas should calculate run-up elevations assuming the spectral deep-water wave period recorded during the 27 January 1983 southerly storm (T=22 seconds), since these longer- period waves will generate higher breaker heights for a given water depth (Muir-Wood and Fleming, 1981; US Army Corps of Engineers, 1984 A). Previously-published tsunami run-up predictions (Houston and Garcia, 1974) are considered inadequate for such design. Other investigators suggest that a 25 to 30 year recurrence interval (return period) should be assumed for such devastating, long-period subtropical storm waves (Seymour er al, 1984; Walker et al, 1984) during design of protective devices. Long-term measures in sea level position (Plate 7), documented through comprehensive tide gauge studies of both the Pacific and Atlantic seaboards (Kaufman and Pilkey, 1979; Hoffman et al, 1983; Emery and Aubrey, 1986) should also be considered during design of protective devices such as seawalls or revetments, as should the predicted returns of astronomically-generated perigean spring tides (Wood, 1986; Appendix E).

In order to minimize the erosive scour effects at the seaward toe of designed seawalls or revetments (discussed above), all protective devices constructed within the northern Capistrano Beach and Doheny Beach State Park areas (Figure 2B) should be provided with a "scour blanket", consisting of rip-rap stone placed at the seaward toe of such structures. Such a scour blanket would minimize erosion, in compliance with Section 30253 of the Coastal Act and the Capistrano Beach Local Coastal Program. Seawalls would probably not significantly exacerbate high natural run-up elevation hazards within the Doheny Beach State Park or Capistrano Beach Park areas, because the flatter beach profile here minimizes design breaker height, because existing recreational structures and facilities are set back 200 to 300 feet beyond the Mean High Water (MHW) line and FP-3 Flood Hazard (storm wave run-up limit) Line (Figure 2B), and because the inherent erosive damage from onshore protective devices stands greater chance of being quickly replenished by cross-shore transport of the large littoral sand supplies of this zone. Commensurately, preliminary run-up elevations calculated for this zone are much less than for beaches to the south (Moffatt and Nichol, 1985). Plates 1 through 3 depict offshore breakwaters and sandfills (artificial

Figure 2 (Following Page): Site Conditions, Capistrano Beach/Doheny Beach Subunit

A - Residential structures on narrow beach with steep profile; note existing inadequate timber bulkheads (Arrows), southern Capistrano Beach Private Community

B - Wide lower-gradient beach, Capistrano Beach Park and Doheny Beach State Park to the north, existing structures in recreational zone on beach require revetment protection.

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beach nourishment) with one symbol because the two different protection measures produce the same net result, albeit with different side-effects.

Sandfills and Offshore Breakwaters

In 1959, the US Army Corps of Engineers recommended a periodic sandfill (nourishment) program for the Doheny-Capistrano Beach area. This alternative was, and still remains, the most technically effective and cost-effective long-term beach stabilization approach for this coastal subunit. Beach nourishment programs in the Sunset Beach area to the north have been applied since the 1940's (State of California, 1977B; Shaw, 1980; Griggs and Savoy, 1985) although an unfavorable side effect is temporarily oversteepened foreshore profile and commensurately increased breaker heights (US Army Corps of Engineers, 1984A), at least until the shore face sediment equilibrium is restored and a flatter beach profile achieved.

The Capistrano Beach Local Coastal Program (1988) indicates that the Orange County Flood Control District plans to modify the San Juan Creek channel in order to increase sediment yield to the Capistrano and Doheny Beach areas. Despite this intended effort, it is recommended that dredge materials periodically excavated from the Dana Point Harbor channels should be placed in the shoreface areas downcoast (south) of the mouth of San Juan Creek, assuming that such dredge sediment is unaffected from surface runoff contaminants flowing into the harbor from the commercial and residential zones of Lantern Bay and adjacent blufftop areas. Currently, such dredge sediment is considered contaminated above EPA and CEQA quality-control levels by storm drain runoff, and is thus hauled to submarine canyons offshore and disposed. Original quantities of sandfills necessary to replenish Capistrano Beach were estimated by the Beach Erosion Control Board of the Army Corps of Engineers (1959); recalculation of quantities and placement may be necessary to account for the sheltering effects of the Harbor breakwaters and San Juan Creek sediment detention basins, check dams and concrete embankments. Periodicities of three to seven years are currently employed for artificial beach nourishment of 330,000 cubic yards per year in the Sunset Beach area to the north; this program has met with moderate success (Moffatt and Nichol, 1985).

Offshore breakwaters, experimentally utilized for beach replenishment and stabilization in several areas along the US Coast, including Santa Monica Beach (Army Corps of Engineers, 1984A), are recommended here as the most effective long-term mitigative alternative against beach erosion and coastal property damage. The method involves a rip-rap revetment constructed several hundred yards offshore which reduces longshore current velocity, enhances coarse sediment deposition leeward of the revetment, and increases beach width through gradual buildup of sand over a relatively low-gradient zone between revetment and former shoreline position. The broad depositional zone and reduction in current velocity and wave energy leeward of the revetment, and flat-gradient replenished zone, avoids the erosional problems and breaker height/run-up increases along temporarily-steepened beach profiles from the sandfill method, and the inherent erosion or self-cannibalization hazards of onshore seawalls or revetments (Army Corps of Engineers, 1950; 1984A; Muir-Wood and Fleming, 1981). Detrimental effects of offshore breakwaters include high cost, transfer of erosion problems to downcoast areas, removal of beach front property from immediate shoreline proximity, and wave-refraction disruption of recreational activities immediately seaward of the breakwater (e.g., surfing, swimming, pleasure boating, etc.)

Shoreline Protection and Planning Policies

As with urban development in any areas of environmental hazard, planning polices must be sensitive to the frequent incompatibility between public safety and private interests. Partial defrayment of costs associated with construction of an offshore breakwater, extending far enough south to prevent downcoast transfer of erosion, may come from revenues derived from the formation of a Geologic Hazard Abatement District (discussed below) by homeowners in the Doheny Beach/Capistrano Beach subunit. Either sandfills or offshore breakwaters will promote adequate width of beach, meeting both the Local Coastal Program requirements for recreational needs and Coastal Act policies concerning public access, a presently acute problem at the southern Capistrano Beach private community (LCP, p. 40).

The Local Coastal Program (Policy 39) recommends a periodic monitoring of shoreline position changes due either to natural or urbanization activities affecting sand replenishment along Doheny and Capistrano Beach, as a means of "preventing" beach erosion. Given the wealth of existing data on historical shoreline processes and behavior along this coastal stretch (Army Corps of Engineers, 1959; 1984B; 1985C; 1985D; 1986; 1987A;B; 1988C; R and M Consultants, 1982; Moffatt and Nichol, 1985; this investigation), we recommend that implementation of corrective measures should commence immediately, without the delays associated with additional data collection or refinement, such as additional shoreline monitoring.

II. Capistrano Bluffs/Palisades Subunit

Plate 3 summarizes the geotechnical constraints and mitigative alternatives of this subunit; the high frequency of red and pink constraint severity ratings illustrated in Plate 4 highlight the imperative need for mitigation and effective long-range planning in this subunit.

Static factors and subaerial bluff erosion processes which control geotechnical constraints and geologic stability along the Capistrano Bluffs are discussed below (Section III B and C); these factors and processes are schematically illustrated in Figures 9 and 10, and representative existing conditions and constraints illustrated in Figure 3. Principal natural factors and urbanization conditions which have influenced mitigative alternatives include the following: 1) density of tension fractures or joints exposed within the bluff face; 2) height and angle of repose of the talus cone at the toe of the bluff; 3) thickness and condition of terrace deposits along the blufftop and bluff edge; 4) presence and intensity of groundwater seepage through the bluff face; 5) presence or absence of joint-defined incipient blockfalls and recent landslides; 6) presence of existing structures and their proximity to the bluff edge, 7) presence and quality of existing surface drainage control devices, and 8) historic blufftop erosion and bluff face retreat as documented on aerial photographs and historic coastal maps. Mitigative recommendations are discussed below in detail from geographic south to north within the subunit.

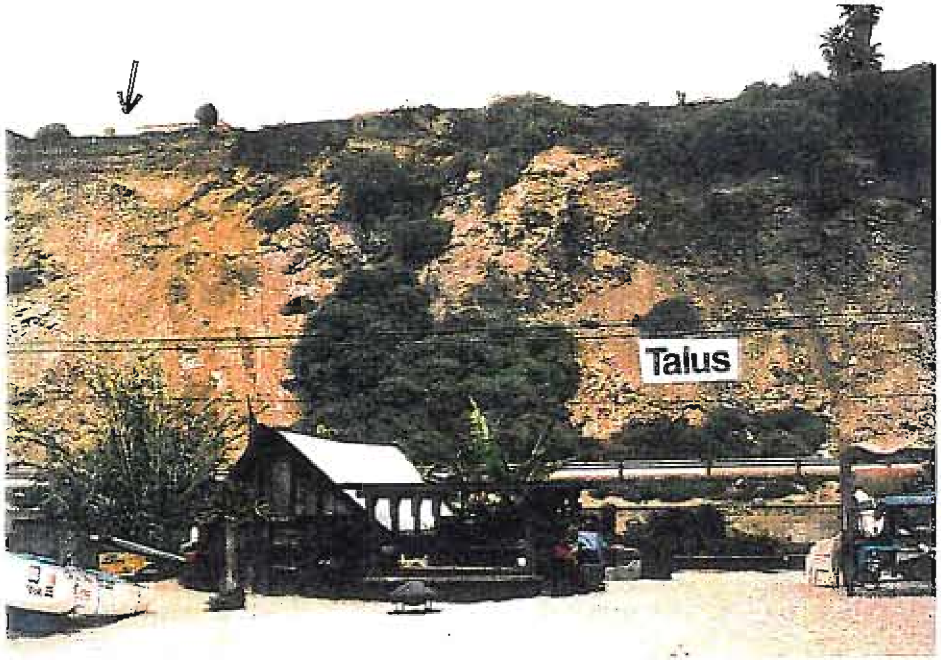
Camino Capistrano To Delgado Road

The coastal bluff zone between the southern end of Camino Capistrano and Delgado Road, including the residential lots along La Ventana Street, is considered prone to blockfall landsliding in the near future, due to proximity of existing residential structures, to overwatering of yards and resultant heavy seepage along geologic contacts between artificial fill, terrace deposits and bedrock, and due to poor surface drainage control. Density of existing vegetation along the bluff edge suggests that this zone is highly susceptible to failure, as recently exemplified by a blockfall landslide in April, 1989 (Figure 3A). Corrective measures by CALTRANS involved removal and excavation of slide debris, placement of modular concrete barriers to protect the highway and resultant steepening of the angle of repose of the existing talus cone at the bluff toe, thus reducing gross bluff face stability. Design of a permanent engineered retaining wall at the bluff toe in this area is recommended, with sufficient freeboard to permit accumulation of subsequent blockfall-debris to a more stable angle of repose, and prevent overtopping and blockage of adjacent Pacific Coast Highway. Structural underpinning of residential foundations not currently on caisson-and-grade beam systems is recommended for structures located at least 25 feet from the existing bluff edge, where the bluff is fronted by talus piles high enough to produce natural setback planes providing a minimum 40-foot "safety zone" (see Figure 10 for example) against future joint-controlled failures. Deep pile (caisson) underpinning is considered useless for homes located near the bluff edge where talus cones are minimal to absent, since no natural buttress is provided against large tensional failures. For redevelopment (razing and rebuilding) or proposed seaward additions to lots in this zone, permitting should require a minimum 40-foot structural setback from the existing bluff edge. The 25-foot setback presently mandated by Coastal Act guidelines (1976, 1977 and 1980) and adopted in the Local Coastal Program (1988), is considered inadequate, given the rates of historical bluff erosion and failure in this zone (see Section IIIC, subsection II, below). Blufftop erosion control, such as the measures outlined in State publications (Amimoto, 1978) and County guidelines (County of Orange, 1978, 1981) should be implemented. Use of corrugated polyethylene tubing for blufftop erosion control is not recommended; blufftop catch basins with schedule 40 PVC drain pipes or suitable substitutes should be employed, and should be adequately extended to drain at the toe of the existing bluff or talus cone. Blufftop retaining walls and/or fill placement to form bluff edge berms, or to redirect surface drainage towards streets, is not recommended, since associated grading operations

Figure 3 (Following Page) - Representative site conditions, Capistrano Bluffs/Palisades Subunit

A - Recent (1989) blockfall, Southern Capistrano Bluffs, related to groundwater seepage problems and inadequate surface drainage control (Arrow). Geometry of failure constrained by height of existing talus cone (illustrated.)

B - Recent Incipient Blockfall, north of Estrella Stairs, partially stabilized by existing talus cone at toe of slide; current surface drainage device is inadequate (arrow.)



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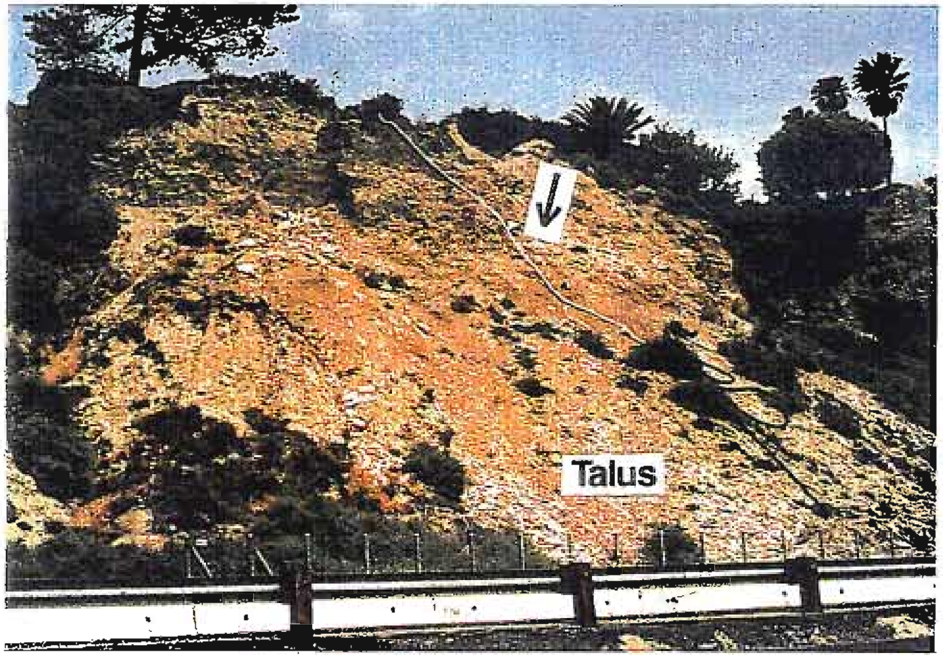

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may further damage the eroded bluff-top. This recommendation retains consistency with Policies 30 and 31 of the existing Local Coastal Program (1988).

Delgado Road To Camino Mira Costa

The pink color-coded zone between Delgado Road and Camino Mira Costa (Plate 4) possesses fewer seepage problems, more stable talus cones possessing shallower angles of repose, more adequate structural setbacks for existing homes and generally lower-density residential development than the zone south of Delgado Road. For reasons discussed above, a minimum 40-foot structural setback should be maintained for all subsequent blufftop development in this zone. Deepened caisson and grade beam foundations are recommended for all new structures, to be designed on a site-specific basis considering local static factors and talus/bluff-face geometries. Erosion-control measures as discussed above should also be employed (Note: the lower-severity code for this zone is <u>not</u> meant to imply that future bluff erosion and failure cannot occur here!).

Camino Mira Costa To Palisades Drive

The lengthy bluff zone extending from Camino Mira Costa northward to the toe of Palisades Drive is zoned for very high hazard severity due to the propensity of recent landslides (e.g., Estrella Stairs, Pines Park district, numerous small blockfalls between Mill Pond Road and Vista Azul Drive), the high density of existing residential structures, poor existing structural setbacks and substandard erosion control measures by individual homeowners. Despite the presence of locally high talus cones, deep caisson foundations are not recommended for much of this area due to the severity of erosion and seepage problems, and due to the proximity of many existing residences to the bluffedge. Those deep pile foundation systems which are employed should probably be designed with end-bearing rather than friction piles, since frictional support of piles would likely be lost during subsequent progressive blockfalls, similar to those affecting this zone during the 1978, 1980 and 1983 storms.

Seepage control, involving either horizontal subdrains emplaced along terrace/bedrock contacts or local dewatering wells, may be effective within the subzones between Vista Azul and Mill Pond Road and adjacent to the damaged Estrella stairs. Costs for establishing dewatering wells may be offset if the extracted groundwater is reclaimed by local water districts under the auspices of drought-mandated, federally-subsidized wastewater reclamation programs. Toe-of-bluff retaining walls with adequate freeboard are recommended for the talus-free zones between Pines Park and Palisades Drive and between Estrella Stairs and Pines Park, to replace the existing CALTRANS modular retaining structures. No new structures should be permitted within the Pines Park recreational zone or the blufftop area adjacent to the Mill Pond Road erosional re-entrant, due to the presence of weakened bedrock seepage, and erosion in these areas. Open-space re-zoning should be considered for undeveloped blufftop lots in this area; such zoning would provide unrestricted public ocean views consistent with Scenic Resource polices (esp. Policy 42) of the Local Coastal Program, while restricting stability-threatening development, consistent with Coastal Act Section 30253. The several incipient landslides within the Estrella Stairs vicinity (Figure 3B) should be anticipated for complete failure during subsequent heavy rainfalls; corrective grading, rock bolts or retaining/crib walls are not considered feasible alternatives against blockfall until erosion and groundwater problems are corrected. Site-specific geotechnical investigations should be performed prior to construction of the proposed Pines Park public accessway to Pacific Coast Highway, given the substantial blockfall landslide hazard of this zone, in compliance with Section 30212 (a) of the Coastal Act.

The orange-coded subzone along Palisades Drive (Plate 4) has a more impressive record of historical slope stability, due in part to the graded slope with blufftop retaining wall upslope from the roadway; this retaining wall, coupled with existing terrace drains and PVC downdrains extending from blufftop lots, provide an excellent example of adequate drainage and bluff erosion control. These measures cannot be applied to most of the actively eroding bluffs elsewhere in this subunit, however, due to the need to avoid potentially damaging grading and construction operations along the blufftops and to avoid the increase in erodible slope area (refer to Section 22, existing Capistrano Beach LCP). Effective surface erosion control (see County of Orange guidelines, 1978; 1981) and toe-of-slope retaining walls are recommended for the slope area below Palisades drive and Gazebo Park (Plate 3), to mitigate mudflow/landslide damage to the tourist-serving commercial district below this area. Slope failures during the 1978 storm season caused local damage to structures in this subzone.

Doheny Palisades Commercial Area

Toe-of-slope retaining walls are recommended as protection against slope failures along bluffs in the commercial subzone north of Palisades Drive. Earth-fill buttresses may also be suitable in local areas along the commercial zone, given the available equipment access, albeit through a corresponding setback and reduction in lot size. Existing erosion-control features in this zone, including polyethylene drain pipe, are considered inadequate. Seepage is locally excessive at the northwestern end of this zone along the geologic contact between artificial fills and siltstone bedrock. Structural underpinning of existing blufftop homes utilizing deepened caisson footings would normally be suitable in this area due to the shallow natural "setback planes" (see Figure 10) afforded by the large talus accumulations (R and M Consultants, 1982). However, remedial construction involving deepening of footings is not advisable here, given the proximity of several existing homes to the actively eroding, unstable blufftop. Effective groundwater seepage and surficial erosion control measures are considered the most logical and cost-effective mitigation alternatives, particularly since many blufftop homes presently feature deepened foundations. Well-point dewatering systems may be a viable option for seepage control.

Dana Bluffs

The Dana Bluffs area proper, at the northern end of the Capistrano Bluffs subunit, should be provided with similar mitigative features for groundwater and surface erosion control as the commercial subzone to the south. Open-space land-use designations should be applied to undeveloped blufftop lots, to minimize property damage and meet scenic resource/coastal view requirements of the Coastal Act and existing LCP. An engineered retaining wall, possibly including long rock bolt anchors, should be provided for the talus-free, undermined bluff face at the extreme north end of Dana Bluffs; the retaining wall should possess sufficient freeboard to prohibit slide debris from reaching the adjacent roadway, as well as upgraded backdrain systems to minimize groundwater accumulations. Deep foundation underpinning should be applied to blufftop homes south of this proposed retaining wall, where existing structural setbacks and high talus cones would make such underpinning feasible (Figure 10). Minimum 40-foot bluff-edge structural setbacks should be employed for any permitted redevelopment projects.

Four "universal" recommendations to minimize subsequent bluff failure in the subunit include 1) no permits for remedial grading or construction should be issued for areas on or within of 50 feet of the limits of any known landslide or incipient blockfall, contrary to the suggestion of Policy 24 of the existing Capistrano Beach LCP; 2) no access paths or stairways should be constructed on existing talus cones, 3) there should be restricted removals of talus debris, since such operations eventually lead to talus oversteeping and failure; 4) minimizing blufftop watering, possibly through planting of drought-resistant vegetation.

III. Dana Cove and Harbor Subunit

Mitigative recommendations for this subunit were based on the following considerations: 1) exposure of adversely-oriented joint planes in bluff faces; 2) presence of weakly-cemented erodible sandstone beds within bluffs behind Dana Point Harbor Drive, 3) proximity of medium-density residential and commercial structures to The existing blufftop; 4) relatively poor surface-drainage control conditions; 5) presence and geometry of talus accumulations at blufftoes, and 6) historical erosion record.

Lantern Bay Project Area

The existing 1:1 (horizontal:vertical) cut slopes of the Lantern Bay Project Area along Dana Point Harbor Drive (graded in 1982-1984) are assigned the lowest (yellow) hazard severity code level, due to the presence of favorably-oriented (e.g., into-slope) bedding planes, laid back slope gradient and adequate tri-level surface drainage ditches. Erodible sandstones of the Capistrano Formation have been subject to locally severe billing since construction however; therefore, additional surficial erosion control methods (such as jute matting, stabilizing landscape vegetation, etc.) and toe-of-slope slough walls are recommended to prevent debris accumulation along these slope areas.

Dana Harbor Park Area

The bluff face and blufftop zone along Dana Point Harbor Park is currently designated for Open-Space/Conservation land use, requiring the bluff face to remain preserved in its natural, undeveloped state (Dana Point Local Coastal Program, 1986). Improved land use would have extended this designation to the adjacent blufftop area as well, within a 25-to-40-foot setback zone, prior to the construction of Dana Point harbor in 1966-1970 (Klemme, 1979) (Plates 4 and 5). Construction of the harbor breakwaters effectively shielded this zone from further marine erosion processes, particularly high southerly waves such as those associated with the 1939, 1958 and 1983 storm periods (Section IIIC, subsection II, below; Plate 8). Rainfall irrigation of properties within the blufftop medium-density-residential zone, coupled with storm drain outfall at the bluff face re-entrant between the Streets of the Amber and Violet Lanterns, accelerates erosion of friable Capistrano Formation sandstones along this seacliff, in turn leaving massive, resistant conglomerate interbeds precariously undermined and prone to failure along well-developed joint surfaces. Relatively fresh talus block accumulations beneath this re-entrant (Figure 3A), and at other points along the blufftoe, attests to this continuing erosional process during the 20-year period following harbor construction. The process is particularly acute where significant thicknesses of erodible terrace deposits overlie the bedrock, such as the zone immediately west of Amber Lantern. Accelerated retreat of these bluff top terrace deposits, due to poor drainage control and irrigation practices by homeowners, increases exposure and erosion rate of subjacent sandstone bedrock, and thus increases rate of bluff face retreat and talus accumulations (see Figure 9). It is evident that areas with existing residential structures nearest to the bluff edge coincide with zones of accelerated bluff top erosion and large toe-of-bluff talus accumulations.

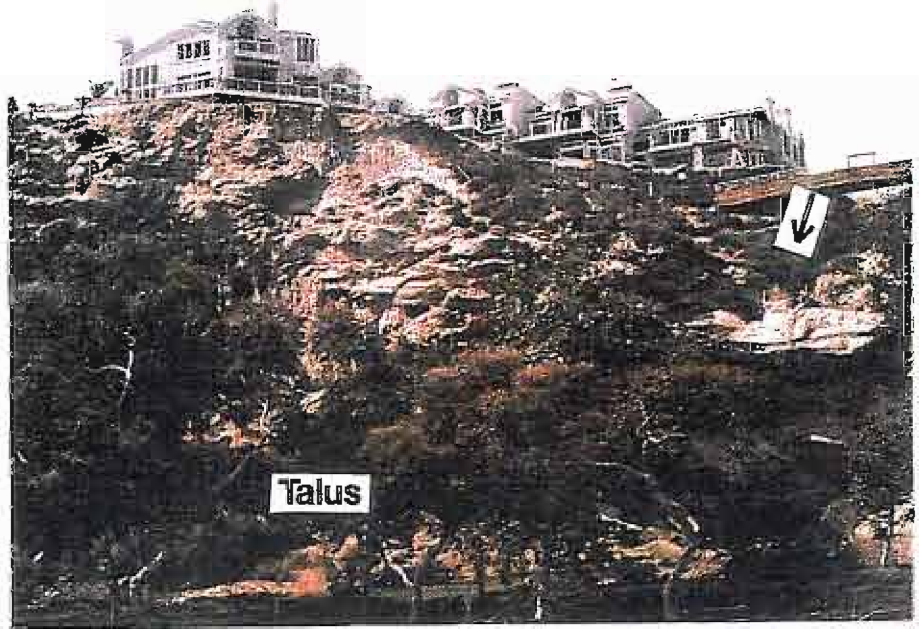
In consideration of these conditions, the following mitigative measures are recommended, as graphically depicted on Plate 2):1) implementation of adequate surface drainage control and irrigation practices by blufftop property owners, including planting of drought-tolerant vegetation, reduction of landscape watering, construction of catch basins and surface drainage swales to divert runoff northward into storm drains along Santa Clara Street; avoidance of bluff-face structures such as gunnite facing; and elimination or removal of drainpipes which drain over the bluff edge; 2) City planners should interface with County Flood Control District officials to abandon the storm drain outfall between Amber and Violet Lantern, since this runoff not only continues to accelerate re-entrant erosion and blockfalls; but carries contaminated waters into Dana Point Harbor; such contamination apparently exceeds CEQA levels, and presently makes Dana Harbor dredge sediment unusable for beach nourishment along adjacent Doheny Beach State Park. Diversion of runoff from Santa Clara Street into a separate inland storm drain system is thus advised; the

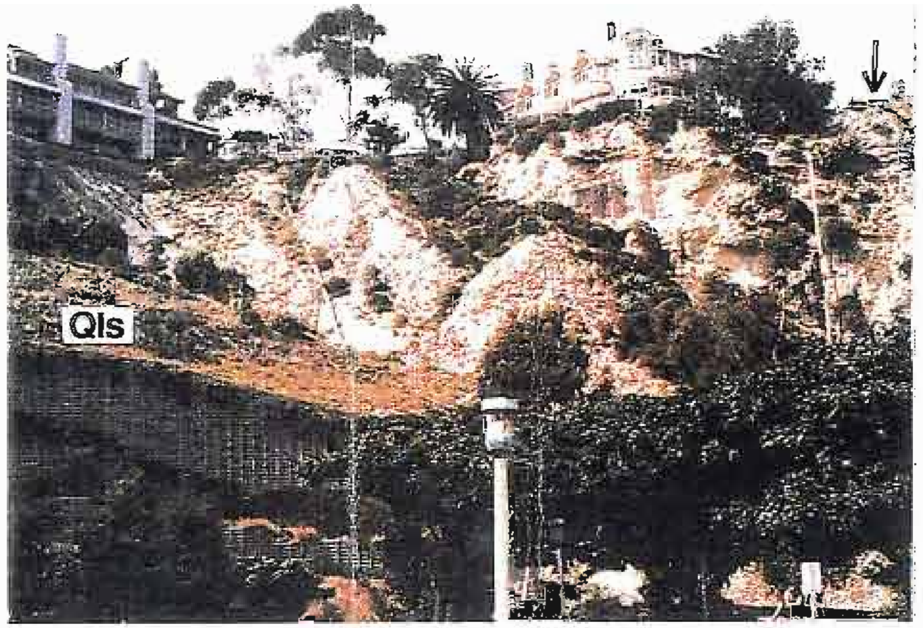
Figure 4 (Following Page) - Representative Site Conditions, Dana Cove and Harbor Subunit

A - Erosional re-entrant (arrow) with storm drain outfall and recent blockfalls; talus cone at toe of adjacent (inactive) seacliff provides partial bluff face stabilization, if adequate surface and groundwater drainage is maintained.

B - Stabilized Cannons Restaurant slope failure (1980), with crib wall and retaining wall/rock anchor elements. Subaerial erosion continues to cause bluff retreat, particularly in zone of poorly consolidated terrace sands below high-density residential structure near blufftop at right. (arrow)

C - Incipient slope failures, groundwater seepage problems and erosion along poorly-constructed fill slope below Cove Road near Marine Studies Institute. AF = artificial fill, TSO = San Onofre Breccia. Arrow points to CMP erosion-control device along contact.





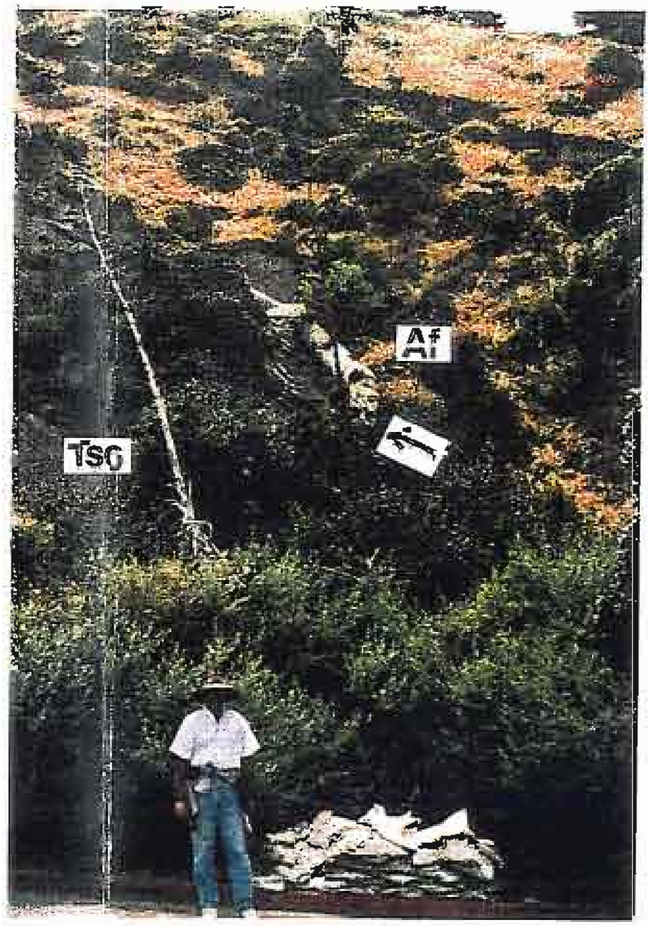


FIGURE 4

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existing outfall is considered to be incompatible with allowable bluff drainage facilities as defined for the Coastal Conservation District within the existing Local Coastal Program; 3) in compliance with policies 1,9, and 18 of the existing Land Use Element, regarding a 50-Year design-life safety period relative to bluff erosion, it is recommended that new or redeveloped blufftop lots between Violet Lantern and the Lantern Bay sector be required to maintain a 40-foot minimum structural setback, and that no grading be permitted within this setback zone other than minor drainage berms; no structures or grading operations of any sort should be allowed at the blufftop for similar reasons; 4) a 25-foot structural setback with deep caisson and grade beam foundation elements should be required for new or redeveloped structures between Amber Lantern and the commercial zone near Cannons Restaurant; the large talus cone in this area results in migration of the setback plane towards the bluff, and commensurately increases the Relative effectiveness of deepened footings (see Figure 10). Although bedrock units in this subunit are more resistant to erosion than the weak siltstones of the Capistrano Bluffs/Palisades subunit, it should be kept in mind that natural processes of bluff retreat are identical between the two subunits; such processes will ultimately continue despite the implementation of mitigative techniques, albeit at a slower rate.

Cannons/Cove Road Area

The commercial district extending from Cannons Restaurant to the boundary of the Dana Point Headlands subunit, including Cove Road and adjacent bluff face, has been given a high (pink) severity rating (Plate 4), due to 1) the presence of historic slope failures within highly fractured bedrock, (Figure 3B), 2) bedrock (San Onofre Breccia) with oblique out-of-slope dip components; 3) thick erodible terrace deposits at blufftop, and 4) seepage along the improperly-graded artificial fill slope along Cove Road (Figure 3C). The 1980 failure of the bluff face within highly sheared, weak bedrock along the fault zone beneath Cannons Restaurant followed heavy rainfall and buildings of abnormal pore pressures; a much larger, deep-seated landslide occurred on the same site during the early 20th century, probably during the 1916 storms. Stabilization of the 1980 failure involved construction of a crib wall and shotcrete retaining structure with deep rock anchors (Kerwin, 1989). Future bedrock failures within the San Onofre Breccia can be minimized through application of the erosion-control alternatives discussed above; construction of earth-fill buttresses with toe-of-slope retaining walls are recommended for mitigation of slope failures below Cove Road. Fill buttresses should feature adequate keyways and subdrainage; existing seepage and surficial failures along the fill/bedrock contact below Cove Road (Figure 3C) are an artifact of poor Grading code conformance (Orange County EMA, 1981) with regards to subdrainage and fill slope construction. Retaining walls should be designed with adequate freeboard, and may be utilized above Cove Road as well, to minimize debris accumulation hazards.

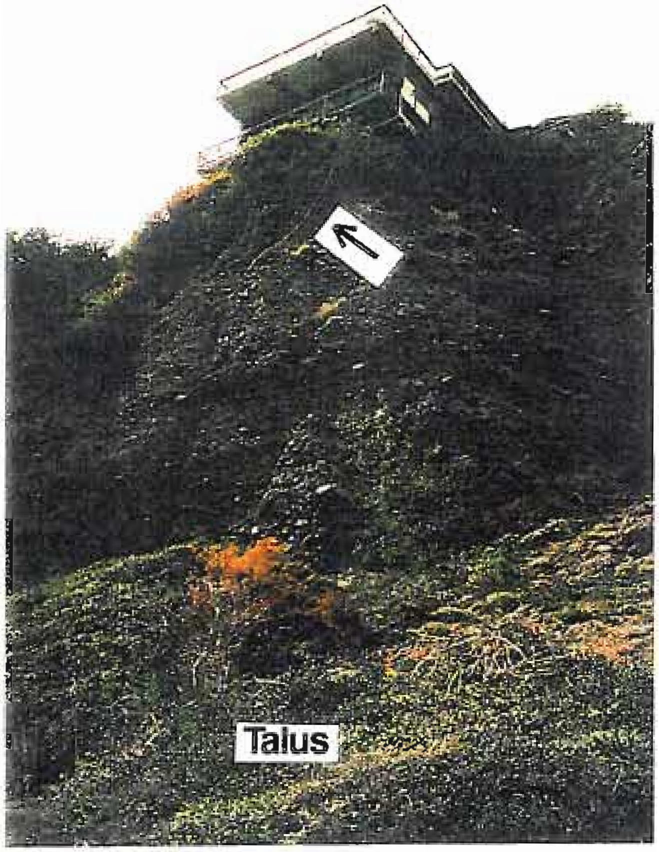
IV. Dana Point Headlands Subunit

Static and dynamic natural factors which impose geotechnical constraints in the Dana Point Headlands subunit include: 1)active marine erosion due to lack of a protective beach, exacerbated by direct exposure to severe southern storms and unfavorable refraction patterns for intermediate-to long-period waves (Plate 8A); 2) adversely-oriented tectonic and tension (unloading) joint patterns exposed within the bluff face; 3) locally thick accumulations of highly erodible terrace sands along the blufftop; 4) faulted and fractured bedrock exposed along the west-facing promontory of the headland, historically subject to landslides and the formation of hazardous sea caves, sea arches and accelerated bluff retreat (Figure 5B) (particularly during the storm period of the late 19th Century, when over 100 feet of retreat occurred) (Army Corps of Engineers, 1959; Plate 1; Plates 4,5; Section III C, subsection II, below). These four conditions have prompted the moderate to severe hazard codes illustrated on Plate 4, despite the presence of inherently low erodibility potential of the San Onofre Breccia bedrock comprising the headlands. The existing Local Coastal Program Land Use Regulation for the Headlands sector (1988) applies "Other Open Space" designation to a zone extending from 50 to 400 feet inland of the existing bluff edge along the entire headlands subunit. This land use designation allows for "other permitted usage" including public parking, public rest rooms and maintenance structures. It is recommended that all permitted structures be provided with blufftop setback distances as depicted on Plate 1, which are dependent upon local conditions and historic erosion history (Plates 4;5). Furthermore, given the inherent seepage problems associated with onsite sewage absorption systems, it is recommended that public rest rooms not be permitted within the other Open Space land use district. Additionally, modifications or expansion of effluent disposal systems for existing blufftop structures should not be permitted. Erosion-control measures along the proposed blufftop trail (Local Coastal Program, 1986) should incorporate the suggestions discussed above (Dana Cove and Harbor subunit), and should be reviewed ba a certified engineering geologist prior to implementation, as well as periodically during the design life of the trail system. To minimize long-term liability, the City should also consider purchasing the privately-owned cobble beaches along the base of the sea cliffs as well as the existing homes within the high-density-residential district along the bluff top (severe hazard code, pink color, Plate 4). Upon acquisition by the City, this district should be re-zoned for Open Space/Conservation Use, subject to the recommendations discussed above. Warning signs should also be posted adjacent to and within existing sea caves along the west-facing headland promontory, to discourage public access and minimize liability in the event of their collapse. Further mitigation of sea cave hazards are not anticipated (i.e., filling with rip-rap stone, construction of seawall, concrete slurry plug, etc.), assuming that the 100-foot blufftop setbacks recommended on Plate 1 will be implemented by the City. Construction of access stairways should not be permitted either within this west-facing promontory zone or elsewhere along the sea cliffs, due to the erosion problems which inherently develop

Figure 5 - Representative Site Conditions, Dana Point Headlands Subunit (Following Page)

- A - Single-Family Residential Structure at Bluff Edge, within Coastal Act 25-foot-setback zone. Arrow indicates inadequate surface drainage control. Talus cone at toe of seacliff provides only partial stabilization against seacliff failure.
- B - Low-altitude (1983) oblique airphoto of headlands; Arrow at left indicates zone of large, deep seated landslide which first failed during 1884-1891 storm period; central arrow indicates sea caves formed along prominent joint sets during 1983 storm; arrow at right indicates blockfall which failed during 1983 storm.

Note lack of sandy beach; entire headlands subject to active marine erosion.



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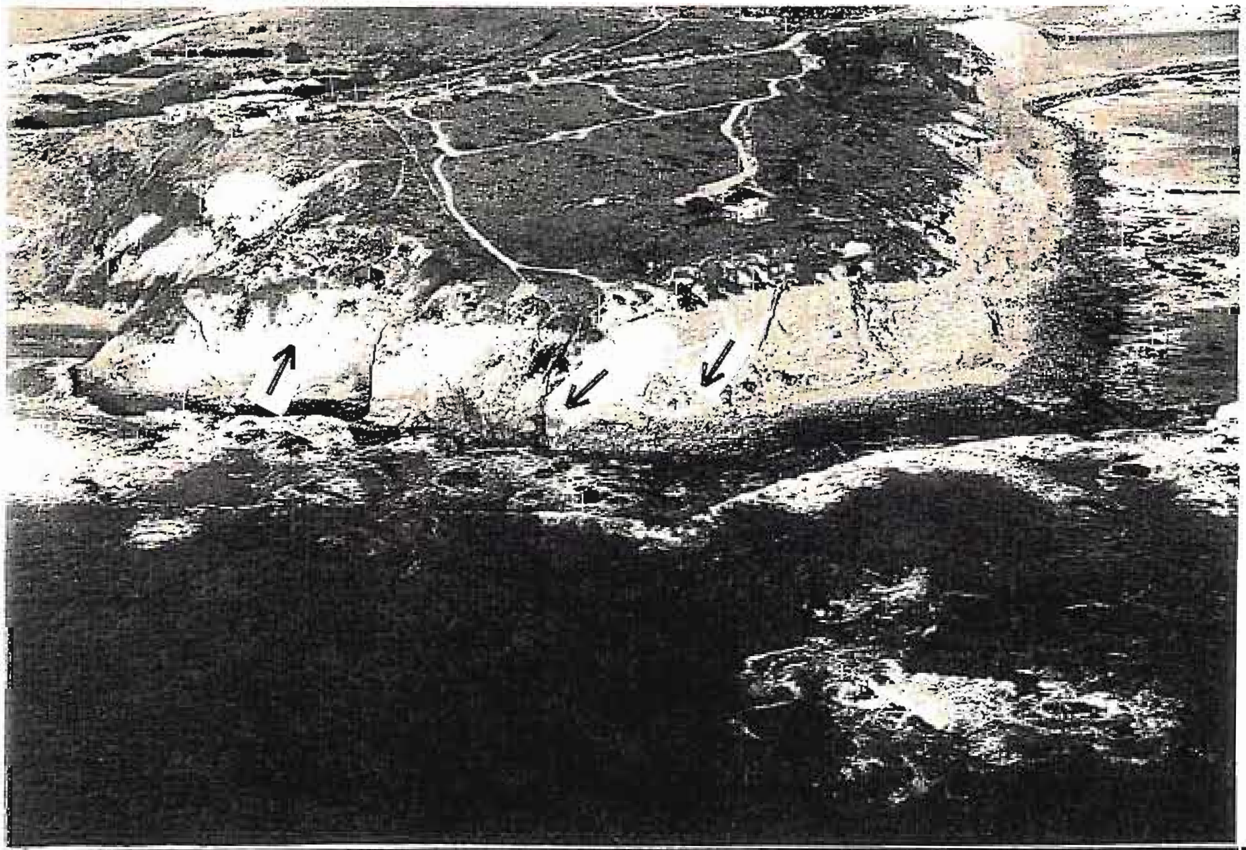

B

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REPRESENTATIVE SITE CONDITIONS
DANA POINT
HEADLANDS SUBUNIT

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adjacent to such structures. In light of the erosional history of this Headlands segment, it is probable that the existing Blufftop structures (Figure 5A) will not be safe from the threat of bluff retreat over the next 50-year-period.

V. Niguel Shores Subunit

Static and dynamic natural factors and processes impacting the geotechnical constraints of the Niguel Shores subunit include 1) the presence of large deep-seated bedrock landslides, 2) design storm wave run-up elevations locally exceeding existing beach grade; 3) the presence of small "pocket" beaches with sediment yields restricted to erosion of adjacent urbanized blufftops and watersheds; 4) thick deposits of erodible terrace sand deposits prone to excessive erosion and retreat. These factors, coupled with residential development, engineered fills and existing protective devices at beach grade, have prompted the mitigative recommendations and hazard severity codes of Plates 1 and 4.

Southern Dana Strand Area

The southern end of the subunit, at the south end of Dana Strand beach, has been rated as very high severity (Plate 4). This zone has been subject to severe blufftop erosion of the thick terrace sands in the graben zone of an ancient bedrock landslide immediately below the southern extent of Dana Strand Road. The existing high density residential land use of this blufftop has led to development of new homes in this area which are located too close to the existing bluff edge. Overwatering and improper landscaping in this zone have contributed to groundwater seepage, surficial erosion and bluff retreat, as have the recent storms of 1978, 1980 and 1983. Structural underpinning of foundation systems with deep soils embedded into bedrock should be considered for any existing blufftop residences not currently provided with such foundations. Any new or redeveloped structures permitted for this zone should not be constructed within 60 feet of the existing bluff edge, given the record of historical erosion in this zone. Access trails or stairways should not be constructed between Dana Strand Road and the beach recreational area within this high-risk area.

Niguel Shores

The remainder of Dana Strand Beach (Niguel Shores) and adjacent inland residential developments possess moderate geotechnical hazards due to locally high storm wave elevations and erosion of buttress fills constructed along the toe of the massive landslides of this zone (Plate 1). The most recent such erosion destroyed the inadequately-designed stone revetment at the toe of the Breakers Isle fill slope during the southerly storms of January, 1983 (Moffatt and Nichol, 1985); this storm proved that the Dana Point headland does not provide adequate sheltering effect from such storms, as once believed. Although historical maps and coastal airphotos suggest that this beach is in a state of dynamic equilibrium due to cross-shore sand transport and erosion of terrace sands from adjacent bluffs (such as the erosion associated with greater than 150 feet of bluff retreat during the 1938-1941 storm period), the urbanization of the bluffs over the past twenty years has diminished the effective sand budget to this coastal stretch. Therefore, construction of an offshore breakwater of periodic beach nourishment program is recommended for long-term beach stabilization of the shoreline position. Public recreational structures, as allowed through the existing LCP land use designations, should not be permitted unless such long-term stabilization is implemented. In the meantime, redesign of the damaged revetment at Breakers Isle should be undertaken, conforming with the design breaker height data from the 1939 and 1983 storms (discussed below, Section IIIC, subsection II).

Ritz Carlton Headland

The resistant small headland below the Ritz Carlton hotel has not moved significantly within the time span or the resolution of available coastal maps and airphotos. The existing rip-rap revetment was damaged negligibly during the January, 1983 storms; therefore, existing mitigative measures along the shoreline at this headland are apparently adequate at the present time, particularly if beach nourishment is implemented along Niguel Shores, since local wave refraction patterns along pocket beaches tend to cause littoral drift both northward and southward (Griggs & Savoy, 1985; Moffatt and Nichol, 1985). As an independent quality assurance measure, breaker heights reported at Dana Point during the 1939 storm should be used to calculate revetment dimensions required for this location.

Salt Creek Beach

Available historical shoreline behavior data suggest that Salt Creek beach, north of the Ritz Carlton headland, has been consistently progradational or accretionary, with local retreat and erosion during large storm years (e.g., 1939,1958,1983). Shoreline equilibrium is generally rapidly restored along this beach following storm wave erosion, however, due to the predominantly cross-shore sand transport mode and relative lack of longshore transport southward out of the system around the Dana Point headland. For this reason, the existing

revetment at the toe of the buttress fill of the Ritz Cove residential development is probably sufficient to prevent design storm-wave erosion. However, given the calculated design run-up elevations in excess of natural beach grade between the Ritz Carlton headland and Salt Creek outfall, structures at beach grade, allowed under the current (public recreational) land use designation (Laguna Niguel Development Plan and Feature Plan, 1987), are not recommended.

Figure 6 - Representative Site Conditions, Niguel Shores Subunit (Following page)

A - View South to south end of Dana Strand Beach; Arrow at left indicates zone of poorly consolidated, actively eroding terrace sands in graben (headscarp) zone of ancient landslide, adjacent to homes constructed at bluff edge; arrow at right indicates large bedrock landslides which failed during severe 1884-1891 storm period.

B - View north; Damaged & partially repaired rip-rap revetment (arrow) at toe of landslide buttress fill slope, Niguel Shores (Breakers Isle) private residential community. Note width of beach.

C - View north; Wide, low-gradient (shallow profile) sandy beach at Salt Creek Beach Park. Arrow points to rip-rap revetment, constructed at toe of landslide buttress fill for Ritz Cove residential development; revetment designed utilizing wave data from 1983 storms.

A

B

C

FIGURE 6

REPRESENTATIVE SITE CONDITIONS
NIGUEL SHORES SUBUNIT

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VI Monarch Bay Subunit

Processes and factors affecting geotechnical constraints within the Monarch Bay Subunit (Plate 1), and thus the relative hazard severity rating (Plate 4), include the following: 1) presence of locally oblique, out-of-slope bedding orientations, 2) presence of historic slope failures adjacent to blufftop residential developments, 3) inadequate blufftop erosion control and subsequent accelerated erosion of terrace materials 4) active marine erosion at bluff toe due to narrow cobble and sand beaches.

The combination of the above-mentioned factors has prompted a high (pink) severity code rating for the bluff face and blufftop zone between the Mouth of Salt Creek and minor promontory east of Three Arch Bay beach. Blufftop drainage of the Monarch Bay residential community should be diverted toward Crown Coast Road and Beach Club Drive where feasible, or diverted into catch basins and outletted through schedule 40 PVC pipes well beyond the erodible bluff-edge of those lots possessing seaward drainage. Structural setbacks for many of the existing blufftop homes are well within the required 25-foot Coastal Act setback zone; those homes on shallow foundations at grade should consider deep caissons as additional safety measures, to be embedded a sufficient depth into bedrock below terrace deposits to achieve desired bearing capacity. Such deep foundations are particularly recommended in areas upslope from historic (1938 storm) slope failures in this zone (Plates 1,4,5) since these areas will be most susceptible to movements during future periods of heavy rainfall, much like the 1980 near-disaster at the Cannons Restaurant landslide in the Dana Cove and Harbor subunit. Given the potentially severe marine erosion conditions along these sea cliffs and the high runup elevations associated with 1983 storm waves along Salt Creek Beach, recreational facility structures, allowed under the current land use designation, should not be permitted on the beach. This recommendation will be consistent with the Ocean Protection Devices and Beach Erosion policies of the existing South Laguna LCP. Finally, re-zoning of the bluff face and blufftop areas in this zone to Open Space/Conservation, while maintaining a recreational zoning for the adjacent beach, should be considered by the City in order to preserve the bluff face in its natural state.

The northern segment of this subunit, adjacent to Three Arch Bay Beach, has had negligible shore line or bluff retreat as determined from available historical records. New blufftop structures should conform to the current Coastal Act 25-foot-setback policy, and blufftop erosion and drainage control measures should be implemented by individual homeowners. Access stairways are not recommended between the blufftops and beach areas along any of

Figure 7 - Representative Site Conditions, Monarch Bay Subunit (Following Page)

A - Blufftop residences along Crown Cove Road; vegetated slopes within zone subjected to historic landslides (1938 and 1969 storms) (arrows), as well as present-day erosion of blufftop terrace sands. Blufftop lot gradients slope seaward locally greater than 2%. Several structures located inside 25-foot Coastal Act setback zone (based on precise definition of bluff edge).

B - Western end of subunit; stable seacliff exposed to active marine erosion processes (on left), adjacent to zone with historic slope failure (arrow). Lack of sand beach promotes effectiveness of active marine erosion.

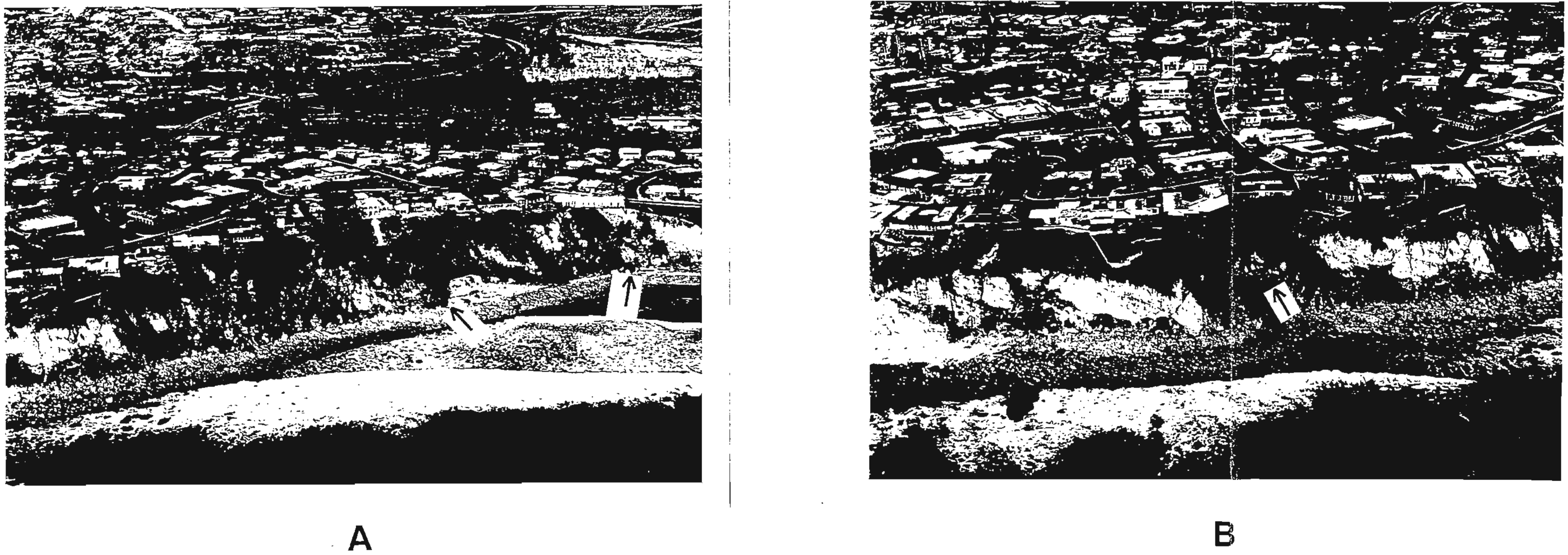

FIGURE 7

REPRESENTATIVE SITE CONDITIONS
MONARCH BAY SUBUNIT

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VII GEOLOGIC HAZARD ABATEMENT DISTRICTS

There are a number of areas within the City of Dana Point coastal zone where geologic hazards are an acute concern to property owners and the general public. There are currently four options for coping with acute geologic hazards: (1) private individuals voluntarily perform remedial earthwork and grading on their own initiative and at private expense under Grading Permits issued by EMA Regulation: (2) private individuals perform remedial earthwork and grading at private expense after being ordered to do so by the Building Official, following procedures for hazardous conditions set forth in Section 7-1-812 of County Grading Code; (3) public agencies, such as EMA Public Works or CALTRANS, perform remedial earthwork and grading on public property at public expense, often using federal or state disaster relief funds if the geologic hazard can be linked to an officially-declared "disaster", such as intense winter rains or earthquakes; and (4) property owners may form a legal entity known as a Geologic Hazard Abatement District (GHAD), which performs remedial earthwork funded by local property taxes and revenue bonds.

Legislation concerning abatement districts became effective in 1980 as Division 17 of the California Public Resources Code (Sections 26500 through 26601). The first GHAD in California is the Abalone Cove Landslide Abatement District in Rancho Palos Verdes (Bandy, 1980). A GHAD may be formed by either (1) resolution of the Orange County Board of Supervisors, or (2) a petition signed by the owners of not less than 10 percent of the real property to be included within the proposed district. A geologic report signed by a Certified Engineering Geologist must be prepared to serve as a "plan of control" for the geologic hazard. After a properly scheduled public hearing, during which time the GHAD may be vetoed by owners of more than 50 percent of the assessed valuation of the proposed districts, the Orange County Board of supervisors can order the formation of the GHAD. They may appoint five owners of real property to serve as the initial Board of Directors, or may appoint itself to act in that capacity. After establishment of a GHAD, funds may be obtained by use of the Improvement Act of 1911, the Municipal Improvement Act of 1913, or the Improvement Bond Act of 1915. Property tax assessment may be made on a subjective proportional-point basis so that each property owner pays his fair share.

SECTION III

SUMMARY OF TECHNICAL DATA FOR COASTAL ZONE

A. GENERAL SUMMARY: COASTAL PROCESSES AND EROSION HISTORY

Through the application of the analytical methods discussed above (Section IB), an appraisal has been completed identifying the segments of the Dana Point coastal zone which have been most significantly affected by historical erosion, as well as those areas considered to pose the greatest likelihood of subsequent shoreline retreat and public hazard from an urban planning viewpoint. These two types of areas are not necessarily coincident, given that the former areas are defined exclusively upon natural static and dynamic conditions, whereas the definition of the latter areas incorporates urbanization conditions, as well.

In summary, Dana Point coastal erosion and property damage has been linked temporally to historical major storm periods and the processes inherent to such storms, particularly excessive Rainfall, elevated sea levels and unusually large breaker heights. These negative effects are balanced somewhat by the large quantities of sediment transported to the shoreline during storm floods, such as occurred along San Juan Creek during the storms of 1884, 1916, 1938, 1952, 1968-69 and 1977-1978. The largest coastal changes attributed to individual storm periods documented in the present study include 150 feet of blufftop/bluff face erosion and retreat along Niguel Shores during the 1938 to 1941 storm period, 100 feet of landslide-related retreat along the western promontory of Dana Point Headlands during the 1884 to 1891 storm period, 75 feet of retreat along the south-facing segment of the Headlands during the same period, 100 feet of local blockfall landslide retreat in this same south-facing Headlands zone during the 1938 to 1941 storm period, approximately 200 feet of retreat of the former rock headland located at the position of the eastern Dana Harbor breakwater during the 1884 to 1891 and 1938 to 1941 storm periods, localized 30 to 50 feet of blufftop retreat in the Capistrano Bluffs/Doheny Palisades area during the 1884-1891 and 1938-1941 storm periods, and 50 to 60 feet of beach retreat during the storms and perigean spring tides of 1939, 1962, 1974 and 1983 in the Capistrano Beach and southern Niguel Shores (Dana Strand Beach) areas.

The present investigation, as well as previous investigations by other consultants (U.S. Army Corps of Engineers, 1987A, B; 1988c) reveals that subaerial erosion (discussed below), directly impacting coastal blufftop retreat, is much more pronounced on historical survey maps that are shoreline position changes related to marine erosion. This is explained by the tendency for active marine erosion processes (e.g. wave attack) to remove erosional debris, thus making shoreline changes less evident on historical maps. For those coastal areas artificially removed from the influences of marine erosion (e.g. Capistrano Bluffs/Palisades; Dana Cove area), such processes obviously play no role in directly affecting shoreline behavior. The present study has also documented that subtropical storms from the south or southeast have produced the largest-magnitude historical erosion, associated with periodic strong El Nino/Southern Oscillation Events (ENSO)(see Plate 7); the blocking effect of the Channel Islands tends to reduce severe storm wave damage form Pacific Basin storms (Plate 8), although there is historical evidence of such storms occasionally causing significant coastal damage.

Correctly interpreting the past historical coastal erosion record, and thus successfully predicting future shoreline behavior, requires an understanding of the natural conditions influencing the Dana Point littoral zone. These conditions include static geologic factors (principally bedrock lithology and structural geology), steady state dynamic processes (littoral sediment transport and longshore currents, short and long-term sea level fluctuations, wave refraction patterns and natural erosion processes) and episodic or storm-related dynamic processes (historic meteorologic cycles, storm wave azimuth and sizes, coastal sediment delivery during flooding, and large-scale changes in beach or coastal bluff configurations). Each of these significant static or dynamic processes is discussed briefly in the following section.

B. NATURAL STATIC FACTORS

As depicted in Table 1 (Severity Index Matrix), natural static factors influencing coastal erosion rates are 1)general lithology and erodibility of geologic units in the coastal zone, including bedrock exposed in coastal bluffs or sea cliffs; 2)structural geology of the bedrock exposed in coastal bluffs, including orientation and density of bedding planes, joints (fractures) and faults, and 3)presence or absence of prior slope failures, either blockfalls, surficial slumps or deep-seated bedrock landslides along coastal bluffs. These factors are briefly summarized for each of the six subunits below:

Monarch Bay subunit

The lithologic units of this subunit include bedrock consisting of the San Onofre Breccia (Tso symbol, Plate 1), comprised of massive, well-cemented sandy conglomerate, breccia and local well-bedded sandstones, and surficial units consisting of marine terrace (Qtm symbol, Plate 1) comprised of poorly consolidated to loose, massive to laminated yellowish brown to reddish brown coarse sand. A permeable basal gravel layer is locally present along the erosional contact between terrace deposits and subjacent San Onofre Breccia. Terrace deposits occur locally up to 20 feet in thickness, and are highly erodible. Massive conglomerates of the San Onofre Breccia are relatively low in erodibility; sandstone units have a slightly higher erodibility potential. Structural geology of the San Onofre Breccia is dominated by relatively uniform bedding dipping between 20 and 40 degrees southeast, possessing shallow (five to ten degree) dip components out-of-slope. Local bedding plane variations occur adjacent to the high-angle north-to-northeast-striking faults exposed within the sea cliff. Historic bluff failures, with rotational landsliding occurred during the 1938 storm, are geometrically defined by shallow out-of-slope bedding within sandy, well-bedded units of the San Onofre Breccia; the bedrock is additionally sheared between two of the high-angle faults mentioned above. Several small-scale blockfall-type slope failures occurred here during 1938, and 1939 as well. Partial reactivation of the large landslide occurred during the 1968-69 storm period.(Vedder et al, 1957; Edgington, 1974).

Niguel Shores Subunit

Lithologic units exposed in this subunit include highly-erodible marine terrace sands with basal gravel layer as described for the Monarch Bay subunit above; terrace deposits locally exceed 30 feet in thickness in the southern half of the subunit. Bedrock units include San Onofre Breccia, Monterey Formation and Capistrano Formation. Lithologically the San Onofre Breccia is similar to that exposed within the Monarch Bay sea cliffs, with local well-bedded conglomeratic sandstones exposed in the bluffs at the southern end of the subunit. An exposure of probable San Onofre Breccia (Plate 1, Map Symbol Tso (?) forms the southern flank of the Ritz Carlton headlands, where it is apparently interbedded with the Monterey Formation (Plate 1, Map Symbol Tm). The low erodibility of the unit has resulted in the formation of this headland. The Monterey is the most widely exposed bedrock in this subunit, and consists of well-bedded diatomaceous shales, silty shale, siltstone, chert and calcareous shales; the unit is generally expansive, highly fractured and locally highly erodible, although the more siliceous or calcareous units tend to resist erosion fairly well (Neblett, 1966;Edgington, 1974). The Capistrano Formation, exposed locally within and adjacent to landslide masses in the Salt Creek Beach/Ritz Cove area, consists of brownish-grey to dark gray micaceous siltstone and silty shales; it generally exhibits poorer bedding than the Monterey Formation, upon which it rests conformably to unconformably. It is generally moderately to highly erodible, and loses shear strength rapidly when saturated, as does the Monterey Formation.

Bedrock structure within the Niguel Shores subunit is defined by east-treading, west-plunging folds, including two large synclines north and south of Ritz Carlton headland, respectively. Bedding of all units generally dips steeply to the north or south, except within fold axes, where it dips generally to the west.

This subunit features the largest bedrock landslides in the entire Dana Point coastal zone. A large (20-acre) slide occurs upslope from Salt Creek Beach north of Ritz Carlton headland (Plate 1); it failed within the stratigraphically lower portion of the Capistrano Formation. An even larger (40-acre) landslide complex occurs along the entire Dana Strand Beach area, within the Monterey Formation. The toes of both large slides extend offshore and are buried beneath recent beach deposits, indicating that both failed in prehistoric times during an ancient sea level lowstand. Both landslides failed westward down the axes of the above-described bedrock synclines, and both have been at least partially stabilized with gravity fill buttresses during residential developments at Ritz Cove and Breakers Isle. The southern portion of the 40-area Dana Strand slide complex has not been effectively stabilized against future movement; neither have large, ancient bedrock landslides within the San Onofre Breccia at the southernmost edge of the subunit. Several smaller landslides have occurred marginal to these larger failures.

Dana Cove and Harbor Subunit

Lithologic units exposed within the inactive coastal bluffs of this subunit include bedrock of San Onofre Breccia (both massive conglomerate and well-bedded sandstones) and Capistrano Formation, in fault contact with one another. The Capistrano Formation, exposed within the bluffs behind Dana Harbor Park, consists of two facies: A) massive to thinly-bedded grey, micaceous siltstone, (Map Symbol, Tc_sH) and B) coarse sandstone, breccia and well-bedded conglomerates occupying a channel-like lithosome (body), which comprises the majority of the bluff face along Dana Harbor Park and the graded cut slopes of the Lantern Bay project sector (Map Symbol Tc_{ss+cg}). There is an extreme difference in erodibility between interbedded sandstone and conglomerate; differential erosion has produced deeply undermined conglomerate "ledges" along these bluffs. Differential erosion between the Capistrano Formation overall and the San Onofre Breccia produced the Dana Cove re-entrant and adjacent Dana Point Headland. Percentage of conglomerate within the Capistrano Formation decreases eastward, resulting in readily erodible sandstones exposed within the graded slopes in the Lantern Bay area. Surficial units in this area consist of ten-to-fifteen-foot thick nonmarine terrace deposits (Map Symbol Qtn) comprised of sand, silt and clay existing as a cover above the marine terrace sands.

Structural geology of the Dana Cove and Harbor subunit includes bedding dipping 10 to 30 degrees northwest to northeast (Plate 2) Slight out-of-slope bedding components occur adjacent to a large inactive north-trending fault separating San Onofre Breccia and Capistrano Formation in the vicinity of Cannons Restaurant. Dominant joint systems include near-vertical, north-trending joints mechanically related to the adjacent Cannons Restaurant fault, plus east-trending, south-dipping high-angle joints, possibly formed as tension features, oriented adversely with respect to the bluff face.

Despite the presence of favorably-oriented bedding planes, the bluff face in this subunit has been historically subject to small-to-moderate-sized blockfall landslides, kinematically controlled by adversely-oriented joint systems and hastened by excessive surface erosion of the bluff top due to poor irrigation practices. Oblique out-of-slope bedding fostered the large historic landslide in the bluff face, adjacent to the 1980 Cannons Restaurant failure (Kerwin, 1980); both slope failures were facilitated by groundwater percolating along shattered, weakened bedrock along the large fault discussed above. Surficial slumps have occurred within the artificial fill slope below Cove Road, due in part to poor grading practices and partially to inadequate surface drainage control (Neblett, 1966).

Dana Point Headlands Subunit

Lithologic units of this subunit include erodible marine terrace deposits (as described above, from 15 to 30 feet thick) and resistant San Onofre Breccia bedrock, as described above. The central, south-facing flank of the Dana Point headland consists of massively-bedded resistant breccia, with sandier units exposed at the far eastern point and western promontory of the headland (Edgington, 1974).

Geologic structure within the south-facing sea cliffs includes bedding planes dipping into-slope (northeast), tectonic joints dipping steeply normal to bluff-face or slightly out-of-slope, and tension (stress-release) joints dipping 50 to 75 degrees directly out-of-slopes. Structure along the west-facing promontory includes randomly-oriented bedding within numerous sheared blocks lying between north-to-northeast-trending, high-angle faults.

Historic landslides occur along the western face of the headland (Plate 1); the closely-spaced faults and joints in this zone, coupled with the moderately-well-developed, continuous bedding planes within the sandy facies of the San Onofre Breccia , have promoted slope failure. The larger slides occurred predominantly during the 1884-1891, 1916 and 1938-1941 storm periods, although smaller blockfalls have occurred subsequently. The largest of the deep-seated, rotational landslides is over two acres in size. Despite the erosional resistance of the massive conglomerate units exposed along the south-facing section of the Headlands, the combination of active marine erosion and adversely-oriented tension joint systems along this zone have made it historically prone to small, albeit hazardous, bluff failures, as evidenced by the significant talus accumulations along the cobble beaches in this area.

Capistrano Bluffs/Palisades Subunit

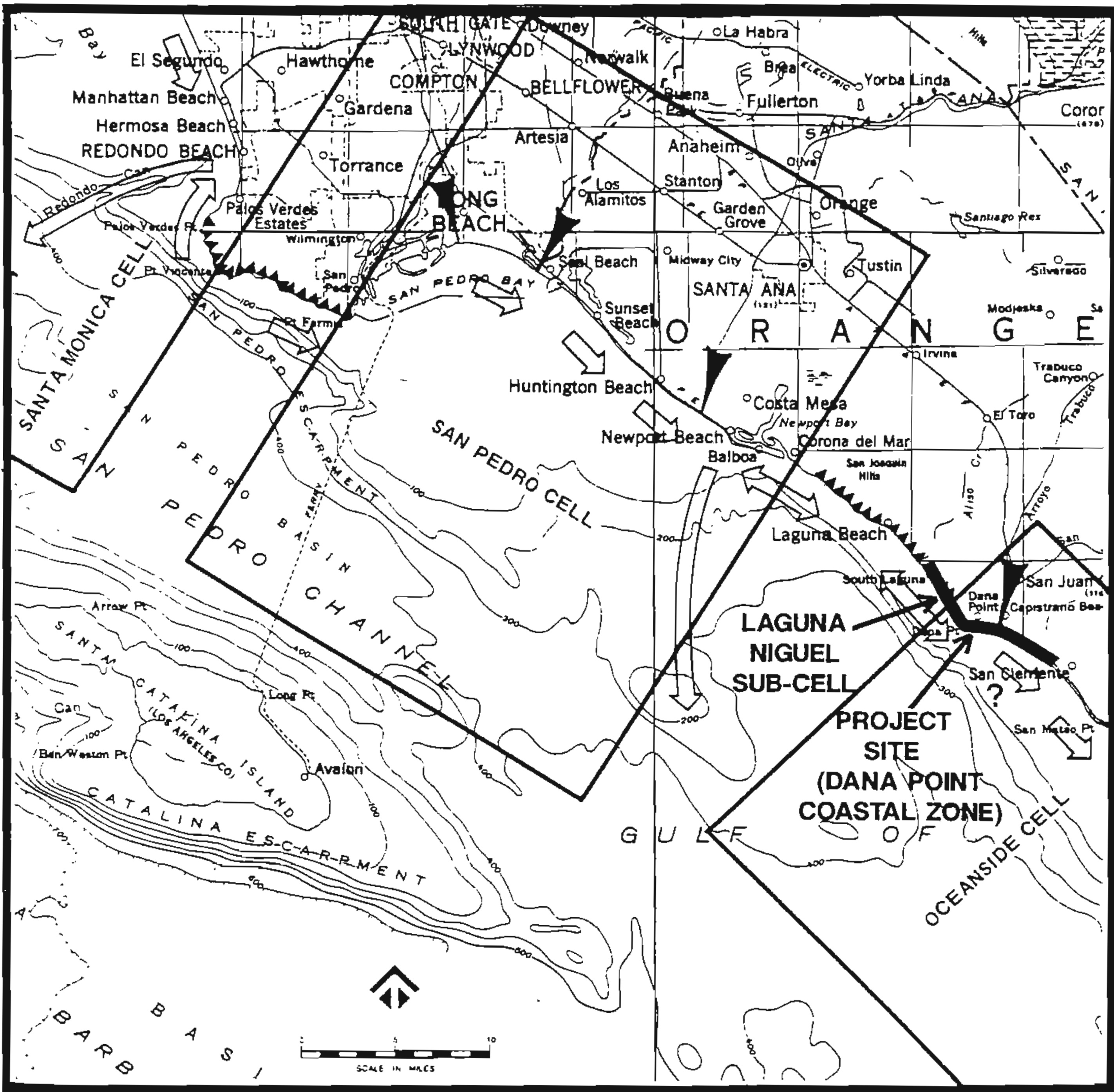
Lithologic units exposed within the inactive sea cliffs of this subunit include both marine and nonmarine terrace deposits (Plate 3; Map Symbols Qtm and Qtn), attaining a cumulative maximum thickness of twenty feet, and bedrock of the Capistrano Formation (Tc_{slt}), which is well exposed along Coast Highway. In these outcrops, the unit is primarily massive to poorly-bedded siltstone, and shaly, laminated to thin-bedded, diatomaceous siltstone. Minor constituents and "marker beds" include cross-bedded sand beds up to one foot in thickness, discontinuous calcareous concretion beds, hard siliceous beds, and thin clays (Edgington, 1974; R&M Consultants, 1982). Two primary types of siltstone can be distinguished in the bluff based on erodibility, degree of jointing, and bedding plane characteristics. The relative abundance of these two types often is a significant factor in the degree of hazard which the bluff presents to both the housing structures on the bluff top and the road or structures at toe-of-bluff. The bedrock of the Capistrano Formation is generally homoclinal throughout the Capistrano Bluffs subunit, inclined between 10 and 25 degrees towards the northeast (into the bluff face) with a general strike of about N65W. In the southern portion of the study area near Poche Beach, the bedding planes are locally subhorizontal, with dips up to seven degrees out-of-slope.

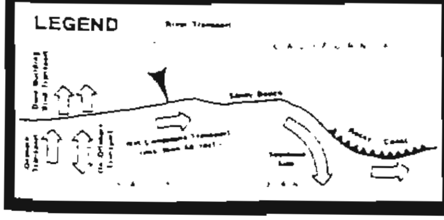
There are three prominent joint sets which appear to control the geometry of the Capistrano bluffs. The principle joint set is N50W, 73 degrees south, which is approximately orthogonal to bedding; these are tension (stress-release) joints which generally form the cliff face. Two other joint sets (N85W, 80 degrees south and N40E, 90 degrees) are near-vertical planes which form steep columns along the cliff face. These columns appear to fall periodically through tensile failure onto talus cones at the toe of the bluffs. These joint sets have therefore controlled the majority of the historic blockfall slope failures along Capistrano Bluffs. The shaly, well-bedded, diatomaceous siltstone generally forms steep cliffs and has well-developed joint sets orthogonal to bedding planes; it forms blocks of siltstone up to ten feet or more in maximum dimension along a combination of joint faces and bedding planes. When this type of siltstone occurs near the top of the bluff, relatively large block falls pose a hazard to the road below and contribute to rapid bluff retreat (R&M Consultants, 1982). Several large historic and incipient slope failures have formed in the bluff zone between the end of Camino Mira Costa and Pines Park in this fashion (Figure 3B).

Capistrano Bluffs blockfall landslides are indicative of surficial erosion rather than deep-seated bedrock movement. They pose an acute hazard to residences which have been sited too close to either the brink of the cliff or the toe of slope. The base of the coastal bluffs has an "apron" of talus. Talus is a heterogeneous accumulation of block fall debris and slope wash which derived from erosion of the bluff face. The talus generally has an angle of repose of 33 to 37 degrees. The active talus cones are free from vegetation, but older or inactive talus cones may be entirely covered by brush.

Figure 10 is a schematic geologic cross section of the terrace bluffs which shows the general morphology of the talus apron or cone relative to the bluff face. The geologic structure shown in Figure 10 represents composite field data, determined from geologic mapping along the entire Capistrano Bluffs; it does not represent any one site.

Most of the talus cones are variable in height from 20 to 40 feet. Higher talus cones are generally indicative of bluffs which possess a lower hazard of large future blockfalls than those with short talus cones. The height and angle of repose of the talus cone is the best-estimate of the recommended structural set back plane for blufftop residences. Figure 10 shows that this plane is measured from the toe of the talus slope, and not from the base of the exposed bedrock in the bluff face. Instead, the controlling geologic factors are the dominant joint systems. Available data indicates that the entire Capistrano Bluffs/Palisades subunit has been subject to historical blockfall landsliding to some degree. The susceptibility to such failures has been increased through urbanization, (see subsection D,





LITTORAL CELLS

STATE OF CALIFORNIA **SOURCE:** THE RESOURCES AGENCY

DEPARTMENT OF NAVIGATION & OCEAN DEVELOPMENT

DNOD

1977

PN: 89312-2
DATE: 6/29/90
FIG. NO: 8

LITORAL CELL & SEDIMENT TRANSPORT DANA POINT COASTAL ZONE

ZEISER
GEOTECHNICAL, INC.

below), principally through poor surface drainage control and landscape irrigation practices which yield accelerated blufftop erosion of terrace sands, exposure of larger sections of bedrock in the bluff face, and reduce bedrock shear strength through accumulation of excessive groundwater. Such problems are particularly acute in the northernmost (Dana Bluffs) and southern one-third segments of the subunit.

Capistrano Beach/Doheny Beach Subunit

Erosion and transport of unconsolidated beach sands (Map Symbol Qb) and gravel are controlled by the littoral processes described below. Available sand thickness data from jet probe surveys indicate that beach sands are generally ten to fifteen feet in thickness (US Army Corps of Engineers, 1988B). Because sediment is not supplied to these beaches via erosion of adjacent terrace bluffs, due to separation of the Capistrano Bluffs and adjacent beach by the highway and railroad grades, the source for the majority of the beach sediment in this subunit is the San Juan Creek outfall to the north.

C. NATURAL DYNAMIC FACTORS

I. Steady State Coastal Processes

Long-term behavior of a specific stretch of shore-line, including historical coastal erosion, cannot be fully understood unless natural dynamic conditions and processes within the littoral cell including the coastal site are understood. The following subsections describe such dynamic natural processes as they affect the Dana Point coastal zone. Questions of coastal structure design for erosion prevention and beach nourishment issues and long-term stability, are tied to an understanding of natural littoral processes.

Littoral Sediment Budget and Transport

Along the California coast, most beach sand comes either from river and stream runoff or from erosion of coastal cliffs and bluffs. Measurements of sediment transport in rivers indicate that coastal streams, particularly during times of flood flows, are the major suppliers of sand to our beaches along most of the California coast. It has been estimated that 75 percent to 95 percent of the beach sand was originally derived form streams (Shepard and Wanless; 1971; Griggs and Savoy, 1985). Beaches have often been observed to be much wider in the summers following winters with high rainfall, due to the delivery of large amounts of sand to the beaches by high streamflow.

Coastal cliffs can also be important sediment contributors if they consist of or break down into sand-sized material (sandstone and granite, for example). Cliffs and bluffs which are composed of silt or clay-sized material (shales or mudstones, for example), on the other hand, will not contribute significantly to the beach. The contributions of beach sand by coastal cliffs can be important locally, particularly where the cliffs are comprised predominantly of sandstones and conglomerates and are rapidly eroding earthier via natural or man-induced (urbanization) erosion. Recent statistical studies of grain size, shape and mineralogic composition suggest that subaerial cliff and terrace erosion has been dominant in the production of coarse-grained sediment delivered to the coast of southern Orange and San Diego counties during much of the 20th Century (U.S. Army Corps of Engineers, 1985c; Osborne and others, 1989). Once sand arrives at the coast, waves and wave-induced currents provide the energy necessary to form the beach and to move the beach materials along the coast. The direction of this movement, or littoral drift, of sand along the beach is determined by the dominant angle of wind-driven wave approach. For example, along much of the Dana Point coast, summer waves from the northwest drive littoral drift southward along the beaches. During the winter months, waves often arrive from the west-southwest or southeast , resulting in a northward littoral drift (see Plate 8).

When waves break so that there is an angle between the crest of the breaking wave and the beach, the momentum of the breaking wave has a component along the beach in the direction of wave propagation. This results in the generation of longshore currents that flow parallel to the beach inside of the breaker zone. These currents are largely responsible for the littoral drift of beach material. After flowing parallel to the beach as longshore currents, the water is returned seaward along relatively narrow zones by rip currents. The net onshore transport of water by wave action in the breaker zone, the lateral transport inside of the breaker zone by longshore currents, and the seaward return of the flow through the surf zone by rip currents constitute a nearshore circulation system. The pattern which results from this circulation commonly takes the form of an eddy. (Muir-Wood and Fleming, 1981).

In general, longshore currents in southern California have a net movement toward the south or southeast (Shepard and Wanless, 1971; U.S. Army Corps of Engineers, 1970; 1984b; 1985c; 1986). The shoreline is divided into smaller transport or depositional units known as littoral cells (see Figure 8). Sediment set in motion by the longshore current at the beginning of a cell moves in a southerly or downcoast direction until it reaches a submarine canyon or headland or other obstruction that marks the end of a cell. Sediment may be trapped in the head of the canyon to eventually flow into the deep water offshore, be blown inland on sand dunes, or trapped on the beach at the end of the cell to move on- and offshore with the seasons (Griggs and Savoy, 1985). Two littoral cells are present within the Dana Point coastal zone; the northern segment of the Oceanside littoral cell, with its major source of sediment at the San Juan Creek outfall, and the Laguna Niguel Sub-cell between the Dana Point and Monarch Bay headlands, with sediment source from the Salt Creek outfall and adjacent terraces. The Laguna Niguel sub-cell can be further subdivided into two pocket beaches (Salt Creek; Dana Strand/Niguel Shores) (State of California, 1977A). Net longshore sediment transport in the Oceanside littoral cell is from north to south; previous littoral drift rate estimates indicate an annual loss of 100,000 cubic yards of sediment from the northern segment of the cell (U.S. Army Corps of Engineers, 1959; 1987b). There are no submarine canyons proximal to the Dana Point coastal zone which could otherwise channel littoral sediment offshore. Net sediment transport within the pocket beaches (see Appendix B, Glossary of Coastal Terms) of the Laguna Niguel sub-cell is seasonally onshore-offshore, due to north-south wave refraction from rocky headlands at both the north and southern ends of the sub-cell (Figure 8). Accurate estimates do not exist concerning the quantities of sediment, if any," leaking" south around Dana Point headland; the effectiveness of pocket beaches in inhibiting longshore transport is unknown (U.S. Army Corps of Engineers, 1959; 1987b; Inman, 1978; Griggs and Savoy, 1985).

The two most important facts which coastal residents and planners must remember about beaches are, (1) they are temporary features that undergo regular and sometimes dramatic seasonal changes; the beach and the ocean are in a dynamic equilibrium, such that when one changes, the other must adjust. So if a house is built on a wide beach during the summer, it should be no surprise to the owner to find the ocean in the living room during a winter storm; (2) where fronting a bluff or sea cliff, beaches act as effective buffers or shock absorbers against wave attack.

As a dynamic and fragile feature, a beach may grow, shrink, alter its shape, or even disappear in a single storm. During the winter large, steep, closely spaced waves scour away and remove beach sands to form one or a number of low offshore bars. When the weather calms in the spring, smaller waves that are less steep and more widely spaced push the available sand back inshore and rebuild the wide summer beach. This is a natural seasonal process within the Dana Point coastal zone (U.S. Army Corps of Engineers, 1986).

A final note concerning the littoral segment budget: Annual rainfall is erratic here and, contrary to our perceptions, southern California has been in a period of protracted drought. During the 30 years from 1946 to 1976, only the 1969-70 winter had floods of consequence; it is such large floods which transport great volumes of sand downstream to naturally nourish the beaches.

Sea level Processes and Variations

The dynamic status of the Dana Point littoral system can be further understood by examining the daily, monthly, and yearly events recorded by local tide gauges, a more refined application of coastal engineering may be employed in future planning. Sea level data is taken from information supplied by NOAA and from tide gauge stations on offshore islands. The NOAA data set provides sea levels above a datum level, which in turn is a known distance below shore bench marks.

The tide gauge itself measures the distance from a reference mark (RM) to sea level (SL) within a stilling well where wave action is damped, and this number is recorded on punched tape. Independent calibration with an electric water-contact tape measure establishes the distance between RM and SL. Values are recorded within .01 feet (.3 cm) resolution. The tide gauge data from San Diego and Los Angeles was plotted and drawn between 1924 and 1983 (Plate 7). These sites were selected because they possess lengthy temporal durations, and give a regional perspective of short-term and long-term sea level fluctuations.

Tide gauge records for San Diego and Los Angeles illustrated on Plate 7, show yearly means. This graph gives on overall historical perspective, and demonstrates the ability of sea levels to record oceanic and atmospheric events (Emery and Aubrey, 1986). Most noticeable is the progressive rise in sea level from the 1920's to the present. Also clearly evident are significant abrupt events; high water peaks are clearly shown in 1941,1958,1972, and especially 1982-83. These years were associated with periods of extreme warm water along the California coast, termed the EL Nino/Southern-Oscillation Event (ENSO), which are accompanied by wet rainy seasons with very concentrated rainfall produced by subtropical storms (see Plate 6).

These short and long-term changes in sea levels are of great importance to planners and coastal engineers with respect to the future location and relocation of water-front structures, buildings and protective devices. Current research indicates a Rough 15-year periodicity for the El Nino event, which is otherwise an annual process, albeit on a smaller scale (Emery & Aubrey, 1986).

Sea levels reach a minimum in the spring of the year, usually in March and April, under the impact of northwest winds offshore which set up coastal upwelling at that time. Levels rise to a summer high in August due to thermal expansion, when water temperatures peak. The winter months reflect the onset of offshore winds in October and November and the winter storms of January and February. Planners in coastal areas should understand that tides are higher in the winter than in the summer months, because of the following effects: (1) there is an increase in gravitational pull related to the position of the earth in its orbit (perigee) (earth-moon-sun relationship); (2) the tidal height will increase during storms, as the wind set-up component tends to pile water up along the coast; (3) barometric pressure changes related to winter storm conditions tend to allow expansion of the water mass; (4) wavelength and wave height increase related to the length of the fetch, the velocity of the wind during winter months, and the volume of water being transported shoreward by wave action (Slosson et al, 1987).

It is the daily average which records the lunar influence (semidiurnal tides) as well as the passage of storms and wind direction stress. Generally a southerly wind along with lowing pressure will cause a rise in sea level, while northeast winds and rising pressure will cause a drop. Historically elevated, long-period deep water waves, associated with warm water and low-pressure warm air masses from tropical latitudes, may thus be explained by this phenomena, such as the large waves striking Dana Harbor during the 1939 tropical storm.

Recent research of long-term tide gauge data indicates that the central and southern California coastline has ben subjected to long-term, progressive sea level rise on the order of 3mm per yr, after corrections for large-scale tectonic uplift of the coastal zone (Kaufman and Pileky, 1979; Hoffman et al, 1983; Emery and Aubrey, 1986). Given the resultant effect of a continual, progressive sea level rise on stillwater elevating and breaker heights in the foreshore zone (Muir-Wood and Fleming, 1981; U.S. Army Corps of Engineers, 1984A) all future shoreline protection devices along the Dana Point coastal zone should incorporate this net progressive rise into their design (Walker and others, 1984).

Seimiduimal tides are cause by the gravitational attractions of the Moon and Sun upon the oceans. Two times during each month, at new moon (conjunction) and full moon (opposition) the Earth, Moon, and Sun come into direct alignment in celestial longitude and, due to the combination of their gravitational forces, enhanced tide-raising forces result. Tides produced at these times are called spring tides (Appendix B). Since the lunar orbit is elliptical in shape, once each revolution the Moon also attains its closet monthly approach to the Earth, a position known as perigee.

Ordinarily, the passage of the Moon through perigee and the alignments of Moon, Earth, and Sun at new moon or full moon (either position being called syzygy) do not take place at the same time. Commensurable relationships between the lengths of the synodic and anomalistic months do, however, make this possible. On the relatively infrequent occasions when these two phenomena occur within 1 1/2 days of each other, the resultant astronomical configuration is described as perigee-syzygy, and the tides of increased daily range thus generated are termed proxigean spring tides.

Whenever such alignments between perigee and syzygy occur within a few hours or less of each other, augmented dynamic influences act to increase the eccentricity of the lunar orbit, and hence also the orbital velocity of the Moon itself. The tide-raising force varies inversely as the cube of the distance between the Earth and Moon (or Sun). On certain occasions, lunar passage through perigee involves a particularly close approach of the Moon to the Earth. To distinguish these cases of unusually close perigee, the new term "proxigee" has been devised, and the associated tides of increased amplitude and range are designated "proxigean spring tides" (Wood, 1978; 1986).

In recent years, the National Ocean Survey examined the origin, nature and impact of severe tidal flooding (Proxigean Spring Tides) in worldwide lowland coastal regions, resulting from the coincidence of astronomical and meteorological forces. The results of this work are found first in a volume entitled "The Strategic Role of Proxigean Spring Tides In Nautical History and North American Coastal Flooding, 1635-1976" (U.S. Government Printing Office, 1978). At these times the tides build up faster, tidal currents increase, and, when accompanied by a strong inshore wind, the ocean waters pour into the estuaries faster than they can escape on the ebb. The pileup of water behind offshore bars results in a destructive breaching from the landward side, and the ocean begins to reshape the shoreline.

Thus, should a severe sea storm and a strong onshore wind coincide at the time of perigean spring tides, severe erosion of beaches and unprotected coastal bluffs is to be expected. Appendix E (from Wood, 1986) itemizes cases of historical coastal flooding and/or coastal erosion which occurred in a near-concurrent relationship with perigean spring tides accompanied by strong onshore winds. The most damaging recent storms affecting the Dana Point coastal zone occurred in January 1978, February 16 to 20, 1980, and January 27 to 31, 1983; all these storm periods occurred directly on the perigean spring tides, accompanied by extremely strong onshore winds. The January 27 to 31, 1983 event also coincided with an extreme rise in sea levels initiated by an anomalously warm-water event, termed the El Nino (see Plate 7 - Tide Gauge Records/Sea Level Curve). Erosion of the beaches and unprotected cliffs was severe at these times along the entire southern California coastline (Kuhn and Shepard, 1984).

Future predictions of perigee (proxigee)-syzygy alignment are given in Appendix E (years 1900 A.D. to year 2164) (from Wood, 1978 and 1986). These tables should be employed by planners and coastal engineers to account for future elevated seas during periods of either, should there be distinct onshore winds coupled with a severe storm and/or warm-water El Nino.

Examples of coastal erosion damage directly affecting the Capistrano Beach area during 1962 and 1974 perigean spring tide conditions are included in Appendix E, while historical coastal erosion records (newspaper articles) of perigean spring tides from 1914 to 1974 are presented in Appendix C. The next major perigee-syzygy coincidence predicted to affect the southern California area is expected to occur on December 2, 1990. Dana Point city planners should establish short-term emergency preparedness guidelines to protect coastal property during this predicted tidal event.

Wave Direction And Refraction

Most waves form when wind creates friction as it blows across the ocean surface. The size of the waves that break on the beach on any particular day depend mainly on the offshore wind characteristics; particularly how long, how fast, and over what distance (fetch) of the sea's surface the wind blows. The longer, harder, and farther the wind blows, the larger we can expect the waves to be. Waves will gradually move out from a storm area and sort themselves into a regular pattern known as ***swell***. These latter waves that we see breaking on our beach may have travelled hundreds or thousands of miles across the ocean from their point of origin (Shepard and Wanless: 1971; State of California, 1977A; Griggs and Savoy, 1985).

As waves reach the shallow water near the shoreline, their height increases until they become unstable to the point that they break. Waves usually break where the ratio of wave height to water depth is about 3:4; in other words a 3-foot-high wave will break in about 4 feet of water. As the water shallows near the coast, the portion of the waves closest to the beach "feels" the sea floor first and begins to slow down; meanwhile, the seaward portion of the wave crest continues to travel at almost its original speed. This results in the bending or ***refraction*** of the wave toward the shoreline. On an irregular coast, refraction causes wave energy to be concentrated at promontories and dispersed in bays.

Wave-refraction diagrams indicate the manner in which waves with selected directions and periods reach the shore. The resultant littoral current produced by these waves is dependent upon the angle with which these waves reach the shore and upon the degrees of their convergence, or divergence, both in the immediate and adjacent area. The direction of waves from any single generating area may vary as much as 30°. Frequently, waves from two or more sources may reach an area concurrently. For these reasons, a precise solution of the resultant littoral current to be expected from existing wave patterns cannot be computed. Refraction diagrams, based upon possible avenues of approach and observed wave periods and directions, (US Army Corps of Engineers, 1959) have been drawn for the Dana Point coastline for 12-second-period waves with azimuths of 180°, 205°, 250° and 275° (Plate 8A). Positions along the shoreline where several refracted wavefronts coincide (e.g., southern Niguel Shores, southwest promontory of Dana Point headlands, southern Capistrano Beach) are zones of concentrated wave energy and resultant erosion. These three areas along the Dana Point coastline have indeed experienced significant marine erosion problems.

At present, there appear to be four principal tracks along which storm and non-storm waves advance on the southern California coast, as depicted in Plate 8B (Marine Advisers, 1961; US Army Corps of Engineers, 1986; Meteorology International, Inc, 1977).

The most common type of wave originates in low pressure areas south of Alaska and advance from the northwest down the coast of California, often bypassing the southern part of the state before turning eastward. Possessing great energy, particularly along California's north coast, these conditions generate 20- to 30-foot deep water waves (Marine Advisers, 1960A,B; 1961; US Army Corps of Engineers, 1986). The offshore Channel Islands have a significant blocking effect on these waves, as illustrated in Plate 8B.

A second major wave system, from a Hawaiian Island source area, originates in the open Pacific, sometimes causing more damage than a tsunami. They approach the southern California coast from the west. These waves are also frequently blocked or filtered by the Channel Islands (Plate 8B). Hurricane-generated storm waves from the west coast of Mexico, the third major wave system, come from the south, but occur in the summer and early fall rather than during the winter months.

Waves coming from southern hemisphere hurricanes, the last major wave system, originates in the Antarctic-New Zealand area and occasionally causes great damage at selected sites along the southern California Coast. These waves approach the coast from the south-southwest and occur predominantly during the summer (Plate 8B).

Subaerial And Marine Erosion Processes

In a time frame spaning tens to hundreds of years, the erosion of sea cliffs, bluffs and coastal canyons is temporally episodic, aerially site-specific, and directly related to prevailing meteorological conditions (Kuhn and Shepard, 1984, Kuhn and Osborne, 1989). An understanding of the character of sea cliff erosion is essential to the identification of littoral sand sources, and the quantification of sediment budgets in associated nearshore dispersal systems (US Army Corps of Engineers 1984B; 1986; 1988C).

The Dana Point coastal zone consists of approximately 85% coastal bluffs. Topographic profiles of these bluffs largely are determined by the dominant erosive process forming the bluffs, and the erosive resistance of contained rock or sediment.

As indicated by Emery and Kuhn (1982), sea cliffs undergo three main evolutionary stages: (1) ACTIVE - cliffs that consist of bedrock exposed to continuous retreat under the influence of both marine and subaerial erosion agents and processes (examples in the Dana Point coastal zone include the Monarch Bay and Dana Point Headlands subunits; the Ritz Carlton Headland area also falls in this category.); (2) INACTIVE - cliffs that are mantled, especially along their bases, by a cone of talus having slopes from 25° to 35°, and commonly supporting land vegetation, including trees (the coastal bluffs of Dana Cove and Harbor subunit are contained within this classification.); and (3) FORMER - cliffs that have been removed from the influences of marine processes so that subaerial erosion rounds the crests and provides material for stream deposition. Examples of such former sea cliffs occur within the Capistrano Bluffs/Palisades and Niguel Shore subunits, where coastal cliffs are separated from the beach by a rock-protected railroad right-of-way or urbanized zones.

Profiles of active sea cliffs appear to be controlled by two major agents; namely, marine and subaerial erosion. Marine erosion is accomplished at the base of the sea cliffs by abrasion, biological activity, solution by ocean water, and quarrying of blocks (via direct wave attack). Effects of abrasion are materially increased by sediment (mainly sand and pebbles) carried in suspension. relatively rapid marine erosion produces oversteepening of the lower part of the cliffs (even undercutting or notching, as is common in limestone) that leads to block falls, slumps or other kinds of mass movements (Emery and Kuhn, 1982).

Subaerial erosion takes the form of gullying and rainwash by surface runoff and slumping and landsliding induced by groundwater that increases pore pressures, causes clay minerals to expand, and causes loss of shear strength in saturated bedrock units. Saturated clay layers may serve as planes of slip for landslides. Where subaerial processes are dominant, the associated cliffs characteristically have large talus or alluvial cones at their bases, such as in the Capistrano Bluffs and Dana Cove and Harbor subunits.

Construction by man has increased erosion via both marine and subaerial processes. Damming of rivers has reduced the contribution of sediment to the ocean, narrowing beaches and increasing wave erosion of sea cliffs (see Subsection D below). Erosion has been counterbalanced partly by local construction of sea walls and revetment barriers. Home construction atop cliffs, and even on bluff faces has also increased subaerial erosion through construction of stormdrains, fences, and access stairways, removal of ground cover, oversteepening, overloading, and both accidental and intentional releases of water along the bluff face and into the bluff itself. Only partial compensation can be achieved by local provision of drains and gutters; in fact, many examples are known from the Dana Point coastline where increased local erosion was caused by inadequate examples of such protective measures.

II. EPISODIC STORM PROCESSES

Historic Meteorologic Fluctuations

Climate fluctuations affect the rates of both marine and subaerial erosion. In making estimates of changes likely to occur in the Dana Point coastal area one must have information concerning the occurrence and the types of historic climatic change. Most important is whether or not the changes occurred gradually or suddenly. If the latter is true, a recurrence of stormy, wet climatic conditions would certainly increase erosion rates and coastal damage as compared with that of recent decades.

Emery and Kuhn (1982) and Kuhn and others (1989) examined geologic records, sediment core records from offshore basins, and meteorological indicators (rainfall records, tree rings, sea surface temperatures) to document climatic fluctuations which have occurred in southern California during the past century. Rainfall records in southern California are complete back to 1850, and from them the clearest trend in recent decades (Plate 6) is the marked decrease in annual precipitation from 1947 to 1977. This benign period is also recorded in tree rings, as closely-spaced tree-ring widths reflect low rainfall amounts and cool air temperature. Varve thickness from offshore sediment piston and box cores indicate the rate of deposition of silt and clay into offshore basins during years of rainfall. Douglas (1976) compared tree-rings dated back to 1671 A.D. with measurements of average ocean temperatures off southern California and Baja California, obtaining transfer functions which allow estimates for historical water temperatures. These historic regional warm water data are linked to increased rainfall, and correspond reasonably well with the other meteorologic data indicators.

Taking qualitative data into consideration, one can detect a general parallelism of indicators for past rainfall for southern California. The periods 1883-1892, 1934-1945, and 1978-1990 exhibited unusually high rainfall and runoff. Large storm waves during these periods were accompanied by substantial retreat of sea cliffs, which destroyed southern Orange County and San Diego County coastal railroad tracks and roads in the 1880's. Oceanfront lots, houses, and trains were destroyed in the 1930's and 1940's, and railroad trestles, piers, and houses were lost in the late 1970's (Kuhn and Shepard, 1979, 1980) and early 1980's (Kuhn and Shepard, 1984). The intervening periods 1842-1883 (except for 1851, 1862, 1867 and 1873), 1892-1934, and 1947-1977 generally exhibited lower annual rainfall, runoff and lower ground-water tables. The later dry periods were times of sea cliff stability, except where urbanization was especially active. As a result, sea cliffs generally exhibited freshly-exposed rock during wet periods, and became partially covered by talus during dry periods (Emery and Kuhn, 1982).

Southerly Storms of the 1830's

Perhaps the most alarming fact learned form historical climatologic research of the California Coast concerns the violent storms of the early part of the 19th century as reported by ships' officers and by Richard Henry Dana in his book "Two Years before the Mast" (Kuhn and Shepard, 1984). Dana's book describes conditions along the California coast from, San Diego north to Monterey, during the 1830's.

In his book, Dana recounted and described the "great winds" of the period which approached the coast from the southeast. "This wind (the south-easter) is the bane of the coast of California. Between the months of November and April, (including a part of each), which is the rainy season in this latitude, you are never safe from it, and accordingly, in the ports which are open to it, vessels are obliged during these months to lie at anchor at a distance of three miles from the shore, ready to slip and go to sea at a moment's warning. The only ports which are safe from this wind are San Francisco and Monterey in the north, and San Diego in the south."

These storms were described by Dana, as well as by various ship captains, as worse than the weather sometimes reported near Cape Horn. They describe 50-and even 60-foot waves, such as we have not encountered in recent years. These storms were said to have southeast winds, and it seems highly probable that they were of the same type as those which still hit Baja California today. There is considerable evidence that these storms occurred during a period when the water along the California coast was unusually warm. Between 1853 and 1857, the "Blake" Railroad Survey identified and catalogued sub-tropical species of fish off San Diego. Numerous tropical species of fish fauna were recorded off San Diego between 1850 and 1870. These severe storms ceased to be a regular occurrence around 1866, and apparently the last one to occur was during February 1871.

There is no doubt that floods of the past century were caused by rainfall much greater than experienced during the relatively recent period of south county urbanization times (Kuhn and Shepard, 1984; Kuhn and others, 1989).

1862 Flood Period: "The Noachian Deluge"

During the early years of the Civil War, in the winter of 1861-62, southern California, and the entire west coast of the United States appears to have had a rainy season completely anomalous relative to anything experienced since Anglo occupation of the region (Kuhn and Shepard, 1984). The state was sufficiently populated at the time, so there is little doubt concerning the accuracy of the reports.

In the middle of a drought period (1842-1883), the greatest flood occurred since the coming of the missionary fathers; the flood of 1861-62 was thus appropriately termed the "Noachian Deluge", and the winter was remarkable for extraordinary floods throughout the state. The rain commenced in December 1861 and continued for more than 50% of the time until February of the following year. In November, over four inches fell; nearly ten inches fell in December, and in January 24.5 inches fell. One-hundred-two inches (eight and a half feet) of rain fell at Tuolumne in central California as of January 31, 1862. The Sacramento and San Joaquin Valleys- a region 250 to 300 miles long and an average of 20 miles wide, (a district of five thousand or six thousand square miles), was covered by a shallow inland lake as a result of the 1862 floods (Farquhar, 1966). A recent flood control publication (San Diego County Flood Control District, 1976) compared all major floods of years past and notes: "Of all recorded floods, the flood of 1862 is considered by most to have been the largest. Rain began to fall on Christmas Day and continued for about six weeks with intensity increasing on the last few days of the sixth week, when the worst flooding occurred. In San Diego's Mission Valley, the flow covered the entire valley floor."

The Great Intermittent Floods of 1884 to 1891

An abrupt climatic change along southern California began during the winter of 1883-1884, and continued through 1891 (Kuhn and Shepard, 1984) (Plate 6). The weather was characterized by tremendous downpours; the highest daily, monthly, and annual rainfall levels on record in San Diego County were during this period. The winters of 1884, 1886, 1889, 1890 and 1891 brought unusually severe cyclonic sea storms to southern California. The intense rainfall caused sediment saturation of the coastal bluffs, and large storm swell coupled with high tides coincided with river basin flooding.

Pyke (1975) researched the meteorological implications for the period between 1884 and 1891. he reported that among all the seasons of heavy southwest United States rainfall prior to 1900 occurring around the times of major equatorial warm water anomalies, three years were "historically quite outstanding." Those years were the seasons 1883-1884, 1889-1890, and 1890-1891.

Storm year of Record: 1883-1884

The winter of 1883-1884 was one of the wettest of record in Southern California. The following rainfall was recorded in numerous locations. The rainfall was temporally very concentrated, and fell predominately in the latter part of February and the first week of March, 1884 (see Plate 6 for rainfall curves).

As of April 1, 1884, the California Southern Railroad, which had begun operations between San Bernardino and San Diego only a year earlier, announced to its stockholders that is was bankrupt and in debt $200,000-$250,000 (1884 dollars), as a result of the storms and flooding. By the second week in June, 50 to 80 inches of rain had fallen throughout the back county of San Diego County (Kuhn and Shepard, 1984).

Troxell and others (1942) note that in Los Angles and surrounding areas: "The flood of 1884 ranks among the major floods -- in fact, there were two floods in 1884. The first came the later part of February; it did little damage, but a great quantity of water fell, apparently utilizing much of the absorptive capacity of the ground."

The year 1884 may have been the most severe with respect to flooding and landslide activity. News articles and other references describe widespread flooding extending form southern California to central Arizona. Some references suggest that essentially all bridges were destroyed between Los Angeles and Tucson. Age dating of many younger landslides of southern California indicates an approximate age of 100 years, which would be in agreement with damage attributed to the storms of 1884 (Slosson and Krohn, 1982).

Tropical Storm Years: 1889-1891

Between 1889 and 1891, southern California was once again battered by numerous record-breaking subtropical storms from the south/southeast, accompanied by exceptionally heavy rainfall. During this period, the U.S. Coast and Geodetic Survey (USCGS) conducted topographic and bathymetic surveys along the coast of San Diego County. The U.S.C.G.S. (1889) topographic notes indicate that the bluffs showed "new erosion during each winter storm and as the characteristic feature of this coast." (Kuhn and Shepard, 1984).

One exceptional storm hit Encinitas in San Diego County on the evening of 12 October, 1889 (U.S. Army Signal Service, 1889). Between 10 p.m. of the 12th and 6 a.m. on the 13th, 7.58 inches of rain fell during an 8-hour period (U.S. Army Corps of Engineers, 1977). this apparently was related to a tropical storm front (U.S. Army Corps of Engineering, 1988).

Floods prevailed in southern California resulting from the heavy rain. Railroad and telegraphic communication was generally cut off from Los Angeles. The Los Angeles River washed away its banks in many places north of the city, destroying much valuable property. Considerable property was destroyed in the San Fernando Valley. South of the city, the Los Angles River changed its course, taking the old channel toward Ballona Creek from which it was diverted during the storm in December, 1884, flooding the country and destroying much valuable property. The San Gabriel River was diverted into a new channel some distance above Duarte, making a current about 1,000 feet wide, which flooded the areas below lower Duarte. (Monthly Weather Review, February, 1891).

August of 1891 was the warmest recorded period until that time along the Pacific Coast (U.S. Signal Service, 1891). Paradoxically, although no rainfall was reported over the greater part of California, a world record rainfall was verified at Campo (near the Mexican border) on August 12, 1891, when 11.5 inches fell in eighty minutes (U.S. Weather Bureau, 1960; U.S. Army Corps of Engineers, 1988c). Much arroyo cutting and channeling of streams and rivers occurred in southern Arizona and coastal southern California during the storm year of 1891 (Cooke and Reeves, 1976).

The significance of these exceptional storms from 1884-91, so far as Dana Point coastal erosion is concerned, is perhaps greatest with respect to the concentrated heavy rains that produced them. Similar, but less intense rains in more recent times have caused heavy erosion of sea cliffs. One can well imagine how these concentrated downpours would have incised deeply into the more erodible coastal cliffs, resulting in landslides and bluff failures far greater in size or effect that anything observed along the Dana Point coastal zone in recent years. Comparison of historical coastal Geodetic Survey maps to younger U.S.G.S. topographic maps suggest significant coastal erosion in the Dana Point area during these tropical storms.

Infrequent Floods During The Early Half Of The 20th Century, 1900-1938

The most significant flood of the present century in southern Orange County occurred in 1916 (US Army Corps of Engineers, 1988c). The County of San Diego Department of Flood Control (1976) indicated "There were actually two separate storms in the month of January 1916, causing two separate floods". The period of the first storm was from 14 January to 21 January. The second storm locally hit San Diego and southern Orange Counties from 25 January to 30 January. The County of San Diego (1976) indicated: "Both storms fell on a standard watershed which rapidly carried the flow to the rivers. When the storm hit, the streams were converted from normally dry creek beds to torrents that soon overran their banks, causing widespread damage from the Santa Clara River to the Mexican border, and from the mountain divide to the Pacific Ocean."

During the storm of February 1916, the tropical storms that caused the flooding destroyed the railroad line in Temecula Gorge. Following this storm year, sections of railroad line between Fallbrook and Temecula were completely abandoned and a new "surf line" was routed along the coast from San Diego to Los Angles via San Juan Capistrano.
At San Diego, the Sweetwater Reservoir dam was topped, and the flow over the dam was 3.5 feet deep. At this time, 50 feet of an earth-filled dike north of the dam was topped and the dike washed away, forming a break 75 feet and long 30 feet below the parapet of the dam. The flood flow then by-passed the dam and inundated the valley extending to San Diego Bay. Practically all important railway and highway bridges were either washed out or rendered useless, and for nearly a month all supplies had to be brought into coastal cities by ship.

Record Flood In Southern California: 1938

In March 1938, following antecedent rains, a series of storms affected the coastal California region from San Luis Obispo to San Diego, causing an estimated property damage of over 78 million dollars (1916 dollars). Records indicated runoff of more than 1000 cfs/sq mi. and debris flows of 70 acre-feet per mile (Troxell and others, 1942).

At the mouth of San Juan Creek near Dana Point large quantities of sediment flowed to the coast, forming a very large sand delta and significantly widening the Doheny and Capistrano Beach areas to the south (U.S. Army Corps of Engineers, 1985D). Severe blufftop erosion and retreat affected the Dana Point coastal zone during this storm period (Plate 5) (discussed below, Section 3c). Severe flooding occurred along all major Orange County watersheds, inundating major roadways and causing 45 deaths.

Record Tropical Storm of 1939

In September, 1939, great storm wave damage occurred along the southern California coastline due to a tropical storm. The San Pedro-Long Beach area was particularly hard hit by waves exceeding 40 feet in height (Horrer, 1950).

This tropical storm generated the most severe damaging waves of the past previous 50-year period, and approached from the southeast. The breakers had consistent wave heights greater than 24 feet at Oceanside and Dana Point (Marine Advisers, 1961). Long-period deep-water waves as high as 45 feet were recorded locally within the Catalina Channel (Marine Advisers, 1960 A). Eyewitness accounts from residents of the Dana Point areas during this period indicate that storm waves completely inundated Capistrano Beach and the Santa Fe railroad grade, causing minor erosion at the toe of the Capistrano Bluffs district.

Storm Year of Record: 1940-41

During the period between December 23, 1940, and January 7, 1941, a documented series of storms produced a 30 foot-deep-water swell which, when coupled with high tides and heavy rainfall, caused severe damage along the Pacific Coast south into Mexico (Kuhn and Shepard, 1979, 1984). (Plates 6 and 7). Both marine and subaerial erosion damage occurred to the Dana Point coastal zone during these storms (Plate 5).

Pyke (1972) notes that: "During the greater winter season of 1940-1941, a pattern of warm and moderately heavy storms also prevailed in California; and because of the persistent recurrence of these storms, some all-time annual rainfall totals were recorded. The 1940-41 season, in contrast to the other periods of warm, west-southwesterly type storms, occurred during the climax of an extremely prominent equatorial Pacific Ocean warm period, one of the greatest in oceanographic history."

The Quiescent Period: 1947-1977

Between 1947 and 1977 there were few severe storms causing significant coastal erosion, and much less rainfall than in the first half of the 20th century or late 19th century (County of San Diego, 1976). Ganus (1977) examined tree rings and rainfall records, and notes that during the years between 1946 and 1973, there was a series of dry years and stated: "the rainfall curve clearly indicates that since 1946 the San Diego area has been in a drought. Southern California has not experienced such a long dry period since the late 1500's".

The most significant erosional and wet years that affected south coastal Orange County during this period were the winters of 1951-52, 1957-58 and 1965-66, with the stormy winter of 1968-69 bringing the largest waves and concentrated rainfall (Plates 6 and 7). These storms produced record runoffs in many locations from San Luis Obispo to San Bernardino, including coastal areas, but dwindled in the mountains of Camp Pedleton directly north of Oceanside before reaching San Diego (County of San Diego, 1976).

During storms of 1951-52, 1962 and January 1974, extremely high waves damaged coastal structures and houses at Capistrano Beach. The 1962 and 1974 storms coincided with extreme perigean spring tides (discussed above, Section 3C) coupled with severe onshore winds (Wood, 1978, 1986). Blufftop retreat along Capistrano Bluffs and Niguel Shores, and marine erosion of seacliffs along Dana Cove, has been documented for the 1951-52 storm period (Plate 5; see Section 3C below).

Storm Years Of Record: 1977-78 To 1990

A return to more stormy conditions became apparent with the wet and stormy winters of 1977-78, 1979-80 and 1982-83. During these winters, record rainfalls (Plate 6) and destruction of coastal property occurred as a result of large storm related surf. The winter of 1982-83 alone produced more significant coastal erosion and greater damage to coastal property extending from Baja California to Washington State than had occurred since the devastating storms of 1940-41 (Kuhn and Shepard, 1984; Kuhn and others, 1989).

During the late fall and winter of 1977-78, intense rainfall and large storm waves damaged property along the southern California coast as well as inland. In San Diego County, rainfall was concentrated in the northern sections (County of San Diego, 1978). Along the cliffs at Camp Pedleton and San Onofre State Park, extensive coastal bluff-face gullying and headward erosion of coastal canyons occurred, along with a landslide measuring 700 feet long by 300 to 350 feet wide. The beaches along this section of coast widened markedly as a result of the gullying of the bluff face and headward erosion of coastal canyons (Kuhn and Shepard, 1984; Kuhn and others, 1989). Similar subaerial erosion and coastal bluff landslides occurred along Capistrano Beach (Plates 4 and 5).

As indicated by Armstrong (1982), the 1977-78 storm season caused the most severe erosion damage to the California coastline within the past 40 years. The storms of that year caused more than 4 million dollars' worth of damage to public property. This winter was the first of a series of wet storm years, which may be compared with those of the late 1930's and early 1940's (Kuhn and Shepard, 1984; US Army Corps of Engineers, 1987 A).

Storm periods during January and February 1980 (Plate 6) were characterized by a succession of rapidly moving storm fronts originating to the south. Intense rainfall at Camp Pendleton (approximately 10 inches total) rapidly flowed into culverts located beneath Interstate 5, and incised canyons into the coastal bluffs. Canyons were cut headward as much as 235 feet on the 20th of February alone (Kuhn and Shepard, 1980). These high rainfalls caused more subaerial erosion along this section of coast than had occurred in decades, and brought a significant amount of sediment directly to the beach. Numerous mudslides occurred among the bluff fronting Pacific Coast Highway at Capistrano Beach and San Clemente (Plates 4 and 5). The rainfall at San Juan Capistrano totalled 9 inches in January, and 12.7 inches for the period between the 13th and 21st of February.

The storms along the Pacific Coast during the winter of 1982-83 (Plate 6) were responsible for greater erosion and damage to coastal property as a result of wave action than had occurred since the winter of 1940-41 (Kuhn and Shepard 1979, 1984; Griggs and Savoy, 1985). At many sites along San Diego and Orange Counties, as much as 10 to 20 feet of coastal erosion (e.g., bluff retreat) was documented during the storm lasting from the 27th to the 31st of January alone (Kuhn and Shepard, 1984). Many coastal sites that had shown little to no significant erosion for decades were rapidly and drastically altered from the combination of wave action and subaerial erosion. Beach cobbles and riprap became airborne projectiles, damaging or destroying buildings located along beaches. Significant erosion was documented within both Niguel Shores and Capistrano Beach areas (Plates 4 and 5) (discussed below).

On January 17, 1988, a storm of exceptional intensity approached the coast of central and southern California. Within a 24-hour period, it would break every historical record for the strength of its low pressure system, the speed of its winds and the height of the waves it generated. This event occurred over such a brief duration that is was impossible to forecast with available technology, yet its impact was felt along hundreds of miles of American and Mexican coastline (Seymour, 1989).

Coupled with the increased runup associated with the very large waves, the storm resulted in substantial flooding of low-lying coastal areas, overwash fans of sand, and waves exceeding 30 feet in height offshore and associated breaker heights (h_B) exceeding 18 feet. The storm caused extensive erosion of beaches in San Diego, Orange and Los Angeles Counties.

Rocks were sand-blasted completely clean of excrusting growths, and cobbles were substantially rearranged at submarine depths much greater than generally assumed to represent the limit of sediment transport by waves in this region.

The unusual storms of January 1978, winter 1980, and winter 1982-1983, and January 1988, signal a dramatic return to the wet, stormy meteorologic conditions such as those affecting the Dana Point coastal zone prior to 1945, and are events that coastal engineers and planners must account for in the design of coastal structures and protective measures. In general, past coastal protective devices have been inadequately designed for such conditions (Ganus, 1977; Walker et al, 1984; US Army Corps of Engineers, 1988c; Slosson et al, 1987).

Storm Wave and Azimuth and Size

As discussed above, there are four principal deep-water wave azimuths impinging on the Dana Point coastal zone; of these, three wave directions have been associated with severely elevated deep-water and breaking wave heights during historic storm periods.

The first type of storm wave originates in low-pressure areas south of the Aleutian Islands and advances from the northwest. We are likely to have 20-foot breakers and winds up to 40 mph with such storms. The main force comes with the northwest wind, and the waves have great capacity for producing coastal erosion, even through much of the Southern California coast is partially protected by the Channel islands and the westward bulge of the Santa Barbara/Point Conception area (Shepard & Wanless, 1971; State of California, 1977A). The last severe sea storm of this type to be documented occurred between December 23, 1940, and January 7, 1941 (Kuhn and Shepard, 1979; 1984).

A second type of storm comes from the open Pacific and often passes through the Hawaiian Islands, sometimes causing more damage than a tsunami. These come into the California coast from the west. Storms of this type were responsible for extensive damage to homes, piers and roads along the coast during April 1958 and the winters of 1977-78 and 1979-80 (Garza and Peterson, 1982; Kuhn and Shepard, 1984). These storms brought greater than normal rainfalls levels which initiated landslides and greatly accelerated coastal erosion in the Niguel Shores, Dana Cove and Capistrano Bluffs subunits, as well as to the south in the Camp Pendleton and San Onofre areas (US Army Corps of Engineers, 1987A).

The third type of storm is associated with the El Nino (ENSO) event, and often devastates the coast of Baja California to the south, then dissipates westward (Griggs and Savoy, 1985).

In the summer of 1934 we had such a storm, possibly from the southern hemisphere. Thirty-foot breakers pounded the Newport-Balboa area, many piers and roads were destroyed, and beach cottages were undermined. The Long Beach breakwater was severely damaged and many homes in the eastern part of Long Beach were undermined or destroyed by a similar, but more severe storm in 1939 (Horrer, 1950; US Army Corps of Engineers, 1988C). Long-period (e.g., T> 18 sec.) deep-water waves are characteristically associated with these southern storm swells, due to the long fetch within which waves are generated (Marine Advisers, 1960A; B; 1961).

If this type of storm wave does reach the southern California coastline, it is generally accompanied by southerly winds and huge southwest waves that can be disastrous to south-facing coasts such as Malibu, Newport, Laguna, Long Beach and Dana Point headland. Prior to 1983 the most recent hurricane-generated storm of this type reached the southern California coast in September 1939. Despite the presence of groins, jetties, breakwaters, and other coastal structures, beaches were overrun and numerous homes and structures at Long Beach and Newport were severely damaged or destroyed.

With the warm water event of 1982-83 in the Pacific, storms of this type have become more frequent. The Hawaiian Islands were hit by such a storm in November 1982, causing the most storm damage of the century. Storm waves from the 1983 event caused considerable erosion damage to the engineered revetment at southern Niguel Shores and to the southern Capistrano Beach residential community (Griggs and Savoy, 1985; Seymour et al, 1984). Seymour, et. al. (1984) have calculated deepwater wave approach directions for a site 50-mi west of Los Angeles. For 42 storms which produced hindcast wave heights of over 10 ft between 1900 and 1983, they found the wave approach direction to be as given below:

Approach Direction	Percent of Storms
South (160° - 220°)[1]	26
West (250° - 290°)	52
North (320° - 350°)	22

[1] includes four presumed hurricanes.

Seymour et. al. (1984) note that the 22 percent of storm waves coming out of the northwest was unexpectedly low. The northwest track has characteristically been assumed to dominate the wave climate off southern California (Shepard and Wanless, 1971; State of California, 1977A). During those years when the El Nino/Southern Oscillation Event (ENSO) exists, large waves out of the west may reach the County of Orange coast from a semi-permanent low, north of Hawaii. Waves out of the north are unlikely then because Bering Sea storms are held to the Aleutians. Tropical storms which approach out of the south develop as surface water temperatures rise. Because ENSO events cause an increase in water temperature, severe waves from the south are more likely when the this condition prevails due to thermal expansion of the water mass. Seymour et. al. (1984) found hurricanes (severe tropical storms) associated with four strong ENSO events (1911, 1925, 1957, 1982). Of the storms out of the south, Seymour et. al. (1984) found 73 percent associated with the ENSO phenomenon, including three of the four fall hurricanes which occurred. Fifty percent of the storms out of the west were associated with ENSO events. No storms out of the north showed this association. The relationship between storms and ENSO events appears significant. The effect of an ENSO event on water surface elevations is most pronounced between August and February (Moffatt and Nichol, 1985).

Storms from January to March 1983 differed significantly from previous storms. Maximum deepwater wave heights varied between 13 and 24 feet for eight storms. Two of the most significant storms produced waves with exceptionally long periods of 22 seconds (Seymour, et. al., 1984). The largest storm of the winter occurred on 27 January, 1983. The energy of that storm, the third largest calculated, was slightly less than the 1939 (September) hurricane out of the south, and slightly less than a storm out of the west which occurred in April 1958. For design purposes, Seymour, et al. (1984) suggest that the 1983 storm year might be expected to occur with a recurrence interval of 25-30 years.

Marine Advisers (1960b) hindcast extreme storm wave heights at Dana Point and Oceanside, involving scanning of weather maps and researching damage reports on file with newspapers and government agencies (and other sources)for indications of high storm waves in the period 1900-1958. From these qualitative reports, 15 storms were selected for complete hindcasting. Of the 15 hindcast events, 2 yielded rather small waves and were not considered further. Statistics for the 13 remaining storms are given below. These waves were then brought through the Channel Islands with a simple blocking model. Refraction by subaerial island features was not accounted for. Using this crude model, the reduction of coastal wave height relative to outside the islands (I/I_o) was calculated. The sheltered waves were then refracted and shoaled to shallow water (breaking wave) using Dana Point bathymetry. The table below gives the sheltered and shoaled statistics, for events with significant breaker heights greater than 10 ft.

Design significant wave data at Dana Cove

Storm Date	Island Shelter Coeff. (I/I_o)	Breaker Refraction Coeff. K_b	Shoaling Coeff. H_b/H_o'	Significant Breaker Height H_b	Significant Period T_s	Breaker Direction
15-25 Sept 1939	.90	1.00	1.00	24.2 ft.	14.0 sec.	204°
28-30 Jan 1915	.92	1.02	1.04	15.9	11.8	235
9-10 Mar 1904	.81	.92	1.12	14.9	12.0	237
20-23 Jan 1943	.93	.96	1.00	14.4	10.8	195
8-10 Mar 1912	.72	.87	1.17	12.8	11.5	243
16-17 Dec 1914	.93	.97	1.02	12.0	9.9	192
26-28 Jan 1916	.87	.97	.97	11.4	9.6	235
1-3 Jan 1915	.61	.88	1.23	10.8	12.4	244

The 15-25 September 1939 storm was the most severe that has occurred since 1900 from the standpoint of wave height. The maximum wind of that tropical storm at the Los Angeles - Long Beach Outer Harbor was 50 knots. Wave heights observed at the harbor ranged from 12 to 40 ft. Swell heights were estimated at 30 ft by people ashore. Ships in the Catalina Channel reported 45 ft high waves. Damage to the Los Angeles - Long Beach Harbor breakwater occurred for the second time (Moffatt and Nichol, 1985). Given the dimensions and orientation of the outer Dana Harbor breakwater, it is feasible that future storms of similar magnitude could severely damage this structure, as well.

Coastal engineers should use the 1939 ENSO significant wave heights for design for design of protective devices, but should additionally consider the effects of long-term sea level rise and perigean spring tides as well, (discussed above). The potential for these three factors acting in conjunction warrant the application of suitable factors of safety to all subsequent coastal design.

Flood Discharge And Sediment Yields

The same large, periodic storms which caused beach and coastal bluff erosion and slope failures also generate large amounts of runoff in coastal watersheds, which result in large discharges of water and sediment to the littoral zone. Coarse sediment delivery by coastal streams is almost non-existent except during these large storm flows. (The expression "coarse sediment" used herein represents sediment sizes larger than 0.062 millimeters in diameter, which are the sediment sizes that accumulate on beaches and on stream beds). The coarse stream sediment delivered to the coast is deposited in the form of a delta, and is subsequently redistributed along the coast by waves and longshore currents. Two important questions which arise are:

(1) How much coarse sediment is lost from beaches, and, more importantly, from the littoral system during major storms.

(2) How much coarse sediment is delivered by coastal streams during these storm events.

Both questions need to be answered by the coastal engineer prior to the implementation of protective devices or programs (jetties, offshore breakwaters, sandfills/nourishment) intended to minimize beach erosion (Stow and Chang, 1987).

The primary input of coarse sediment to the northern segment of the Oceanside littoral cell is from coastal streams and seacliff erosion (Osborne et al, 1989). Longshore sediment transport rates are relatively high, with net transport occurring from the north to south.

The coastal watershed of San Juan Creek draining into the Dana Point coastal zone is limited in areal extent, but yields fairly large amounts of coarse sediment per unit area (US Army Corps of Engineers, 1988A). The climate of this drainage basin is generally semiarid, with most of the precipitation occurring during winter months.

Stream flow in these coastal streams is highly intermittent, with limited base flows and occasional flood flows resulting from winter storm events. Coarse sediment transport capacity is negligible except during flood flows and storm-sustained winter discharges.
Even the strongest flood flows issuing through the mouth of San Juan Creek rapidly decelerate rapidly seaward of the mouth. This results in a rapid deposition of coarse sediments and the formation of a delta. The steep watershed of San Juan Creek is uncontrolled by dams, but significant flood control channel modifications have been made at the lower reaches of the stream.

The greatest limitations to our present ability to make accurate estimates of the littoral sand budget through river discharge are:

(1) The difficulty in accurately measuring sediment transport and important hydraulic variables (particularly large flow events);

(2) The lack of consideration for and understanding of processes occurring at the terminus of coastal streams. Research must be performed that includes extensive measurements, physical analyses and numerical modeling if accurate estimates are to be realized.

The inability to accurately measure coarse sediment transport as bed load, and the logistical difficulties in measuring physical variables during rare flood events, extremely limits the ability to directly measure sand delivery to the sea. This is particularly the case at a river mouth where marine processes further complicate the situation, such as San Juan Creek. The infrequent nature of important sand delivery events means that sediment sampling and other measurements must be acquired by automatic recording equipment, or manually on a contingency basis. In spite of these difficulties, it is imperative to our ability to determine sand delivery rates to acquire measurements of sediment transport and hydraulic variables at several river mouth locations and for multiple flood events. No such requirements have been met to date for a river mouth location in southern California during flood conditions (Stow and Chang, 1987).

Previous estimates of coarse sediment delivery have been compiled and examined for San Juan Creek; four basic methods have been used to estimate sediment delivery:

(1) watershed sediment yield (Taylor, 1983)

(2) statistical/sediment gaging (Kroll and Porterfield, 1969)

(3) analytical transport relationship (US Army Corps of Engineers, 1988A)

(4) numerical simulation modeling

While statistical/sediment gaging methods (Kroll and Porterfield, 1969) are based on actual suspended sediment and stream discharge measurements, the accuracy of coastal sand delivery estimates based on such methods are suspect. This is particularly the case in southern California, where the record length of these measurements is limited, and in most cases spans a time of anamolously dry climate conditions. Added to these potential biases is the fact that a large portion of the sand-size sediment delivery to the coast occurs as bed load transport, which is not sampled. In most cases the bed load transport is estimated as a constant percentage of the suspended load, assuming that the bed load consists of sand-size or larger sediments.

The bottom line to determining accurate estimates of sand delivery by coastal streams is that both field data collection and numerical modeling must be performed in conjunction. If logistical and sampling-related problems can be overcome to directly measure sediment transport and hydraulic variables, then detailed information for only a few flood events and few streams will likely be obtainable. This information will be useful to the calibration of numerical simulation models. The complexity of routing stream water and sediments, accounting for channel adjustments as well as interactions with marine processes, requires computerized simulation methods. The accuracy of simulation model results will improve with increasing field measurements, advances in measuring bed load sediment transport and the development of better sediment transport formulae (Stow and Chang, 1987; US Army Corps of Engineers, 1988A).

Table 2 presents historical flood discharge from significant periods of storm runoff in San Juan Creek, as well as peak daily coarse sediment transport equations which estimate coarse sediment discharge as a function of streamflow (US Army Corps of Engineers, 1988A). Table 2 also presents peak annual sediment yields and peak event discharges associated with selected large flood periods, both prior to and subsequent to channelization of San Juan Creek by the County Flood Control District and Corps of Engineers. These data were obtained through both watershed sediment yield methods and direct measurements at San Juan Creek outfall, or at selected upstream locations. The most striking feature of these pre- and post-channelization floods is the 65% reduction in littoral sediment yield between floods of approximately equivalent water discharge (1938 and 1978; 13,000 and 14,700 cubic feet per second, respectively). Also striking is the approximately 50 percent increase in flood discharge necessary to produce equivalent sediment yields between pre- and post-channelization periods (1938 versus 1969 floods) (Troxell et al, 1942; Vanoni et al, 1982). Such net losses to the littoral sand budget must be accounted for during detailed design of subsequent beach nourishment programs in the Doheny Beach/Capistrano Beach subunit.

TABLE 2 - SAN JUAN CREEK

HISTORICAL FLOOD AND SEDIMENT DISCHARGE

Flood Dates, Peak Yields	Maximum Flood Discharge Cubic Feet Per Second	Estimated Sediment Yield Cubic Yards Per Year
1937	9,240	550,000
1938	13,000	800,000
1943	5,800	350,000
1952	3,300	200,000
1957	5,500	350,000
1969	19,000	770,000
1978	14,700	282,000
1949-1960 Annual Yield (non-storm)		132,000
Post-1960 Annual Yield (non-storm)		45,000

A. Estimates of peak sediment yield for selected historic flood events and annual yield for non-flood years prior to 1960 and flood control channelization (1937 to 1957; Source: Troxell et al, 1942; US Army Corps of Engineers 1959; Moffatt and Nichol, 1985) and similar data for urbanization period subsequent to flood control channel construction (Source: Kroll & Porterfield, 1969; Vanoni et al, 1982; Taylor, 1983; US Army Corps of Engineers, 1988A; Stow and Chang, 1987).

Year	Month/Day	Maximum Flow (cfs)
1929	Mar. 1	4
1930	Mar. 16	1,230
1931	Feb. 5	277
1932	Feb. 9	1,200
1933	Jan. 19	199
1934	Jan. 1	318
1935	Jan. 7	135
1936	Feb. 15	160
1937	Feb. 6	9,240
1937	Feb. 7	9,245
1938	Mar. 2	13,000
1938	Mar. 3	13,000
1939	Dec. 19	275
1940	Feb. 3	790
1941	Feb. 21	1,950
1942	Mar. 15	21
1943	Jan. 23	5,800
1944	Feb. 22	1,360
1945	Mar. 15	600
1946	Dec. 23	350
1947	Nov. 13	59
1948	Feb. 5	9
1949	Feb. 27	4
1950	Jan. 11	4
1951	Mar. 2	2
1952	Mar. 16	3,330
1953	Dec. 20	29
1954	Jan. 25	458
1955	Jan. 18	18
1956	Jan. 27	2,130
1957	Jan. 13	17
1957	Nov. 16	5,500
1958	Apr. 3	2,230

B. Peak flood discharges recorded from gaging station data, San Juan Creek, 1929-1958 (source: US Army Corps of Engineers, 1959).

SIGNIFICANT DAILY AVERAGE DISCHARGE (CFS.)

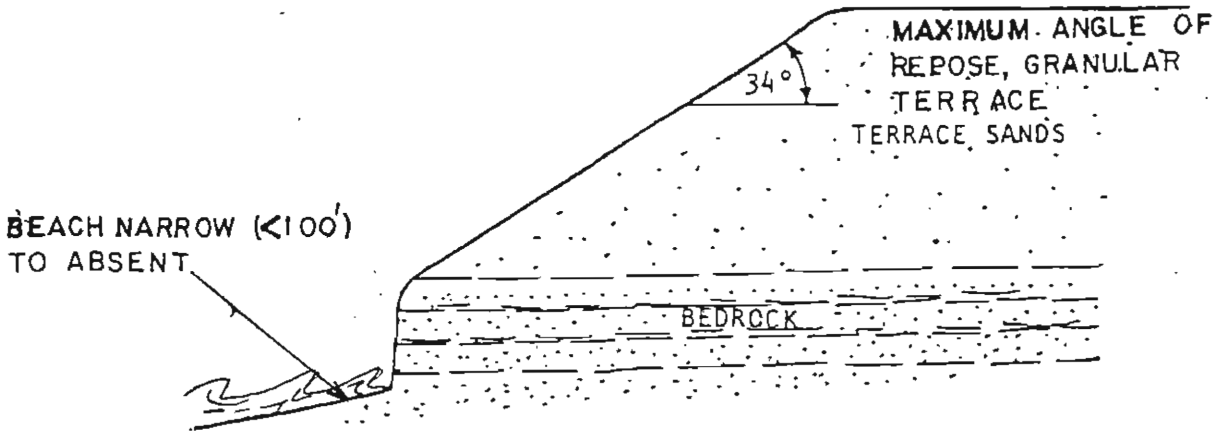
DATE YR	MO	DA	SAN JUAN CREEK	DATE YR	MO	DA	SAN JUAN CREEK	DATE YR	MO	DA	SAN JUAN CREEK	DATE YR	MO	DA	SAN JUAN CREEK
1920	2	23	372	1932	2	20	462	1941	4	27	233	1978	3	30	202
1920	3	23	494	1932	2	21	395	1941	4	28	224	1978	3	31	252
1920	3	24	337	1932	2	22	342	1941	4	29	210	1978	4	1	202
1920	3	27	424	1932	2	23	277	1941	4	30	312	1978	4	2	173
1921	12	20	422	1933	1	30	136	1941	5	1	242	1979	1	6	1036
1921	12	21	460	1936	12	31	542	1942	3	17	18	1979	1	31	1079
1921	12	22	590	1937	2	6	3062	1943	1	23	3229	1979	2	1	690
1921	12	23	410	1937	2	7	4703	1943	3	4	1125	1979	3	19	249
1921	12	25	441	1937	2	8	864	1944	2	23	409	1979	3	20	1430
1921	12	26	2247	1937	2	14	2498	1944	2	24	563	1979	3	29	800
1921	12	27	1130	1937	2	15	1326	1944	2	25	347	1979	3	30	479
1921	12	28	470	1937	3	16	870	1944	2	26	507	1979	3	31	364
1922	1	2	494	1938	3	1	942	1944	2	27	462	1979	4	1	303
1922	1	3	400	1938	3	2	5897	1944	2	28	347	1980	1	29	2711
1922	1	4	353	1938	3	3	4971	1944	2	29	260	1980	1	30	733
1922	1	30	500	1938	3	4	1626	1944	3	1	247	1980	1	31	624
1922	1	31	523	1938	3	5	1020	1944	3	2	229	1980	2	1	355
1922	2	1	353	1938	3	12	1020	1944	3	6	202	1980	2	2	293
1922	2	8	476	1938	3	13	927	1944	3	7	179	1980	2	3	242
1922	2	9	546	1938	3	14	832	1944	3	20	117	1980	2	4	226
1922	2	10	574	1938	3	15	721	1952	1	13	179	1980	2	14	2197
1922	2	11	383	1940	12	24	445	1952	1	16	1709	1980	2	15	7000
1922	2	12	375	1941	2	21	2182	1952	1	17	369	1980	2	16	2640
1922	2	21	470	1941	2	22	1354	1952	1	18	1136	1980	2	17	5104
1922	2	22	410	1941	3	1	1269	1952	3	16	2569	1980	2	18	6420
1922	2	23	386	1941	3	2	1057	1952	3	17	978	1980	2	19	4703
1922	3	11	357	1941	3	3	776	1952	4	2	123	1980	2	20	4037
1922	3	12	395	1941	3	4	1456	1956	1	27	2240	1980	2	21	4090
1922	3	17	590	1941	3	5	1311	1958	3	16	1935	1980	2	22	2503
1922	3	18	410	1941	3	6	989	1958	4	1	1007	1980	2	23	2052
1922	3	19	389	1941	3	7	816	1958	4	2	1531	1980	2	24	1730
1922	3	20	353	1941	3	13	637	1958	4	3	1091	1980	2	25	1162
1926	4	6	704	1941	3	14	927	1958	4	4	1329	1980	2	26	849
1926	4	7	570	1941	3	15	816	1958	4	5	400	1980	2	27	543
1926	4	8	1253	1941	3	16	653	1958	4	6	530	1980	2	28	522
1926	4	9	608	1941	3	17	570	1958	4	7	933	1980	2	29	565
1927	2	14	511	1941	3	18	465	1958	4	8	632	1980	3	1	500
1927	2	15	1332	1941	3	19	379	1965	11	23	1622	1980	3	2	706
1927	2	16	4266	1941	4	1	827	1966	12	5	1950	1980	3	3	1921
1927	2	17	1747	1941	4	2	823	1966	12	6	5104	1980	3	4	1006
1927	2	18	1017	1941	4	3	599	1966	12	7	1626	1980	3	5	1196
1927	2	19	740	1941	4	4	558	1969	1	25	7583	1980	3	6	2000
1927	2	20	577	1941	4	5	773	1969	1	26	3062	1980	3	7	1730
1927	2	21	476	1941	4	6	533	1969	2	24	5104	1980	3	8	1514
1927	2	22	410	1941	4	7	445	1969	2	25	9100	1980	3	9	1534
1927	2	23	351	1941	4	8	405	1969	2	26	5766	1980	3	10	1552
1927	3	4	675	1941	4	9	372	1969	2	27	2355	1980	3	11	1385
1927	3	5	577	1941	4	10	405	1978	1	15	173	1980	3	12	1246
1927	3	6	442	1941	4	11	633	1978	1	16	160	1980	3	13	1004
1927	3	7	380	1941	4	12	550	1978	1	17	199	1980	3	14	933
1927	3	10	410	1941	4	13	525	1978	1	20	179	1980	3	15	835
1931	2	5	64	1941	4	14	504	1978	2	10	2211	1980	3	16	743
1931	12	29	100	1941	4	15	474	1978	2	11	810	1982	3	17	661
1932	2	2	378	1941	4	16	452	1978	2	12	548	1982	3	18	1456
1932	2	9	1492	1941	4	17	405	1978	2	13	2124	1983	2	28	1921
1932	2	10	956	1941	4	18	360	1978	3	1	4864	1983	3	1	2503
1932	2	11	596	1941	4	19	323	1978	3	2	4217	1983	3	2	3313
1932	2	14	335	1941	4	20	300	1978	3	3	4014	1983	3	3	2369
1932	2	15	323	1941	4	21	284	1978	3	4	7262	1983	3	4	1001
1932	2	16	661	1941	4	22	261	1978	3	5	4163	1983	3	5	641
1932	2	17	712	1941	4	23	247	1978	3	6	2950	1983	3	6	479
1932	2	18	638	1941	4	24	247	1978	3	7	1803	1983	3	24	1405
1932	2	19	555	1941	4	25	242	1978	3	12	725	1983	12	25	410
				1941	4	26	233	1978	3	29	204				

C. Historic Recorded Mean Daily Flood Discharges from Significant Storms, 1920-1983.

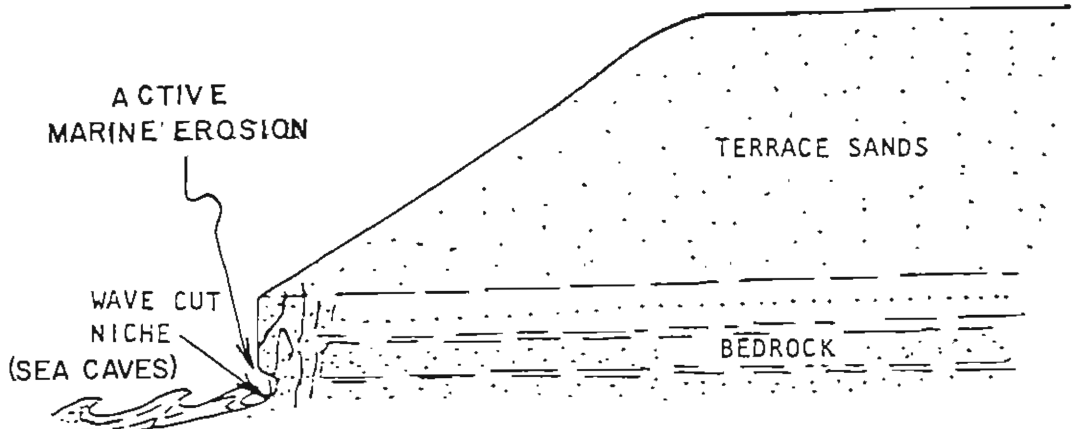
RECONSTRUCTION OF HISTORIC SEDIMENT YIELD (IN TONS/DAY) FOR
SEDIMENT SIZES LARGER THAN 0.0625 mm

DATE YR	MO	DA	SAN JUAN CREEK	DATE YR	MO	DA	SAN JUAN CREEK	DATE YR	MO	DA	SAN JUAN CREEK	DATE YR	MO	DA	SAN JUAN CREEK
1920	2	23	1460	1932	2	20	2041	1941	4	27	712	1978	3	30	573
1920	3	23	2259	1932	2	21	1601	1941	4	28	670	1978	3	31	806
1920	3	24	1255	1932	2	22	1202	1941	4	29	605	1978	4	1	573
1920	3	27	1704	1932	2	23	930	1941	4	30	1116	1978	4	2	451
1921	12	20	1774	1933	1	30	311	1941	5	1	754	1979	1	6	7060
1921	12	21	2030	1936	12	31	2607	1942	3	17	13	1979	1	31	7520
1921	12	22	2975	1937	2	6	37402	1943	1	23	40591	1979	2	1	3701
1921	12	23	1700	1937	2	7	72359	1943	3	4	8821	1979	3	19	708
1921	12	25	1903	1937	2	8	5340	1944	2	23	2225	1979	3	20	11690
1921	12	26	23236	1937	2	14	27342	1944	2	24	2767	1979	3	29	4823
1921	12	27	8164	1937	2	15	10332	1944	2	25	1312	1979	3	30	2155
1921	12	28	2092	1937	3	16	5401	1944	2	26	2354	1979	3	31	1413
1922	1	2	2259	1938	3	1	6105	1944	2	27	2041	1979	4	1	1069
1922	1	3	2218	1938	3	2	102474	1944	2	28	1312	1980	1	29	31000
1922	1	4	1351	1938	3	3	78788	1944	2	29	885	1980	1	30	4153
1922	1	30	2301	1938	3	4	14133	1944	3	1	780	1980	1	31	3237
1922	1	31	2469	1938	3	5	6898	1944	3	2	695	1980	2	1	1363
1922	2	1	1351	1938	3	12	6898	1944	3	6	573	1980	2	2	1013
1922	2	8	2134	1938	3	13	5950	1944	3	7	473	1980	2	3	754
1922	2	9	2637	1938	3	14	5043	1944	3	20	247	1980	2	4	670
1922	2	10	2840	1938	3	15	4042	1952	1	13	473	1980	2	14	22441
1922	2	11	1532	1940	12	24	1928	1952	1	16	8963	1980	2	15	34034
1922	2	12	1483	1941	2	21	22214	1952	1	17	1444	1980	2	16	29771
1922	2	21	2092	1941	2	22	10660	1952	1	18	8139	1980	2	17	82060
1922	2	22	1700	1941	3	1	9640	1952	3	16	28549	1980	2	18	116783
1922	2	23	1551	1941	3	2	7208	1952	3	17	6467	1980	2	19	72359
1922	3	11	1374	1941	3	3	4534	1952	4	2	266	1980	2	20	75554
1922	3	12	1607	1941	3	4	11924	1956	1	27	23124	1980	2	21	76843
1922	3	17	2975	1941	3	5	10151	1958	3	16	10470	1980	2	22	20792
1922	3	18	1700	1941	3	6	6578	1958	4	1	7602	1980	2	23	20207
1922	3	19	1569	1941	3	7	4896	1958	4	2	12800	1980	2	24	15541
1922	3	20	1351	1941	3	13	3341	1958	4	3	17830	1980	2	25	8428
1926	4	6	3900	1941	3	14	5850	1958	4	4	10368	1980	2	26	5206
1926	4	7	2816	1941	3	15	4896	1958	4	5	2187	1980	2	27	2619
1926	4	8	8463	1941	3	16	3473	1958	4	6	2582	1980	2	28	2461
1926	4	9	3114	1941	3	17	2816	1958	4	7	6012	1980	2	29	2779
1927	2	14	2385	1941	3	18	2063	1958	4	8	3302	1980	3	1	2307
1927	2	15	10384	1941	3	19	1586	1965	11	23	14074	1980	3	2	3918
1927	2	16	62282	1941	4	1	4989	1966	12	5	18685	1980	3	3	18256
1927	2	17	15706	1941	4	2	4955	1966	12	6	82060	1980	3	4	6754
1927	2	18	6872	1941	4	3	3044	1966	12	7	14133	1980	3	5	8807
1927	2	19	4210	1941	4	4	2730	1969	1	25	150852	1980	3	6	19551
1927	2	20	2860	1941	4	5	4506	1969	1	26	37402	1980	3	7	15541
1927	2	21	2134	1941	4	6	2546	1969	2	24	82080	1980	3	8	12668
1927	2	22	1698	1941	4	7	1928	1969	2	25	199947	1980	3	9	12918
1927	2	23	1337	1941	4	8	1665	1969	2	26	98982	1980	3	10	13151
1927	3	4	3654	1941	4	9	1465	1969	2	27	24973	1980	3	11	11046
1927	3	5	2869	1941	4	10	1665	1978	1	15	451	1980	3	12	9384
1927	3	6	1005	1941	4	11	3315	1978	1	16	429	1980	3	13	7569
1927	3	7	1512	1941	4	12	2668	1978	1	17	557	1980	3	14	6012
1927	3	10	1698	1941	4	13	2406	1978	1	20	473	1980	3	15	5072
1931	2	5	98	1941	4	14	2331	1978	2	10	22668	1980	3	16	4237
1931	12	29	511	1941	4	15	2121	1978	2	11	4038	1982	3	17	3539
1932	2	2	1496	1941	4	16	1973	1978	2	12	2656	1982	3	18	11924
1932	2	9	12380	1941	4	17	1665	1978	2	13	21316	1983	2	28	10256
1932	2	10	6246	1941	4	18	1393	1978	3	1	76197	1983	3	1	20792
1932	2	11	3810	1941	4	19	1174	1978	3	2	61195	1983	3	2	42213
1932	2	14	1243	1941	4	20	1050	1978	3	3	56706	1983	3	3	25207
1932	2	15	1174	1941	4	21	967	1978	3	4	141139	1983	3	4	6706
1932	2	16	3539	1941	4	22	850	1978	3	5	59988	1983	3	5	3300
1932	2	17	3975	1941	4	23	700	1978	3	6	35318	1983	3	6	2155
1932	2	18	3354	1941	4	24	780	1978	3	7	10571	1983	3	24	12205
1932	2	19	2705	1941	4	25	754	1978	3	12	4803	1983	12	25	1697
				1941	4	26	712	1978	3	29	501				

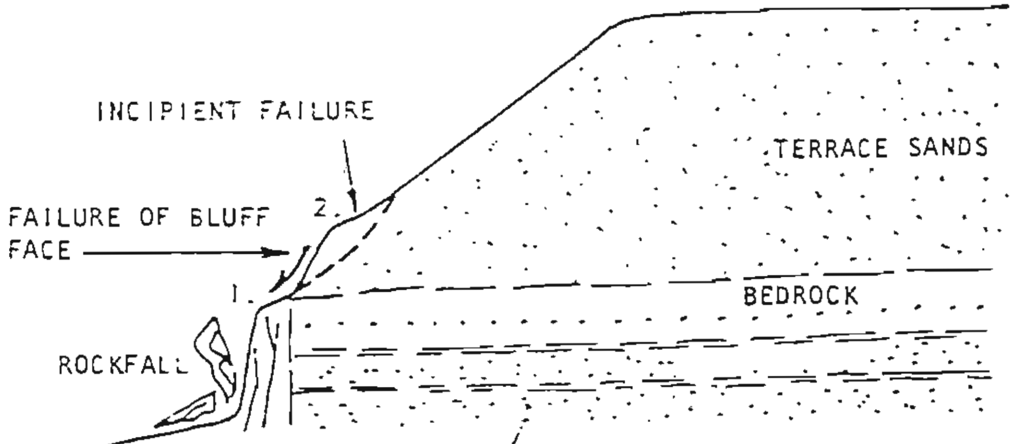
D. Historic Peak Daily Sediment Yields, San Juan Creek, 1920-1983



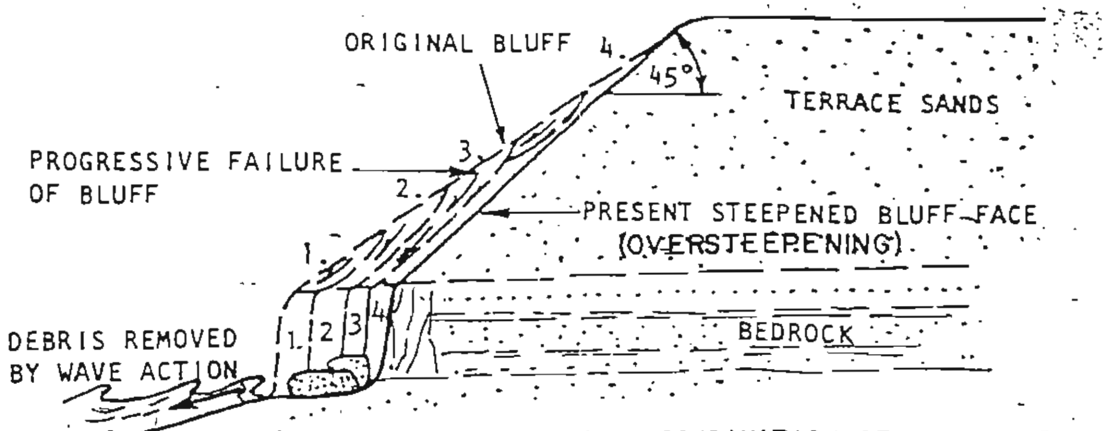
1. STABLE BLUFF (TEMPORARY EQUILIBRIUM)



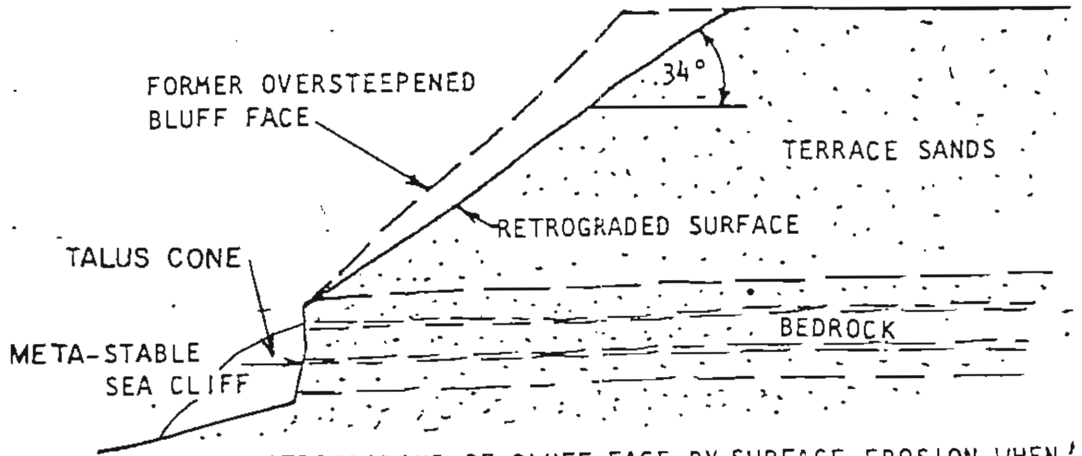
2. WEAKENING BY WAVE ATTACK AND DEVELOPMENT OF TENSION JOINTS



3. FAILURE OF WEAKENED SEA CLIFF AND INITIATION OF FAILURE IN BLUFF FACE



4. RECESSION OF BLUFF FACE BY COMBINATION OF SEA CLIFF AND BLUFF FACE FAILURES



5. RETROGRADING OF BLUFF FACE BY SURFACE EROSION WHEN TOE IS NOT ACTIVELY RETREATING

DIAGRAMS 1-4: DANA POINT HEADLANDS, MONARCH BAY

DIAGRAM 5: CAPISTRANO BLUFFS, DANA COVE/ HARBOR (INACTIVE MARINE EROSION)

FIGURE 9
SCHEMATIC SEQUENCES IN COASTAL BLUFF FAILURE, DANA POINT COASTAL ZONE

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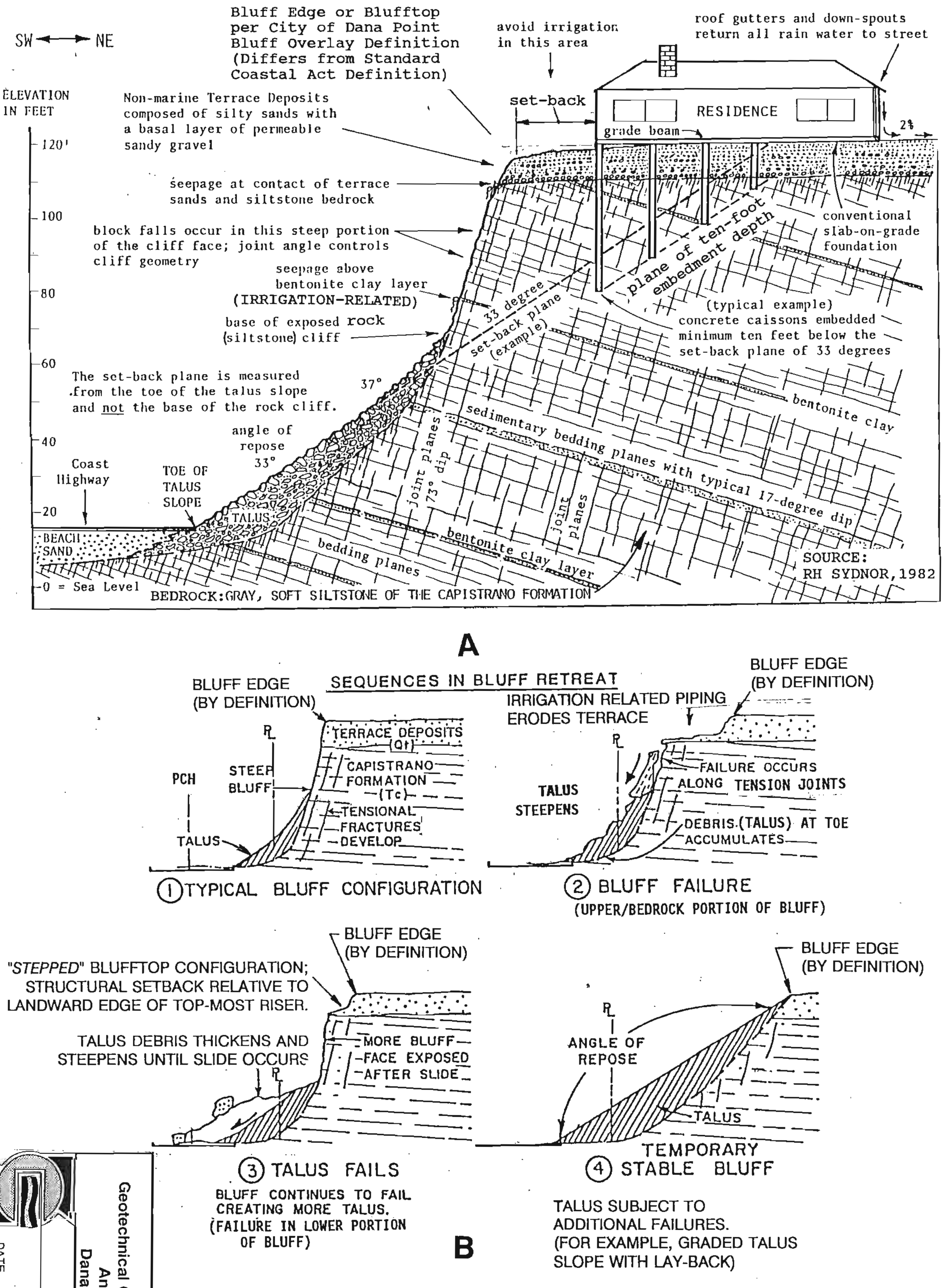

Figure 10
Geotechnical Conditions, Capistrano Bluffs
And Palisades Area
Dana Point Coastal Zone

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Coastal Bluff Landslides And Failures

Natural marine and subaerial processes which yield coastal bluff/sea-cliff erosion and retreat over time are discussed above (Subsection CI) and are detailed more completely in Lee et al (1976), Lee (1980) and Emery and Kuhn (1982). Kuhn and Shepard (1984) discuss the effect on coastal bluff erosion produced by urban landscape irrigation practices, contributing the equivalent of 50 or 60 inches of annual rainfall to surface erosion of blufftop terrace sands, and accumulation of groundwater within bedrock.

As is true for adjacent coastal zones in northern San Diego County (Kuhn and Shepard, 1979; 1980; 1984; US Army Corps of Engineers, 1987A; 1988C), sea-cliff and bluff retreat has been temporally episodic, site specific, and temporally related to prevailing meteorological conditions within the Dana Point coastal zone, and also to the combination of erosive agents, both natural and man-induced, that have acted upon the bluffs.

Prior to the present study, little work had been completed on long-term rates of cliff erosion and recession in the southern Orange County coastal zone; therefore, it was impossible to identify long-term sea-cliff retreat for any specific coastal segment with a meaningful average rate or even a range of rates (US Army Corps of Engineers, 1984b).

Many historical techniques for estimating rates of sea-cliff retreat have either ignored long-term meteorologic effects, or have attributed long-term erosion rates to marine abrasion processes only (e.g., Shepard and Grant, 1947; Norris, 1968; Tinsley, 1972; Kennedy, 1973; Emery and Kuhn, 1980).

Hannan and Hansen (1981) correctly note that the use of an average rate of erosion is inappropriate when computed over a short time interval; they reported a historical rate of sea-cliff retreat at Encinitas of 0.36 foot/year (35 feet/96 years). Even this improvement in methodology may be inadequate to constrain or estimate future rates of retreat, given that available federal government survey maps or aerial photos of the southern California coastal zone (Appendix A) do not pre-date the devastating large-magnitude storms and floods of the period 1830 through 1862, therefore preventing comparisons between pre-and post-storm shoreline position. Additionally, coastal bluff retreat at a given site for a given time period may involve up to 80 feet of bluff failure (landsliding) or over 100 feet (blufftop erosion) during a single storm, followed by up to 30 years of minimal retreat during extended drought period (e.g., the recent 1947 to 1977 drought, discussed above). Given the return to excessive storm conditions between 1978 and 1983 (Kuhn and Shepard, 1984; US Army Corps of Engineers, 1988c) (Plate 6), it becomes meaningless to think of coastline erosion in terms of average rates, particularly from the standpoint of urban planning or public safety. The following summary of bluff failures and erosion is thus treated on a chronological event basis, as depicted on Plates 4 and 5 (in Pocket).

The large storm period between 1884 and 1891 generated the largest single landslide in the Dana Point coastal zone, a 2-acre blockglide failure within the sandy facies of faulted San Onofre Breccia at the western promontory of the headlands subunit (Figure 5B; Plate 1). Reactivation of the ancient large landslide in the sea-cliff at the southern end of Niguel Shores subunit (below Dana Strand Road) occurred during this time period as well. Up to 100 feet of bluff retreat occurred in places during this seven-year period. Up to 30 feet of bluff retreat, due to smaller blockfall landslides, also occurred along the south-facing Dana Point headlands area during these storms.

Either the 1884-1891 or the 1916 storms caused between 15 and 40 feet of blufftop retreat in both the northern Capistrano Bluffs/Palisades subunit ("Dana Bluffs" zone) and south-central Capistrano Bluffs area. This retreat occurred as a combination of both blufftop erosion of terrace sands and joint-controlled blockfalls (R&M Consultants, 1982) (see Figure 9 for illustration of processes). Approximately 40 to 50 feet of seaward migration of the bluff toe occurred between 1885 and 1934 in the same zone, although it is not clear whether this toe migration is due to blockfall (talus), or spoils from the 1928-1930 grading of the Doheny Palisades subdivision. The 1916 storms also generated up to 80 feet of blufftop retreat due to landsliding along the fault zone below Cannons Restaurant, in the Dana Cove and Harbor subunit. Both the 1916 and 1921 storms caused 10 to 20 feet of local blockfall-related bluff retreat along the south-facing promontory of the Dana Point Headlands subunit.

The storms and floods of 1938 through 1941 produced significant coastal bluff erosion. Available maps and photographs do not permit resolution of which storm in this period actually produced damage in specific areas. It seems logical, however, that most wave-induced blockfalls were more prevalent during the 1938 storm, since the large quantities of sediment discharged through coastal streams (see San Juan Creek data, Table 2) during this first storm year would have conceivably provided sediment to local beaches and thus afforded protection to the toe areas of coastal bluffs during subsequent storms. Between 20 and 50 feet of blufftop retreat affected the Monarch Bay coastal bluffs, due to deep-seated bedrock landslides within sandy units of the San Onofre Breccia. Surficial failures within terrace deposits occurred within the blufftop area of the southern Niguel Shore subunit, above Dana Strand beach; total blufftop retreat exceeded 150 feet along this area during the three-year storm period, the greatest single bluff erosion event documented during the present study. Over 50 feet of bluff erosion occurred at the promontory which formerly occupied the present position of the eastern Dana Harbor breakwater.

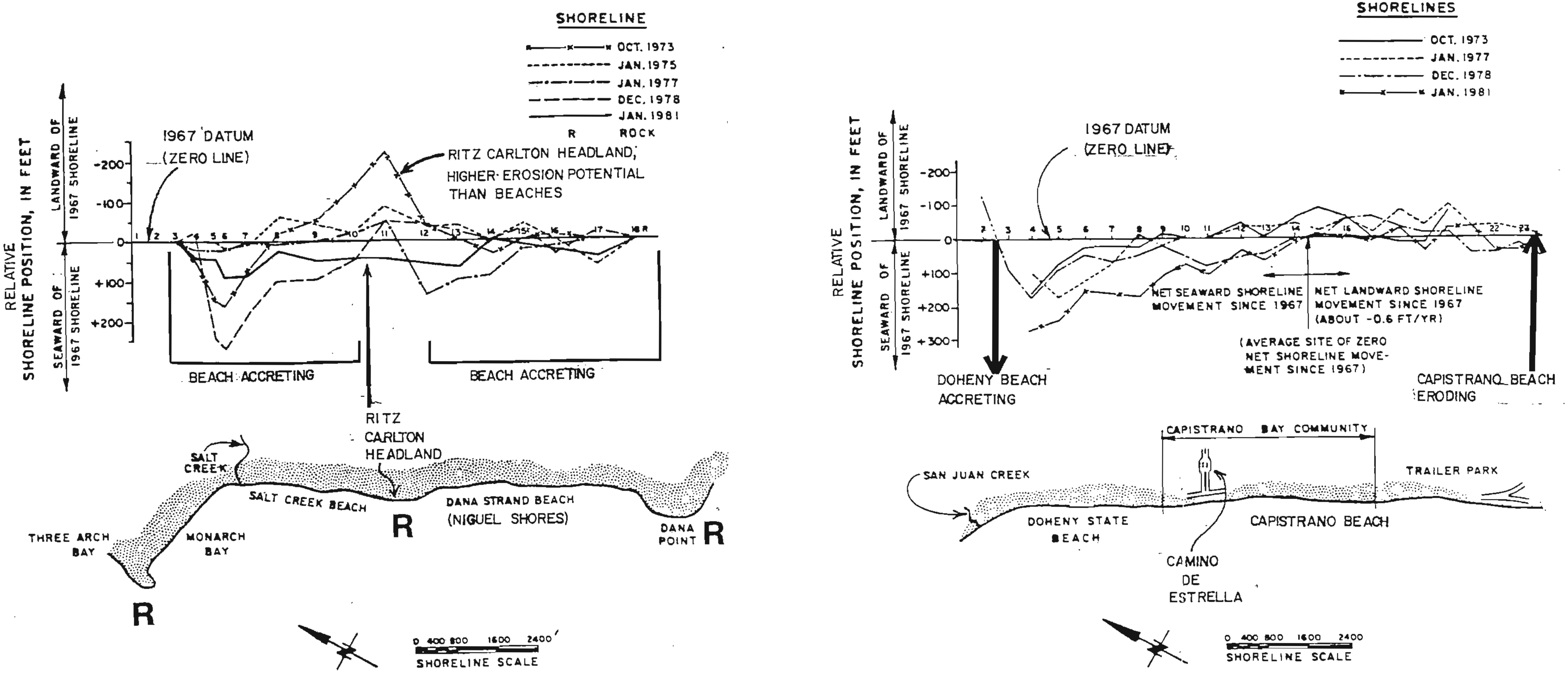
Fifteen to twenty-five feet of blufftop retreat occurred at many places along the Capistrano Bluffs subunit, between Palisades Drive and Camino Mira Costa. Large local blockfalls occurred along the Dana Point headland, with up to 100 of blufftop retreat. This severe erosion of the headland was likely a direct consequence of the elevated 1939 surf along this south-facing sea cliff district.

The 1952 storm produced blufftop landslides in terrace deposits along the southern flank of the Ritz Carlton headland. Within the blufftop of the Dana Cove and Harbor subunit, between 15 and 30 feet of retreat occurred in the segment between Violet Lantern and Old Golden Lantern. Marine erosion also removed large (50 feet) talus cones from the toe area of these sea-cliffs during this storm year. Between 15 and 25 feet of blufftop retreat due to joint-controlled blockfall landslides occurred during the 1952 and 1958 storms in the vicinity of Pines Park and Estrella Stairs.

The 1968-1969 winter storm season produced local reactivation of the 1938 coastal bluff landslides in the Monarch Bay subunit (Figure 7A;B), with additional 10 to 20 feet of bluff retreat. Several blockfalls and 10 to 15 feet of erosion affected the Dana Cove and Harbor bluffs as well during these storms.

The excessive rainfall of the 1978 storms produced joint-controlled blockfalls and 10 to 15 feet of blufftop retreat in the vicinity of the Estrella Stairs, which resulted in their closure. The entire storm period of 1978 through 1983 produced numerous slope failures throughout Orange County (Slosson and Krohn, 1982; Weber, 1979). The Capistrano Bluffs subunit was the hardest hit during this storm period, probably a direct consequence of pre-existing weakened bedrock and groundwater accumulation from residential development and overwatering over the previous 10-year dry interval. Several local areas experienced 10 to 15 feet of blockfall and blufftop retreat during these storm years, including a zone of incipient blockfalls between Pines Park and Estrella Stairs (Figure 3B). The near-disastrous 1980 landslide beneath Cannons Restaurant occurred during a period of excessive rainfall and accumulation of groundwater pore pressures within weak, fractured bedrock. Almost identical conditions were responsible for the 1916 landslide immediately adjacent to the 1980 bluff failure. The effects of poor surface drainage and landscape irrigation practices are evident within both the southern end of the Capistrano Bluffs subunit and southernmost blufftop zone of Niguel Shores (Figure 3A; 6A); in these areas, between 10 to 30 feet of bluff face and blufftop retreat occurred between 1983 and the present due to landsliding caused by erosion and excessive groundwater, even in the absence of major storms.

It should be noted that erosion rates and sediment yield probably were much greater during the extremely stormy years of 1861-62 and 1883-84 than for the storms discussed in the preceding paragraphs. Unfortunately, the effects of these two events on the southern Orange County and San Diego County coastlines cannot be documented at this time, because the baseline topographic surveys of the U.S. Coast and Geodetic Survey were not initiated until 1885, and those of the U.S. Geological Survey until 1891.



SOURCE: MOFFATT & NICHOL, 1985

FIGURE 11
SHORELINE (BEACH) EROSION, 1967-1981
DANA POINT COASTAL ZONE

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Beach Erosion

A net change in beach volume can be the result of three factors: changes in sediment supply from either stream discharge or coastal bluff erosion, cross-shore transport, or a change in the rate of longshore transport (Griggs and Savoy, 1985). Historical beach erosion and changes in shoreline position in the Dana Point coastal zone (Salt Creek Beach, Dana Strand Beach, Doheny Beach State Park and Capistrano Beach) have been a product of these factors and urbanization.

Along the small pocket beaches of the Laguna Niguel sub-cell (Salt Creek and Dana Strand beaches Figure 8), Inman (1978) estimated a seasonal gross transport of 36,000 cubic yards (to the north in the summer and to the south in the winter). These estimates were obtained from beach profiles and aerial photographs. He found that the net transport out of the subcell was more difficult to estimate, but made the following observations: the headlands are more effective in blocking northerly transport than southerly; the strongest waves come from the northwest and thus favor some southerly transport around headlands; in the winter more sand is available offshore were it is easier to move around the headlands. Inman (1978) thus concludes that there must be some net transport to the south. From beach sand roundness data, he makes a very rough estimate of 15,000 cubic yards per year net southerly transport out of the Laguna Niguel sub-cell.

Between 1885 and 1934, a net shoreline advance of 60 to 100 feet has been documented for Salt Creek Beach; 40 to 50 feet of net advance occurred between 1934 and 1948, and 50 feet of advance between 1948 and 1960. Even between the 1967 and 1981 period, during a net reduction in sand supply from adjacent blufftops due to residential development in the adjacent inland Niguel Shores area, a net 100 feet of shoreline advance occurred at Salt Creek beach (Figure 11). During the 1978 storm alone, over 200 feet of advance occurred due to Salt Creek sediment discharge and erosion of adjacent terraces. (US Army Corps of Engineers, 1959 and 1986; Inman, 1978; Moffatt and Nichol, 1985). Shoreline equilibrium is rapidly restored along this beach following storm erosion, due to the effective net cross-shore littoral transport mode within the pocket beach.

Dana Strand Beach south of Ritz Carlton headland exhibited net shoreline advance on the order of 100 feet between 1885 and 1960, as well, when the adjacent blufftop areas were relatively undeveloped, except for a trailer park established in the 1950's. Subsequent to residential development of Niguel Shores and Breakers Isle communities, however, the significant quantities of beach sediment contributed through erosion of adjacent blufftops decreased sharply. As a result, shoreline position between 1960 and 1988 exhibited only a net 30 foot advance, including shoreline erosion during the severe 1974 perigean spring tide conditions, 60 feet of erosion and revetment damage at Breakers Isle during the 1983 storm/perigean spring tide conjunction, and 60 feet of advance due to sediment discharge during the 1978 storm period (Figure 11). Despite great quantities of sediment eroded and transported down San Juan Creek to form large deltas during the 1884 and 1916 storms (Plate 4) and the natural longshore blocking effect of the headlands, Doheny State Beach exhibited net erosion of 150' between 1885 and 1934. Large sediment discharges during the 1938 storm supplied enough sediment to foster 50 to 60 feet of beach advance (accretion) between 1934 and 1948. Lack of sufficient sediment discharge between 1949 and 1960 produced 50 feet of net shoreline erosion. Between 1960 and 1988, particularly since construction of Dana Harbor breakwaters between 1966 to 1969, Doheny State Beach has experienced from 100 to 300 feet of beach advance (accretion) (Figure 11), due to the net effective reduction in longshore transport by the Harbor breakwaters.

Central and southern Capistrano Beach have experienced the most significant beach erosion in the entire Dana Point coastal zone. Between 1885 and 1934, over 75 feet of net progradation (beach advance) occurred, suggesting effective southward longshore transport from the eroding Doheny Beach area upcoast during the same time period. Despite the fact that the beach eroded back to the Santa Fe railroad grade during the 1939 storm, a net advance occurred on the order of 40 feet between 1934 and 1948, supporting the idea of effective longshore transport from the Doheny Beach area prior to Dana Harbor construction. In the absence of major storm sediment discharge between 1948 and 1968, however, a net 60 feet of beach erosion occurred. Severe beach erosion and undermining of the old Capistrano Bay Club occurred during the elevated waves of the 1962 Perigean Spring Tide (see Appendix C). The 1968-1969 storms did not result in significant shoreline retreat at Capistrano Beach, however, because of both the excessive sediment discharges from San Juan Creek during that year, and artificial nourishment on the beach following the 1966 dredging and construction of Dana Point Harbor (Herron, 1980; Shaw, 1980). Significant erosion did occur to San Clemente beaches to the south during this storm (1968-69) period, however. Between 15 and 20 feet of net beach retreat occurred here between 1967 and 1989, reflecting the reduction in effective littoral drift downcoast from Doheny Beach, imposed by Dana Harbor construction. Local severe beach erosion (e.g., up to 60 feet locally) commenced during the 1974 perigean spring tides, as well as during the 1978, 1980 and 1983 storms. Pronounced erosion occurred due to severe wind-driven waves during 1988. Beach front residential structures were undermined during each of these events. Net historical erosion in the Doheny and Capistrano Beach areas can only be reflection of river sediment discharges in storm versus flood years and in net littoral (longshore) sand transport processes, due to the presence or absence of San Juan Creek flood control channelization in the former case, and construction of the Dana Harbor breakwater in the latter, since any littoral sediment contribution from erosion of adjacent Capistrano Bluffs has been prohibited due to the presence of the Santa Fe railroad grade.

D. Urbanization Factors

I. Effects Upon Static and Dynamic Coastal Processes

Human development and urbanization of coastal zones can have either damaging or beneficial influences upon the natural coastal processes and conditions discussed above. Both types of influence have affected the Dana Point coastal zone. The effects of coastal urbanization in general can be classified into five distinct categories: 1) alteration of natural drainage patters in blufftop zones, increasing both blufftop surficial erosion and groundwater seepage from the bluff face; 2) grading and paving of coastal terrace zones, increasing the percentage of impervious, nonerodible surfaces over areas which would otherwise serve as beach sediment sources; 3) private residential or public works developments between coastal bluff and beach zones, inhibiting transport of bluff talus debris into beach areas as a sediment source; 4) Man-made obstructions along the shore line in the path of longshore currents have profound effects upon beaches in the neighboring areas; usually the beaches build seaward up-current from such obstructions, and are eroded downcoast where the supply of sand is diminished. Numerous examples of the effectiveness of coastal structures in interrupting the littoral drift of beach material are found along the California coast, particularly where breakwaters and jetties have been constructed, as at Santa Barbara, Port Huenume, Santa Monica, Redondo, Seal Beach and Sunset Beach; the rate of accretion of sand behind such structures has provided the most reliable information about the rate of littoral drift of sand along the coast; unfortunately, littoral drift rates were either not considered nor well understood prior to design and construction of shoreline "protective" devices in numerous places along the southern California coastline; 5) The channelization or emplacement of detention structures within major sources of stream sediment from inland drainage basins.

II. Coastal Protection Effectiveness

The relative impacts to the Dana Point Coastal Zone of the five urbanization categories discussed above are as follows:

1) Construction of residential structures along the blufftops in the Monarch Bay, Capistrano Beach, Dana Cove and southern Niguel Shores areas, particularly residences without drought-resistant landscaping, with structures set too close to existing bluff edge, or with seaward lot drainage, has accelerated the erosion and retreat of blufftop properties and weakened large zones of bedrock which fail during storms such as those of 1978, 1980 and 1983. Seepage accumulation fosters large bluff failures even during nonstorm years.

2) Construction of residential paved areas along otherwise erodible blufftops inland from recreational beach zones such as Niguel Shores, significantly reduces sediment contribution to pocket beaches, which are not nourished from littoral drift as effectively as long, straight sand beaches. This process illustrates that protection of adjacent blufftops and beach areas is not always feasible.

3) Construction of Pacific Coast Highway and the Santa Fe Railroad grade between Capistrano Bluffs and Capistrano Beach effectively shuts off inland sediment sources to Capistrano Beach, making the beach entirely dependent on longshore transport sand sources for its presentation.

4) Construction of the Dana point Harbor breakwaters has caused a net southward shift in effective longshore current transport of sand beach Doheny State Beach the Capistrano Bach/San Clemente Beach areas downcoast (down current).

5) Flood control channelization of San Juan Creek has drastically reduced the sediment-carrying capacity of this key sediment source within the northern Oceanside littoral cell, minimizing the natural river sand supply to the Doheny Beach. Capistrano Beach subunit.

6) The placement of dredge fills from Dana Point Harbor, or export materials from inland grading operations, has historically minimized beach erosion conditions in the Doheny State Beach/Capistrano subunit. The most striking example was the protective effect to these beaches during the 1968-1969 storm wave period afforded by the 680,000 cubic yards of fills placed during Dana Harbor construction in 1964-1968 (Herron, 1980; Shaw, 1980).

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Vertical Stereoscopic Pairs

Agency	Flight Date	Flight No./Frame No.	Scale
UC Santa Barbara	1929	C703 / 34-36	1" = 1500'
USDA	06/14/38	AXK49 / 108-110	1" = 1667'
USDA	07/02/38	AXK58 / 36-38	1" = 1667'
UC Santa Barbara	10/07/47	C-11730 / 36-37	1" = 600'
USDA	12/12/52	AXK-2K / 125-128	1" = 1667'
USDA	12/12/52	AXK-3K / 48-51 60, 61, 99, 100	1" = 1667'
USCB	03/14/64	C-24733 / 119	1" = 1200'
VTN	01/31/70	61-9 / 217, 218 61-10 / 222-225, 227	1" = 4000'

Low-Altitude (Oblique) Photos

Spence	1924	7427
	01/23/29	E-2428
	05/30/31	E-4903
	07/02/33	E-5184, 5185, 5187
	06/27/35	E-6138, 6139
	05/29/39	E-9505
	07/27/47	E-13016, 13017
	05/03/57	E-15047, 15048

AERIAL PHOTOGRAPHS REVIEWED

Vertical Stereoscopic Pairs

Agency	Flight Date	Flight No./Frame No.	Scale
Fairchild	02/28/32	0-2893	
R.E. Stevenson Collection	12/52	79 - 104	
Scripps Institute of Oceanography	03/83	54662 / 10A	
		5466AA / 13-24	
		5466BB / 1A, 2A, 3-11, 11A, 12	
		5466CC / 11A, 12A, 13A, 14A, 15A, 16A	

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T-5417;	Gulf of Santa Catalina - Dana Point to Laguna Beach, Scale 1:10,000

(2) U.S. Geological Survey Topographic Maps

1948	Dana Point Quadrangle, 7.5-Minute, 1:24,000
1968	Dana Point Quadrangle, 7.5-Minute, 1:24,000
1975	Dana Point Quadrangle, Photorevised 1981, 7.5-Minute, 1:24,000

APPENDIX B

GLOSSARY OF COASTAL TERMS

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GLOSSARY OF COASTAL TERMS

ACCRETION
May be either **Natural** or **Artificial**. Natural accretion is the buildup of land, solely by the action of the forces of nature, on a **Beach** by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. Also **Aggradation**.

ARTIFICIAL NOURISHMENT
The process of replenishing a beach with material (usually sand) obtained from another location.

BEACH
The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach, unless otherwise specified, is the mean low water line. A beach includes **Foreshore** and **Backshore**.

BEACH BERM
A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

BEACH EROSION
The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

BLUFF
A high, steep bank or cliff.

BREAKER
A wave breaking on a shore, over a reef, etc. Breakers may be classified into four types

Spilling - bubbles and turbulent water spill down front face of wave. The upper 25 percent of the front face may become vertical before breaking. Breaking generally across over quite a distance.

APPENDIX B

GLOSSARY OF COASTAL TERMS

BREAKER (Continued)

Plunging - crest curls over air pocket; breaking is usually with a crash. Smooth splash-up usually follows.

Collapsing - breaking occurs over lower half of wave. Minimal air pocket and usually no splash-up. Bubbles and foam present.

Surging - wave peaks up, but bottom rushes forward from under wave, and wave slides up beach face with little or no bubble production. Water surface remains almost plane except where ripples may be produced on the beachface.

BREAKWATER
A structure protecting a shore area, harbor, anchorage, or basin from waves.

BULKHEAD
A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

COASTAL ZONE
Coastal waters and lands that exert a measurable influence on the uses of the sea and its ecology.

CONGLOMERATE
A rock containing rounded fragments of gravel or pebbles cemented together.

CREEP
The imperceptibly slow, more or less continuous downward and outward movement of slope-forming soil or rock.

CURRENT LITTORAL
Any current in the littoral zone caused primarily by wave action, e.g., longshore current, rip current.

CURRENT, LONGSHORE
The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

APPENDIX B

GLOSSARY OF COASTAL TERMS

DESIGN BREAKING WAVE ELEVATION
Highest elevation above the Orange County Vertical Datum (OCVD) that would be directly impacted by breaking waves. The upper limit of breaking waves is based on a design wave height and a design water depth condition with a specified design recurrence interval.

DESIGN LIFE AND RECURRENCE INTERVAL
Orange County requires structures and protective devices be designed for a specific minimum life when acted upon by ocean forces with a specific recurrence interval:

(1) *Design Life, Protective Device:* The design life of a nonexpendable protective device, which must be equal to or greater than 20 years, is the minimum period after construction during which all major components of the device retain their functional and structural design capabilities.

(2) *Design Life, Structural:* The design life of the foundation of a non-expendable structure, which must be equal to or greater than 30 years, is the minimum period after construction during which all major components of the foundation system retain their functional and structural design capabilities.

(3) *Recurrence Interval:* Time period during which one coastal design event can be expected to occur. The 100-year recurrence interval, which has been chosen to be used for the design of structures and protective devices in Orange County, is the statistical probability that one event that produces a design magnitude value of a coastal phenomenon.

DYNAMIC EQUILIBRIUM
A condition that exists along some coastlines where neither erosion nor buildup is occurring, but the beach is continually being shaped by wave action.

FORESHORE
The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

FP-3 LINE
Landward boundary of the coastal region (FP-3 zone) in which structures must be protected from ocean-related hazards in Orange County.

APPENDIX B

GLOSSARY OF COASTAL TERMS

FREEBOARD
The additional height of a structure to prevent overflow. Also, at a given time, the vertical distance between the water level and the top of the structure (sea walls, revetments).

GROIN
A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

GROIN SYSTEM
A series of groins acting together to protect a section of beach. Commonly called a groin field.

GUNNITE
Concrete that is sprayed in a slurry form onto some framework or structure to which it will adhere and harden.

HIGH TIDE, HIGH WATER (HW)
The maximum elevation reached by each rising tide. See **Tide**.

HIGHER HIGH WATER (HHW)
The higher of the two high waters of any tidal day. The single high water occurring daily during periods when the tide is diurnal is considered to be a higher high water.

HINDCASTING, WAVE
The use of historic synoptic wind charts to calculate wave characteristics that probably occurred at some past time.

JETTY
An elongate structure extending into a body of water to direct and confine a stream or tidal flow to a selected channel. Jetties are built in pairs to help protect or stabilize a channel for navigation.

LITTORAL CELL
A self-contained section of coast consisting of 3 elements: (1) a source of beach sand, (2) littoral drift that moves the sand downcoast, and (3) a sink for the sand.

LITTORAL DRIFT
The sedimentary *material* moved in the littoral zone under the influence of waves and currents.

APPENDIX B

GLOSSARY OF COASTAL TERMS

LITTORAL ZONE
In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

LONGSHORE
Parallel to and near the shoreline.

LOWER LOW WATER (LLW)
The lower of the two low waters of any tidal day. The single low water occurring daily during periods when the tide is diurnal is considered to be a lower low water.

MARINE TERRACE
An elevated, seaward-sloping, wave-cut bench or platform exposed by uplift along the coast. Several terraces commonly exist at different elevations.

MEAN HIGHER HIGH WATER (MHHW)
The average height of the higher high waters over a 19-year period. For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-year value.

MEAN HIGH WATER (MHW)
The average height of the high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semidiurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

MUDSTONE
A general group of sedimentary rocks that includes clay, silt, siltstone, claystone, and shale.

NOURISHMENT
The process of replenishing a beach. It may be brought about naturally, by longshore transport, or artificially by the deposition of dredge materials.

OCVD
Orange County Vertical Datum based on mean sea level as obtained periodically (about every 10 years) through an analysis of 19 years of tide record. This datum is not fixed with respect to the center of the earth, but rises or falls with respect to it as the mean sea surface

along the coast of the County of Orange rises or falls. The OCVD is useful in coastal engineering because many design considerations are keyed to mean sea level or mean lower low water (MLLW). MLLW is 2.83 feet lower than OCVD.

OFFSHORE

(1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf.

(2) A direction seaward from the shore.

OPDSL

The Ocean Protective Devise String Line is the seaward limit beyond which the seaward edge of the crest of a protective device may not extend.

OUTFALL

A structure extending into a body of water for the purpose of discharging sewage, storm runoff, or cooling water.

PERIGEAN SPRING TIDES

Tides produced at the time of perigee-syzygy (q.v.) by enhanced gravitational and tide-raising forces accompanying the coincidence of these astronomical events; these tides are characterized by increased amplitudes, range, rate of rise, and duration at maximum.

PERIGEE

The position in the Moon's elliptical orbit around the Earth at which it reaches its closes approach to the Earth in that month. This "minimum distance" is, however, variable. (Cf., Proxigee.)

PERIGEE-SYZYGY

The near-coincidence in time of the phenomena or new of full moon (responsible for spring tides) and that of perigee- the position of closest monthly approach of the moon to the earth; the resulting increased gravitational forces produce tides possessing various special characteristics. (Cf., Perigean Spring Tides.)

PILE

A long, heavy timber or section of concrete or metal to be driven or jetted into the earth or seabed to serve as a support or protection.

PILE, SHEET

A pile with a generally slender flat cross section to be driven into the ground or seabed and meshed or interlocked with like members to form a diaphragm, wall, or bulkhead.

APPENDIX B

GLOSSARY OF COASTAL TERMS

POCKET BEACH
A beach, usually small, in a coastal reentrant or between two littoral barriers.

PROFILE BEACH
The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

PROTECTIVE DEVICE
A seawall, bulkhead, revetment or artificial dune designed to protect a structure located in the FP-3 zone.

PROXIGEAN SPRING TIDES
Tides produced under a particularly close alignment of perigee and syzygy; the resulting increased gravitational perturbations by the Sun draw the Moon considerably closer to the Earth at the lunar perigee position, producing tides proportionately larger than those at perigee-syzygy, and in which the special characteristics of perigean sprint tides (q.v.) are further accentuated.

PROXIGEE
Prefix from the Latin superlative adjective *proximus* -- "nearest".) An extremely close perigee position of the Moon, created irregularly and relatively infrequently by gravitational perturbations resulting from an exceptionally close perigee-syzygy alignment. (Cf., Proxigee-Syzygy.)

RECESSION (of a beach)

(1) A continuing landward movement of the shoreline.

(2) A net landward movement of the shoreline over a specified time. Also **Retrogression.**

REFRACTION (of water waves)

(1) The process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours.

(2) The bending of wave crests by currents.

APPENDIX B

GLOSSARY OF COASTAL TERMS

REFRACTION DIAGRAM
A drawing showing positions of wave crests and/or orthogonals in a given area for a specific deepwater wave period and direction.

REVETMENT
A protective device consisting of a facing of stone, concrete, cast units, etc., build to protect a scarp, embankment or structure against erosion by wave action or currents.

RIPRAP
A wall or facing of large (1-5 ton) rocks stacked along the shoreline to protect the cliffs, bluffs, dunes or structures from wave attack.

ROCKFALL
The relatively free falling of a detached segment of bedrock of any size from a cliff, steep slope, cave, or arch (same as <u>blockfall</u>).

RUNOFF
The discharge of water through surface streams, or the quantity of water discharged through surface streams, usually expressed in units of volume.

RUNUP
The rush of water up a protective device, beach, bluff face or structure on the impacting of a wave. The amount of runup is the vertical distance above stillwater level reached by the rush of water. The wave runup elevation limit is the highest elevation that will be reached by the rush of water from a breaking wave when that wave occurs during the design wave event with the specified design recurrence interval. The highest elevation subject to wetting by spray from the design wave will be greater than the runup elevation.

SAND BUDGET
An accounting of the sand along a particular stretch of coast: the sources, sinks, and rates of movement, or the supply and loss.

SANDSTONE
A cemented or otherwise compacted sediment composed primarily of sand.

SCOUR
Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

APPENDIX B

GLOSSARY OF COASTAL TERMS

SEA CLIFF
A cliff situated at the seaward edge of the coast.

SEAWALL
A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. See also **Bulkhead**.

SETBACK
An exclusion zone adjacent to some hazardous or sensitive feature (an eroding seacliff, for example) in which no building or structures are allowed.

SHOREFACE
The narrow zone seaward from the low tide Shoreline covered by water, over which the beach sands and gravels actively oscillate with changing wave conditions.

SHORELINE
The intersection of a specified plane of water with the shore or beach. (e.g., The highwater shoreline would be the intersection of the plane of mean high water with the shore or beach.)

SIGNIFICANT WAVE PERIOD
An arbitrary period generally taken as the period of the one-third highest waves within a given group. Note that the composition of the highest waves depends on the extent to which the lower waves are considered. In wave record analysis, this is determined as the average period of the most frequently recurring of the larger well-defined waves in the record under study.

SILTSTONE
A fine-grained rock composed of silt-sized particles.

SPRING TIDE
A tide that occurs at or near the time of new or full moon (syzygy), and which rises highest and falls lowest from the mean sea level.

STILLWATER LEVEL
The elevation that the surface of the water would assume if all wave action were absent.

APPENDIX B

GLOSSARY OF COASTAL TERMS

STORM SURGE
A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. See **Wind Setup.**

SYZYGY
An inclusive term used to define the position of the Moon at either new moon (conjunction) or full moon (opposition).

TERRACE
See **Marine Terrace.**

TIDAL RANGE
Although concepts may vary for different purposes, the maximum daily (not diurnal) range represents the difference in tide height between the lower low water (LLW) and the higher high water (HHW) in any tidal day.

WAVE HEIGHT
The vertical distance between a crest and the preceding trough.

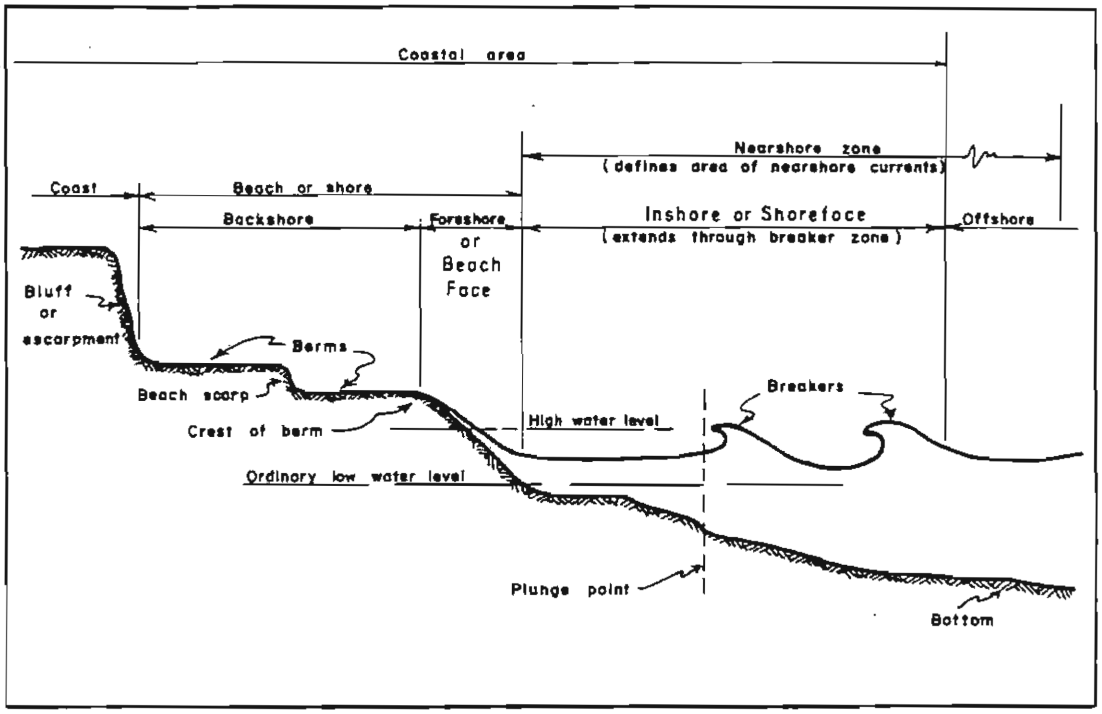
WAVE PERIOD
The time for a wave crest to traverse a distance equal to one wavelength. The time for two successive wave crests to pass a fixed point. See also **Significant Wave Period.**

WIND SETUP

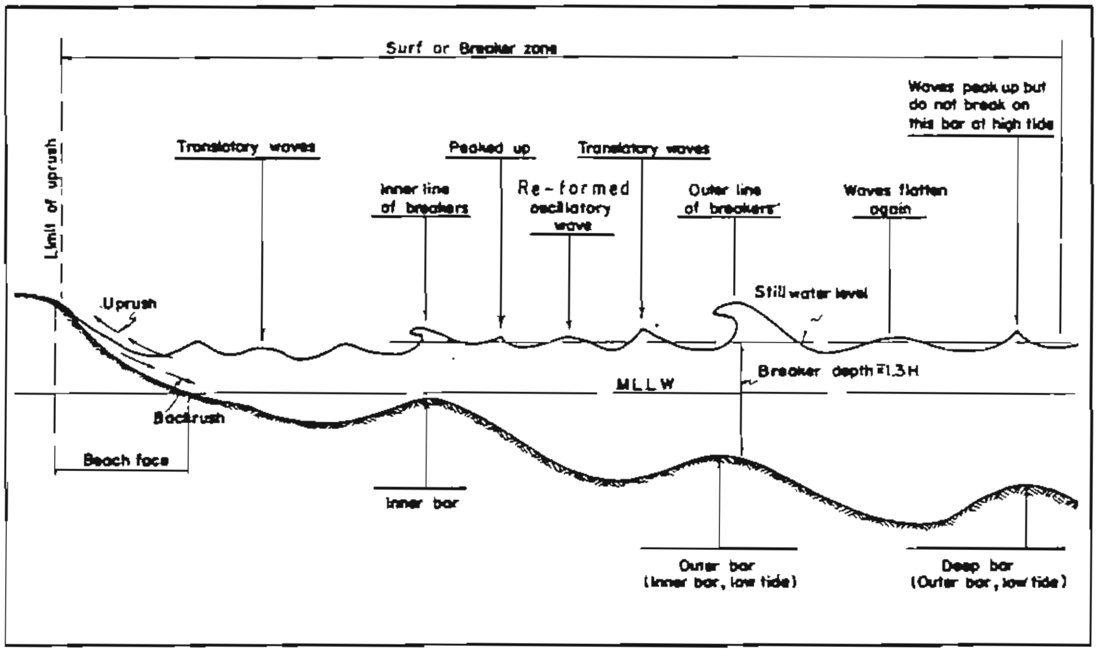
(1) The vertical rise in the stillwater level on the leeward side of the body of water caused by wind stresses on the surface of the water.

(2) The difference in still water levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water.

(3) Synonymous with the **Wind Tide** and **Storm Surge.** **Storm Surge** is usually reserved for use on the ocean and large bodies of water. **Wind Setup** is usually reserved for use on reservoirs and smaller bodies of water.



Beach Profile-Related Terms.



Schematic Diagram of Waves in the Breaker Zone.

APPENDIX C

HISTROICAL COASTAL EROSION RECORDS

The Los Angeles Times
Fri., Dec. 18, 1914
Pt. 2, Page 1, Cols. 4, 5

Destructive.

SEAS LASHED BY GALE BATTER COAST TOWNS

Houses Destroyed, Bulkheads Shattered, Sewer and Gas Mains Severed by Pounding Breakers on Crest of High Tide—More Trouble Feared Today—Loss of Property Many Thousands—No Casualties.

Lashed to a fury by a heavy on-shore gale that lent impetus to an unusually high tide, the sea battered the southern coast early yesterday morning with fury and destroyed property worth many thousands of dollars.

From all along the shore came the same story, of huge waves leaping over barriers and carrying destruction with them. At Long Beach $80,000 damage was done, while at Balboa the loss was also heavy. Railway tracks were washed out at the harbor and traffic delayed for hours. One fatality due to the storm was reported from the sea. There were no casualties ashore.

The off-shore breeze that accompanied the rain of Wednesday night switched to the southeast early in the day, and blew at places forty-five miles an hour. No damage was done here.

Further trouble at coast points is feared for this morning's high-tide period.

TERROR AT LONG BEACH.

Washing houses into the sea, tearing up concrete bulkheads and cement promenades, and spreading terror and damage along the ocean front, the wind, aided in its work of destruction by an extremely high tide and heavy rain, paid a terrifying visit to Long Beach early in the morning. Many persons had narrow escapes from drowning in their seaside bungalows, one of which was completely destroyed, and four are partially washed away.

Great anxiety is felt along the washed-out portions of the beach over this morning's high tide, when more buildings and works are expected to go. A tide of 7.3 feet is expected at 9:15. Many of the houses on the east beach are hanging over a bluff caused by the waves, and, although the owners and occupants of these buildings worked feverishly last night with bags of sand and timbers, they cannot hope to stem the huge tide expected . . .

1914 Dec. 16
0h P.s.t. (−36)

38

The Los Angeles Times
Fri., Dec. 18, 1914
Pt. 2, Page 6, Cols. 3–5

PENINSULA INUNDATED.

In the wake of a forty-five mile gale, the tide rose to unprecedented height at Balboa Beach yesterday morning, broke over the bulkheads, cut 100 feet off the tip end of the peninsula, inundated Collins Island, damaged or wrecked a score of residences and receded, leaving many thousands of dollars damage in its wake . . .

. . . Although the storm was accompanied by a gale from the southeast and the highest tide in nearly twenty years, there was no damage to shipping at the harbor . . .

. . . The tide at 8:50 a.m. reached 7.5 feet, and with the storm behind it backed up the water in the channel and the bay to a hitherto-unknown height.

About 200 feet of the Salt Lake track at Ostend was washed out by the high tide, and train service was demoralized for several hours. Repairs were completed last night and service resumed . . .

1914 Dec. 16
0h P.s.t. (−36)

38

Seattle Post-Intelligencer
Sun., Dec. 9, 1923
Page 16 HH, Col. 3

PACIFIC COUNTY IS HIT BY TIDE

SOUTH BEND, Dec. 8.—Pacific County is still estimating its losses and trying to repair them after the worst combination storm and tide the Willapa Harbor district has known for more than fifteen years . . .

. . . The long and narrow Willapa Bay acted as a gigantic funnel with the wind and tide pushing the water far above the scheduled 10.5 mark and inundating tidelands, the lower lying farms of the county and portions of South Bend and practically the entire city of Raymond . . .

1923 Dec. 7
6.5h P.s.t. (—23)

47

◆

The San Francisco Examiner
Sun., Feb. 14, 1926
Page 1, Col. 4

COAST TIDES ATTACK FILM STARS' HOMES

Ventura Wharf Crumples Under Battering

Highways and Bridges Blocked; Long Beach Sea Wall Is Washed Out

LOS ANGELES, Feb. 13.—(AP)—Southern California was slowly emerging tonight from the three day raging of elements, in which gales and driving rains vied with almost unprecedented high tides, leaving in their converging wakes death, injury and property damage estimated in tens of thousands of dollars . . .

. . . mountainous seas, whipped into fury by off-shore gales, have resulted in three deaths by drowning, one injury and the destruction of one wharf, damage to numerous piers, beaching of many small fishing craft, and wholesale undermining of dwellings, cabins and strand walks on the water fronts . . .

. . . The loss of the Ventura wharf ties up shipping activity entirely at that city, all cargoes having been discharged on the one wharf. Six hundred feet of the structure collapsed . . .

. . . The Coast highway to San Diego was rendered impassable by washouts near San Juan Capistrano and farther south near Oceanside . . .

1926 Feb. 12
6.5h P.s.t. (—5)

48

◆

The San Francisco Examiner
Wed., Aug. 22, 1934
Page 1, Col. 4

HUGE MYSTERY WAVES FLOOD L. A. BEACHES

Forty-foot Water Walls Strike; Two-Story Apartment Swept From Foundations; No Wind

NEWPORT BEACH, Aug. 21.—(AP)—A strangely acting Pacific Ocean, which has been running waves 30 and 40 feet high during the day, got out of bounds at high tide at 6:10 tonight and swept a two-story apartment building from its foundation and damaged other buildings. Part of the city was inundated a few feet . . .

. . . The waves threatened for a time to cut a new channel across from the ocean to Newport Bay, ripping out a large cut in the sand under the apartment building and across Central avenue . . .

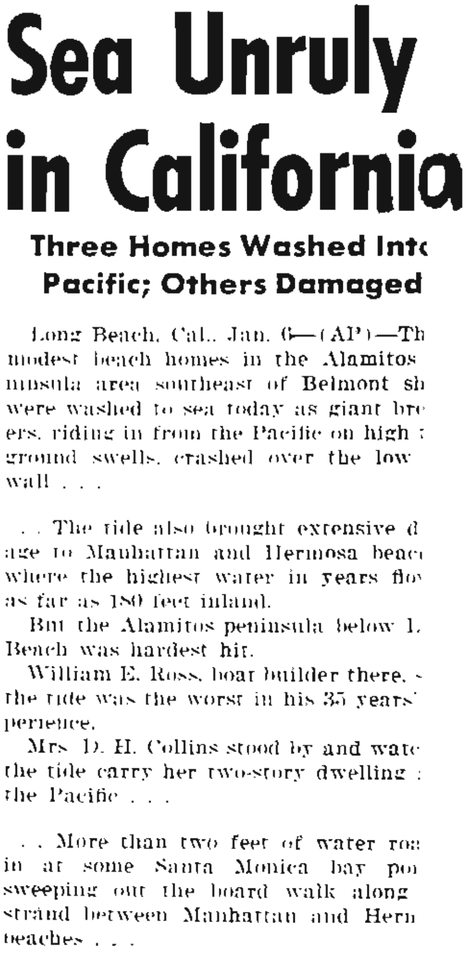
. . . Portions of the Central avenue pavement, the only connecting link between the city and the fashionable residential section on Balboa Peninsula, were torn up, isolating for a time the residents on the peninsula . . .

. . . No wind was reported and no explanation for the unusual waves could be given by weather officials . . .

1934 Aug. 24
0h P.s.t. (—24)

64

The Oregon Daily Journal
Fri., Jan. 6, 1939
Page 1, Col. 7



Sea Unruly in California

Three Homes Washed Int Pacific; Others Damaged

Long Beach, Cal., Jan. 6—(AP)—Th modest beach homes in the Alamitos ninsula area southeast of Belmont sh were washed to sea today as giant bre ers, riding in from the Pacific on high ground swells, crashed over the low wall . . .

. . . The tide also brought extensive d age to Manhattan and Hermosa beac where the highest water in years flo as far as 180 feet inland.

But the Alamitos peninsula below L Beach was hardest hit.

William E. Ross, boat builder there, the tide was the worst in his 35 years' perience.

Mrs. D. H. Collins stood by and watc the tide carry her two-story dwelling the Pacific . . .

. . . More than two feet of water ro in at some Santa Monica bay po sweeping out the board walk along strand between Manhattan and Hern beaches . . .

(See also chapter 7.)

1939 Jan. 5
20h P.s.t. (—14)

F–68

The Oregon Daily Journal
Thurs., Dec. 26, 1940
Page 1, Col. 7 (Final Ed.)

High Tide, Wind Create Damage In Coast Region

. . . A nine-foot tide Wednesday, pushed by a 50-mile-an-hour wind, damaged seawalls and flooded Tillamook farms and the Coast highway.

Hammond, on the Columbia estuary below Astoria, reported today that the tide washed out the approach to the Hammond beach road Wednesday, but that there was no other damage . . .

1940 Dec. 26
17.5h P.s.t. (—87)

70

The Oregon Daily Journal
Fri., Dec. 27, 1940
Page 1, Cols. 1–4 (Final Ed.)

HIGH TIDES SPECTACULAR ON OREGON COAST

DELAKE, Dec. 27.—North Lincoln residents, under bright skies and a span of ocean rainbows, today estimated damage of a two-day Christmas beating by wind, rain and high tides.

Taft had the worst, with damage to the seawall that protects Pacific street along Siletz bay. Mountainous waves drenched that street, littered door yards, dug holes in lawns and removed 200 yards of filling back of the wall.

Nelscott reported damage to the seawall, removal of stairways to beach from Overlook property and piling of logs on the ramp . . .

Angry Seas Still Batter California

LOS ANGELES, Dec. 27.—(AP)—An angry ocean continued today to pummel portions of the California coastline, aiming its severest blows at the little town of Redondo Beach.

A house and a liquor store, normally, even at highest tide, 50 feet away from the water, were undermined in today's assault. Both collapsed.

Two houses which were dropped into the surf yesterday by the gnawing action of 25-foot combers and ground swells were being battered into debris today.

Damage estimates run as high as $250,000 . . .

1940 Dec. 26
17.5 P.s.t. (—87)

70

The Oregonian
Sun., Dec. 29, 1940
Page 6, Col. 2

Coast Awaits New Storms

. . . SAN FRANCISCO, Dec. 28 (AP)—The Pacific seaboard, battered by recent storms, braced itself for more onslaughts of wind and rain Saturday night, while high water flooded many roadways . . .

The Los Angeles Times
Thurs., July 19, 1951
Page 1, Col. 1 (Final Ed.)

Tide Floods Long Beach; Boat Saves 9

. . . Two expectant mothers and five children were among a number of persons evacuated by lifeguard boats from homes flooded by sea water at record high tide last night in the Long Beach Harbor area.

. . . A battery of pumps worked throughout the day yesterday to eliminate sea water which rushed into the area affected by the earth's subsidence.

More than 100 homes in a six-block-square area of the district were flooded following the third record high tide in three nights.

Tides of 7.2 feet swept through harbor area storm drain systems Tuesday night and sent water gushing through streets to flood small homes with as much as 14 inches of water . . .

. . . Some automobiles were left in the flooded streets and others were pushed or towed out of the path of the water.

Each day since Monday, residents said, the tides sent water into the area between Seaside Blvd. and Water St. . . .

. . . The piers at Berth 32 and Berth 33 on the harbor waterfront also were flooded by sea water during the high point of the tide.

The flooding is basically due to the land subsidence in the harbor area, although failure of some sandbag dikes and the plugging of pumps in the area also are blamed for the condition . . .

1951 July 18
1h P.s.t. (—20)

The Los Angeles Times
Tues., Feb. 4, 1958
Part 1, Page 1, Col. 3

Tide, Surf Hit San Diego Bay Community

By a Times Correspondent

IMPERIAL BEACH, Feb. 3—High tides and pounding surf smashed at homes and the boardwalk at the height of today's storm, creating an emergency condition that led to proclamation by Gov. Knight of a state of disaster in this South San Diego Bay community.

At least four families were prepared to evacuate their ocean-front homes. One was partly undermined as the boardwalk in front collapsed.

City crews rushed truck-loads of rock and sand to the beach front in an effort to protect property.

Mayor Cecil Gunthorp telegraphed Gov. Knight that "the City Council has declared a local emergency, wherein all cash reserves have been used and financial assistance is needed."

Under Knight's proclamation, the State will provide aid . . .

1958 Feb. 4
19.5 P.s.t. (+39)

81

The Los Angeles Times
Wed., Feb. 5, 1958
Part 1, Page 2, Cols. 4, 5

High Tides Batter at Southland Coast Areas

High tides, lashed by the same Pacific storm that brought heavy rains to the Southland, battered at Southern California coasts yesterday.

At Oxnard Beach, northwest of Port Hueneme, Navy helicopter and crash-boat crews reported they failed to find the body of a 17-year-old Santa Paula girl who was washed into the sea late Monday. The teen-ager, Judith Lou Nasalroad, was caught by a huge wave while walking on the beach. The tumbling waves swept her into the sea.

On the Alamitos Bay Peninsula near Long Beach, two feet of salt water damaged lawns from 56th to 59th Place along the bayfront. Crews blocked off Ocean Blvd. at 50th Place after a high tide pushed water over a 30-inch cement seawall.

A U.S. Coast and Geodetic Survey team said a 7.1-foot peak tide at 9:50 a.m. caused the flooding. City crews piled sandbags atop the seawall in preparation for a similar tide peak this morning.

In Seal Beach, bulldozers piled up an 8-foot sand dike along Seal Way east of Municipal Pier to guard a row of apartment houses.

In San Diego County, work crews labored in a rainstorm to pile rocks along a section of Imperial Beach waterfront where four homes were undermined by high tides Monday. Gov. Knight declared the beach front a disaster area to make State funds available to work crews . . .

1958 Feb. 4
19.5h P.s.t. (+39)

81

The Los Angeles Times
Fri., March 6, 1970
Page 10, Cols. 1, 2

WINDS, HIGH TIDES

Two Beach Areas Pounded by Surf

Two sections of the Orange County coastline suffered heavy damage Thursday morning from a combined attack by high tides and storm winds.

Seawalls valued at more than $75,000 were battered down by waves which then chewed at the foundations of several luxury homes on the shores of Capistrano Beach.

At Newport Beach, heavy surf again took a mile-long bite of sand from an area of which the pier is the center, and threatened to undermine lifeguard headquarters at the foot of the pier . . .

. . . High tide, cresting at 6.3 feet just before 8 a.m. Thursday, was pushed by westerly winds of 25 to 30 m.p.h. Heavy surf at Capistrano Beach pounded against several hundred feet of wooden seawall protecting homes on Beach Road and smashed it into splinters.

Breakers then chopped away beach sand and sloshed against the foundations of several residences . . .

. . . Anticipating another high tide of about 6.4 feet this morning, residents ordered an emergency haul of rocks and boulders to replace the seawall.

Orange County Weather Central said, however, Thursday's strong winds should be diminished by today . . .

1970 Mar. 6
18h P.s.t. (—32)

92

The Los Angeles Times Fri., April 23, 1971 Part 1, Page 3, Cols. 1, 2

Heavy Surf, Tides and Winds Batter Oxnard Shores Homes

A combination of unusually high tides, heavy surf and strong winds Thursday caused considerable damage to six expensive homes along a three block stretch of Mandalay Beach Road at Oxnard Shores, north of Oxnard Beach.

According to officials, the crescent-shaped beach area, which is annually pounded by the wind and sea, has been under its latest, and perhaps greatest, onslaught for several days.

Thursday, a section of beach 60 feet wide and 12 feet deep disappeared into the ocean.

The damage left the six homes, valued at between $60,000 and $80,000, either hanging over a weak, sandy cliff or stranded on pilings that have "only 5 feet of sand to go before there's nothing to hold them up," Police Capt. Jack Snyder said . . .

1971 Apr. 24
3h P.s.t. (—34)

94

The Los Angeles Times
Wed., Jan. 9, 1974 (CC Ed.)
Part I, Page 1, Cols. 2, 3

Giant Waves Pound Southland Coast, Undermine Beach Homes

Sandbag Barriers Erected to Ward Off Tidal Assault.

Giant wind-driven waves riding on surging high tides battered the Southern California coast Tuesday, damaging homes and flooding nearby areas.

Occupants of many beachfront homes from Santa Barbara to San Clemente erected sandbag barriers throughout the day in preparation for the next high tide at 10:08 a.m. today.

The wave and tidal assault came as rainfall from a five-day storm tapered off after dropping 7.69 inches in the Los Angeles Civic Center.

In Orange County, supervisors proclaimed a "local emergency" for wave-battered coastline sections.

(See also chapter 7.)

1974 Jan. 8
4h P.s.t. (—2)

N-99

The Los Angeles Times Wed., Dec. 26, 1973 Part I, Page 4, Cols. 3–6

Moon, Sun to Produce 2 Unusually High Tides

WASHINGTON (UPI)—A rare relationship of the earth, moon and sun will cause unusually high tides on Jan. 8 and Feb. 7, and forecasters have been alerted to watch for Atlantic storms that could cause severe flooding along low-lying coastal areas.

The National Oceanic and Atmospheric Administration said Tuesday that similar astronomical conditions accompanied by an offshore storm on March 6 and 7, 1972, caused 40 deaths and $500 million in flood damage extending from Long Island, N.Y., to the outer banks of North Carolina.

Fergus J. Wood, a research scientist for the agency, said that without sustained onshore winds, only higher than usual tides would occur on Jan. 8 and Feb. 7. He said there also would be more than the usual number of particularly high tide situations in the upcoming year and "from a statistical point of view, 1974 bears close watching.

The moon's gravitational pull is the major influence on the tides. On Jan. 8 and Feb. 7, the moon will be 1,137 miles closer to the mid-Atlantic coast than usual. In addition on those dates, the sun—which also influences the tides—will be in about the same longitudinal plane as the moon, adding to the moon's effect. Further, the earth will be near its closest annual approach to the sun.

"Therefore, spring tides during these periods will be particularly high," the agency said. A spring tide is higher than normal and occurs twice a month when the moon is full.

The agency said other low-lying coastal areas also could be affected to varying degrees, particularly along the Pacific Coast . . .

1974 Jan. 8
4h P.s.t. (—2)

N-99

The Los Angeles Times Wed., Jan. 9, 1974 (CC Ed.) Part I, Page 1, Cols. 2, 3

Giant Waves Pound Southland Coast, Undermine Beach Homes

Sandbag Barriers Erected to Ward Off Tidal Assault; Five-Day Storm Tapers Off After 7.69-Inch Rainfall

BY DICK MAIN and TOM PAEGEL
Times Staff Writers

Giant wind-driven waves riding on surging high tides battered the Southern California coast Tuesday, damaging homes and flooding nearby areas.

Occupants of many beachfront homes from Santa Barbara to San Clemente erected sandbag barriers throughout the day in preparation for the next high tide at 10 08 a.m. today.

The wave and tidal assault came as rainfall from a five-day storm tapered off after dropping 7.69 inches in the Los Angeles Civic Center.

Mostly fair weather was forecast for today and Thursday and chances of a new storm Friday, feared earlier, appeared to be remote.

Floodwaters and mud and rock slides continued to menace many low-lying areas in foothill and coastal valleys, however.

A local emergency was declared for all of Los Angeles County earlier Tuesday by the Board of Supervisors.

"Conditions of extreme peril to the safety of persons and property have arisen," the board said in its resolution.

Board Chairman Kenneth Hahn said the proclamation, which was forwarded to the state director of the Office of Emergency Services, may clear the way for state financial assistance for storm damage to public property.

In Orange County, supervisors proclaimed a "local emergency" for wave-battered coastline sections . . .

Part I, Page 29, Cols. 2

. . . At least eight homes in the Beach Road community of Capistrano Beach, were damaged, as waves washed sand away, exposing or damaging seawalls, foundations and pilings.

Waves up to 8 feet high slammed into some Orange County beaches during the morning high tide Tuesday.

Sheriff's officers and county firemen were dispatched to endangered beach properties and helped in sandbagging operations.

Breakers wiped out wide sections of many beaches, exposing the pilings of lifeguard headquarters at both San Clemente and Newport Beach.

Part of Pacific Coast Highway was flooded in Huntington Harbor and in Newport Beach.

The morning tides are abnormally high because the present alignment of the earth, sun and moon exerts a stronger than usual gravitational pull upon the ocean.

Tuesday morning's peak tide came at 9:22 a.m. and measured 7.1 feet. A 7-foot tide is expected this morning and Thursday's tide is expected to measure 6.5 feet.

The high tides and battering waves also damaged beachfront homes in Los Angeles County, particularly in Malibu, where occupants of two residences were evacuated . . .

. . . Sheriff's deputies said earth fill was washed out from in back of two homes on pilings facing the ocean at 27036 and 27054 Malibu Colony Cove Road.

Heavy erosion was reported under homes at 25036 Malibu Road and 27308 Escondido Beach Road, but the structures were not evacuated.

Minor damage to sea walls, patios and other outdoor improvements was reported to at least three structures in the Malibu Colony.

At Zuma Beach, waves dug out much of the sandy beach, forcing lifeguards to move four portable lookout stations away from the surfline.

The high tide and waves uprooted more than 20 old pilings from the abandoned and often-burned Pacific Ocean Park pier at Santa Monica. They were towed out to sea to prevent their crashing into Santa Monica Pier.

Roger Pappas, National Weather Service forecaster, said winds which created the towering waves during high tide early Tuesday should subside by this morning, lessening chances of coastal damage.

A small-craft advisory warning of high winds between Point Conception and the Mexican border was lowered at 8 p.m.

The National Weather Service earlier said ocean swells were expected to drop from 4 to 6 feet during the night to 2 to 4 feet today and Thursday.

A storm system in the mid-Pacific which had been expected to arrive in Southern California by Friday apparently has been blocked off by a high-pressure ridge extending southward from the Gulf of Alaska, Pappas said . . .

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FIGURE 117.

Rendezvous with the Sun

"Hey, look! It's right out there," exclaimed Skylab Astronaut Edward Gibson last week. "I tell you, it's one of the most beautiful creations I've ever seen. It's so graceful." Added Skylab Commander Gerald Carr: "It's yellow and orange, just like a flame."

After a journey of billions of miles across the outer reaches of the solar system, the comet called Kohoutek last week finally made its solar rendezvous. And for the first time in astronomical history, a comet's close sweep round the sun—when it is subject to maximum heat and gravitational force—was observed from above the earth's obscuring atmosphere. As they completed their sixth week in orbit, the crew of Skylab 3 made the most of the opportunity.

Equipped with cameras and other scientific gear, the astronauts spent two lengthy observation periods outside their orbital lab. The first—on Christmas Day—covered the interval just before the comet disappeared in the sun's glare, approaching to within some 13 million miles of the sun at speeds of over 250,000 m.p.h.; the second took place after Kohoutek skimmed just across the top of the solar disc. The comet was so close to the sun that they could not see it during their first space walk. But at week's end they more than made up for the loss. Almost as soon as they stepped out of their orbital lab for the second walk, they spotted the comet, glowing brighter than ever. By properly aiming cameras that were specially equipped to block the glare, they took dozens of pictures in different colors—not only of Kohoutek but also of the huge halo of hydrogen gas that surrounds it.

Less Dusty. Scientists must wait to assay this scientific treasure until the crew returns to earth with the film in February, at the end of the 84-day mission. But even from the ground, scientists gathered an enormous amount of data about the comet—perhaps the most intensively observed celestial object in the annals of astronomy.

By taking continuous infra-red (or heat) pictures, for instance, a University of Arizona team led by Astronomer Frank Low determined that as Kohoutek sped toward the sun, it was heated from minus 94° F. to as high as 900° F. in less than three months. A colleague at the University of Arizona, Astronomer Elizabeth Roemer, speculated that Kohoutek may be less dusty than other comets making their first pass round the sun. Otherwise, the dust being boiled off Kohoutek would have produced a more spectacular tail. Perhaps the most intriguing find was made by a radio telescope atop Kitt Peak: while scanning Kohoutek, it picked up the telltale "signature" of methyl cyanide. Another place where that organic compound has been found is in the giant clouds of interstellar dust and gases in which new stars and planetary systems may be forming—one more clue that comets trace back to the solar system's infancy.

Before the encounter, Astronaut Carr spotted a puzzling red color in the comet's tail. That may mean that Kohoutek has more moisture than most comets, for this tint suggests concentrations of hydrogen and oxygen, the two components of water. In other respects, Kohoutek's twin tails—one composed of dust particles, the other of glowing gases—seem to be developing normally. As the comet began its hairpin turn round the sun, the dust tail blown by the slight pressure of sunlight continued to trail behind. But the plasma tail, interacting with the solar wind, moved out in front.

Astronomers are still in disagreement about how bright the comet will appear to viewers on earth. Elizabeth Roemer, for one, doubts that Kohoutek will live up to its earlier billing as "comet of the century." Other scientists are still confident that the comet will put on a good celestial show. In any event, Kohoutek should become visible to the naked eye early in January—about an hour after sunset, just above the southeastern horizon—and could continue to put on a spectacular performance until the middle of the month.

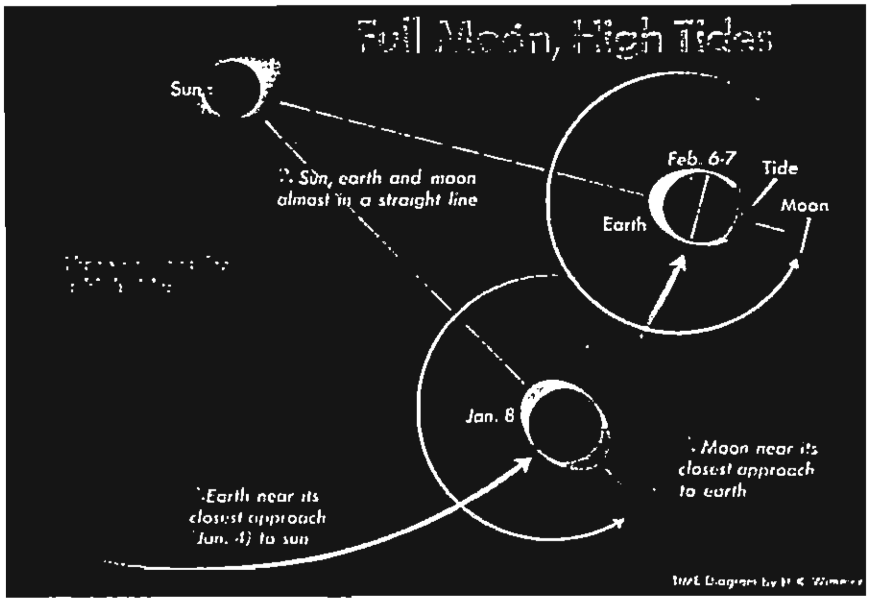
Danger from the Tides

If there are severe storms in either the Atlantic or Pacific oceans around Jan. 8, Americans living in coastal areas may well be hit by bad floods. This unusual warning was sounded last week by federal scientists. Why Jan. 8? Because of a relatively rare combination of circumstances, tides will be abnormally high around that time. Although the tides alone will not cause flooding, strong, persistent onshore winds accompanying a coastal storm would pile the water even higher, spilling it into low-lying areas.

Tides are caused largely by the gravitational tug of the moon, which daily forces great upward and downward movement in the oceans. The pull of the distant sun also influences the tides, and when the orbits of the moon around the earth and the earth around the sun bring all three bodies roughly into line, the tidal changes are much larger than usual. These "spring" tides (named for the verb rather than the season) occur twice a month: when the moon is full and when it is new. Spring tides themselves may be driven to further extremes when the elliptical path of the moon brings it closest to the earth's surface, increasing the effect of lunar gravity.

The year 1974 will bring several such outsize tides. On Jan. 8, and again on Feb. 6-7, the moon will be particularly close to earth. The earth will also be close to the sun, and all three bodies, sun, moon and earth, will have moved almost into a straight line.[*] Thus spring tides along the Atlantic and Pacific coasts in early January and February—and again around July 19 and Aug. 17, when similar conditions will occur—should be particularly extreme.

Scientists know from experience what could happen if a coastal storm should blow up on these dates. Research Scientist Fergus J. Wood, of the National Ocean Survey, recalled last week that a spring tide of 5.2 ft. at Atlantic City in March 1962 was whipped by gusts of up to 70 knots and rose 9.5 ft. above the average low-water mark. Huge waves battered the Atlantic coast. The accompanying floods cost 40 lives and some $500 million in damage.



TIME Diagram by H. K. Wimmer

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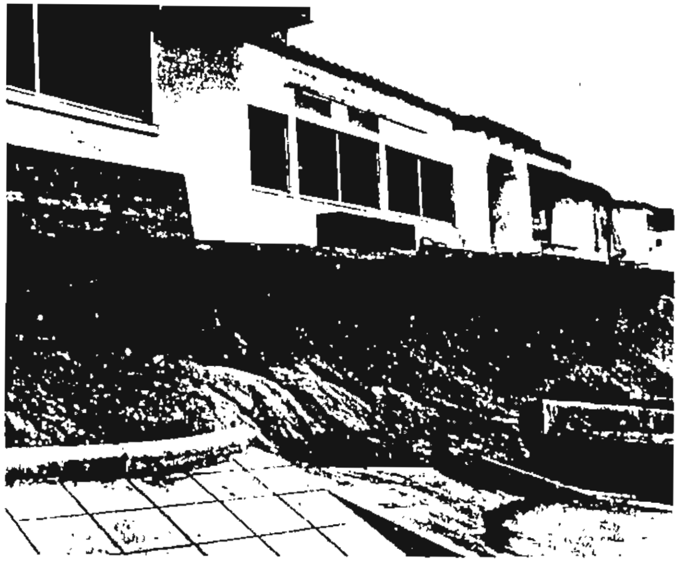
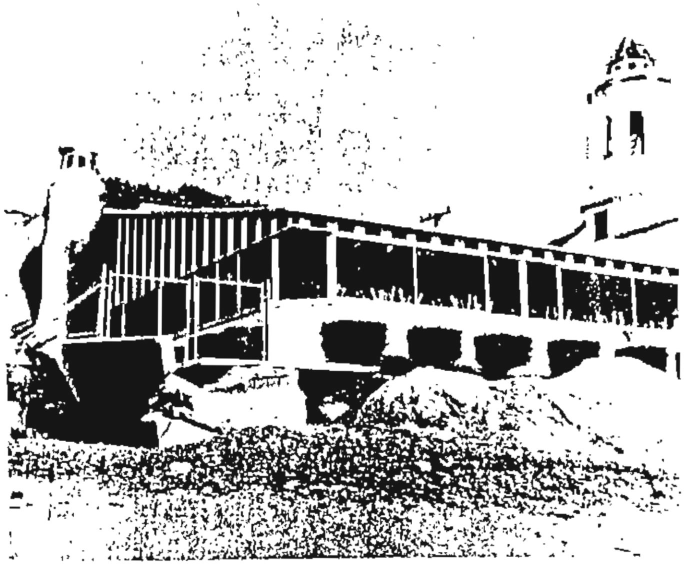
[*] If they were directly in line, the result would be an eclipse of the moon.



Courtesy of The Orange Coast *Daily Pilot*, Costa Mesa, Calif.

Detail of destruction of the concrete walkway and driveway at Capistrano Beach Club resulting from erosion and attrition of the underlying foundation materials by storm-amplified perigean spring tides occurring around the 1962 February 5 date.



Courtesy of The Orange Coast *Daily Pilot*, Costa Mesa, Calif.

Damage to the seawall and protecting parapet at Capistrano Beach Club, Capistrano, Calif., consequent upon the wind-reinforced amplification of already high waters produced in association with the perigee-syzygy alignment of 1962 February 5. (See table 16.)

—Additional Corroborating Cases of Coastal Flooding and/or Coastal Erosion Which Occurred in a Near-Concurrent Relationship With Perigean Spring Tides When Accompanied by Strong, Persistent, Onshore Winds, 1978–1983

(In the United States, all times are given in EST or PST, as appropriate; other cases are in GMT)

Key No.	Date of Flooding	Location of Flooding	Nearest Perigee Date	Nearest Syzygy Date	Separation Interval: Perigee Minus Syzygy (h.)	Type of Syzygy	Mean Epoch of Perigee-Syzygy	Reference Sources for Flooding (See key at end of Table 4d.) *Note:* Page and column numbers may vary considerably between different newspaper editions.
101w	1978 Jan. 8–9	Mission, La Jolla, Del Mar, Oceanside, Manhattan, El Segundo, Malibu, Solromar, Ventura, Sea Cliff, Rincon, and Capitola beaches, Ca.	1978 Jan. 8 0400	Jan. 8 2000	−16	NM	1978 Jan. 8 1200	(30) 1/9/78, pt. I, p. 1, col. 6, p. 3, cols. 1–4; 1/10/78, pt. I, p. 1, cols.3–4, p. 3, col. 4, p. 19, cols. 1–2; *The Evening Tribune*, San Diego, Ca. 1/9/78, p. A-1, col. 5, p. A-6, cols. 1–2; 1/10/78, p. A-1, cols. 2–4, p. A-2, cols. 4–6.
102w	1978 Feb. 6–7	South Mission Beach, Pacific Beach, La Jolla Cove, Balboa Peninsula and Balboa Island, Sunset Beach, Surfside, and Seal Beach, Ca.	1978 Feb. 5 1300	Feb. 7 0654	−42	NM	1978 Feb. 6 1000	(30) 2/8/78, pt. I, p. 1, col. 5, p. 32, col. 1–3.
103	1978 Mar. 3–7	Heavy tidal damage, destruction of seawalls, and severe coastal erosion at Malibu Beach, Ca., and between Las Flores and Encinitas beaches, Ca.; cliff gouging, together with wave-tossed rocks and cobblestones, at Oceanside and Carlsbad, and marine terrace modification at many locations along the San Diego County coast.	1978 Mar. 5 0900	Mar. 8 1836	−82	NM	1978 Mar. 7 0148	(30) 3/4/78, pt. I, p. 1, col. 5, p. 22, col. 1. See also Kuhn, G.K. and Shepard, F.P., "Coastal Erosion in San Diego County, Ca.," in *Proceedings of the Second Symposium on Coastal and Ocean Management*, Billy L. Edge, ed., American Society of Civil Engineers, 1980, v. 3, pp. 1899–1918.
104	1978 Dec 30	Street flooding at Newport Beach, and on Balboa Island and Balboa Peninsula, Ca.	1978 Dec. 30 1400	Dec. 29 1136	$+26\frac{1}{2}$	NM	1978 Dec. 30 0048	(30) 12/30/78, pt. II, p. 14, cols. 1–3 (pix).

(In the United States, all times are given in EST or PST, as appropriate, other cases are in GMT)

Key No.	Date of Flooding	Location of Flooding	Nearest Perigee Date	Nearest Syzygy Date	Separation Interval: Perigee Minus Syzygy (h.)	Type of Syzygy	Mean Epoch of Perigee-Syzygy	Reference Sources for Flooding (See key at end of Table 4d.) *Note*: Page and column numbers may vary considerably between different newspaper editions.
109	1980 Feb. 16–20	Imperial Beach, Ocean Beach, Del Mar, Oceanside, Rincon, Malibu, Oxnard, Capitola, San Francisco Bay area, and Vallejo, Ca.	1980 Feb. 17 0100	Feb. 16 0051	+24	NM	1980 Feb. 16 1255	(30) 2/16/80, pt. II, p. 1, cols. 5–6, p. 16, col 6; 2/20/80, pt. I, p. 1, cols. 2–5 (pix), pt. II, p. 10, cols. 1–3 (pix); 2/21/80, pt. I, p. 3, cols. 1–5 (pix), p. 5, col. 1, pt. II, p. 1, cols. 1–3 (pix); *The Evening Tribune*, San Diego, Ca. 2/20/80, p. A-1, cols. 1–4 (pix), p. 2, cols. 3–4 (pix); 2/21/80, p. A-3, cols. 1–4.
114	1981 Dec. 11	Even without reinforcing winds, coastal streets in Newport Beach, Ca., were inundated when 7.8-foot tides, Orange County's highest of the year, caused flooding on Balboa Peninsula.	1981 Dec. 10 1600	Dec. 11 0041	−9	FM	1981 Dec. 10 2020	(30) 12/12/81, pt. I, p. 1, cols. 2–5 (pix)
117	1982 Nov. 30– Dec. 1	Mission Beach, La Jolla Cove, Del Mar, Cardiff-by-the-Sea, Carlsbad, Laguna Beach, and Malibu Beach, Ca.; Sacramento-San Joaquin Delta, Ca.	1982 Dec. 2 0300	Nov. 30 1621	$+34\frac{1}{2}$	FM	1982 Dec. 1 0941	(30) 12/2/82, pt. II, p. 1, cols. 1–6 (pix), cols. 2–6, p. 5, cols. 1–5, p. 10, cols. 1–6 (pix).

(In the United States, all times are given in EST or PST, as appropriate; other cases are in GMT)

Key No.	Date of Flooding	Location of Flooding	Nearest Perigee Date	Nearest Syzygy Date	Separation Interval: Perigee Minus Syzygy (h.)	Type of Syzygy	Mean Epoch of Perigee-Syzygy	Reference Sources for Flooding (See key at end of Table 4d.) *Note*: Page and column numbers may vary considerably between different newspaper editions.
118w	1983 Jan. 27–31	Lowland portions of the Pacific coast, from Baja California to Oregon, including: Rosarito, Baja California, Mexico; Imperial Beach, Ocean Beach, Mission Beach, Pacific Beach, La Jolla Cove, Del Mar, Cardiff-by-the-Sea, Carlsbad, Oceanside, Las Flores, San Clemente, Capistrano Beach, Laguna Beach, Newport Beach, Huntington Beach, Sunset Beach, Surfside, Seal Beach, Redondo Beach, Santa Monica, Malibu Beach, Carpinteria, Santa Barbara; and Aptos, Capitola, Pacifica, Corte Madera, Richmond, San Rafael, Santa Venetia, and Point Arena, Ca;	1983 Jan. 28 0300	Jan. 28 1426	$11\frac{1}{2}$	FM	1983 Jan. 28 0843	(30) 1/26/83, pt. I, p. 3, col. 1, p. 16, col. 1; 1/27/83, pt. I, p. 1, cols. 4–5 (pix), p. 3, cols. 3–5, p. 18, cols. 1–3, pt. II, p. 1, cols. 1–6, p. 7, cols. 1–6; 1/28/83, pt. I, p. 1, cols. 2–6, p. 3, cols. 1–5, p. 16, cols. 1–2, p. 20, col. 1, pt. II, p. 1, cols. 1–6 (pix); 1/29/83, pt. I, p. 1, cols. 2–4, p. 26, cols. 1–3, p. 27, cols. 1–2, pt. II, p. 1, cols. 1–6 (pix), cols. 5–6, p. 8, cols. 4–5; 1/30/83, pt. I, p. 1, col. 4, p. 3, cols. 1–6, p. 19, cols. 1–2; 1/31/83, pt. I, p. 1, col. 2, p. 3, cols. 1–3; 2/1/83 (total damage assessment), pt. I, p. 1, col. 1, p. 4, cols. 1–3; (51) 1/28/83, p. A10, col. 6; 1/29/83, p. A1, cols. 1–3 (pix), p. 7 ("Y" ed., p. 6), cols. 1–4; *The Register*, Santa Ana, Ca. 1/28/83, p. A1, cols. 1–6, p. A2, cols. 3–6;
119	1983 Feb. 25+	A far less severe flooding situation accompanied this fourth in a series of perigean spring tides—two prevous cases of which (11/30/82 and 1/27/83) were associated with active flooding. However, the unusually high tides in San Pedro Bay, coinciding with a period of extremely heavy rainfall produced by an inmoving Pacific storm, caused the backup of heavily swollen tributary streams in the area of Petaluma, Ca., and overflowing resulted. Similar flooding due to a blocking of hydrological runoff by these augmented tides took place widely throughout the San Francisco Bay area. The combination of heavy rainfall and heightened tides also caused coastal flooding and forced the closing of Highway #1 in the vicinity of Stinson Beach, Ca.	1983 Feb. 25 1400	Feb. 27 0058	−35	FM	1983 Feb. 26 0729	(34) 1/26/83, p. 1, col. 6, p.12, cols. 5–6.

(In the United States, all times are given in EST or PST, as appropriate; other cases are in GMT)

Key No.	Date of Flooding	Location of Flooding	Nearest Perigee Date	Nearest Syzygy Date	Separation Interval: Perigee Minus Syzygy (h.)	Type of Syzygy	Mean Epoch of Perigee-Syzygy	Reference Sources for Flooding (See key at end of Table 4d.) *Note:* Page and column numbers may vary considerably between different newspaper editions.
120	1983 Aug. 8	Pacific Beach, Carlsbad, Oceanside, Capistrano Beach, Laguna Beach, and Malibu Beach, Ca. (The result of perigean spring tides surmounted by a high swell radiating from an intense storm in the south Pacific Ocean.)	1983 Aug. 8 1100	Aug. 8 1118	−18 *min.*	NM	1983 Aug. 8 1109	(30) 8/9/83, pt. I, p. 1, cols. 2–4 (pix), p. 21, cols. 1–4; (32) 8/9/83, p. 3, cols. 1–3 (pix); 8/10/83, p. 3, cols. 1–4; *The Evening Tribune*, San Diego, Ca. 8/8/83, p. A-1, cols. 4–6, p. A-4, cols. 1–4 (pix); 8/9/83, p. A-1, cols. 1–6, p. A-4, cols. 5–6.

APPENDIX D

RECOMMENDED EMERGENCY PREPAREDNESS GUIDELINES

APPENDIX D

EMERGENCY PREPAREDNESS GUIDELINES

DANA POINT COASTAL ZONE

As outlined within Section III of this report (Summary of Technical Data), the history of coastal erosion and coastal geotechnical hazards (beach erosion and flooding, coastal bluff failures, etc.) has been punctuated by episodicity. Some of the episodic processes are predictable within reasonable recurrence intervals (El Nino/Southern- Oscillation-Event storm waves; perigean spring tides) while other processes appear to be relatively random in their frequency and intensity. City planners and homeowners can incorporate existing knowledge of both these episodic and random processes, plus the mitigative recommendations discussed in section II (above), into disaster preparedness policies and measures to minimize loss of coastal property and life. The following emergency preparedness guidelines are recommended:

- o Adoption of zoning and land-use recommendations of this report (e.g., avoid construction within known FP-3 flood hazard zones, such as southern Capistrano Beach or Dana Strand Beach; open-space conservation designations to all non-recreational shoreline areas and undeveloped bluff-top properties, etc.) are considered one of the most effective emergency preparedness policies.

- o Adoption of structural setback recommendations for bluff-tops, as discussed in this report, is the best emergency preparation for coastal bluff landslide disasters, given that prevention is universally more cost-effective than treatment.

- o The City of Dana Point should participate in NFIP (National Flood Insurance Program), administered by FEMA (Federal Emergency Management Agency), to ensure that individual property owners can purchase federally subsidized flood insurance. Prior to incorporation of the City, FEMA prepared Flood Insurance Rate Maps (FIRMs) depicting, among other things, the geographic limits of Special Flood Hazard Areas (areas subject to 100-Year-Floods). Base flood (100-Year-Flood) elevations are not always indicated on all FIRM maps, however, particularly for coastal flood-hazard areas. These coastal areas are designated as V or VE zones, and community flood plain management programs adopted for such zones should require that insurable structures be designed to resist flood inundation due not only to storm wave height but storm wave impact velocity, as well. In V Zones, all new construction or "substantial improvements" to existing structures must be elevated on adequately anchored pilings so that the bottom of structural elements supporting the lowest floor is elevated at or above base flood elevation. The City will be required to implement zoning, construction guidelines and/or special ordinances (such as required setbacks or caisson foundations) as part of their flood plain management measures for Special Flood Hazard Areas prior to the phasing of the NFIP regular program. For details, the regional offices of FEMA can be contacted at 1 (415) 556-9840; existing FIRM maps can be ordered at 1 (800)333-1363.

- City Planners should consider establishing a storm warning or disaster preparedness office, partially a volunteer service, including a public hotline which may be contacted to obtain information on proximity and severity of storms, including warnings for superposition of storm surge, strong wind setup and high tide levels. Existing storm and oceanographic data centers which may serve as interfaces in a disaster preparedness network include the National Ocean Survey (NOS, formerly Coast and Geodetic Survey), the San Diego Regional Office of the National Weather Service (at 1 (619) 297-2107), or the San Diego County Office of Disaster Preparedness (at 1 (619) 565-3490).

- Occupants of beachfront residential communities (Capistrano Beach Community or Niguel Shores) should consider keeping sandbags on hand in the case of elevated flood water conditions. Care should be taken not to place sandbags against existing foundations or other structural elements of private residences, since saturated sandbags create additional surcharge to elements already experiencing static or dynamic loads from flood waters and storm waves.

- Community awareness pamphlets should be prepared for private citizen groups illustrating the best available storm evacuation routes, historical data on potential wave run-up, breaker heights, shoreline retreat potentials from individual storms, etc., for all high or very-high severity level coastal areas (see Plate 4).

- Geologic Hazard Abatement Districts (GHAD's; see Section II above) should be established by the City or by local communities or homeowners associations, to ensure effective mitigative policies for specific areas and permit state-subsidized funding for disaster prevention and preparedness.

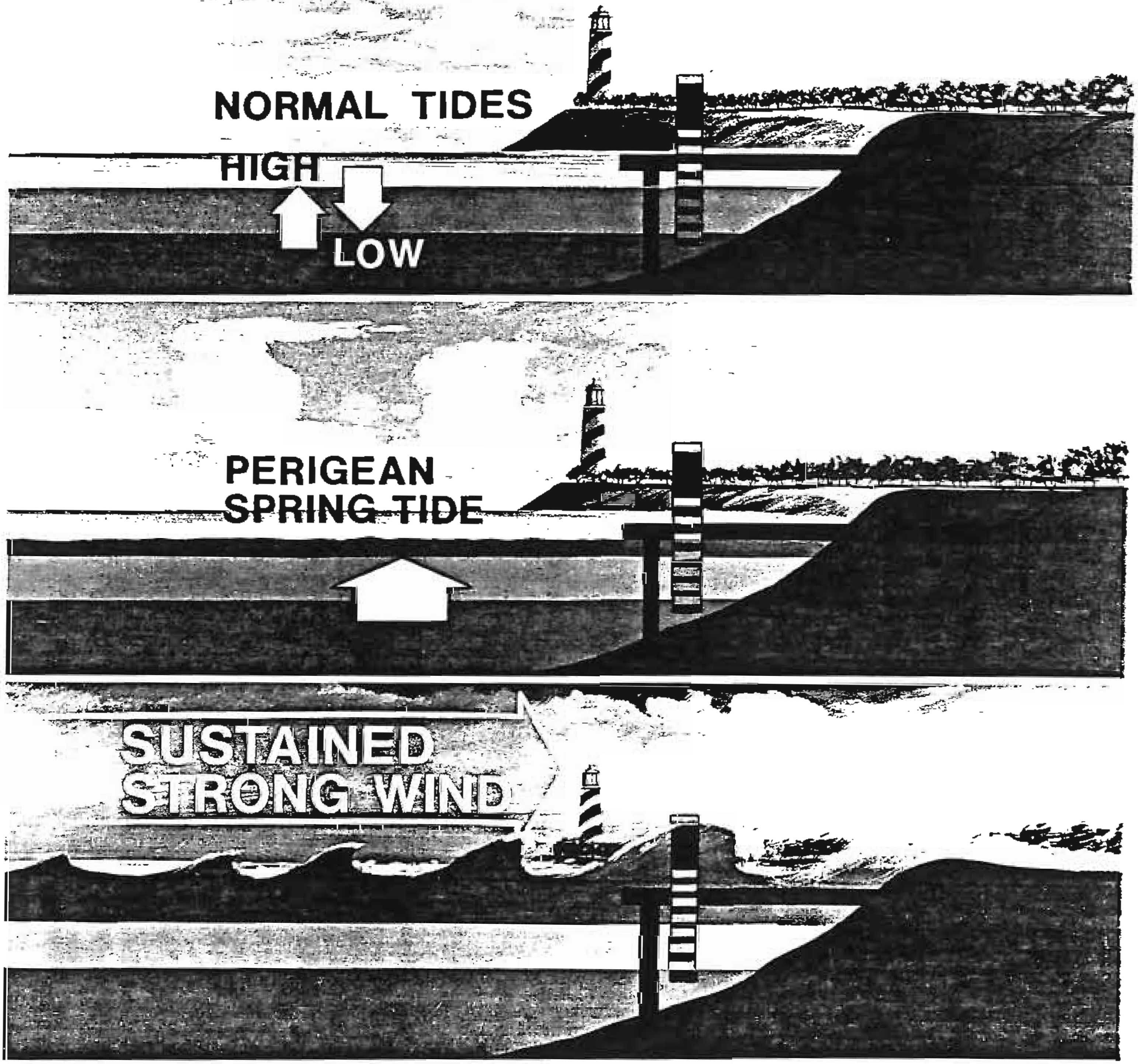
APPENDIX E

AMPLIFIED PERIGEAN SPRING TIDE PREDICTIONS AND DIAGRAM

(1900-2164)

(SOURCE: F.J. WOOD, 1978; 1986)

PERIGEAN SPRING TIDES MAY BE CONDUCIVE TO COASTAL FLOODING



SOURCE: F.J. Wood, 1978, 1986.
(Reprinted by Permission)

Table 16

Designation of Columns

Table 16 is reproduced by electronic composition directly from a computer printout of lunar and solar data provided by the Nautical Almanac Office, U.S. Naval Observatory. This table contains data pertinent to all cases between the years 1600 and 1999 in which lunar perigee and syzygy occur within ±24 mean solar hours of each other.

The arrangement of this table is as follows:

Col. 1 gives the Julian Date to the nearest 0.1 day, corresponding to the time of mean syzygy. This position is based upon the mean apparent motions of the Moon ($13.176396^\circ/^{d}$) and Sun ($0.985647^\circ/^{d}$) and represents the average time at which these two bodies reach syzygy alignment. The apparent discrepancy between the decimal portion of the Julian Day and the time (in hours) given for syzygy in column 2 is due to the fact that the latter time corresponds to true rather than mean syzygy. For any date in history, the Julian Day also starts at noon (Greenwich mean time), whereas all of the times given in column 2 are in Greenwich civil time (or more exactly, ephemeris time) which begins at midnight.

The inclusion of these Julian Dates makes more convenient the subtraction of differences in time, and the establishment of related periodicities between individual occurrences of perigee-syzygy. It is also possible by means of this artifice to determine the day of the week for any instance of tidal flooding, making possible the cross checking of early documentary sources of such flooding.

For all practical purposes, one-half of the difference in hours (col. 9) between true perigee and true syzygy may be algebraically added (as a decimal part of a day) to the Julian Date of mean syzygy to obtain the approximate mean date of perigee-syzygy. Proper allowance must also be made to convert from ephemeris time at Greenwich to local standard time at the location of the flooding by subtraction of the appropriate number of hours which the station is west of Greenwich. For example, in establishing the corresponding day of the week in eastern standard time, 5 hours (0.2^{d}) is subtracted from the Julian Date. The date and decimal portion are then rounded off to the nearest unit. Any resulting decimal value of 0.5^{d} is rounded off, in practice, to the nearest *even* unit, either higher or lower, as the case may be.

The appropriate day of the week is obtained by dividing the entire rounded-off Julian Date by 7. If the remainder is 0, the day is Monday, if 1, Tuesday, etc., through a remainder of 6 for Sunday.

Column 2 contains the year, month, date, and 24-hour time of *true* syzygy (rounded off to the nearest hour) for each case of syzygy associated with a perigee-syzygy alignment in which the two components occur within the prescribed separation-interval of ±24 hours or less.

All dates, regardless of year, are given in the Gregorian (New Style) Calendar. Prior to 1752, if Old Style dates are desired for comparison purposes, the tabulated dates must be corrected according to the procedure outlined at the close of part I, chapter 1.

In the data processing procedure, the necessary reductions have been made, and all times given are in ephemeris time, which corresponds very closely with Greenwich civil time.

Using data referred consistently to Greenwich *civil* time throughout this and subsequent columns of the table, no adjustment is needed for the fact that, after January 1, 1925, the beginning of the astronomical day changed from noon (Greenwich mean time) to the preceding midnight (Greenwich civil time). To convert to eastern standard time, 5 hours should be subtracted; Pacific standard time similarly is 8 hours earlier.

Because of rounding-off and data-truncating procedures used in the computer processing, the times given in this column will not, in all cases, agree exactly with those contained in *The American Ephemeris and Nautical Almanac* and other ephemerides, or as reproduced in various governmental tide tables. Where rounding-off errors combine in the same direction, the differences may amount to as much as an hour. The more accurate ephemeris values have been used in all cases throughout the text where times to the accuracy of minutes are involved; however, the present tabular values will suffice for all instances in which values accurate to the nearest hour are required.

Column 3 indicates the phase of syzygy as either new moon (N) or full moon (F).

Column 4 lists the geocentric horizontal parallax in minutes, seconds, and tenths of seconds of arc, corresponding to the time of true syzygy.

Column 5 contains a series of angular values expressing the rate of orbital motion of the Moon with respect to the perturbed motion of perigee, determined, for the instant of syzygy, in $^\circ/^{d}$. The procedure by which this value ($\Delta\omega_1 = \bar{\gamma}$) stems from the time rate of change of the Moon's true anomaly is explained in the Introduction to table 16. ★—p. 201.33.

The method of using this angle, and that from column 6, to obtain the special value designated in this monograph as the "$\Delta\omega$-syzygy coefficient" is described in chapter 8. This coefficient represents the astronomical portion of a total quantifier indicating the potential for tidal flooding associated with the simultaneous occurrence of perigean spring tides and strong, persistent, onshore winds.

Column 6 tabulates the apparent motion of the Moon in right ascension (expressed likewise, for comparative purposes, in $^\circ/^d$) at the instant of true syzygy.

Column 7 is a tabulation of the apparent declination of the Moon (to the nearest 0.1 degree) at the time of true syzygy.

Column 8 notes the apparent declination of the Sun (to the nearest 0.1 degree) at the time of true syzygy.

Column 9 indicates the increment or decrement (in hours) which, according to algebraic sign, it is necessary to add to, or subtract from, the time of true syzygy in column 2 in order to find the corresponding time of true perigee. This difference in time is consistently taken in the sense perigee minus syzygy, and represents the perigee-syzygy "separation-interval" frequently referred to throughout the volume. With the exception of a few cases caused by the combination of rounding-off errors, no value in column 9 exceeds ±24 hours.

The *mean epoch of perigee syzygy* (see column 8 of table 1) is obtained by dividing the figure in column 9 by 2 and adding the result algebraically to the time of syzygy in column 2.

Column 10 designates the geocentric horizontal parallax of the Moon (in minutes and seconds of arc), in the same manner as column 4, but now as it applies to the slightly different time and position of true perigee.

Column 11 repeats the instantaneous value of the rate of the Moon's motion with respect to perigee (in $^\circ/^d$), described under column 5, but now referred to the time of true perigee. (Alternate symbols $\Delta\omega_1 = \bar{\gamma}$.) ★—p. 201.33.

Column 12 gives the apparent motion of the Moon in right ascension (expressed also in $^\circ/^d$) for the instant of true perigee.

Column 13 reproduces column 7, but gives the apparent declination of the Moon (in degrees and tenths) at the time of true perigee.

Column 14 provides the corresponding apparent declination of the Sun (in degrees and tenths) at the time of true perigee.

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2415079.8	1900/ 3/ 1–11	N	61 28.2	17.052	14.161	– 3.0	– 7.6	1	61 28.2	17.052	14.158	– 2.9	– 7.6
2415109.4	1900/ 3/30–21	N	61 4.5	16.923	14.250	8.0	3.8	–22	61 12.1	16.880	14.064	2.9	3.5
2415271.8	1900/ 9/ 9– 5	F	61 18.4	16.910	14.141	– 1.0	5.5	14	61 21.6	16.899	14.182	2.2	5.3
2415301.3	1900/10/ 8–13	F	61 25.0	17.028	14.597	9.3	– 5.8	– 7	61 26.1	17.022	14.480	7.7	– 5.7
2415463.7	1901/ 3/20–13	N	61 3.4	16.948	14.184	3.5	– 0.3	21	61 11.0	16.957	14.472	8.0	0.0
2415493.2	1901/ 4/18–22	N	61 24.3	17.020	15.053	12.8	10.8	– 1	61 24.3	17.019	15.034	12.7	10.8
2415522.8	1901/ 5/18– 6	N	60 58.7	16.868	15.796	19.0	19.4	–23	61 7.3	16.849	15.404	16.4	19.2
2415685.2	1901/10/27–15	F	61 20.5	17.047	15.170	13.6	–12.7	13	61 23.1	17.044	15.451	15.4	–12.9
2415714.7	1901/11/26– 1	F	61 24.2	17.114	16.080	19.0	–20.8	– 9	61 25.9	17.113	15.954	18.3	–20.7
2415877.1	1902/ 5/ 7–23	N	61 2.8	16.905	15.388	15.7	16.7	20	61 9.8	16.916	15.795	17.8	17.0
2415906.7	1902/ 6/ 6– 6	N	61 22.8	16.949	16.153	19.2	22.6	– 1	61 22.8	16.949	16.146	19.1	22.5
2415936.2	1902/ 7/ 5–13	N	60 58.6	16.787	15.743	18.1	22.8	–23	61 7.2	16.792	16.021	19.2	22.9
2416098.6	1902/12/15– 4	F	61 26.0	17.095	16.159	18.9	–23.2	10	61 27.7	17.084	16.164	18.8	–23.2
2416128.2	1903/ 1/13–14	F	61 24.1	17.075	15.756	16.7	–21.6	–12	61 26.5	17.065	15.945	17.7	–21.7
2416290.6	1903/ 6/25– 6	N	61 3.9	16.817	15.925	18.5	23.4	21	61 10.8	16.812	15.819	17.6	23.4
2416320.1	1903/ 7/24–13	N	61 23.5	16.923	15.597	15.4	20.1	– 1	61 23.5	16.923	15.615	15.6	20.1
2416349.6	1903/ 8/22–20	N	60 58.7	16.853	14.664	8.9	12.0	–23	61 7.4	16.857	15.100	12.6	12.3
2416512.1	1904/ 2/ 1–17	F	61 27.1	17.104	15.396	13.7	–17.4	7	61 28.1	17.105	15.272	12.7	–17.3
2416541.6	1904/ 3/ 2– 3	F	61 18.5	17.050	14.639	6.0	– 7.4	–15	61 22.0	17.038	14.835	8.6	– 7.6
2416704.0	1904/ 8/11–13	N	61 3.2	16.867	15.085	12.8	15.3	20	61 10.1	16.860	14.802	9.5	15.1
2416733.5	1904/ 9/ 9–21	N	61 23.3	17.019	14.629	5.1	5.2	– 2	61 23.4	17.020	14.641	5.3	5.3
2416763.1	1904/10/ 9– 6	N	60 57.6	16.933	14.374	– 3.9	– 6.1	–24	61 6.9	16.947	14.381	0.7	– 5.7
2416925.5	1905/ 3/21– 5	F	61 26.0	17.068	14.516	1.8	0.0	5	61 26.6	17.065	14.508	0.6	0.1
2416955.0	1905/ 4/19–14	F	61 14.7	16.919	14.632	– 7.3	11.1	–16	61 19.0	16.914	14.506	– 4.2	10.8
2417117.4	1905/ 9/28–22	N	61 7.6	16.952	14.318	0.7	– 2.0	19	61 13.8	16.916	14.404	– 3.3	– 2.3
2417147.0	1905/10/28– 7	N	61 27.1	17.047	14.764	– 8.6	–12.9	– 2	61 27.3	17.048	14.731	– 8.1	–12.9
2417338.9	1906/ 5/ 8–14	F	61 25.9	16.935	15.029	–12.1	16.9	5	61 26.4	16.937	15.128	–12.9	17.0
2417368.4	1906/ 6/ 6–21	F	61 13.2	16.858	15.811	–18.3	22.6	–16	61 17.7	16.836	15.527	–16.4	22.5
2417530.9	1906/11/16– 9	N	61 13.0	17.003	15.060	–13.9	–18.6	17	61 18.1	16.985	15.496	–16.6	–18.7
2417560.4	1906/12/15–19	N	61 27.4	17.118	16.160	–19.9	–23.2	– 5	61 27.8	17.114	16.088	–19.5	–23.2
2417752.3	1907/ 6/25–21	F	61 23.3	16.931	16.387	–21.6	23.4	5	61 23.7	16.934	16.425	–21.7	23.4
2417781.9	1907/ 7/25– 5	F	61 11.0	16.881	16.075	–20.6	19.9	–17	61 15.6	16.885	16.328	–21.6	20.1
2417944.3	1908/ 1/ 3–22	N	61 16.1	17.104	16.493	–22.7	–22.9	15	61 19.9	17.092	16.453	–22.4	–22.8
2417973.8	1908/ 2/ 2– 9	N	61 25.2	17.105	15.879	–19.5	–17.2	– 8	61 26.0	17.105	16.064	–20.4	–17.2
2418165.8	1908/ 8/12– 5	F	61 24.9	16.938	15.591	–18.5	15.1	5	61 25.3	16.932	15.451	–17.7	15.0
2418195.3	1908/ 9/10–12	F	61 13.2	16.901	14.288	– 9.4	5.0	–16	61 17.9	16.906	14.703	–13.2	5.2
2418357.7	1909/ 2/20–11	N	61 19.8	17.049	14.919	–15.4	–11.0	12	61 22.6	17.039	14.587	–12.7	–10.9
2418387.2	1909/ 3/21–20	N	61 23.2	17.006	13.939	– 4.3	0.2	– 9	61 24.6	16.995	14.060	– 6.7	0.1
2418579.2	1909/ 9/29–13	F	61 27.5	16.994	13.815	– 1.9	– 2.3	4	61 27.8	16.994	13.804	– 0.7	– 2.4
2418608.7	1909/10/28–22	F	61 12.5	17.029	14.136	10.5	–13.1	–17	61 17.9	17.008	13.849	5.9	–12.9
2418771.1	1910/ 4/ 9–21	N	61 18.1	16.992	13.727	4.4	7.5	12	61 20.3	17.005	13.902	7.5	7.7
2418800.7	1910/ 5/ 9– 6	N	61 18.1	16.979	14.792	16.2	17.1	–11	61 19.9	16.968	14.463	13.7	17.0
2418992.6	1910/11/17– 0	F	61 28.7	17.122	15.272	19.1	–18.7	3	61 28.8	17.122	15.373	19.7	–18.8
2419022.2	1910/12/16–11	F	61 9.6	17.052	16.773	26.2	–23.3	–20	61 16.2	17.041	16.263	24.1	–23.2
2419184.6	1911/ 5/28– 6	N	61 16.9	16.947	16.064	23.5	21.3	11	61 18.9	16.948	16.476	25.1	21.4

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2419214.1	1911/ 6/26-13	N	61 17.5	16.898	17.162	27.5	23.4	-10	61 19.4	16.900	17.081	27.2	23.4
2419376.5	1911/12/ 6- 3	F	61 5.4	17.010	16.478	25.8	-22.3	22	61 13.7	16.970	17.096	27.7	-22.5
2419406.1	1912/ 1/ 4-13	F	61 31.6	17.112	17.249	27.6	-22.8	1	61 31.6	17.112	17.248	27.6	-22.8
2419435.6	1912/ 2/ 3- 0	F	61 6.3	16.988	15.434	21.5	-17.0	-22	61 14.4	16.951	16.396	25.3	-17.2
2419598.0	1912/ 7/14-13	N	61 17.9	16.886	16.781	26.6	21.7	11	61 19.9	16.882	16.424	25.2	21.6
2419627.5	1912/ 8/12-20	N	61 18.2	16.928	14.973	18.9	14.9	-10	61 20.1	16.927	15.433	21.1	15.0
2419789.9	1913/ 1/22-16	F	61 10.0	17.030	16.008	24.1	-19.7	19	61 16.7	17.013	15.204	20.2	-19.5
2419819.5	1913/ 2/21- 2	F	61 29.2	17.105	14.204	13.4	-10.8	- 2	61 29.3	17.103	14.282	14.0	-10.8
2420011.4	1913/ 8/31-21	N	61 17.8	16.974	13.785	10.1	8.6	10	61 19.7	16.968	13.572	6.9	8.5
2420041.0	1913/ 9/30- 5	N	61 18.0	17.021	13.413	- 3.6	- 2.6	-11	61 20.1	17.031	13.379	- 0.3	- 2.4
2420203.4	1914/ 3/12- 4	F	61 11.2	17.032	13.370	3.2	- 3.7	18	61 16.8	17.021	13.390	- 2.2	- 3.4
2420232.9	1914/ 4/10-13	F	61 26.6	17.013	13.922	-10.6	7.8	- 4	61 26.8	17.014	13.826	- 9.4	7.7
2420424.9	1914/10/19- 7	N	61 22.6	17.030	14.213	-13.3	- 9.7	9	61 24.1	17.015	14.548	-15.8	- 9.8
2420454.4	1914/11/17-16	N	61 20.2	17.042	16.068	-23.7	-18.9	-12	61 22.9	17.038	15.578	-21.5	-18.8
2420616.8	1915/ 4/29-14	F	61 12.9	16.900	15.033	-18.8	14.2	17	61 17.8	16.895	15.755	-22.2	14.5
2420646.3	1915/ 5/28-22	F	61 25.7	16.914	16.833	-26.1	21.4	- 5	61 26.0	16.910	16.709	-25.7	21.4
2420838.3	1915/12/ 6-18	N	61 25.9	17.083	17.049	-26.6	-22.4	8	61 26.9	17.083	17.136	-26.8	-22.5
2420867.8	1916/ 1/ 5- 5	N	61 17.0	17.101	16.500	-24.9	-22.7	-15	61 20.8	17.080	16.901	-26.3	-22.8
2421030.2	1916/ 6/15-22	F	61 10.8	16.855	16.903	-26.3	23.3	17	61 15.6	16.865	16.719	-25.5	23.3
2421059.8	1916/ 7/15- 5	F	61 23.3	16.942	15.967	-22.2	21.6	- 5	61 23.7	16.941	16.125	-22.9	21.6
2421251.7	1917/ 1/23- 8	N	61 26.5	17.135	15.321	-18.4	-19.5	4	61 26.9	17.133	15.158	-17.4	-19.5
2421281.2	1917/ 2/21-18	N	61 12.3	17.017	13.925	- 7.2	-10.6	-17	61 17.4	17.007	14.325	-11.7	-10.8
2421443.7	1917/ 8/ 3- 5	F	61 11.9	16.881	14.789	-15.2	17.7	17	61 16.6	16.860	14.356	-11.3	17.5
2421473.2	1917/ 9/ 1-12	F	61 25.7	16.950	13.972	- 4.3	8.4	- 4	61 26.1	16.954	14.025	- 5.5	8.5
2421665.1	1918/ 3/12-20	N	61 27.2	17.037	14.017	1.2	- 3.4	2	61 27.4	17.038	14.027	1.8	- 3.3
2421694.7	1918/ 4/11- 5	N	61 8.6	16.927	14.555	12.2	8.0	-19	61 14.7	16.891	14.207	7.8	7.7
2421857.1	1918/ 9/20-13	F	61 15.3	16.909	14.059	3.2	1.3	16	61 19.6	16.895	14.263	7.1	1.0
2421886.6	1918/10/19-22	F	61 27.1	17.051	14.942	13.5	- 9.9	- 6	61 27.7	17.047	14.817	12.4	- 9.8
2422049.0	1919/ 3/31-21	N	60 57.7	16.903	14.261	7.8	4.0	24	61 7.0	16.918	14.788	12.8	4.4
2422078.6	1919/ 4/30- 6	N	61 23.5	17.003	15.466	16.5	14.4	1	61 23.6	17.005	15.507	16.8	14.5
2422108.1	1919/ 5/29-13	N	61 3.6	16.885	16.173	21.2	21.5	-20	61 10.3	16.871	15.921	19.7	21.4
2422270.5	1919/11/ 8- 0	F	61 17.9	17.049	15.582	17.1	-16.2	14	61 21.5	17.046	15.916	18.8	-16.4
2422300.0	1919/12/ 7-10	F	61 26.5	17.131	16.356	20.8	-22.5	- 7	61 27.5	17.131	16.320	20.5	-22.5
2422462.5	1920/ 5/18- 6	N	60 57.0	16.858	15.730	18.5	19.5	24	61 6.1	16.872	16.073	19.9	19.7
2422492.0	1920/ 6/16-14	N	61 22.6	16.944	16.239	20.0	23.3	1	61 22.6	16.944	16.232	20.0	23.3
2422521.5	1920/ 7/15-20	N	61 4.0	16.818	15.501	16.8	21.5	-20	61 10.7	16.827	15.902	18.8	21.6
2422683.9	1920/12/25-13	F	61 23.6	17.093	16.116	19.0	-23.4	12	61 26.1	17.077	16.005	18.3	-23.4
2422713.5	1921/ 1/23-23	F	61 26.4	17.077	15.401	14.5	-19.4	-10	61 28.0	17.071	15.605	15.8	-19.5
2422875.9	1921/ 7/ 5-14	N	60 58.5	16.787	15.741	17.9	22.8	23	61 7.3	16.777	15.451	15.7	22.7
2422905.4	1921/ 8/ 3-20	N	61 23.7	16.929	15.226	12.9	17.5	2	61 23.7	16.928	15.197	12.7	17.5
2422935.0	1921/ 9/ 2- 4	N	61 4.4	16.898	14.444	5.1	8.1	-20	61 11.1	16.900	14.729	8.8	8.5
2423097.4	1922/ 2/12- 1	F	61 24.7	17.086	14.993	10.4	-14.0	10	61 26.4	17.086	14.860	8.8	-13.9
2423126.9	1922/ 3/13-11	F	61 21.1	17.046	14.510	1.8	- 3.1	-12	61 23.5	17.036	14.587	4.1	- 3.3
2423289.3	1922/ 8/22-21	N	60 58.3	16.851	14.702	9.3	11.8	23	61 7.0	16.838	14.497	5.1	11.5
2423318.9	1922/ 9/21- 5	N	61 24.0	17.034	14.535	0.8	1.0	1	61 24.0	17.033	14.533	0.6	1.0

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2423348.4	1922/10/20–14	N	61 3.3	16.978	14.641	– 8.0	–10.2	–21	61 10.7	16.987	14.490	– 4.1	– 9.9
2423510.8	1923/ 4/ 1–13	F	61 23.7	17.043	14.543	– 2.6	4.3	8	61 24.9	17.040	14.596	– 4.1	4.4
2423540.3	1923/ 4/30–22	F	61 17.9	16.920	14.985	–10.9	14.7	–14	61 20.9	16.917	14.802	– 8.6	14.5
2423702.8	1923/10/10– 6	N	61 3.4	16.947	14.379	– 3.5	– 6.3	22	61 11.3	16.904	14.644	– 7.7	– 6.6
2423732.3	1923/11/ 8–15	N	61 28.1	17.062	15.145	–12.0	–16.4	0	61 28.1	17.062	15.141	–11.9	–16.4
2423761.8	1923/12/ 8– 2	N	61 2.9	17.001	15.738	–17.7	–22.6	–23	61 11.5	16.964	15.441	–15.4	–22.5
2423924.2	1924/ 5/18–22	F	61 23.9	16.913	15.414	–14.8	19.6	7	61 24.9	16.914	15.563	–15.7	19.7
2423953.8	1924/ 6/17– 5	F	61 16.8	16.870	16.044	–19.0	23.4	–14	61 20.0	16.854	15.905	–18.1	23.3
2424116.2	1924/11/26–17	N	61 9.2	17.000	15.451	–16.3	–21.0	20	61 15.6	16.977	15.868	–18.4	–21.1
2424145.7	1924/12/26– 4	N	61 28.4	17.122	16.287	–20.0	–23.4	– 3	61 28.5	17.120	16.273	–19.9	–23.4
2424337.7	1925/ 7/ 6– 5	F	61 21.6	16.921	16.323	–20.8	22.7	7	61 22.6	16.923	16.301	–20.7	22.7
2424367.2	1925/ 8/ 4–12	F	61 15.1	16.912	15.698	–17.9	17.3	–14	61 18.3	16.917	15.989	–19.3	17.5
2424529.6	1926/ 1/14– 7	N	61 12.4	17.091	16.247	–21.2	–21.4	17	61 17.5	17.076	16.031	–20.0	–21.3
2424559.1	1926/ 2/12–17	N	61 26.2	17.101	15.396	–16.1	–13.8	– 5	61 26.6	17.102	15.529	–16.9	–13.8
2424751.1	1926/ 8/23–13	F	61 23.8	16.945	15.115	–14.9	11.6	7	61 24.7	16.936	14.932	–13.5	11.5
2424780.6	1926/ 9/21–20	F	61 17.5	16.939	14.154	– 5.2	0.8	–13	61 20.9	16.943	14.375	– 8.4	1.0
2424943.0	1927/ 3/ 3–19	N	61 16.1	17.024	14.495	–11.3	– 7.0	15	61 20.0	17.012	14.234	– 7.9	– 6.7
2424972.6	1927/ 4/ 2– 4	N	61 24.5	16.997	13.979	0.0	4.5	– 6	61 25.3	16.989	13.996	– 1.8	4.4
2425164.5	1927/10/10–21	F	61 26.7	17.004	13.920	2.3	– 6.5	7	61 27.4	17.005	13.972	4.0	– 6.6
2425194.0	1927/11/ 9– 7	F	61 16.8	17.062	14.646	13.9	–16.6	–15	61 20.9	17.043	14.287	10.3	–16.4
2425356.5	1928/ 4/20– 5	N	61 14.4	16.959	14.011	8.3	11.4	14	61 17.7	16.976	14.345	11.8	11.6
2425386.0	1928/ 5/19–13	N	61 19.9	16.976	15.342	18.8	19.8	– 7	61 20.9	16.968	15.079	17.2	19.7
2425577.9	1928/11/27– 9	F	61 28.3	17.131	15.849	21.5	–21.1	5	61 28.6	17.131	16.021	22.3	–21.2
2425607.5	1928/12/26–20	F	61 13.8	17.070	16.933	26.3	–23.3	–18	61 19.1	17.062	16.727	25.4	–23.4
2425769.9	1929/ 6/ 7–14	N	61 13.5	16.922	16.480	25.0	22.7	13	61 16.7	16.922	16.851	26.2	22.8
2425799.4	1929/ 7/ 6–21	N	61 19.8	16.909	17.045	26.8	22.7	– 8	61 20.9	16.914	17.107	26.9	22.7
2425991.4	1930/ 1/14–22	F	61 31.3	17.109	16.855	26.0	–21.3	2	61 31.4	17.108	16.797	25.8	–21.3
2426020.9	1930/ 2/13– 9	F	61 10.6	16.993	14.857	18.0	–13.5	–20	61 17.3	16.963	15.721	22.2	–13.8
2426183.3	1930/ 7/25–21	N	61 14.9	16.877	16.242	24.5	19.7	13	61 18.0	16.868	15.717	22.2	19.6
2426212.9	1930/ 8/24– 4	N	61 20.9	16.950	14.468	15.3	11.4	– 8	61 22.0	16.951	14.764	17.2	11.5
2426375.3	1931/ 2/ 3– 0	F	61 5.1	17.005	15.322	21.2	–16.9	22	61 13.3	16.985	14.483	16.1	–16.6
2426404.8	1931/ 3/ 4–11	F	61 29.0	17.090	13.816	9.2	– 6.7	– 1	61 29.0	17.090	13.821	9.3	– 6.7
2426434.3	1931/ 4/ 2–20	F	61 3.5	16.926	13.362	– 4.6	4.8	–22	61 11.6	16.905	13.344	2.1	4.4
2426596.8	1931/ 9/12– 4	N	61 15.4	16.974	13.494	6.0	4.6	14	61 18.3	16.966	13.381	2.0	4.4
2426626.3	1931/10/11–13	N	61 21.0	17.049	13.629	– 7.8	– 6.8	– 8	61 22.3	17.056	13.503	– 5.3	– 6.6
2426788.7	1932/ 3/22–12	F	61 6.2	16.990	13.284	– 1.1	0.7	21	61 13.4	16.982	13.547	– 7.3	1.0
2426818.2	1932/ 4/20–21	F	61 26.7	17.000	14.338	–14.5	11.7	– 1	61 26.7	17.000	14.284	–14.1	11.6
2426847.8	1932/ 5/20– 5	F	61 0.8	16.796	16.011	–24.4	19.9	–23	61 9.6	16.780	15.072	–19.8	19.7
2427010.2	1932/10/29–15	N	61 20.7	17.037	14.698	–17.2	–13.5	12	61 23.0	17.018	15.200	–19.9	–13.7
2427039.7	1932/11/28– 1	N	61 23.2	17.062	16.683	–26.1	–21.2	–10	61 25.1	17.058	16.325	–24.7	–21.2
2427202.1	1933/ 5/ 9–22	F	61 7.9	16.858	15.580	–22.1	17.4	20	61 14.4	16.855	16.412	–25.3	17.6
2427231.7	1933/ 6/ 8– 5	F	61 26.2	16.906	17.195	–27.6	22.8	– 2	61 26.2	16.905	17.167	–27.5	22.8
2427261.2	1933/ 7/ 7–12	F	60 59.9	16.790	16.540	–26.2	22.6	–24	61 8.9	16.770	17.100	–27.8	22.7
2427423.6	1933/12/17– 3	N	61 24.3	17.083	17.223	–27.5	–23.3	9	61 25.8	17.081	17.177	–27.3	–23.3
2427453.1	1934/ 1/15–14	N	61 19.9	17.107	16.032	–23.3	–21.2	–13	61 22.7	17.091	16.521	–25.2	–21.3

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2427615.6	1934/ 6/27– 5	F	61 6.0	16.824	16.780	–26.4	23.3	20	61 12.5	16.833	16.294	–24.4	23.3
2427645.1	1934/ 7/26–12	F	61 24.3	16.951	15.454	–20.2	19.5	– 2	61 24.4	16.951	15.523	–20.6	19.6
2427674.6	1934/ 8/24–20	F	60 58.5	16.842	13.793	– 9.4	11.1	–24	61 7.7	16.861	14.535	–15.5	11.5
2427837.0	1935/ 2/ 3–16	N	61 24.9	17.125	14.740	–15.5	–16.7	7	61 25.7	17.122	14.524	–13.9	–16.6
2427866.6	1935/ 3/ 5– 3	N	61 15.5	17.017	13.672	– 3.2	– 6.4	–16	61 19.4	17.010	13.885	– 7.3	– 6.7
2428029.0	1935/ 8/14–13	F	61 7.6	16.868	14.274	–12.2	14.6	19	61 14.0	16.841	13.889	– 7.1	14.3
2428058.5	1935/ 9/12–20	F	61 27.1	16.973	13.796	– 0.3	4.3	– 2	61 27.1	16.974	13.800	– 0.8	4.3
2428088.0	1935/10/12– 5	F	61 0.1	16.902	14.198	11.7	– 7.0	–24	61 9.7	16.889	13.816	5.5	– 6.7
2428250.5	1936/ 3/23– 4	N	61 25.6	17.019	14.025	5.5	0.9	5	61 26.1	17.020	14.096	6.8	1.0
2428280.0	1936/ 4/21–13	N	61 12.3	16.930	14.994	16.2	11.9	–17	61 16.9	16.900	14.550	12.6	11.7
2428442.4	1936/ 9/30–21	F	61 11.6	16.907	14.124	7.5	– 3.0	19	61 17.4	16.890	14.538	11.9	– 3.3
2428471.9	1936/10/30– 6	F	61 28.7	17.071	15.410	17.4	–13.7	– 3	61 28.9	17.069	15.321	16.8	–13.7
2428663.9	1937/ 5/10–13	N	61 22.2	16.983	15.924	19.8	17.6	5	61 22.5	16.989	16.027	20.3	17.6
2428693.4	1937/ 6/ 8–21	N	61 7.9	16.901	16.415	22.6	22.9	–18	61 13.0	16.892	16.357	22.2	22.8
2428855.8	1937/11/18– 8	F	61 14.8	17.049	16.006	20.1	–19.2	17	61 19.5	17.043	16.311	21.3	–19.3
2428885.4	1937/12/17–19	F	61 28.3	17.143	16.447	21.6	–23.4	– 5	61 28.8	17.143	16.482	21.7	–23.4
2429077.3	1938/ 6/27–21	N	61 21.8	16.940	16.145	20.0	23.3	4	61 22.1	16.937	16.084	19.7	23.3
2429106.9	1938/ 7/27– 4	N	61 8.9	16.848	15.155	14.8	19.4	–17	61 13.8	16.859	15.581	17.3	19.5
2429269.3	1939/ 1/ 5–21	F	61 20.7	17.085	15.880	18.3	–22.6	14	61 24.2	17.064	15.640	16.8	–22.6
2429298.8	1939/ 2/ 4– 8	F	61 28.1	17.075	14.996	11.7	–16.5	– 8	61 29.2	17.071	15.161	13.0	–16.5
2429490.7	1939/ 8/15– 4	N	61 23.3	16.934	14.846	9.9	14.4	4	61 23.6	16.933	14.780	9.1	14.3
2429520.3	1939/ 9/13–11	N	61 9.4	16.939	14.330	1.0	4.0	–17	61 14.6	16.940	14.452	4.5	4.3
2429682.7	1940/ 2/23–10	F	61 21.7	17.062	14.648	6.7	–10.2	12	61 24.2	17.062	14.556	4.4	–10.0
2429712.2	1940/ 3/23–20	F	61 23.1	17.040	14.517	– 2.6	1.2	–10	61 24.7	17.032	14.499	– 0.6	1.0
2429904.2	1940/10/ 1–13	N	61 24.1	17.047	14.574	– 3.5	– 3.2	3	61 24.3	17.045	14.598	– 4.2	– 3.3
2429933.7	1940/10/30–22	N	61 8.4	17.016	15.009	–11.8	–14.0	–18	61 14.3	17.021	14.767	– 8.7	–13.7
2430096.1	1941/ 4/11–21	F	61 20.9	17.014	14.699	– 6.7	8.4	11	61 22.9	17.011	14.842	– 8.6	8.6
2430125.7	1941/ 5/11– 5	F	61 20.5	16.921	15.380	–14.0	17.8	–11	61 22.5	16.920	15.204	–12.5	17.7
2430288.1	1941/10/20–14	N	60 58.8	16.940	14.565	– 7.6	–10.3	25	61 8.4	16.890	14.999	–11.7	–10.7
2430317.6	1941/11/19– 0	N	61 28.5	17.075	15.544	–14.8	–19.3	2	61 28.5	17.073	15.577	–15.1	–19.3
2430347.1	1941/12/18–10	N	61 7.8	17.023	15.951	–18.4	–23.4	–20	61 14.9	16.990	15.830	–17.4	–23.4
2430509.6	1942/ 5/30– 6	F	61 21.3	16.889	15.741	–16.7	21.7	9	61 23.1	16.889	15.899	–17.6	21.7
2430539.1	1942/ 6/28–12	F	61 19.9	16.881	16.106	–18.9	23.3	–11	61 22.0	16.870	16.096	–18.8	23.3
2430701.5	1942/12/ 8– 2	N	61 5.0	16.995	15.749	–17.8	–22.6	22	61 12.8	16.966	16.048	–19.1	–22.7
2430731.0	1943/ 1/ 6–13	N	61 28.7	17.122	16.208	–19.2	–22.6	– 1	61 28.7	17.122	16.211	–19.2	–22.6
2430760.6	1943/ 2/ 5– 0	N	61 1.1	17.021	15.323	–15.4	–16.2	–24	61 10.0	16.983	15.799	–17.9	–16.5
2430923.0	1943/ 7/17–12	F	61 19.4	16.910	16.091	–19.3	21.3	11	61 21.2	16.911	15.973	–18.7	21.2
2430952.5	1943/ 8/15–20	F	61 18.5	16.941	15.305	–14.7	14.1	–11	61 20.7	16.946	15.551	–16.2	14.3
2431114.9	1944/ 1/25–15	N	61 8.3	17.072	15.849	–18.9	–19.1	20	61 14.6	17.054	15.508	–16.7	–18.9
2431144.5	1944/ 2/24– 2	N	61 26.7	17.095	14.979	–12.2	– 9.9	– 3	61 26.8	17.095	15.046	–12.7	–10.0
2431336.4	1944/ 9/ 2–20	F	61 22.1	16.952	14.733	–11.0	7.7	10	61 23.7	16.938	14.557	– 8.9	7.6
2431365.9	1944/10/ 2– 4	F	61 21.2	16.974	14.166	– 0.9	– 3.5	–11	61 23.5	16.976	14.237	– 3.6	– 3.3
2431528.4	1945/ 3/14– 4	N	61 11.9	16.993	14.223	– 7.0	– 2.7	17	61 17.0	16.982	14.088	– 2.9	– 2.4
2431557.9	1945/ 4/12–13	N	61 25.2	16.987	14.163	4.1	8.7	– 5	61 25.6	16.981	14.130	3.0	8.6
2431749.8	1945/10/21– 6	F	61 25.5	17.013	14.165	6.3	–10.6	8	61 26.7	17.013	14.313	8.4	–10.7

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2431779.4	1945/11/19–15	F	61 20.5	17.090	15.193	16.7	–19.5	–13	61 23.5	17.073	14.841	14.1	–19.4
2431941.8	1946/ 5/ 1–13	N	61 10.1	16.922	14.393	11.8	15.0	17	61 14.7	16.943	14.884	15.5	15.2
2431971.3	1946/ 5/30–21	N	61 21.1	16.972	15.840	20.7	21.8	– 5	61 21.6	16.968	15.679	19.9	21.7
2432163.3	1946/12/ 8–18	F	61 27.3	17.137	16.320	23.1	–22.7	7	61 28.1	17.135	16.512	23.8	–22.7
2432192.8	1947/ 1/ 7– 5	F	61 17.5	17.083	16.833	25.4	–22.5	–16	61 21.6	17.078	16.891	25.5	–22.5
2432355.2	1947/ 6/18–21	N	61 9.6	16.897	16.713	25.5	23.4	17	61 14.1	16.893	16.931	26.2	23.4
2432384.7	1947/ 7/18– 4	N	61 21.6	16.921	16.724	25.2	21.2	– 5	61 22.1	16.925	16.830	25.6	21.2
2432576.7	1948/ 1/26– 7	F	61 30.4	17.103	16.294	23.6	–19.0	4	61 30.8	17.100	16.151	23.0	–18.9
2432606.2	1948/ 2/24–17	F	61 14.4	16.994	14.378	14.1	– 9.7	–18	61 19.8	16.971	15.049	18.3	– 9.9
2432768.6	1948/ 8/ 5– 4	N	61 11.4	16.867	15.631	21.8	17.0	16	61 15.8	16.852	15.006	18.5	16.8
2432798.2	1948/ 9/ 3–11	N	61 23.1	16.970	14.075	11.4	7.5	– 5	61 23.5	16.971	14.224	12.8	7.6
2432990.1	1949/ 3/14–19	F	61 28.1	17.071	13.595	5.0	– 2.4	2	61 28.2	17.072	13.573	4.4	– 2.4
2433019.7	1949/ 4/13– 4	F	61 7.9	16.933	13.657	– 8.7	8.9	–20	61 14.4	16.915	13.416	– 2.9	8.6
2433182.1	1949/ 9/22–12	N	61 12.4	16.973	13.360	1.8	0.3	16	61 16.6	16.962	13.408	– 2.9	0.1
2433211.6	1949/10/21–21	N	61 23.4	17.073	14.004	–11.8	–10.8	– 6	61 24.1	17.077	13.847	–10.1	–10.7
2433374.0	1950/ 4/ 2–21	F	61 0.7	16.943	13.362	– 5.4	5.0	23	61 9.6	16.938	13.919	–12.1	5.3
2433403.6	1950/ 5/ 2– 5	F	61 26.2	16.985	14.867	–18.0	15.2	1	61 26.2	16.985	14.906	–18.2	15.2
2433433.1	1950/ 5/31–13	F	61 5.9	16.813	16.577	–26.4	21.9	–21	61 12.9	16.802	15.823	–23.2	21.8
2433595.5	1950/11/ 9–23	N	61 18.4	17.041	15.286	–20.6	–16.9	14	61 21.6	17.018	15.921	–23.4	–17.1
2433625.0	1950/12/ 9–10	N	61 25.7	17.076	17.148	–27.7	–22.8	– 8	61 26.9	17.074	16.953	–27.0	–22.7
2433787.4	1951/ 5/21– 6	F	61 2.4	16.815	16.123	–24.7	20.0	22	61 10.7	16.811	16.927	–27.4	20.2
2433817.0	1951/ 6/19–13	F	61 26.1	16.899	17.344	–28.2	23.4	0	61 26.1	16.900	17.343	–28.2	23.4
2433846.5	1951/ 7/18–19	F	61 5.4	16.823	16.131	–24.7	21.1	–20	61 12.5	16.808	16.886	–27.2	21.2
2434008.9	1951/12/28–12	N	61 22.0	17.079	17.123	–27.5	–23.3	11	61 24.3	17.076	16.879	–26.6	–23.3
2434038.5	1952/ 1/26–22	N	61 22.3	17.109	15.442	–20.9	–18.8	–10	61 24.3	17.096	15.910	–23.0	–18.9
2434200.9	1952/ 7/ 7–13	F	61 0.7	16.793	16.440	–25.6	22.6	22	61 9.1	16.799	15.657	–22.2	22.5
2434230.4	1952/ 8/ 5–20	F	61 24.7	16.959	14.895	–17.6	16.8	1	61 24.7	16.959	14.858	–17.4	16.8
2434259.9	1952/ 9/ 4– 3	F	61 4.3	16.891	13.517	– 5.6	7.2	–20	61 11.6	16.906	13.994	–11.4	7.6
2434422.4	1953/ 2/14– 1	N	61 22.6	17.111	14.198	–12.1	–13.2	9	61 24.1	17.106	13.979	– 9.7	–13.0
2434451.9	1953/ 3/15–11	N	61 18.2	17.015	13.566	1.1	– 2.2	–13	61 21.0	17.010	13.610	– 2.6	– 2.4
2434614.3	1953/ 8/24–20	F	61 2.9	16.853	13.823	– 8.7	11.0	23	61 11.1	16.821	13.581	– 2.5	10.7
2434643.8	1953/ 9/23– 4	F	61 27.9	16.993	13.765	3.9	0.1	1	61 27.9	16.992	13.769	4.0	0.1
2434673.4	1953/10/22–13	F	61 5.8	16.947	14.645	15.7	–11.1	–21	61 13.6	16.932	14.089	10.5	–10.7
2434835.8	1954/ 4/ 3–12	N	61 23.5	16.996	14.192	9.8	5.2	8	61 24.4	16.999	14.373	11.6	5.3
2434865.3	1954/ 5/ 2–20	N	61 15.5	16.931	15.532	19.8	15.4	–14	61 18.9	16.907	15.074	17.1	15.2
2435027.7	1954/10/12– 5	F	61 7.5	16.904	14.343	11.7	– 7.2	21	61 14.7	16.883	14.993	16.4	– 7.5
2435057.3	1954/11/10–15	F	61 29.7	17.087	15.953	20.8	–17.1	– 1	61 29.7	17.086	15.926	20.7	–17.1
2435086.8	1954/12/10– 1	F	61 2.0	17.037	16.593	24.5	–22.8	–23	61 11.2	16.999	16.424	23.5	–22.7
2435249.2	1955/ 5/21–21	N	61 20.3	16.962	16.359	22.4	20.2	7	61 21.1	16.971	16.486	22.9	20.2
2435278.7	1955/ 6/20– 4	N	61 11.7	16.916	16.474	23.2	23.4	–14	61 15.3	16.912	16.603	23.6	23.4
2435441.2	1955/11/29–17	F	61 11.2	17.047	16.360	22.4	–21.4	19	61 17.2	17.036	16.520	22.8	–21.6
2435470.7	1955/12/29– 4	F	61 29.4	17.150	16.319	21.5	–23.3	– 4	61 29.6	17.151	16.380	21.8	–23.3
2435662.6	1956/ 7/ 8– 5	N	61 20.3	16.935	15.877	19.3	22.5	6	61 21.1	16.929	15.723	18.4	22.5
2435692.2	1956/ 8/ 6–11	N	61 13.2	16.878	14.765	12.1	16.6	–14	61 16.7	16.890	15.130	14.8	16.8
2435854.6	1957/ 1/16– 6	F	61 17.3	17.072	15.485	16.7	–21.0	16	61 21.8	17.046	15.146	14.2	–20.8

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2435884.1	1957/ 2/14–17	F	61 29.3	17.069	14.613	8.2	–12.9	– 6	61 29.9	17.067	14.712	9.4	–13.0
2436076.1	1957/ 8/25–12	N	61 22.3	16.939	14.512	6.3	10.8	6	61 23.1	16.935	14.447	4.9	10.7
2436105.6	1957/ 9/23–19	N	61 13.9	16.976	14.344	– 3.3	– 0.2	–14	61 17.6	16.975	14.324	– 0.2	0.0
2436268.0	1958/ 3/ 5–18	F	61 18.1	17.034	14.408	2.6	– 6.0	14	61 21.7	17.034	14.409	– 0.4	– 5.8
2436297.5	1958/ 4/ 4– 4	F	61 24.6	17.031	14.663	– 6.9	5.5	– 8	61 25.5	17.025	14.587	– 5.4	5.4
2436489.5	1958/10/12–21	N	61 23.6	17.058	14.747	– 7.7	– 7.4	6	61 24.2	17.054	14.831	– 8.8	– 7.5
2436519.0	1958/11/11– 7	N	61 12.9	17.049	15.435	–15.1	–17.3	–16	61 17.4	17.051	15.177	–12.9	–17.1
2436681.4	1959/ 4/23– 5	F	61 17.5	16.981	14.963	–10.6	12.3	13	61 20.4	16.978	15.204	–12.6	12.5
2436711.0	1959/ 5/22–13	F	61 22.6	16.921	15.755	–16.5	20.3	– 8	61 23.7	16.921	15.634	–15.7	20.2
2436902.9	1959/11/30– 9	N	61 28.3	17.083	15.889	–17.0	–21.5	4	61 28.5	17.080	15.940	–17.3	–21.6
2436932.5	1959/12/29–19	N	61 12.2	17.039	15.975	–18.3	–23.2	–18	61 17.8	17.011	16.035	–18.4	–23.3
2437094.9	1960/ 6/ 9–13	F	61 18.1	16.864	15.954	–18.0	23.0	13	61 20.9	16.863	16.057	–18.4	23.0
2437124.4	1960/ 7/ 8–20	F	61 22.4	16.892	15.998	–18.0	22.4	– 9	61 23.6	16.886	16.065	–18.3	22.4
2437286.8	1960/12/18–11	N	61 0.3	16.986	15.893	–18.6	–23.4	24	61 9.7	16.950	15.993	–18.7	–23.4
2437316.4	1961/ 1/16–22	N	61 28.5	17.119	15.952	–17.6	–20.8	1	61 28.5	17.119	15.934	–17.4	–20.8
2437345.9	1961/ 2/15– 8	N	61 5.5	17.028	14.961	–11.9	–12.7	–21	61 12.9	16.997	15.399	–14.9	–13.0
2437508.3	1961/ 7/27–20	F	61 16.6	16.899	15.738	–17.1	19.1	13	61 19.4	16.899	15.532	–15.7	19.0
2437537.8	1961/ 8/26– 3	F	61 21.4	16.969	14.958	–11.0	10.5	– 8	61 22.7	16.973	15.119	–12.4	10.6
2437700.3	1962/ 2/ 5– 0	N	61 3.5	17.047	15.383	–15.9	–16.1	22	61 11.4	17.027	15.004	–12.7	–15.9
2437729.8	1962/ 3/ 6–10	N	61 26.6	17.085	14.679	– 8.0	– 5.8	0	61 26.6	17.085	14.692	– 8.2	– 5.8
2437759.3	1962/ 4/ 4–20	N	61 0.5	16.895	14.189	1.8	5.7	–23	61 9.2	16.870	14.287	– 3.2	5.4
2437921.7	1962/ 9/14– 4	F	61 19.8	16.956	14.474	– 6.8	3.6	13	61 22.4	16.939	14.362	– 4.1	3.4
2437951.3	1962/10/13–13	F	61 24.3	17.006	14.320	3.2	– 7.7	– 9	61 25.8	17.006	14.293	1.2	– 7.6
2438113.7	1963/ 3/25–12	N	61 7.0	16.955	14.106	– 2.6	1.6	20	61 13.6	16.946	14.143	1.9	2.0
2438143.2	1963/ 4/23–21	N	61 25.4	16.974	14.466	7.9	12.5	– 3	61 25.5	16.971	14.433	7.4	12.5
2438172.7	1963/ 5/23– 4	N	60 57.4	16.829	15.209	16.6	20.4	–24	61 6.9	16.789	14.686	12.2	20.2
2438335.2	1963/11/ 1–14	F	61 23.7	17.019	14.521	10.0	–14.3	11	61 25.7	17.018	14.776	12.3	–14.5
2438364.7	1963/12/ 1– 0	F	61 23.6	17.111	15.703	18.8	–21.7	–11	61 25.7	17.097	15.422	17.1	–21.6
2438527.1	1964/ 5/11–21	N	61 5.2	16.882	14.824	14.7	18.1	19	61 11.4	16.907	15.428	18.3	18.3
2438556.6	1964/ 6/10– 4	N	61 21.8	16.967	16.216	21.8	23.0	– 2	61 21.9	16.965	16.157	21.6	23.0
2438748.6	1964/12/19– 3	F	61 25.8	17.138	16.605	23.8	–23.4	8	61 27.1	17.134	16.744	24.3	–23.4
2438778.1	1965/ 1/17–14	F	61 20.7	17.090	16.513	23.6	–20.7	–14	61 23.7	17.089	16.741	24.4	–20.8
2438940.5	1965/ 6/29– 5	N	61 5.0	16.870	16.729	25.3	23.2	19	61 11.2	16.862	16.708	25.0	23.2
2438970.1	1965/ 7/28–12	N	61 22.8	16.933	16.265	22.9	19.0	– 3	61 22.9	16.936	16.334	23.2	19.0
2438999.6	1965/ 8/26–19	N	60 56.4	16.812	14.549	14.9	10.3	–25	61 6.0	16.830	15.440	19.9	10.6
2439162.0	1966/ 2/ 5–16	F	61 29.0	17.091	15.674	20.5	–15.9	6	61 29.7	17.086	15.455	19.4	–15.8
2439191.5	1966/ 3/ 7– 2	F	61 17.8	16.994	14.045	9.9	– 5.5	–16	61 21.9	16.975	14.493	13.9	– 5.8
2439354.0	1966/ 8/16–12	N	61 7.3	16.856	15.029	18.5	13.8	19	61 13.2	16.835	14.403	14.1	13.5
2439383.5	1966/ 9/14–19	N	61 24.6	16.988	13.826	7.3	3.4	– 2	61 24.7	16.989	13.873	8.0	3.4
2439575.4	1967/ 3/26– 3	F	61 26.7	17.049	13.546	0.6	1.9	5	61 27.1	17.051	13.549	– 0.6	2.0
2439605.0	1967/ 4/24–12	F	61 11.8	16.939	14.089	–12.5	12.7	–17	61 16.8	16.924	13.702	– 7.6	12.5
2439767.4	1967/10/ 3–20	N	61 9.0	16.970	13.389	– 2.4	– 3.9	19	61 14.5	16.956	13.649	– 7.7	– 4.2
2439796.9	1967/11/ 2– 6	N	61 25.3	17.093	14.514	–15.5	–14.5	– 4	61 25.6	17.095	14.381	–14.5	–14.5
2439988.9	1968/ 5/12–13	F	61 25.2	16.969	15.454	–21.0	18.2	4	61 25.4	16.968	15.609	–21.8	18.3
2440018.4	1968/ 6/10–20	F	61 10.5	16.830	16.984	–27.5	23.1	–18	61 15.8	16.824	16.504	–25.7	23.0

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2440180.8	1968/11/20– 8	N	61 15.5	17.042	15.905	−23.5	−19.7	16	61 19.8	17.014	16.583	−26.0	−19.9
2440210.4	1968/12/19–18	N	61 27.6	17.086	17.372	−28.3	−23.4	− 6	61 28.2	17.085	17.324	−28.1	−23.4
2440402.3	1969/ 6/29–20	F	61 25.4	16.892	17.249	−28.0	23.2	4	61 25 6	16.893	17.189	−27.8	23.2
2440431.8	1969/ 7/29– 3	F	61 10.3	16.856	15.607	−22.4	18.8	−18	61 15.7	16.845	16.392	−25.4	19.0
2440594.2	1970/ 1/ 7–21	N	61 19.2	17.071	16.758	−26.5	−22.3	13	61 22 3	17.066	16.297	−24.7	−22.3
2440623.8	1970/ 2/ 6– 7	N	61 24.1	17.107	14.828	−17.8	−15.7	− 8	61 25.4	17.097	15.197	−19.8	−15.8
2440815.7	1970/ 8/17– 3	F	61 24.4	16.967	14.359	−14.4	13.6	4	61 24,6	16.966	14.241	−13.4	13.5
2440845.3	1970/ 9/15–11	F	61 9.5	16.936	13.373	− 1.5	3.1	−18	61 15.1	16.947	13.600	− 6.8	3.4
2441007.7	1971/ 2/25–10	N	61 19.8	17.091	13.761	− 8.2	− 9.3	11	61 22.1	17.086	13.599	− 5.0	− 9.1
2441037.2	1971/ 3/26–19	N	61 20.4	17.012	13.624	5.4	2.2	−10	61 22.3	17.008	13.538	2.3	2.0
2441229.2	1971/10/ 4–12	F	61 28.1	17.011	13.894	8.1	− 4.2	3	61 28.2	17.008	13.953	8.9	− 4.2
2441258.7	1971/11/ 2–21	F	61 11.0	16.986	15.221	19.5	−14.8	−18	61 17.2	16.970	14.577	15.3	−14.5
2441421.1	1972/ 4/13–21	N	61 20.7	16.970	14.513	13.9	9.3	9	61 22.4	16.974	14.844	16.2	9.5
2441450.6	1972/ 5/13– 4	N	61 18.2	16.930	16.109	22.8	18.4	−11	61 20.5	16.912	15.718	21.0	18.3
2441613.1	1972/10/22–13	F	61 3.0	16.900	14.710	15.8	−11.2	24	61 11.8	16.873	15.578	20.4	−11.5
2441642.6	1972/11/20–23	F	61 30.1	17.098	16.495	23.6	−19.9	1	61 30.1	17.099	16.527	23.8	−19.9
2441672.1	1972/12/20–10	F	61 7.0	17.062	16.666	25.1	−23.4	−21	61 14.6	17.029	16.807	25.3	−23.4
2441834.5	1973/ 6/ 1– 5	N	61 17.8	16.939	16.691	24.4	22.0	9	61 19.3	16.950	16.768	24.6	22.1
2441864.1	1973/ 6/30–12	N	61 15.0	16.930	16.330	23.1	23.2	−12	61 17.4	16.929	16.585	24.0	23.2
2442026.5	1973/12/10– 2	F	61 7.1	17.040	16.557	23.9	−22.9	21	61 14.5	17.024	16.462	23.2	−23.0
2442056.0	1974/ 1/ 8–13	F	61 30.0	17.152	15.984	20.5	−22.2	− 2	61 30.0	17.153	16.022	20.7	−22.3
2442085.5	1974/ 2/ 6–23	F	61 1.7	16.970	14.423	11.7	−15.5	−24	61 11.0	16.952	15.132	16.6	−15.8
2442248.0	1974/ 7/19–12	N	61 18.3	16.930	15.471	17.8	20.9	10	61 19.9	16.920	15.216	16.1	20.8
2442277.5	1974/ 8/17–19	N	61 16.9	16.906	14.387	9.0	13 4	−12	61 19.2	16.918	14.644	11.5	13.5
2442439.9	1975/ 1/27–15	F	61 13 3	17.053	14.999	14.3	−18.5	18	61 19.0	17.021	14.626	10.7	−18.3
2442469.4	1975/ 2/26– 1	F	61 30.0	17.059	14.310	4.4	− 9.0	− 3	61 30.2	17.059	14.348	5.2	− 9.1
2442661.4	1975/ 9/ 5–19	N	61 20.7	16.943	14.270	2.4	6.8	10	61 22.2	16.937	14.256	0.3	6.7
2442690.9	1975/10/ 5– 4	N	61 17.7	17.009	14.499	− 7.6	− 4.5	−13	61 20.3	17.006	14.374	− 5.0	− 4.3
2442853.3	1976/ 3/16– 3	F	61 14.0	16.999	14.299	− 1.7	− 1.7	16	61 18.7	17.001	14.443	− 5.2	− 1.5
2442882.9	1976/ 4/14–12	F	61 25.5	17.019	14.938	−11.0	9.6	− 5	61 26.0	17.015	14.848	−10.1	9.5
2443074.8	1976/10/23– 5	N	61 22.6	17.066	15.042	−11.8	−11.4	8	61 23.7	17.061	15.204	−13.1	−11.6
2443104.3	1976/11/21–15	N	61 16.8	17.075	15.851	−17.8	−20.0	−13	61 20.2	17.076	15.648	−16.4	−19.9
2443266.8	1977/ 5/ 3–13	F	61 13.4	16.944	15.298	−14.1	15.7	16	61 17.7	16.942	15.609	−16.0	15.9
2443296.3	1977/ 6/ 1–21	F	61 24.1	16.920	16.047	−18.3	22.1	− 6	61 24.6	16.921	15.996	−18.0	22.1
2443488.2	1977/12/10–18	N	61 27.5	17.089	16.108	−18.4	−22.9	5	61 28.1	17.083	16.138	−18.5	−23.0
2443517.8	1978/ 1/ 9– 4	N	61 16.0	17.050	15.816	−17.2	−22.2	−16	61 20.4	17.027	16.013	−18.2	−22.2
2443680.2	1978/ 6/20–21	F	61 14.3	16.839	16.012	−18.4	23.4	15	61 18.3	16.834	15.998	−18.2	23.4
2443709.7	1978/ 7/20– 3	F	61 24.3	16.902	15.748	−16.4	20.7	− 5	61 24.8	16.900	15.832	−16.8	20.8
2443901.7	1979/ 1/28– 6	N	61 27.7	17 111	15.583	−15.1	−18.3	4	61 27.9	17.113	15.526	−14.7	−18.3
2443931.2	1979/ 2/26–17	N	61 9.4	17.032	14.674	− 7.9	− 8.8	−19	61 15.3	17.007	14.996	−11.1	− 9.0
2444093.6	1979/ 8/ 8– 3	F	61 13.2	16.888	15.331	−14.3	16.3	16	61 17.3	16.885	15.080	−12.0	16.2
2444123.2	1979/ 9/ 6–11	F	61 23.7	16.995	14.702	. 7.0	6 6	− 6	61 24.4	16.997	14 778	− 8.0	6.7
2444285.6	1980/ 2/16– 9	N	60 58.2	17.014	14.933	−12.4	−12.6	24	61 7.8	16.993	14 612	− 8.2	−12.2
2444315.1	1980/ 3/16–19	N	61 25.9	17.072	14.517	− 3.7	− 1.4	1	61 26.0	17.072	14.509	− 3.4	− 1 4
2444344.6	1980/ 4/15– 4	N	61 5.0	16.901	14.421	5.8	9.8	−21	61 12.0	16.882	14.338	1.6	9.5

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2444507.1	1980/ 9/24–12	F	61 17 1	16.958	14.354	– 2.5	– 0.6	15	61 20.7	16.937	14.352	0.6	– 0 9
2444536.6	1980/10/23–21	F	61 26.9	17.033	14.598	7.2	–11.7	– 7	61 27.7	17 033	14.526	5.8	–11.6
2444699.0	1981/ 4/ 4–20	N	61 1.5	16.912	14.137	1 6	5.9	23	61 9.8	16.907	14.372	6.5	6.3
2444728.5	1981/ 5/ 4– 4	N	61 25.0	16.959	14.847	11.2	15 9	1	61 25.0	16.959	14 853	11.3	15 9
2444758.1	1981/ 6/ 2–12	N	61 2.6	16.847	15.637	18 3	22 2	–22	61 10 1	16.815	15.212	15.3	22.1
2444920.5	1981/11/11–23	F	61 21 3	17.023	14 944	13.2	–17.6	13	61 24.2	17.021	15.284	15.5	–17.7
2444950.0	1981/12/11– 9	F	61 26.1	17 126	16 094	20 1	–23.0	– 9	61 27.5	17.116	15.920	19.2	–23.0
2445112.4	1982/ 5/23– 5	N	60 59 8	16.839	15.243	17 1	20 5	22	61 7.8	16.868	15 872	20.2	20.7
2445142.0	1982/ 6/21–12	N	61 21 9	16.962	16.419	22 2	23 4	0	61 21.9	16.962	16.422	22.2	23.4
2445171.5	1982/ 7/20–19	N	61 0 1	16.844	16.164	21.9	20.6	–22	61 7.8	16.860	16.426	22.7	20.8
2445333.9	1982/12/30–12	F	61 23.7	17.135	16.657	23.5	–23.2	10	61 25.7	17.128	16.679	23.5	–23 1
2445363.4	1983/ 1/28–22	F	61 23.3	17.093	16.056	21.0	–18.2	–11	61 25.5	17.094	16.344	22.2	–18.3
2445525.9	1983/ 7/10–12	N	60 59.9	16.842	16.533	24.3	22.3	22	61 7.9	16.829	16.245	22.8	22 2
2445555.4	1983/ 8/ 8–19	N	61 23.4	16.945	15.747	20.0	16.1	1	61 23.4	16.945	15.737	19.9	16.1
2445584.9	1983/ 9/ 7– 3	N	61 2.3	16.858	14.235	10.9	6.3	–22	61 10.0	16.873	14.875	15.7	6.7
2445747.3	1984/ 2/17– 1	F	61 26.9	17.075	15.093	16.9	–12.3	8	61 28.1	17.067	14.838	15.1	–12.2
2445776.9	1984/ 3/17–10	F	61 20.7	16.990	13.876	5.6	– 1.2	–13	61 23.7	16.975	14.120	9.1	– 1 4
2445939.3	1984/ 8/26–19	N	61 2.7	16.845	14.507	14.8	10 1	22	61 10.4	16.816	13.979	9.4	9.8
2445968.8	1984/ 9/25– 3	N	61 25.6	17.004	13.735	3.0	– 0.9	0	61 25.6	17.004	13.736	3.1	– 0.9
2445998.3	1984/10/24–12	N	61 1 3	16.982	13.898	– 9.8	–11.9	–22	61 9.7	16.967	13.609	– 3.6	–11.6
2446160.8	1985/ 4/ 5–12	F	61 24.7	17.023	13.660	– 3.6	6.2	6	61 25.6	17.027	13.740	– 5.5	6.3
2446190.3	1985/ 5/ 4–20	F	61 15.2	16.943	14.620	–15.8	16.1	–15	61 18.9	16.931	14.172	–12.1	16.0
2446352.7	1985/10/14– 5	N	61 5.2	16.966	13.574	– 6.5	– 8.1	20	61 12.1	16.949	14.079	–12.3	– 8.4
2446382.2	1985/11/12–14	N	61 26.5	17.109	15.111	–18.7	–17.8	– 1	61 26.6	17.110	15.046	–18.4	–17.8
2446411.8	1985/12/12– 1	N	60 58.2	17.004	16.659	–26.4	–23.1	–24	61 8.0	16.982	15.926	–23.3	–23.0
2446574.2	1986/ 5/23–21	F	61 23 5	16.950	16.025	–23.4	20.6	6	61 24.2	16.948	16.277	–24.4	20.7
2446603.7	1986/ 6/22– 4	F	61 14 5	16.846	17.175	–27.9	23.4	–15	61 18.4	16.844	16.984	–27.1	23.4
2446766.1	1986/12/ 1–17	N	61 12.1	17.041	16.456	–25.6	–21.8	18	61 17.6	17.006	17.042	–27.5	–21.9
2446795.7	1986/12/31– 3	N	61 28 8	17.092	17.312	–28.0	–23.1	– 4	61 29.1	17.091	17.352	–28.1	–23.1
2446987.6	1987/ 7/11– 4	F	61 24.1	16.885	16.926	–27.0	22.2	6	61 24.8	16.885	16.736	–26.3	22.2
2447017.2	1987/ 8/ 9–10	F	61 14.7	16.888	15.048	–19.6	15.9	–15	61 18.6	16.880	15.732	–22.7	16.1
2447179.6	1988/ 1/19– 5	N	61 15 8	17.059	16 190	–24.6	–20 5	16	61 20.0	17.051	15.556	–21.8	–20.4
2447209.1	1988/ 2/17–16	N	61 25.4	17.101	14.277	–14.2	–12.1	– 7	61 26.1	17.094	14.516	–15.9	–12.2
2447401.1	1988/ 8/27–11	F	61 23.6	16.974	13.908	–10.8	9.9	6	61 24.2	16.972	13.761	– 9.0	9.8
2447430.6	1988/ 9/25–19	F	61 14.1	16.978	13.383	2.7	– 1.2	–15	61 18.2	16.986	13.401	– 1.9	– 0.9
2447593.0	1989/ 3/ 7–18	N	61 16 4	17.065	13.468	– 4.0	– 5.1	14	61 19.6	17.061	13.425	0.0	– 4.8
2447622.5	1989/ 4/ 6– 4	N	61 22.1	17.006	13.849	9.6	6.4	– 9	61 23.2	17.004	13.684	7.3	6 3
2447814.5	1989/10/14–21	F	61 27 8	17.026	14.190	12.3	– 8.4	5	61 28.2	17.021	14.351	13.7	– 8.4
2447844.0	1989/11/13– 6	F	61 15.6	17.020	15.871	22.8	–18.0	–16	61 20.4	17.004	15.239	19.6	–17.8
2448006.4	1990/ 4/25– 4	N	61 17.4	16.941	14.964	17.8	13.1	13	61 20.0	16.946	15.460	20.4	13.3
2448036.0	1990/ 5/24–12	N	61 20 3	16.928	16.647	25.3	20.8	– 9	61 21.7	16.916	16 383	24.2	20 7
2448227.9	1990/12/ 2– 8	F	61 30 0	17.106	16.937	25.7	–21.9	3	61 30.1	17.108	16.988	25.9	–22.0
2448257.4	1990/12/31–19	F	61 11.4	17 081	16 489	24.7	–23 1	–19	61 17 6	17.054	16.903	26 0	23 1
2448419 9	1991/ 6/12–12	N	61 14 7	16.915	16.854	25.6	23 1	12	61 17.3	16.927	16.783	25.2	23 2
2448449.4	1991/ 7/11–19	N	61 17.7	16.944	16.002	22.1	22 1	– 9	61 19.1	16 945	16.293	23.3	22 1

TABLE 16

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2448611.8	1991/12/21−10	F	61 2.5	17.029	16.533	24.4	−23.4	24	61 11.4	17.007	16.120	22.4	−23.4
2448641.3	1992/ 1/19−21	F	61 29.9	17.150	15.498	18.6	−20.3	1	61 30.0	17.150	15.477	18.5	−20.3
2448670.9	1992/ 2/18− 8	F	61 6.4	16.975	14.039	8.1	−11.8	−22	61 14.1	16.964	14.586	13.3	−12.2
2448833.3	1992/ 7/29−20	N	61 15.7	16.924	14.983	15.6	18.6	12	61 18.3	16.909	14.659	13.0	18.4
2448862.8	1992/ 8/28− 3	N	61 20.0	16.934	14.075	5.4	9.7	− 9	61 21.4	16.944	14.213	7.6	9.8
2449025.2	1993/ 2/ 7− 0	F	61 8.7	17.028	14.497	11.3	−15.4	20	61 15.9	16.992	14.178	6.6	−15.1
2449054.8	1993/ 3/ 8−10	F	61 30.0	17.046	14.130	0.2	− 4.8	− 2	61 30.1	17.046	14.131	0.6	− 4.8
2449084.3	1993/ 4/ 6−19	F	61 2.0	16.877	14.437	−10.6	6.7	−24	61 11.1	16.836	14.128	− 5.2	6.3
2449246.7	1993/ 9/16− 3	N	61 18.7	16.946	14.150	− 1.7	2.7	12	61 21.0	16.936	14.241	− 4.5	2.5
2449276.2	1993/10/15−12	N	61 21.0	17.037	14.796	−11.8	− 8.6	−10	61 22.7	17.034	14.614	− 9.8	− 8.5
2449438.7	1994/ 3/27−11	F	61 9.2	16.960	14.332	− 6.1	2.6	19	61 15.4	16.965	14.661	−10.0	2.9
2449468.2	1994/ 4/25−20	F	61 25.9	17.005	15.320	−14.9	13.3	− 3	61 26.0	17.003	15.258	−14.4	13.3
2449660.1	1994/11/ 3−14	N	61 21.0	17.072	15.428	−15.4	−15.1	10	61 22.8	17.066	15.659	−16.8	−15.2
2449689.7	1994/12/ 3− 0	N	61 20.1	17.095	16.178	−19.8	−22.0	−12	61 22.5	17.096	16.079	−19.2	−22.0
2449852.1	1995/ 5/14−21	F	61 8.8	16.904	15.649	−17.1	18.7	18	61 14.6	16.902	15.960	−18.6	18.9
2449881.6	1995/ 6/13− 4	F	61 25.0	16.919	16.201	−19.4	23.2	− 3	61 25.2	16.920	16.201	−19.4	23.2
2450073.6	1995/12/22− 2	N	61 26.2	17.091	16.149	−18.8	−23.4	8	61 27.3	17.082	16.112	−18.6	−23.4
2450103.1	1996/ 1/20−13	N	61 19.2	17.056	15.513	−15.4	−20.2	−14	61 22.6	17.038	15.775	−16.9	−20.3
2450265.5	1996/ 7/ 1− 4	F	61 9.9	16.814	15.900	−18.1	23.1	18	61 15.5	16.804	15.732	−16.9	23.0
2450295.0	1996/ 7/30−11	F	61 25.6	16.913	15.407	−14.0	18.4	− 3	61 25.7	16.912	15.460	−14.4	18.4
2450487.0	1997/ 2/ 7−15	N	61 26.3	17.099	15.178	−12.0	−15.2	6	61 26.8	17.102	15.091	−11.1	−15.1
2450516.5	1997/ 3/ 9− 1	N	61 12.9	17.034	14.501	− 3.7	− 4.5	−16	61 17.5	17.013	14.678	− 6.8	− 4.8
2450678.9	1997/ 8/18−11	F	61 9.2	16.877	14.932	−11.0	13.0	18	61 14.8	16.870	14.707	− 7.8	12.8
2450708.5	1997/ 9/16−19	F	61 25.4	17.018	14.564	− 2.7	2.4	− 3	61 25.6	17.019	14.583	− 3.4	2.5
2450900.4	1998/ 3/28− 3	N	61 24.7	17.055	14.498	0.7	2.9	4	61 24.9	17.055	14.506	1.4	2.9
2450930.0	1998/ 4/26−12	N	61 9.1	16.907	14.754	9.5	13.5	−18	61 14.5	16.893	14.559	6.1	13.3
2451092.4	1998/10/ 5−20	F	61 13.8	16.959	14.374	1.7	− 4.9	17	61 18.7	16.933	14.515	5.3	− 5.2
2451121.9	1998/11/ 4− 5	F	61 28.8	17.056	14.969	10.7	−15.3	− 4	61 29.2	17.056	14.896	9.9	−15.3
2451313.9	1999/ 5/15−12	N	61 24.1	16.943	15.254	14.0	18.8	3	61 24.2	16.945	15.316	14.5	18.9
2451343.4	1999/ 6/13−19	N	61 7.2	16.864	15.938	19.2	23.2	−18	61 13.0	16.840	15.676	17.5	23.2
2451505.8	1999/11/23− 7	F	61 18.5	17.025	15.370	15.7	−20.3	15	61 22.4	17.019	15.738	17.8	−20.4
2451535.3	1999/12/22−18	F	61 28.0	17.136	16.306	20.5	−23.4	− 7	61 28.8	17.129	16.237	20.2	−23.4

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	
2451727.3	2000/ 7/ 1-19	N	61 21.4	16.956	16.426	21.7	23.0	3	61 21.5	16.958	16.430	21.7	23.0
2451756.8	2000/ 7/31- 2	N	61 5.3	16.880	15.803	19.4	18.2	-18	61 11.1	16.896	16.182	21.0	18.4
2451919.2	2001/ 1/ 9-20	F	61 21.1	17.126	16.477	22.4	-22.0	13	61 24.0	17.116	16.350	21.7	-21.9
2451948.8	2001/ 2/ 8- 7	F	61 25.4	17.092	15.558	17.7	-14.9	-9	61 26.8	17.094	15.818	19.1	-15.1
2452140.7	2001/ 8/19- 3	N	61 23.5	16.957	15.247	16.5	12.8	3	61 23.6	16.952	15.163	16.0	12.7
2452170.2	2001/ 9/17-11	N	61 7.7	16.901	14.059	6.7	2.1	-19	61 13.6	16.912	14.449	11.1	2.4
2452332.7	2002/ 2/27- 9	F	61 24.3	17.053	14.621	12.8	-8.3	10	61 26.2	17.043	14.385	10.4	-8.2
2452362.2	2002/ 3/28-18	F	61 23.0	16.984	13.873	1.3	3.1	-11	61 25.1	16.973	13.954	4.2	3.0
2452524.6	2002/ 9/ 7- 3	N	60 57.7	16.833	14.109	10.8	6.2	25	61 7.3	16.796	13.764	4.5	5.8
2452554.1	2002/10/ 6-11	N	61 25.9	17.017	13.802	-1.2	-5.1	3	61 26.0	17.017	13.810	-1.8	-5.2
2452583.7	2002/11/ 4-21	N	61 6.6	17.022	14.397	-13.3	-15.5	-20	61 13.3	17.005	13.970	-8.3	-15.3
2452746.1	2003/ 4/16-20	F	61 22.1	16.993	13.920	-7.5	10.2	9	61 23.6	17.000	14.117	-10.0	10.3
2452775.6	2003/ 5/16- 4	F	61 18.1	16.945	15.190	-18.6	19.0	-13	61 20.6	16.936	14.769	-15.9	18.9
2452938.0	2003/10/25-13	N	61 0.8	16.961	13.900	-10.4	-12.1	23	61 9.4	16.938	14.649	-16.3	-12.4
2452967.6	2003/11/23-23	N	61 27.2	17.121	15.721	-21.4	-20.4	1	61 27.2	17.121	15.740	-21.5	-20.4
2452997.1	2003/12/23-10	N	61 3.4	17.027	16.902	-26.8	-23.4	-22	61 11.5	17.009	16.523	-25.2	-23.4
2453159.5	2004/ 6/ 3- 4	F	61 21.3	16.930	16.499	-25.1	22.4	9	61 22.7	16.927	16.781	-26.1	22.4
2453189.0	2004/ 7/ 2-11	F	61 18.0	16.862	17.127	-27.4	23.0	-12	61 20.6	16.864	17.169	-27.5	23.0
2453351.5	2004/12/12- 1	N	61 8.2	17.035	16.841	-26.9	-23.1	21	61 15.1	16.994	17.189	-27.9	-23.1
2453381.0	2005/ 1/10-12	N	61 29.5	17.093	16.984	-26.7	-21.9	-2	61 29.6	17.093	17.036	-26.9	-21.9
2453572.9	2005/ 7/21-11	F	61 22.2	16.879	16.426	-25.2	20.4	9	61 23.6	16.876	16.082	-23.8	20.3
2453602.5	2005/ 8/19-18	F	61 18.5	16.918	14.528	-16.2	12.6	-12	61 21.1	16.912	15.037	-19.1	12.7
2453764.9	2006/ 1/29-14	N	61 11.8	17.041	15.518	-21.9	-17.9	18	61 17.2	17.032	14.800	-18.0	-17.7
2453794.4	2006/ 2/28- 1	N	61 26.1	17.092	13.852	-10.2	-8.1	-5	61 26.4	17.088	13.970	-11.4	-8.2
2453986.4	2006/ 9/ 7-19	F	61 22.2	16.980	13.582	-6.8	5.9	8	61 23.5	16.977	13.470	-4.2	5.8
2454015.9	2006/10/ 7- 3	F	61 18.1	17.016	13.556	6.9	-5.4	-13	61 21.1	17.020	13.421	3.1	-5.2
2454178.3	2007/ 3/19- 3	N	61 12.4	17.034	13.339	0.3	-0.7	15	61 16.8	17.031	13.475	5.0	-0.5
2454207.9	2007/ 4/17-12	N	61 23.2	17.000	14.230	13.7	10.4	-6	61 23.8	16.998	14.049	12.0	10.3
2454399.8	2007/10/26- 5	F	61 26.9	17.038	14.640	16.3	-12.3	7	61 27.8	17.031	14.936	18.1	-12.4
2454429.3	2007/11/24-15	F	61 19.6	17.047	16.508	25.4	-20.6	-15	61 23.2	17.033	15.988	23.2	-20.4
2454591.7	2008/ 5/ 5-12	N	61 13.4	16.908	15.502	21.2	16.4	15	61 17.3	16.914	16.132	23.8	16.6
2454621.3	2008/ 6/ 3-19	N	61 21.9	16.925	17.060	27.0	22.4	-6	61 22.6	16.918	16.939	26.6	22.4
2454813.2	2008/12/12-17	F	61 29.3	17.110	17.184	27.0	-23.1	5	61 29.7	17.112	17.186	27.0	-23.1
2454842.8	2009/ 1/11- 4	F	61 15.3	17.093	16.091	23.4	-21.8	-17	61 20.2	17.072	16.675	25.5	-21.9
2455005.2	2009/ 6/22-20	N	61 11.0	16.891	16.803	25.9	23.4	15	61 14.8	16.902	16.503	24.7	23.4
2455034.7	2009/ 7/22- 3	N	61 19.8	16.957	15.538	20.3	20.3	-7	61 20.5	16.959	15.780	21.5	20.3
2455226.7	2010/ 1/30- 6	F	61 29.3	17.143	14.941	16.0	-17.7	3	61 29.5	17.142	14.855	15.4	-17.6
2455256.2	2010/ 2/28-17	F	61 10.5	16.979	13.758	4.2	-7.8	-20	61 16.8	16.972	14.098	9.3	-8.1
2455418.6	2010/ 8/10- 3	N	61 12.6	16.918	14.478	12.7	15.6	15	61 16.4	16.896	14.149	9.1	15.4
2455448.1	2010/ 9/ 8-10	N	61 22.5	16.959	13.871	1.4	5.6	-6	61 23.3	16.967	13.911	3.1	5.7
2455610.6	2011/ 2/18- 8	F	61 3.5	16.995	14.050	7.7	-11.7	23	61 12.4	16.956	13.876	1.9	-11.4
2455640.1	2011/ 3/19-18	F	61 29.6	17.030	14.096	-4.1	-0.5	1	61 29.6	17.030	14.101	-4.3	-0.5
2455669.6	2011/ 4/18- 3	F	61 6.7	16.885	14.833	-14.7	10.7	-21	61 14.0	16.850	14.370	-10.1	10.4
2455832.0	2011/ 9/27-11	N	61 16.1	16.948	14.172	-6.0	-1.6	14	61 19.5	16.935	14.418	-9.3	-1.8
2455861.6	2011/10/26-20	N	61 23.6	17.060	15.222	-15.8	-12.5	-7	61 24.7	17.057	15.034	-14.4	-12.4

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
				°/DAY	°/DAY	°		h		°/DAY	/DAY		
2456024.0	2012/ 4/ 6-19	F	61 3.9	16.915	14.506	-10.4	6.8	22	61 11.8	16.924	15.044	-14.6	7.2
2456053.5	2012/ 5/ 6- 4	F	61 25.7	16.989	15.765	-18.3	16.6	-1	61 25.7	16.989	15.758	-18.2	16.6
2456083.0	2012/ 6/ 4-11	F	61 2.1	16.834	16.243	-21.6	22.5	-22	61 10.0	16.824	16.090	-20.6	22.4
2456245.5	2012/11/13-22	N	61 18.9	17.076	15.852	-18.6	-18.3	13	61 21.6	17.067	16.100	-19.8	-18.4
2456275.0	2012/12/13- 9	N	61 22.9	17.111	16.343	-20.9	-23.2	-10	61 24.5	17.111	16.357	-20.9	-23.2
2456437.4	2013/ 5/25- 4	F	61 3.6	16.861	15.951	-19.4	21.0	22	61 11.1	16.860	16.157	-20.2	21.1
2456466.9	2013/ 6/23-12	F	61 25.3	16.918	16.182	-19.7	23.4	-1	61 25.3	16.918	16.186	-19.7	23.4
2456496.5	2013/ 7/22-18	F	61 2.9	16.783	15.258	-15.3	20.1	-22	61 10.9	16.786	15.750	-18.0	20.3
2456658.9	2014/ 1/ 1-11	N	61 24.3	17.088	15.994	-18.4	-23.0	10	61 26.0	17.076	15.859	-17.6	-22.9
2456688.4	2014/ 1/30-22	N	61 21.9	17.058	15.132	-12.7	-17.5	-12	61 24.4	17.044	15.386	-14.5	-17.6
2456850.8	2014/ 7/12-11	F	61 4.9	16.788	15.632	-17.0	21.9	22	61 12.3	16.773	15.319	-14.6	21.8
2456880.4	2014/ 8/10-18	F	61 26.3	16.923	15.035	-11.1	15.4	0	61 26.3	16.923	15.040	-11.2	15.4
2456909.9	2014/ 9/ 9- 2	F	61 2.8	16.886	14.349	-2.7	5.4	-22	61 10.9	16.879	14.593	-7.0	5.7
2457072.3	2015/ 2/19- 0	N	61 24.2	17.083	14.811	-8.3	-11.5	7	61 25.3	17.087	14.725	-6.9	-11.4
2457101.8	2015/ 3/20-10	N	61 15.8	17.032	14.461	0.7	-0.2	-15	61 19.3	17.015	14.503	-2.2	-0.4
2457264.3	2015/ 8/29-19	F	61 4.8	16.864	14.598	-7.2	9.3	21	61 12.0	16.855	14.470	-3.2	9.0
2457293.8	2015/ 9/28- 3	F	61 26.5	17.039	14.558	1.6	-1.9	-1	61 26.6	17.039	14.556	1.4	-1.8
2457323.3	2015/10/27-12	F	61 1.3	16.966	14.792	10.1	-12.8	-23	61 10.3	16.964	14.564	6.0	-12.4
2457485.7	2016/ 4/ 7-11	N	61 22.9	17.035	14.614	4.9	7.1	6	61 23.5	17.036	14.674	6.1	7.2
2457515.3	2016/ 5/ 6-20	N	61 12.7	16.912	15.148	12.7	16.8	-16	61 16.7	16.902	14.916	10.3	16.7
2457677.7	2016/10/16- 4	F	61 10.1	16.957	14.524	5.9	-9.0	20	61 16.4	16.927	14.820	9.5	-9.3
2457707.2	2016/11/14-14	F	61 30.2	17.074	15.380	13.8	-18.4	-2	61 30.3	17.074	15.339	13.4	-18.4
2457899.2	2017/ 5/25-20	N	61 22.5	16.925	15.625	16.2	21.1	5	61 23.1	16.929	15.728	16.8	21.1
2457928.7	2017/ 6/24- 3	N	61 11.4	16.879	16.075	19.3	23.4	-16	61 15.6	16.863	15.988	18.7	23.4
2458091.1	2017/12/ 3-16	F	61 15.1	17.023	15.727	17.6	-22.2	17	61 20.2	17.014	16.041	19.1	-22.3
2458120.7	2018/ 1/ 2- 2	F	61 29.4	17.141	16.308	20.0	-22.9	-4	61 29.7	17.137	16.311	20.0	-22.9
2458312.6	2018/ 7/13- 3	N	61 20.3	16.951	16.250	20.5	21.8	5	61 20.8	16.952	16.200	20.2	21.8
2458342.1	2018/ 8/11-10	N	61 9.9	16.914	15.404	16.3	15.2	-16	61 14.2	16.929	15.777	18.3	15.4
2458504.6	2019/ 1/21- 5	F	61 17.9	17.112	16.116	20.3	-20.0	15	61 21.8	17.099	15.858	18.9	-19.8
2458534.1	2019/ 2/19-16	F	61 26.9	17.088	15.106	14.0	-11.2	-7	61 27.7	17.091	15.289	15.2	-11.3
2458726.0	2019/ 8/30-11	N	61 22.9	16.967	14.827	12.7	9.0	5	61 23.4	16.958	14.704	11.5	8.9
2458755.6	2019/ 9/28-19	N	61 12.5	16.940	14.030	2.4	-2.1	-16	61 16.9	16.948	14.209	6.2	-1.9
2458918.0	2020/ 3/ 9-18	F	61 21.0	17.026	14.298	8.5	-4.1	12	61 23.9	17.014	14.134	5.5	-3.9
2458947.5	2020/ 4/ 8- 3	F	61 24.8	16.977	14.023	-2.9	7.3	-9	61 26.2	16.968	13.996	-0.6	7.2
2459139.5	2020/10/16-20	N	61 25.8	17.028	14.016	-5.3	-9.3	4	61 26.1	17.027	14.078	-6.4	-9.3
2459169.0	2020/11/15- 5	N	61 11.3	17.055	14.957	-16.3	-18.6	-17	61 16.6	17.037	14.487	-12.5	-18.4
2459331.4	2021/ 4/27- 4	F	61 18.9	16.960	14.293	-11.1	13.9	11	61 21.4	16.969	14.629	-14.0	14.0
2459360.9	2021/ 5/26-11	F	61 20.5	16.946	15.731	-20.7	21.2	-9	61 22.1	16.939	15.406	-19.0	21.1
2459552.9	2021/12/ 4- 8	N	61 27.3	17.129	16.253	-23.2	-22.3	2	61 27.4	17.128	16.337	-23.6	-22.3
2459582.4	2022/ 1/ 2-19	N	61 8.0	17.044	16.880	-26.2	-22.9	-20	61 14.6	17.029	16.851	-25.9	-22.9
2459744.8	2022/ 6/14-12	F	61 18.5	16.910	16.803	-26.0	23.3	11	61 20.8	16.903	17.019	-26.7	23.3
2459774.4	2022/ 7/13-19	F	61 20.9	16.879	16.860	-26.1	21.7	-10	61 22.5	16.882	17.033	-26.6	21.8
2459936.8	2022/12/23-10	N	61 3.8	17.025	16.984	-27.3	-23.4	23	61 12.2	16.976	16.986	-27.0	-23.4
2459966.3	2023/ 1/21-21	N	61 29.6	17.091	16.459	-24.6	-19.8	0	61 29.6	17.091	16.461	-24.6	-19.8
2459995.8	2023/ 2/20- 7	N	61 4.0	16.977	14.378	-15.2	-11.0	-22	61 12.2	16.931	15.297	-20.4	-11.3

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2460158.3	2023/ 8/ 1-19	F	61 19.7	16.872	15.829	-22.7	17.9	11	61 22.0	16.866	15.358	-20.4	17.8
2460187.8	2023/ 8/31- 2	F	61 21.7	16.946	14.106	-12.4	8.8	-10	61 23.3	16.942	14.427	-14.9	8.9
2460350.2	2024/ 2/ 9-23	N	61 7.3	17.017	14.846	-18.6	-14.6	20	61 14.0	17.007	14.154	-13.6	-14.3
2460379.7	2024/ 3/10- 9	N	61 26.3	17.080	13.586	-5.9	-3.8	-2	61 26.3	17.078	13.621	-6.6	-3.9
2460571.7	2024/ 9/18- 3	F	61 20.3	16.984	13.408	-2.7	1.7	11	61 22.3	16.980	13.394	0.7	1.5
2460601.2	2024/10/17-12	F	61 21.5	17.049	13.893	11.0	-9.5	-11	61 23.5	17.052	13.665	8.0	-9.4
2460763.6	2025/ 3/29-11	N	61 7.8	16.996	13.377	4.5	3.6	18	61 13.6	16.997	13.748	10.0	3.9
2460793.2	2025/ 4/27-20	N	61 23.8	16.991	14.741	17.4	14.1	-4	61 24.0	16.990	14.604	16.5	14.1
2460985.1	2025/11/ 5-13	F	61 25.4	17.047	15.211	19.9	-15.9	10	61 27.0	17.038	15.641	21.9	-16.0
2461014.7	2025/12/ 4-23	F	61 23.0	17.068	17.027	27.3	-22.4	-12	61 25.6	17.057	16.690	26.0	-22.3
2461177.1	2026/ 5/16-20	N	61 8.9	16.873	16.059	24.0	19.3	18	61 14.2	16.879	16.730	26.4	19.4
2461206.6	2026/ 6/15- 3	N	61 23.0	16.922	17.277	27.9	23.3	-4	61 23.2	16.919	17.262	27.9	23.3
2461398.5	2026/12/24- 2	F	61 28.0	17.110	17.170	27.3	-23.4	7	61 28.9	17.112	17.052	26.8	-23.4
2461428.1	2027/ 1/22-12	F	61 18.6	17.100	15.545	21.3	-19.7	-14	61 22.4	17.084	16.170	23.9	-19.8
2461590.5	2027/ 7/ 4- 3	N	61 6.8	16.866	16.532	25.5	22.9	18	61 12.1	16.875	15.971	23.1	22.8
2461620.0	2027/ 8/ 2-10	N	61 21.3	16.970	15.004	17.9	17.8	-4	61 21.6	16.972	15.145	18.7	17.8
2461812.0	2028/ 2/10-15	F	61 28.2	17.132	14.397	12.7	-14.4	5	61 28.6	17.128	14.270	11.5	-14.3
2461841.5	2028/ 3/11- 1	F	61 14.2	16.980	13.614	-0.0	-3.6	-17	61 19.1	16.976	13.745	4.8	-3.8
2462003.9	2028/ 8/20-11	N	61 9.0	16.910	14.016	9.4	12.2	17	61 14.2	16.881	13.763	4.7	11.9
2462033.5	2028/ 9/18-18	N	61 24.5	16.982	13.802	-2.7	1.4	-3	61 24.7	16.987	13.785	-1.7	1.5
2462225.4	2029/ 3/30- 2	F	61 28.5	17.010	14.218	-8.4	3.8	3	61 28.7	17.010	14.275	-9.2	3.9
2462254.9	2029/ 4/28-11	F	61 11.0	16.691	15.340	-18.4	14.3	-19	61 16.7	16.861	14.805	-14.7	14.1
2462417.4	2029/10/ 7-19	N	61 13.0	16.949	14.345	-10.3	-5.8	17	61 17.6	16.931	14.784	-14.0	-6.1
2462446.9	2029/11/ 6- 5	N	61 25.7	17.079	15.740	-19.4	-16.1	-6	61 26.2	17.076	15.592	-18.6	-16.0
2462609.3	2030/ 4/18- 3	F	60 58.0	16.866	14.810	-14.4	10.8	25	61 7.8	16.880	15.543	-18.6	11.2
2462638.8	2030/ 5/17-11	F	61 25.0	16.972	16.210	-21.1	19.4	3	61 25.1	16.973	16.256	-21.3	19.4
2462668.4	2030/ 6/15-19	F	61 7.0	16.856	16.368	-22.5	23.3	-20	61 13.1	16.849	16.443	-22.6	23.3
2462830.8	2030/11/25- 7	N	61 16.3	17.077	16.234	-21.2	-20.8	15	61 19.9	17.066	16.414	-21.8	-20.9
2462860.3	2030/12/24-18	N	61 25.0	17.121	16.300	-21.1	-23.4	-8	61 26.0	17.122	16.399	-21.5	-23.4
2463022.7	2031/ 6/ 5-12	F	60 57.8	16.816	16.138	-21.0	22.6	24	61 7.4	16.815	16.126	-20.6	22.7
2463052.3	2031/ 7/ 4-19	F	61 25.1	16.917	15.986	-19.2	22.8	2	61 25.2	16.915	15.943	-18.9	22.8
2463081.8	2031/ 8/ 3- 2	F	61 8.3	16.819	14.895	-12.9	17.6	-19	61 14.4	16.824	15.371	-16.0	17.8
2463244.2	2032/ 1/12-20	N	61 21.8	17.082	15.666	-17.1	-21.6	12	61 24.3	17.066	15.434	-15.5	-21.5
2463273.7	2032/ 2/11- 6	N	61 24.1	17.056	14.748	-9.5	-14.2	-10	61 25.7	17.045	14.939	-11.3	-14.3
2463436.2	2032/ 7/22-19	F	60 59.4	16.763	15.248	-15.2	20.0	24	61 8.8	16.741	14.848	-11.4	19.8
2463465.7	2032/ 8/21- 2	F	61 26.4	16.933	14.691	-7.7	12.0	2	61 26.5	16.933	14.661	-7.2	11.9
2463495.2	2032/ 9/19-10	F	61 8.2	16.933	14.322	1.5	1.2	20	61 14.6	16.924	14.384	-2.5	1.5
2463657.6	2033/ 3/ 1- 8	N	61 21.6	17.062	14.536	-4.3	-7.4	10	61 23.4	17.067	14.494	-2.3	-7.3
2463687.2	2033/ 3/30-18	N	61 18.3	17.029	14.560	5.0	4.1	-12	61 20.7	17.015	14.497	2.6	3.9
2463849.6	2033/ 9/ 9- 2	F	60 59.9	16.851	14.364	-3.1	5.2	24	61 9.0	16.838	14.400	1.6	4.9
2463879.1	2033/10/ 8-11	F	61 27.1	17.056	14.686	5.8	-6.1	2	61 27.1	17.056	14.702	6.1	-6.1
2463908.6	2033/11/ 6-21	F	61 6.8	17.007	15.204	13.6	-16.3	-21	61 14.0	17.002	14.910	10.5	-16.0
2464071.1	2034/ 4/18-19	N	61 20.4	17.012	14.848	8.9	11.1	9	61 21.7	17.013	14.984	10.3	11.2
2464100.6	2034/ 5/18- 3	N	61 15.8	16.915	15.545	15.4	19.6	-13	61 18.6	16.909	15.346	13.9	19.4
2464263.0	2034/10/27-13	F	61 5.9	16.953	14.783	9.7	-12.9	22	61 13.8	16.918	15.208	13.2	-13.2

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			' "	°/DAY	°/DAY	°	°	h	' "	°/DAY	°/DAY	°	°
2464292.5	2034/11/25-23	F	61 30.9	17.088	15.764	16.2	-20.9	-1	61 30.9	17.088	15.761	16.2	-20.9
2464322.1	2034/12/25- 9	F	61 5.2	17.011	15.953	18.6	-23.4	-22	61 13.7	16.971	15.923	18.0	-23.4
2464484.5	2035/ 6/ 6- 3	N	61 20.4	16.906	15.900	17.7	22.6	9	61 21.6	16.910	16.001	18.2	22.7
2464514.0	2035/ 7/ 5-10	N	61 15.0	16.894	16.036	18.7	22.8	-13	61 17.9	16.884	16.088	18.8	22.8
2464676.4	2035/12/15- 1	F	61 11.3	17.018	15.948	18.6	-23.2	19	61 17.6	17.004	16.124	19.3	-23.3
2464706.0	2036/ 1/13-11	F	61 30.1	17.141	16.116	18.6	-21.5	-2	61 30.3	17.139	16.143	18.8	-21.5
2464897.9	2036/ 7/23-10	N	61 18.6	16.945	15.933	18.5	19.9	9	61 19.8	16.945	15.804	17.7	19.8
2464927.5	2036/ 8/21-18	N	61 13.9	16.946	15.034	12.8	11.7	-13	61 16.9	16.960	15.324	14.8	11.9
2465089.9	2037/ 1/31-14	F	61 14.1	17.092	15.656	17.5	-17.2	17	61 19.2	17.075	15.324	15.2	-17.0
2465119.4	2037/ 3/ 2- 0	F	61 27.9	17.080	14.759	9.8	-7.1	-5	61 28.3	17.083	14.857	10.9	-7.2
2465311.4	2037/ 9/ 9-18	N	61 21.8	16.976	14.525	8.6	5.0	8	61 22.9	16.963	14.412	6.8	4.8
2465340.9	2037/10/ 9- 3	N	61 16.7	16.974	14.146	-1.8	-6.4	-14	61 19.9	16.980	14.167	1.3	-6.1
2465503.3	2038/ 3/21- 2	F	61 17.2	16.993	14.134	4.2	0.2	15	61 21.2	16.981	14.091	0.6	0.5
2465532.8	2038/ 4/19-11	F	61 26.2	16.967	14.303	-6.8	11.3	-7	61 26.8	16.961	14.225	-5.2	11.2
2465724.8	2038/10/28- 4	N	61 25.0	17.036	14.355	-9.0	-13.1	7	61 25.8	17.035	14.500	-10.6	-13.2
2465754.3	2038/11/26-14	N	61 15.4	17.081	15.506	-18.7	-21.0	-15	61 19.4	17.064	15.083	-16.0	-20.9
2465916.7	2039/ 5/ 8-11	F	61 15.2	16.924	14.734	-14.3	17.1	15	61 18.7	16.936	15.197	-17.3	17.3
2465946.3	2039/ 6/ 6-19	F	61 22.3	16.946	16.170	-22.1	22.7	-7	61 23.1	16.942	15.974	-21.2	22.7
2466138.2	2039/12/15-17	N	61 26.8	17.134	16.618	-24.2	-23.3	4	61 27.1	17.132	16.716	-24.6	-23.3
2466167.7	2040/ 1/14- 3	N	61 12.1	17.055	16.618	-24.7	-21.4	-17	61 17.4	17.045	16.855	-25.4	-21.5
2466330.2	2040/ 6/24-19	F	61 15.0	16.888	16.893	-26.0	23.4	15	61 18.5	16.878	16.945	-26.1	23.4
2466359.7	2040/ 7/24- 2	F	61 23.3	16.896	16.431	-24.0	19.8	-7	61 24.1	16.900	16.627	-24.7	19.8
2466551.6	2041/ 2/ 1- 6	N	61 29.1	17.084	15.841	-21.7	-17.0	2	61 29.2	17.084	15.766	-21.4	-17.0
2466581.2	2041/ 3/ 2-16	N	61 8.2	16.981	14.001	-11.1	-6.9	-20	61 14.9	16.942	14.668	-16.2	-7.2
2466743.6	2041/ 8/12- 2	F	61 16.7	16.866	15.217	-19.6	14.9	14	61 20.1	16.856	14.690	-16.4	14.7
2466773.1	2041/ 9/10- 9	F	61 24.3	16.972	13.820	-6.3	4.7	-6	61 25.2	16.969	13.982	-10.3	4.8
2466935.5	2042/ 2/20- 8	N	61 2.1	16.986	14.261	-14.8	-10.8	22	61 10.5	16.977	13.700	-8.8	-10.5
2466965.1	2042/ 3/21-17	N	61 25.8	17.065	13.493	-1.6	0.5	0	61 25.8	17.065	13.493	-1.6	0.5
2466994.6	2042/ 4/20- 2	N	61 1.3	16.920	13.891	11.9	11.5	-22	61 9.3	16.894	13.475	5.5	11.2
2467157.0	2042/ 9/29-11	F	61 17.8	16.986	13.395	1.6	-2.6	13	61 20.9	16.982	13.536	5.6	-2.8
2467186.5	2042/10/28-20	F	61 24.3	17.078	14.377	14.9	-13.4	-8	61 25.6	17.079	14.119	12.7	-13.3
2467349.0	2043/ 4/ 9-19	N	61 2.6	16.953	13.575	8.7	7.8	21	61 10.1	16.958	14.223	14.6	8.1
2467378.5	2043/ 5/ 9- 3	N	61 23.8	16.981	15.330	20.6	17.3	-1	61 23.9	16.981	15.288	20.4	17.3
2467408.0	2043/ 6/ 7-11	N	60 59.6	16.806	16.851	27.5	22.8	-23	61 8.0	16.793	16.162	24.7	22.7
2467570.4	2043/11/16-22	F	61 23.5	17.054	15.838	23.0	-18.9	12	61 25.8	17.041	16.352	25.0	-19.0
2467600.0	2043/12/16- 8	F	61 25.8	17.084	17.330	28.2	-23.3	-10	61 27.6	17.076	17.199	27.8	-23.3
2467762.4	2044/ 5/27- 4	N	61 3.6	16.835	16.553	26.2	21.4	20	61 10.8	16.841	17.118	28.0	21.5
2467791.9	2044/ 6/25-10	N	61 23.4	16.919	17.257	28.0	23.4	-1	61 23.4	16.918	17.270	28.1	23.4
2467821.5	2044/ 7/24-17	N	60 58.9	16.825	15.623	22.8	19.6	-23	61 7.4	16.821	16.587	26.3	19.8
2467983.9	2045/ 1/ 3-10	F	61 26.1	17.105	16.886	26.6	-22.8	10	61 27.6	17.106	16.601	25.5	-22.7
2468013.4	2045/ 2/ 1-21	F	61 21.5	17.102	14.944	18.4	-16.8	-13	61 24.2	17.091	15.501	21.2	-16.9
2468175.8	2045/ 7/14-10	N	61 2.0	16.840	16.074	24.2	21.6	21	61 9.1	16.846	15.285	20.4	21.4
2468205.4	2045/ 8/12-18	N	61 22.2	16.982	14.471	14.9	14.7	-1	61 22.3	16.982	14.504	15.2	14.7
2468234.9	2045/ 9/11- 2	N	60 58.1	16.882	13.362	2.3	4.5	-24	61 6.8	16.910	13.742	9.0	4.8
2468397.3	2046/ 2/21- 0	F	61 26.4	17.116	13.936	9.0	-10.6	6	61 27.3	17.110	13.811	7.1	-10.5

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2468426.8	2046/ 3/22- 9	F	61 17.5	16.979	13.629	-4.4	0.8	-14	61 21.2	16.977	13.577	-0.1	0.5
2468589.2	2046/ 8/31-18	N	61 4.8	16.900	13.648	5.7	8.4	21	61 11.6	16.865	13.555	-0.1	8.1
2468618.8	2046/ 9/30- 2	N	61 25.8	17.003	13.888	-7.0	-2.8	-1	61 25.8	17.004	13.866	-6.6	-2.8
2468648.3	2046/10/29-11	N	60 59.4	16.938	14.998	-18.3	-13.6	-23	61 8.7	16.922	14.290	-12.9	-13.3
2468810.7	2047/ 4/10-11	F	61 26.8	16.987	14.496	-12.6	8.0	5	61 27.4	16.987	14.652	-13.9	8.1
2468840.3	2047/ 5/ 9-19	F	61 14.7	16.896	15.906	-21.6	17.5	-17	61 19.0	16.871	15.393	-18.9	17.3
2469002.7	2047/10/19- 4	N	61 9.4	16.948	14.668	-14.4	-9.9	18	61 15.4	16.926	15.307	-18.3	-10.2
2469032.2	2047/11/17-13	N	61 27.2	17.093	16.283	-22.4	-19.0	-3	61 27.4	17.091	16.203	-22.1	-19.0
2469224.2	2048/ 5/27-19	F	61 23.7	16.952	16.578	-23.3	21.5	5	61 24.1	16.956	16.636	-23.5	21.5
2469253.7	2048/ 6/26- 2	F	61 11.3	16.876	16.298	-22.6	23.3	-16	61 15.9	16.873	16.567	-23.6	23.4
2469416.1	2048/12/ 5-16	N	61 13.2	17.075	16.488	-22.9	-22.5	16	61 17.9	17.060	16.499	-22.8	-22.6
2469445.6	2049/ 1/ 4- 2	N	61 26.6	17.127	16.046	-20.4	-22.7	-5	61 27.1	17.128	16.176	-21.0	-22.7
2469637.6	2049/ 7/15- 2	F	61 24.2	16.916	15.639	-17.9	21.5	5	61 24.6	16.912	15.517	-17.2	21.4
2469667.1	2049/ 8/13- 9	F	61 13.0	16.854	14.525	-9.9	14.5	-16	61 17.5	16.860	14.905	-13.2	14.7
2469829.5	2050/ 1/23- 5	N	61 18.7	17.070	15.220	-14.9	-19.4	14	61 22.1	17.050	14.928	-12.5	-19.3
2469859.1	2050/ 2/21-15	N	61 25.6	17.051	14.425	-5.7	-10.3	-8	61 26.7	17.043	14.532	-7.4	-10.5
2470051.0	2050/ 9/ 1-10	F	61 25.9	16.942	14.424	-3.9	8.1	4	61 26.3	16.941	14.396	-2.8	8.1
2470080.5	2050/ 9/30-18	F	61 13.0	16.976	14.430	5.8	-3.1	-17	61 17.9	16.965	14.341	2.3	-2.8
2470243.0	2051/ 3/12-17	N	61 18.5	17.036	14.384	-0.0	-3.1	12	61 21.0	17.044	14.433	2.5	-2.9
2470272.5	2051/ 4/11- 2	N	61 20.2	17.024	14.792	9.2	8.3	-10	61 21.8	17.013	14.667	7.4	8.1
2470464.4	2051/10/19-19	F	61 27.0	17.071	14.941	9.9	-10.2	4	61 27.3	17.070	15.006	10.6	-10.2
2470494.0	2051/11/18- 5	F	61 11.6	17.042	15.632	16.5	-19.2	-18	61 17.3	17.036	15.359	14.4	-19.0
2470656.4	2052/ 4/29- 3	N	61 17.4	16.985	15.167	12.5	14.7	11	61 19.6	16.987	15.379	14.1	14.8
2470685.9	2052/ 5/28-11	N	61 18.3	16.919	15.882	17.5	21.6	-10	61 20.1	16.916	15.762	16.7	21.6
2470848.3	2052/11/ 6-21	F	61 1.3	16.948	15.113	13.2	-16.4	24	61 10.8	16.906	15.596	16.1	-16.7
2470877.9	2052/12/ 6- 7	F	61 31.1	17.098	16.048	17.8	-22.6	2	61 31.2	17.098	16.065	17.9	-22.6
2470907.4	2053/ 1/ 4-18	F	61 9.9	17.028	15.870	17.8	-22.6	-20	61 16.9	16.994	16.034	18.4	-22.7
2471069.8	2053/ 6/16-11	N	61 17.7	16.887	16.031	18.4	23.4	11	61 19.7	16.890	16.071	18.5	23.4
2471099.3	2053/ 7/15-18	N	61 18.0	16.909	15.843	17.3	21.4	-11	61 19.8	16.903	15.967	17.9	21.4
2471261.8	2053/12/25- 9	F	61 6.9	17.009	15.986	18.8	-23.4	22	61 14.7	16.989	15.969	18.3	-23.3
2471291.3	2054/ 1/23-20	F	61 30.3	17.136	15.782	16.4	-19,2	-1	61 30.3	17.136	15.794	16.5	-19.3
2471320.8	2054/ 2/22- 7	F	61 2.7	16.988	14.739	9.8	-10.1	-24	61 11.5	16.964	15.203	13.5	-10.4
2471483.2	2054/ 8/ 3-18	N	61 16.3	16.939	15.536	15.8	17.3	11	61 18.4	16.937	15.343	14.4	17.2
2471512.8	2054/ 9/ 2- 1	N	61 17.4	16.976	14.743	8.8	7.9	-10	61 19.3	16.987	14.922	10.7	8.0
2471675.2	2055/ 2/11-23	F	61 9.8	17=066	15.184	14.2	-13.8	19	61 16.2	17.046	14.859	11.0	-13.5
2471704.7	2055/ 3/13- 9	F	61 28.3	17.070	14.548	5.5	-2.9	-3	61 28.4	17.071	14.580	6.2	-2.9
2471896.7	2055/ 9/21- 2	N	61 20.1	16.983	14.360	4.3	0.8	11	61 22.0	16.965	14.308	2.0	0.6
2471926.2	2055/10/20-11	N	61 20.3	17.005	14.395	-5.8	-10.4	-11	61 22.5	17.008	14.315	-3.4	-10.2
2472088.6	2056/ 3/31-10	F	61 12.8	16.956	14.125	-0.1	4.5	18	61 18.1	16.944	14.238	-4.1	4.8
2472118.2	2056/ 4/29-19	F	61 26.9	16.955	14.679	-10.3	14.9	-4	61 27.2	16.951	14.603	-9.4	14.8
2472310.1	2056/11/ 7-12	N	61 23.7	17.043	14.779	-12.4	-16.6	9	61 25.1	17.040	15.012	-14.2	-16.7
2472339.6	2056/12/ 6-23	N	61 18.9	17.101	15.964	-20.3	-22.7	-13	61 21.9	17.086	15.654	-18.5	-22.6
2472502.1	2057/ 5/18-19	F	61 10.8	16.886	15.185	-16.9	19.8	17	61 15.8	16.900	15.720	-19.7	19.9
2472531.6	2057/ 6/17- 2	F	61 23.6	16.945	16.447	-22.7	23.4	-4	61 23.9	16.943	16.368	-22.4	23.4
2472723.5	2057/12/26- 1	N	61 25.7	17.135	16.755	-24.3	-23.4	7	61 26.5	17.131	16.803	-24.5	-23.3

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
				°/DAY	°/DAY	°		h		°/DAY	°/DAY	°	
2472753.1	2058/ 1/24-12	N	61 15.6	17.062	16.186	-22.4	19.1	-15	61 19.7	17.055	16.564	-23.8	-19.2
2472915.5	2058/ 7/ 6- 3	F	61 11.0	16.865	16.759	-25.2	22.7	17	61 15.9	16.851	16.590	-24.4	22.6
2472945.0	2058/ 8/ 4-10	F	61 25.0	16.913	15.918	-21.3	17.1	-5	61 25.3	16.916	16.057	-21.9	17.2
2473137.0	2059/ 2/12-14	N	61 28.0	17.074	15.233	-18.2	-13.6	4	61 28.3	17.073	15.091	-17.4	-13.5
2473166.5	2059/ 3/14- 0	N	61 11.9	16.982	13.787	-6.8	-2.6	-18	61 17.3	16.949	14.197	-11.5	-2.9
2473328.9	2059/ 8/23-10	F	61 13.1	16.859	14.665	-16.0	11.4	17	61 17.9	16.844	14.171	-11.8	11.1
2473358.4	2059/ 9/21-17	F	61 26.3	16.995	13.688	-4.1	0.5	-4	61 26.6	16.993	13.741	-5.4	0.6
2473550.4	2060/ 4/ 1- 2	N	61 24.9	17.047	13.568	2.7	4.8	2	61 25.0	17.050	13.587	3.4	4.8
2473579.9	2060/ 4/30-10	N	61 5.6	16.929	14.410	15.4	15.1	-19	61 11.9	16.909	13.865	10.2	14.8
2473742.3	2060/10/ 9-19	F	61 14.9	16.987	13.544	5.7	-6.8	16	61 19.1	16.981	13.883	10.3	-7.0
2473771.9	2060/11/ 8- 4	F	61 26.6	17.101	14.968	18.3	-16.8	-5	61 27.2	17.102	14.741	16.9	-16.7
2473934.3	2061/ 4/20- 3	N	60 56.9	16.905	13.913	12.6	11.7	24	61 6.2	16.914	14.847	18.7	12.0
2473963.8	2061/ 5/19-11	N	61 23.3	16.969	15.928	23.2	19.9	2	61 23.3	16.970	15.998	23.5	20.0
2473993.3	2061/ 6/17-18	N	61 4.6	16.826	17.113	28.1	23.4	-20	61 11.2	16.820	16.765	26.7	23.4
2474155.8	2061/11/27- 7	F	61 21.0	17.057	16.429	25.4	-21.2	13	61 24.2	17.039	16.929	27.0	-21.3
2474185.3	2061/12/26-17	F	61 28.0	17.095	17.357	28.3	-23.3	-8	61 29.2	17.090	17.395	28.3	-23.3
2474347.7	2062/ 6/ 7-11	N	60 58.1	16.795	16.901	27.7	22.8	24	61 7.0	16.800	17.194	28.4	22.9
2474377.2	2062/ 7/ 6-18	N	61 23.2	16.916	17.001	27.3	22.6	2	61 23.3	16.916	16.955	27.1	22.6
2474406.8	2062/ 8/ 5- 1	N	61 4.3	16.863	15.079	20.1	16.9	-20	61 10.9	16.861	15.996	24.1	17.2
2474569.2	2063/ 1/14-19	F	61 23.7	17.096	16.375	25.0	-21.2	11	61 25.9	17.095	15.927	23.1	-21.1
2474598.7	2063/ 2/13- 6	F	61 23.8	17.100	14.381	14.9	-13.3	-11	61 25.7	17.092	14.800	17.6	-13.5
2474761.1	2063/ 7/25-18	N	60 56.6	16.815	15.490	22.2	19.5	24	61 5.7	16.815	14.570	16.9	19.3
2474790.7	2063/ 8/24- 1	N	61 22.6	16.993	14.004	11.4	11.1	2	61 22.6	16.992	13.958	11.0	11.1
2474820.2	2063/ 9/22- 9	N	61 3.7	16.929	13.332	-1.9	0.2	-20	61 10.6	16.951	13.445	4.2	0.6
2474982.6	2064/ 3/ 3- 8	F	61 24.1	17.095	13.607	4.9	-6.5	9	61 25.6	17.087	13.539	2.2	-6.3
2475012.2	2064/ 4/ 1-18	F	61 20.2	16.976	13.810	-8.6	5.1	-13	61 22.8	16.976	13.619	-5.0	4.9
2475174.6	2064/ 9/11- 2	N	61 0.2	16.889	13.408	1.7	4.3	23	61 8.8	16.847	13.553	-5.0	3.9
2475204.1	2064/10/10-11	N	61 26.6	17.020	14.138	-11.2	-7.0	0	61 26.6	17.019	14.163	-11.5	-7.0
2475233.6	2064/11/ 8-20	N	61 5.0	16.977	15.628	-21.7	-17.0	-21	61 12.6	16.959	14.873	-17.5	-16.7
2475396.0	2065/ 4/20-19	F	61 24.6	16.961	14.914	-16.6	11.9	7	61 25.7	16.961	15.200	-18.3	12.0
2475425.6	2065/ 5/20- 2	F	61 18.0	16.899	16.459	-24.3	20.1	-13	61 21.0	16.880	16.056	-22.6	20.0
2475588.0	2065/10/29-12	N	61 5.4	16.946	15.121	-18.3	-13.7	21	61 12.8	16.918	15.917	-22.0	-14.0
2475617.5	2065/11/27-22	N	61 28.1	17.103	16.759	-24.8	-21.3	-1	61 28.1	17.103	16.743	-24.7	-21.3
2475647.1	2065/12/27- 9	N	61 0.2	17.041	16.410	-24.4	-23.3	-24	61 9.4	17.002	16.788	-25.5	-23.3
2475809.5	2066/ 6/ 8- 3	F	61 21.7	16.932	16.799	-24.7	22.9	7	61 22.7	16.937	16.793	-24.7	22.9
2475839.0	2066/ 7/ 7-10	F	61 15.1	16.896	16.039	-21.9	22.5	-14	61 18.3	16.896	16.418	-23.4	22.6
2476001.4	2066/12/17- 0	N	61 9.5	17.069	16.542	-23.8	-23.4	19	61 15.5	17.049	16.305	-22.6	-23.4
2476031.0	2067/ 1/15-11	N	61 27.6	17.129	15.622	-18.8	-21.1	-3	61 27.8	17.130	15.728	-19.4	-21.1
2476222.9	2067/ 7/26-10	F	61 22.7	16.915	15.191	-15.9	19.4	8	61 23.7	16.907	14.990	-14.4	19.3
2476252.4	2067/ 8/24-17	F	61 17.2	16.889	14.203	-6.4	10.9	-14	61 20.4	16.894	14.448	-9.5	11.1
2476414.9	2068/ 2/ 3-14	N	61 15.0	17.052	14.732	-12.1	-16.5	16	61 19.6	17.029	14.445	-8.7	-16.3
2476444.4	2068/ 3/ 4- 0	N	61 26.7	17.043	14.211	-1.6	-6.2	-6	61 27.2	17.038	14.242	-3.0	-6.3
2476636.3	2068/ 9/11-17	F	61 24.8	16.949	14.270	0.2	4.0	8	61 25.7	16.948	14.291	1.8	3.9
2476665.9	2068/10/11- 2	F	61 17.3	17.014	14.679	10.0	-7.3	-14	61 20.8	17.002	14.483	7.1	-7.1
2476828.3	2069/ 3/23- 1	N	61 14.7	17.005	14.372	4.3	1.2	15	61 18.3	17.016	14.555	7.3	1.4

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°		h	′ ″	°/DAY	°/DAY	°	
2476857.8	2069/ 4/21-10	N	61 21.6	17.016	15.139	13.1	12.1	-7	61 22.5	17.008	15.001	11.9	12.0
2477049.8	2069/10/30- 4	F	61 26.5	17.083	15.299	13.7	-13.9	6	61 27.1	17.082	15.424	14.6	-14.0
2477079.3	2069/11/28-14	F	61 15.9	17.070	16.000	18.7	-21.5	-16	61 20.3	17.065	15.823	17.5	-21.4
2477241.7	2070/ 5/10-11	N	61 13.8	16.954	15.521	15.7	17.8	14	61 17.1	16.957	15.772	17.1	17.9
2477271.2	2070/ 6/ 8-18	N	61 20.4	16.921	16.099	18.8	22.9	-7	61 21.4	16.921	16.066	18.6	22.9
2477463.2	2070/12/17-16	F	61 30.8	17.104	16.171	18.6	-23.4	4	61 31.0	17.102	16.171	18.6	-23.4
2477492.7	2071/ 1/16- 3	F	61 14.1	17.039	15.626	16.2	-20.9	-19	61 19.8	17.012	15.916	17.7	-21.1
2477655.1	2071/ 6/27-18	N	61 14.3	16.867	15.994	18.3	23.3	14	61 17.5	16.867	15.921	17.7	23.3
2477684.7	2071/ 7/27- 1	N	61 20.4	16.923	15.537	15.1	19.2	-7	61 21.4	16.921	15.667	15.9	19.3
2477847.1	2072/ 1/ 5-18	F	61 2.0	16.995	15.832	18.0	-22.6	24	61 11.4	16.968	15.621	16.3	-22.4
2477876.6	2072/ 2/ 4- 5	F	61 29.9	17.127	15.385	13.5	-16.3	1	61 30.0	17.128	15.362	13.3	-16.3
2477906.1	2072/ 3/ 4-15	F	61 7.1	16.994	14.523	5.6	-5.9	-21	61 14.3	16.975	14.830	9.4	-6.3
2478068.6	2072/ 8/14- 1	N	61 13.5	16.933	15.128	12.6	14.1	14	61 16.7	16.927	14.917	10.4	14.0
2478098.1	2072/ 9/12- 9	N	61 20.2	17.004	14.563	4.7	3.8	-8	61 21.3	17.012	14.643	6.2	3.9
2478260.5	2073/ 2/22- 7	F	61 4.9	17.032	14.774	10.3	-9.9	22	61 12.8	17.011	14.536	6.3	-9.6
2478290.0	2073/ 3/23-17	F	61 28.1	17.056	14.482	1.2	1.5	0	61 28.1	17.057	14.483	1.3	1.5
2478319.6	2073/ 4/22- 2	F	61 3.1	16.848	14.545	-8.1	12.4	-23	61 11.4	16.830	14.375	-3.6	12.1
2478482.0	2073/10/ 1-10	N	61 17.9	16.988	14.337	0.0	-3.5	13	61 20.7	16.965	14.387	-2.7	-3.7
2478511.5	2073/10/30-19	N	61 23.3	17.030	14.749	-9.5	-14.2	-8	61 24.7	17.032	14.626	-7.8	-14.1
2478673.9	2074/ 4/11-18	F	61 7.8	16.914	14.252	-4.2	8.7	20	61 14.6	16.904	14.542	-8.4	9.0
2478703.5	2074/ 5/11- 2	F	61 27.1	16.941	15.101	-13.3	18.0	-1	61 27.1	16.940	15.066	-13.0	17.9
2478733.0	2074/ 6/ 9-10	F	61 0.8	16.803	15.829	-19.4	23.0	-24	61 9.6	16.771	15.416	-16.6	22.9
2478895.4	2074/11/18-21	N	61 21.9	17.047	15.232	-15.2	-19.5	11	61 24.0	17.043	15.523	-17.0	-19.6
2478925.0	2074/12/18- 7	N	61 21.8	17.115	16.257	-21.0	-23.4	-10	61 23.9	17.103	16.090	-20.1	-23.4
2479087.4	2075/ 5/30- 3	F	61 5.8	16.846	15.582	-18.7	21.8	20	61 12.5	16.862	16.095	-21.1	21.9
2479116.9	2075/ 6/28-10	F	61 24.2	16.944	16.528	-22.5	23.3	-2	61 24.2	16.943	16.518	-22.5	23.3
2479146.4	2075/ 7/27-17	F	60 58.7	16.806	15.923	-20.8	19.1	-24	61 7.7	16.820	16.356	-22.4	19.3
2479308.9	2076/ 1/ 6-10	N	61 24.1	17.133	16.649	-23.4	-22.5	9	61 25.4	17.126	16.594	-23.2	-22.4
2479338.4	2076/ 2/ 4-21	N	61 18.6	17.065	15.683	-19.3	-16.1	-14	61 21.7	17.060	16,078	-21.1	-16.2
2479500.8	2076/ 7/16-10	F	61 6.4	16.842	16.434	-23.6	21.2	20	61 13.0	16.822	16.046	-21.8	21.0
2479530.3	2076/ 8/14-17	F	61 26.1	16.929	15.401	-18.0	13.9	-1	61 26.1	16.931	15.451	-18.3	13.9
2479559.9	2076/ 9/13- 1	F	61 0.8	16.844	13.993	-8.1	3.5	-24	61 9.8	16.845	14.596	-13.6	3.9
2479722.3	2077/ 2/22-23	N	61 26.3	17.060	14.718	-14.3	-9.7	6	61 27.0	17.058	14.547	-12.9	-9.6
2479751.8	2077/ 3/24- 8	N	61 15.2	16.981	13.739	-2.5	1.7	-15	61 19.3	16.954	13.927	-6.7	1.5
2479914.2	2077/ 9/ 2-17	F	61 9.1	16.851	14.227	-12.1	7.5	20	61 15.3	16.831	13.850	-7.0	7.2
2479943.8	2077/10/ 2- 1	F	61 27.7	17.016	13.715	0.1	-3.8	-2	61 27.8	17.015	13.716	-0.4	-3.7
2480135.7	2078/ 4/12-10	N	61 23.3	17.026	13.798	6.7	8.9	5	61 23.7	17.032	13.885	8.1	9.0
2480165.2	2078/ 5/11-18	N	61 9.5	16.937	14.992	18.3	18.1	-17	61 14.3	16.921	14.419	14.3	18.0
2480327.7	2078/10/21- 3	F	61 11.4	16.986	13.842	9.7	-10.8	18	61 17.0	16.978	14.401	14.6	-11.1
2480357.2	2078/11/19-13	F	61 28.2	17.120	15.599	21.1	-19.6	-4	61 28.5	17.121	15.449	20.4	-19.6
2480549.1	2079/ 5/30-19	N	61 22.1	16.957	16.452	25.1	21.9	4	61 22.4	16.956	16.605	25.7	21.9
2480578.7	2079/ 6/29- 2	N	61 9.2	16.846	17.137	27.9	23.2	-18	61 14.0	16.845	17.110	27.6	23.3
2480741.1	2079/12/ 8-15	F	61 18.0	17.056	16.882	26.9	-22.8	16	61 22.3	17.033	17.239	28.0	-22.8
2480770.6	2080/ 1/ 7- 2	F	61 29.7	17.100	17.104	27.3	-22.4	-6	61 30.3	17.098	17.236	27.7	-22.4
2480962.6	2080/ 7/17- 1	N	61 22.5	16.913	16.550	25.7	21.1	5	61 22.8	16.913	16.385	25.1	21.0

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			"	°/DAY	°/DAY	°	'	h	' "	°/DAY	°/DAY	°	'
2480992.1	2080/ 8/15- 8	N	61 9.2	16.898	14.552	16.9	13.7	-17	61 14.1	16.898	15.304	20.9	13.9
2481154.5	2081/ 1/25- 4	F	61 20.7	17.082	15.729	22.6	-18.8	13	61 23.8	17.078	15.168	19.8	-18.7
2481184.0	2081/ 2/23-14	F	61 25.5	17.095	13.924	11.0	-9.4	-8	61 26.7	17.089	14.188	13.4	-9.6
2481376.0	2081/ 9/ 3- 9	N	61 22.3	17.003	13.648	7.6	7.2	4	61 22.6	17.000	13.576	6.3	7.2
2481405.5	2081/10/ 2-17	N	61 8.8	16.971	13.463	-6.1	-4.0	-17	61 14.1	16.988	13.357	-0.8	-3.8
2481567.9	2082/ 3/14-17	F	61 21.1	17.068	13.435	0.6	-2.2	11	61 23.5	17.060	13.482	-2.8	-2.0
2481597.5	2082/ 4/13- 2	F	61 22.4	16.973	14.153	-12.8	9.2	-10	61 24.2	16.972	13.882	-9.9	9.0
2481789.4	2082/10/21-19	N	61 26.8	17.035	14.549	-15.3	-11.0	3	61 26.9	17.031	14.665	-16.1	-11.1
2481819.0	2082/11/20- 4	N	61 10.0	17.009	16.274	-24.6	-19.8	-18	61 16.0	16.990	15.593	-21.5	-19.6
2481981.4	2083/ 5/ 2- 3	F	61 21.8	16.932	15.434	-20.2	15.4	10	61 23.7	16.932	15.853	-22.1	15.5
2482010.9	2083/ 5/31-10	F	61 20.7	16.901	16.914	-26.3	22.0	-11	61 22.7	16.887	16.677	-25.4	21.9
2482173.3	2083/11/ 9-20	N	61 0.9	16.942	15.657	-21.7	-17.1	24	61 10.0	16.908	16.500	-24.9	-17.4
2482202.8	2083/12/ 9- 7	N	61 28.4	17.110	17.070	-26.3	-22.8	1	61 28.4	17.110	17.077	-26.3	-22.8
2482232.4	2084/ 1/ 7-17	N	61 5.0	17.060	16.088	-23.4	-22.3	-21	61 12.6	17.026	16.725	-25.6	-22.4
2482394.8	2084/ 6/18-10	F	61 19.2	16.911	16.819	-25.4	23.4	10	61 21.0	16.917	16.666	-24.7	23.4
2482424.3	2084/ 7/17-17	F	61 18.4	16.916	15.629	-20.4	20.9	-11	61 20.4	16.918	16.017	-22.1	21.0
2482586.7	2084/12/27- 9	N	61 5.3	17.059	16.361	-23.7	-23.3	21	61 12.8	17.033	15.852	-21.2	-23.2
2482616.3	2085/ 1/25-20	N	61 27.9	17.127	15.100	-16.4	-18.6	-1	61 28.0	17.127	15.147	-16.7	-18.7
2482645.8	2085/ 2/24- 7	N	60 59.6	16.952	13.815	-5.2	-9.2	-25	61 9.0	16.924	14.309	-11.2	-9.5
2482808.2	2085/ 8/ 5-17	F	61 20.6	16.914	14.703	-13.3	16.6	11	61 22.5	16.901	14.459	-10.9	16.5
2482837.8	2085/ 9/ 4- 1	F	61 20.7	16.921	13.974	-2.5	7.0	-11	61 22.8	16.926	14.084	-5.3	7.1
2483000.2	2086/ 2/13-22	N	61 10.8	17.028	14.275	-8.6	-13.0	19	61 16.6	17.003	14.070	-4.3	-12.7
2483029.7	2086/ 3/15- 8	N	61 27.2	17.032	14.136	2.6	-1.9	-3	61 27.4	17.029	14.120	1.8	-2.0
2483221.7	2086/ 9/23- 1	F	61 23.2	16.955	14.249	4.4	-0.2	10	61 24.8	16.953	14.370	6.7	-0.4
2483251.2	2086/10/22-10	F	61 20.9	17.047	15.061	14.1	-11.3	-12	61 23.4	17.036	14.811	11.9	-11.1
2483413.6	2087/ 4/ 3- 9	N	61 10.3	16.969	14.501	8.6	5.5	17	61 15.3	16.985	14.852	12.0	5.7
2483443.1	2087/ 5/ 2-18	N	61 22.5	17.007	15.564	16.7	15.6	-5	61 22.9	17.002	15.459	16.0	15.6
2483635.1	2087/11/10-12	F	61 25.3	17.092	15.713	17.1	-17.3	8	61 26.4	17.090	15.882	18.0	-17.4
2483664.6	2087/12/ 9-23	F	61 19.5	17.092	16.233	20.1	-22.9	-14	61 22.9	17.089	16.192	19.8	-22.8
2483827.0	2088/ 5/20-19	N	61 9.6	16.920	15.849	18.2	20.3	16	61 14.3	16.924	16.063	19.2	20.4
2483856.6	2088/ 6/19- 2	N	61 21.8	16.924	16.154	19.3	23.4	-5	61 22.2	16.925	16.179	19.4	23.4
2484048.5	2088/12/28- 1	F	61 29.8	17.106	16.101	18.4	-23.2	6	61 30.4	17.102	16.046	18.1	-23.2
2484078.0	2089/ 1/26-11	F	61 17.8	17.046	15.279	13.8	-18.5	-16	61 22.2	17.024	15.607	15.8	-18.6
2484240.5	2089/ 7/ 8- 2	N	61 10.5	16.848	15.792	17.4	22.4	16	61 15.0	16.843	15.587	15.9	22.3
2484270.0	2089/ 8/ 6- 8	N	61 22.3	16.936	15.180	12.4	16.4	-4	61 22.7	16.936	15.268	13.1	16.5
2484461.9	2090/ 2/14-14	F	61 29.0	17.114	15.001	10.0	-12.7	3	61 29.2	17.115	14.952	9.4	-12.7
2484491.5	2090/ 3/16- 0	F	61 11.0	16.997	14.437	1.3	-1.6	-19	61 16.8	16.982	14.575	4.9	-1.9
2484653.9	2090/ 8/25- 9	N	61 10.1	16.926	14.767	9.0	10.5	16	61 14.6	16.917	14.602	6.0	10.3
2484683.4	2090/ 9/23-17	N	61 22.5	17.028	14.513	0.4	-0.5	-5	61 23.0	17.033	14.525	1.4	-0.4
2484845.8	2091/ 3/ 5-16	F	60 59.4	16.991	14.473	6.1	-5.8	24	61 9.1	16.971	14.388	1.4	-5.4
2484875.4	2091/ 4/ 4- 2	F	61 27.4	17.040	14.556	-3.1	5.7	1	61 27.5	17.039	14.566	-3.4	5.8
2484904.9	2091/ 5/ 3-10	F	61 7.8	16.857	14.932	-11.5	15.8	-20	61 14.4	16.843	14.670	-8.0	15.6
2485067.3	2091/10/12-18	N	61 15.2	16.991	14.449	-4.2	-7.7	16	61 19.1	16.964	14.629	-7.2	-7.9
2485096.8	2091/11/11- 4	N	61 25.8	17.051	15.166	-12.7	-17.5	-7	61 26.5	17.052	15.050	-11.6	-17.4
2485259.3	2092/ 4/22- 2	F	61 2.2	16.867	14.489	-8.0	12.5	23	61 10.8	16.859	14.942	-12.2	12.8

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2485288.8	2092/ 5/21-10	F	61 26.7	16.926	15.509	-15.7	20.4	1	61 26.7	16.926	15.530	-15.8	20.5
2485318.3	2092/ 6/19-17	F	61 6.0	16.825	16.039	-19.8	23.4	-20	61 12.9	16.800	15.833	-18.4	23.4
2485480.7	2092/11/29- 6	N	61 19.5	17.048	15.641	-17.3	-21.6	13	61 22.5	17.042	15.930	-18.8	-21.7
2485510.3	2092/12/28-16	N	61 24.2	17.124	16.342	-20.8	-23.2	-9	61 25.6	17.115	16.305	-20.6	-23.2
2485672.7	2093/ 6/ 9-10	F	61 0.3	16.804	15.863	-19.9	23.0	23	61 8.8	16.821	16.242	-21.4	23.1
2485702.2	2093/ 7/ 8-17	F	61 24.2	16.943	16.414	-21.5	22.3	1	61 24.3	16.943	16.408	-21.5	22.3
2485731.8	2093/ 8/ 7- 0	F	61 4.3	16.848	15.524	-17.9	16.2	-20	61 11.4	16.861	16.017	-20.2	16.5
2485894.2	2094/ 1/16-19	N	61 21.8	17.125	16.336	-21.7	-20.7	11	61 23.8	17.117	16.163	-20.8	-20.6
2485923.7	2094/ 2/15- 6	N	61 21.1	17.064	15.200	-15.7	-12.5	-12	61 23.3	17.062	15.527	-17.6	-12.7
2486086.1	2094/ 7/27-18	F	61 1.3	16.818	15.978	-21.3	19.0	23	61 9.8	16.792	15.438	-18.3	18.7
2486115.7	2094/ 8/26- 1	F	61 26.6	16.945	14.947	-14.3	10.3	1	61 26.6	16.944	14.919	-14.0	10.3
2486145.2	2094/ 9/24- 9	F	61 6.5	16.892	13.923	-3.8	-0.7	-21	61 13.7	16.890	14.254	-8.9	-0.4
2486307.6	2095/ 3/ 6- 8	N	61 24.1	17.041	14.344	-10.1	-5.5	0	61 25.3	17.039	14.193	-8.0	-5.4
2486337.1	2095/ 4/ 4-17	N	61 18.0	16.978	13.851	1.7	6.0	-14	61 21.0	16.956	13.869	-1.8	5.8
2486499.5	2095/ 9/14- 1	F	61 4.5	16.843	13.932	-7.9	3.3	22	61 12.4	16.818	13.741	-2.1	3.0
2486529.1	2095/10/13-10	F	61 28.5	17.033	13.896	4.3	-7.9	0	61 28.5	17.033	13.899	4.3	-8.0
2486558.6	2095/11/11-19	F	61 4.3	17.019	14.736	15.9	-17.7	-22	61 12.5	16.991	14.170	10.7	-17.4
2486721.0	2096/ 4/22-18	N	61 21.1	17.001	14.155	10.5	12.7	7	61 22.1	17.010	14.350	12.3	12.8
2486750.6	2096/ 5/22- 2	N	61 12.9	16.943	15.568	20.7	20.6	-15	61 16.4	16.932	15.063	17.9	20.5
2486913.0	2096/10/31-11	F	61 7.5	16.983	14.264	13.4	-14.5	21	61 14.5	16.972	15.023	18.3	-14.8
2486942.5	2096/11/29-22	F	61 29.3	17.135	16.182	23.3	-21.8	-2	61 29.3	17.135	16.123	23.0	-21.7
2486972.0	2096/12/29- 8	F	61 0.6	17.002	16.918	26.9	-23.2	-24	61 10.3	16.980	16.750	26.0	-23.2
2487134.5	2097/ 6/10- 2	N	61 20.4	16.943	16.825	26.2	23.1	7	61 21.2	16.941	16.990	26.8	23.1
2487164.0	2097/ 7/ 9- 9	N	61 13.2	16.865	16.930	26.8	22.2	-14	61 16.6	16.869	17.134	27.4	22.3
2487326.4	2097/12/19- 0	F	61 14.5	17.051	17.107	27.6	-23.4	18	61 20.0	17.022	17.207	27.7	-23.4
2487355.9	2098/ 1/17-11	F	61 30.8	17.101	16.627	25.5	-20.6	-4	61 31.1	17.100	16.767	26.0	-20.6
2487547.9	2098/ 7/28- 9	N	61 21.2	16.910	15.976	23.4	18.8	7	61 22.0	16.909	15.679	22.1	18.7
2487577.4	2098/ 8/26-16	N	61 13.5	16.931	14.107	13.3	10.0	-14	61 17.0	16.932	14.641	17.0	10.2
2487739.8	2099/ 2/ 5-13	F	61 17.1	17.062	15.051	19.5	-15.7	15	61 21.3	17.056	14.462	15.7	-15.5
2487769.4	2099/ 3/ 6-23	F	61 26.7	17.086	13.617	6.8	-5.2	-6	61 27.4	17.082	13.745	8.7	-5.4
2487961.3	2099/ 9/14-17	N	61 21.5	17.011	13.436	3.5	3.1	7	61 22.3	17.006	13.398	1.4	3.0
2487990.8	2099/10/14- 2	N	61 13.3	17.009	13.759	-10.2	-8.2	-15	61 17.2	17.021	13.494	-5.9	-8.0
2488153.3	2100/ 3/26- 1	F	61 17.6	17.036	13.431	-3.7	2.2	14	61 21.0	17.028	13.648	-7.8	2.4
2488182.8	2100/ 4/24-10	F	61 24.1	16.967	14.637	-16.6	13.0	-8	61 25.1	16.967	14.354	-14.6	12.9
2488374.7	2100/11/ 2- 3	N	61 26.4	17.047	15.094	-19.0	-14.7	6	61 26.9	17.041	15.326	-20.2	-14.8
2488404.3	2100/12/ 1-13	N	61 14.3	17.035	16.835	-26.7	-21.9	-16	61 19.1	17.017	16.336	-24.8	-21.8
2488566.7	2101/ 5/13-10	F	61 18.3	16.900	15.997	-23.2	18.4	13	61 21.3	16.900	16.499	-25.1	18.5
2488596.2	2101/ 6/11-17	F	61 22.9	16.902	17.194	-27.5	23.1	-8	61 24.0	16.893	17.124	-27.2	23.1
2488788.2	2101/12/20-15	N	61 28.1	17.112	17.141	-26.9	-23.4	4	61 28.3	17.114	17.106	-26.8	-23.4
2488817.7	2102/ 1/19- 2	N	61 9.2	17.072	15.596	-21.5	-20.5	-19	61 15.5	17.044	16.354	-24.5	-20.6
2488980.1	2102/ 6/30-18	F	61 16.0	16.890	16.620	-25.2	23.2	13	61 18.9	16.895	16.262	-23.7	23.1
2489009.6	2102/ 7/30- 1	F	61 21.0	16.935	15.128	-18.2	18.6	-9	61 22.2	16.938	15.444	-19.9	18.7
2489172.1	2103/ 1/ 8-18	N	61 0.6	17.043	15.959	-22.7	-22.3	23	61 9.6	17.012	15.223	-18.7	-22.1
2489201.6	2103/ 2/ 7- 5	N	61 27.7	17.121	14.563	-13.4	-15.5	0	61 27.8	17.121	14.546	-13.2	-15.5
2489231.1	2103/ 3/ 8-15	N	61 4.2	16.956	13.637	-1.1	-5.0	-22	61 11.9	16.935	13.889	-6.9	-5.3

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2489393.5	2103/ 8/18- 1	F	61 18.0	16.912	14.238	-10.1	13.3	13	61 20.9	16.893	14.013	-6.8	13.2
2489423.1	2103/ 9/16- 9	F	61 23.7	16.952	13.870	1.6	2.8	-9	61 25.0	16.955	13.873	-0.6	3.0
2489585.5	2104/ 2/26- 7	N	61 6.0	16.998	13.909	-4.8	-9.0	21	61 13.3	16.972	13.865	0.5	-8.7
2489615.0	2104/ 3/26-16	N	61 27.1	17.019	14.213	7.0	2.4	-1	61 27.1	17.018	14.193	6.6	2.4
2489644.6	2104/ 4/25- 1	N	60 59.8	16.879	15.109	16.9	13.2	-24	61 8.8	16.831	14.534	12.2	12.9
2489807.0	2104/10/ 4- 9	F	61 21.1	16.960	14.376	8.7	-4.5	12	61 23.6	16.956	14.639	11.4	-4.7
2489836.5	2104/11/ 2-18	F	61 24.0	17.074	15.547	17.8	-15.0	-9	61 25.6	17.065	15.301	16.3	-14.8
2489998.9	2105/ 4/14-18	N	61 5.3	16.928	14.765	12.8	9.6	19	61 11.8	16.949	15.292	16.3	9.8
2490028.5	2105/ 5/14- 2	N	61 22.8	16.996	16.011	19.7	18.6	-2	61 22.9	16.994	15.964	19.5	18.6
2490220.4	2105/11/21-21	F	61 23.6	17.098	16.115	19.8	-20.0	10	61 25.5	17.094	16.272	20.5	-20.1
2490249.9	2105/12/21- 7	F	61 22.7	17.109	16.273	20.6	-23.4	-11	61 25.0	17.107	16.366	21.0	-23.4
2490412.4	2106/ 6/ 2- 2	N	61 4.9	16.884	16.085	20.1	22.1	20	61 11.1	16.888	16.164	20.2	22.2
2490441.9	2106/ 7/ 1- 9	N	61 22.7	16.927	16.032	19.0	23.1	-2	61 22.8	16.928	16.066	19.2	23.1
2490471.4	2106/ 7/30-16	N	60 56.5	16.780	14.976	13.6	18.5	-24	61 5.9	16.791	15.548	17.1	18.7
2490633.8	2107/ 1/ 9-10	F	61 28.3	17.103	15.845	17.4	-22.2	8	61 29.4	17.095	15.715	16.6	-22.1
2490663.4	2107/ 2/ 7-20	F	61 20.9	17.047	14.902	10.7	-15.3	-14	61 24.2	17.032	15.189	13.1	-15.5
2490825.8	2107/ 7/20- 9	N	61 6.0	16.828	15.457	15.8	20.7	20	61 12.2	16.817	15.145	13.2	20.6
2490855.3	2107/ 8/18-16	N	61 23.5	16.949	14.831	9.1	13.1	-2	61 23.6	16.949	14.864	9.5	13.2
2491047.3	2108/ 2/26-22	F	61 27.4	17.096	14.693	6.1	-8.8	6	61 26.0	17.097	14.646	5.0	-8.7
2491076.8	2108/ 3/27- 8	F	61 14.5	16.998	14.468	-3.1	2.7	-16	61 19.0	16.986	14.479	0.2	2.4
2491239.2	2108/ 9/ 5-17	N	61 6.3	16.918	14.497	5.0	6.6	19	61 12.3	16.904	14.441	1.3	6.3
2491268.7	2108/10/ 5- 1	N	61 24.1	17.049	14.596	-3.9	-4.7	-3	61 24.3	17.052	14.580	-3.4	-4.7
2491460.7	2109/ 4/15-10	F	61 26.1	17.020	14.757	-7.2	9.8	4	61 26.5	17.018	14.808	-7.9	9.9
2491490.2	2109/ 5/14-18	F	61 11.9	16.865	15.344	-14.3	18.7	-18	61 17.0	16.855	15.076	-11.9	18.6
2491652.6	2109/10/24- 3	N	61 12.1	16.992	14.661	-8.1	-11.7	17	61 17.2	16.959	14.987	-11.2	-11.9
2491682.2	2109/11/22-12	N	61 27.6	17.068	15.581	-15.3	-20.2	-4	61 28.0	17.068	15.505	-14.8	-20.1
2491874.1	2110/ 6/ 2-18	F	61 25.7	16.910	15.842	-17.4	22.2	3	61 26.0	16.912	15.899	-17.7	22.2
2491903.6	2110/ 7/ 2- 1	F	61 10.7	16.847	16.072	-19.3	23.1	-18	61 15.9	16.828	16.063	-19.1	23.1
2492066.1	2110/12/11-14	N	61 16.7	17.047	15.935	-18.6	-23.0	16	61 20.6	17.037	16.146	-19.6	-23.0
2492095.6	2111/ 1/10- 1	N	61 25.9	17.128	16.220	-19.7	-22.1	-7	61 26.7	17.121	16.265	-19.9	-22.1
2492287.5	2111/ 7/21- 1	F	61 23.7	16.942	16.138	-19.7	20.6	3	61 23.9	16.942	16.086	-19.5	20.6
2492317.1	2111/ 8/19- 8	F	61 9.4	16.888	15.134	-14.5	12.9	-18	61 14.7	16.900	15.569	-17.1	13.1
2492479.5	2112/ 1/29- 4	N	61 19.0	17.113	15.891	-19.1	-18.2	13	61 21.9	17.102	15.626	-17.5	-18.0
2492509.0	2112/ 2/27-14	N	61 23.0	17.061	14.809	-11.6	-8.5	-9	61 24.5	17.060	15.028	-13.4	-8.7
2492701.0	2112/ 9/ 6- 9	F	61 26.5	16.960	14.603	-10.2	6.3	3	61 26.7	16.956	14.534	-9.4	6.2
2492730.5	2112/10/ 5-17	F	61 11.7	16.935	14.000	0.4	-5.0	-18	61 17.2	16.931	14.110	-3.9	-4.7
2492892.9	2113/ 3/17-16	N	61 21.2	17.018	14.132	-5.7	-1.2	11	61 23.2	17.016	14.048	-3.1	-1.0
2492922.5	2113/ 4/16- 1	N	61 20.3	16.973	14.104	5.7	10.0	-11	61 22.3	16.956	14.012	3.0	9.9
2493114.4	2113/10/24-18	F	61 28.7	17.047	14.212	8.1	-11.9	2	61 26.8	17.049	14.260	8.8	-11.9
2493143.9	2113/11/23- 4	F	61 9.4	17.054	15.315	18.5	20.3	-20	61 16.0	17.028	14.752	14.6	-20.1
2493306.4	2114/ 5/ 5- 2	N	61 18.4	16.974	14.599	13.8	16.1	9	61 20.1	16.986	14.916	16.0	16.3
2493335.9	2114/ 6/ 3- 9	N	61 15.8	16.948	16.063	22.4	22.3	-11	61 18.1	16.941	15.696	20.6	22.2
2493498.3	2114/11/12-20	F	61 3.2	16.976	14.763	16.6	-17.8	23	61 11.7	16.963	15.650	21.2	-18.0
2493527.8	2114/12/12- 6	F	61 29.8	17.145	16.622	24.6	-23.1	1	61 29.8	17.145	16.633	24.6	-23.1
2493557.4	2115/ 1/10-17	F	61 5.6	17.019	16.721	25.7	-22.0	-22	61 13.6	17.003	16.918	26.2	-22.1

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
				″/DAY	″/DAY	°		h		″/DAY	″/DAY	°	
2493719.8	2115/ 6/22-10	N	61 18.1	16.928	16.989	26.6	23.4	9	61 19.7	16.924	17.073	26.8	23.4
2493749.3	2115/ 7/21-16	N	61 16.6	16.885	16.541	25.0	20.5	-11	61 18.9	16.891	16.848	26.1	20.6
2493911.7	2115/12/31- 9	F	61 10.5	17.042	17.061	27.3	-23.1	20	61 17.3	17.005	16.841	26.3	-23.1
2493941.3	2116/ 1/29-19	F	61 31.3	17.097	16.022	22.8	-18.0	-2	61 31.4	17.097	16.108	23.1	-18.0
2494133.2	2116/ 8/ 8-16	N	61 19.3	16.908	15.362	20.5	15.9	10	61 20.9	16.903	14.971	18.4	15.8
2494162.7	2116/ 9/ 7- 0	N	61 17.2	16.961	13.786	9.3	6.1	-12	61 19.6	16.962	14.108	12.5	6.2
2494325.2	2117/ 2/16-21	F	61 13.0	17.036	14.436	15.8	-12.1	18	61 18.4	17.029	13.912	11.1	-11.9
2494354.7	2117/ 3/18- 7	F	61 27.4	17.074	13.479	2.5	-0.9	-4	61 27.7	17.071	13.513	3.8	-1.0
2494546.6	2117/ 9/26- 1	N	61 20.2	17.018	13.382	-0.7	-1.2	9	61 21.6	17.010	13.439	-3.5	-1.3
2494576.2	2117/10/25-10	N	61 17.2	17.042	14.210	-14.2	-12.1	-13	61 20.0	17.050	13.854	-10.7	-12.0
2494738.6	2118/ 4/ 6- 9	F	61 13.5	16.999	13.591	-7.9	6.4	16	61 18.1	16.992	14.030	-12.5	6.7
2494768.1	2118/ 5/ 5-18	F	61 25.3	16.960	15.219	-20.0	16.3	-6	61 25.7	16.960	14.990	-18.7	16.3
2494960.1	2118/11/13-12	N	61 25.5	17.056	15.719	-22.3	-18.0	7	61 26.5	17.047	16.053	-23.7	-18.0
2494989.6	2118/12/12-22	N	61 18.2	17.055	17.210	-28.0	-23.1	-14	61 21.8	17.039	16.956	-27.1	-23.1
2495152.0	2119/ 5/24-18	F	61 14.3	16.866	16.522	-25.7	20.8	16	61 18.5	16.866	17.004	-27.2	20.9
2495181.5	2119/ 6/23- 1	F	61 24.4	16.902	17.248	-27.9	23.4	-6	61 25.0	16.897	17.290	-28.0	23.4
2495373.5	2120/ 1/ 1- 0	N	61 27.3	17.112	16.941	-26.5	-23.1	5	61 27.7	17.113	16.805	-26.0	-23.1
2495403.0	2120/ 1/30-11	N	61 13.0	17.079	15.020	-18.9	-17.8	-17	61 17.9	17.057	15.759	-22.4	-18.0
2495565.4	2120/ 7/11- 1	F	61 12.3	16.869	16.224	-24.2	22.1	16	61 16.5	16.872	15.654	-21.6	22.0
2495595.0	2120/ 8/ 9- 8	F	61 23.0	16.954	14.607	-15.4	15.7	-5	61 23.6	16.956	14.807	-16.7	15.8
2495786.9	2121/ 2/17-14	N	61 27.0	17.112	14.085	-9.8	-11.9	2	61 27.1	17.111	14.028	-9.0	-11.8
2495816.5	2121/ 3/18-23	N	61 8.3	16.959	13.609	3.2	-0.7	-19	61 14.5	16.942	13.631	-2.2	-1.0
2495978.9	2121/ 8/28- 9	F	61 14.9	16.908	13.850	-6.5	9.6	15	61 18.9	16.885	13.717	-2.2	9.4
2496008.4	2121/ 9/26-16	F	61 26.1	16.979	13.914	5.8	-1.4	-5	61 26.7	16.982	13.854	4.2	-1.3
2496170.8	2122/ 3/ 8-15	N	61 0.6	16.961	13.672	-0.6	-4.8	24	61 9.6	16.936	13.863	5.5	-4.4
2496200.3	2122/ 4/ 7- 1	N	61 26.4	17.003	14.447	11.3	6.7	1	61 26.5	17.004	14.470	11.5	6.7
2496229.9	2122/ 5/ 6- 9	N	61 4.5	16.889	15.656	20.3	16.5	-21	61 11.7	16.849	15.047	16.7	16.3
2496392.3	2122/10/15-18	F	61 18.5	16.963	14.653	12.9	-8.6	14	61 21.9	16.957	15.083	15.9	-8.8
2496421.8	2122/11/14- 3	F	61 26.4	17.097	16.081	21.0	-18.1	-7	61 27.4	17.089	15.891	20.1	-18.1
2496584.2	2123/ 4/26- 1	N	60 59.8	16.883	15.139	16.6	13.3	23	61 8.1	16.910	15.806	20.0	13.6
2496613.8	2123/ 5/25- 9	N	61 22.6	16.983	16.407	22.1	20.9	1	61 22.6	16.984	16.413	22.1	20.9
2496643.3	2123/ 6/23-17	N	61 0.7	16.849	16.203	22.1	23.4	-22	61 8.2	16.849	16.439	22.8	23.4
2496805.7	2123/12/ 3- 5	F	61 21.4	17.101	16.418	21.8	-22.0	13	61 24.1	17.095	16.485	22.0	-22.1
2496835.3	2124/ 1/ 1-16	F	61 25.2	17.120	16.103	20.2	-23.0	-9	61 26.8	17.120	16.286	21.0	-23.1
2496997.7	2124/ 6/12-10	N	60 59.5	16.846	16.170	21.2	23.2	22	61 7.7	16.848	16.026	20.2	23.2
2497027.2	2124/ 7/11-17	N	61 22.9	16.930	15.750	18.0	22.0	0	61 22.9	16.930	15.741	18.0	22.0
2497056.7	2124/ 8/10- 0	N	61 2.3	16.819	14.619	10.8	15.5	-22	61 9.7	16.832	15.129	14.6	15.8
2497219.2	2125/ 1/19-19	F	61 26.2	17.095	15.450	15.5	-20.2	9	61 27.9	17.084	15.252	14.0	-20.1
2497248.7	2125/ 2/18- 5	F	61 23.5	17.046	14.564	7.1	-11.6	-12	61 25.9	17.034	14.762	9.5	-11.8
2497411.1	2125/ 7/30-17	N	61 1.1	16.808	15.040	13.5	18.4	22	61 9.1	16.790	14.690	9.7	18.1
2497440.6	2125/ 8/29- 0	N	61 24.2	16.961	14.543	5.4	9.4	0	61 24.2	16.960	14.539	5.3	9.4
2497470.2	2125/ 9/27- 8	N	61 2.0	16.933	14.332	-4.0	-1.7	-22	61 9.7	16.932	14.321	0.5	-1.3
2497632.6	2126/ 3/ 9- 7	F	61 25.3	17.073	14.499	1.9	-4.6	7	61 26.4	17.075	14.494	0.3	-4.4
2497662.1	2126/ 4/ 7-16	F	61 17.5	16.997	14.675	-7.3	6.9	-14	61 20.8	16.987	14.556	-4.6	6.7
2497824.5	2126/ 9/17- 1	N	61 2.0	16.908	14.344	0.8	2.4	21	61 9.7	16.891	14.452	-3.5	2.1

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			' "	°/DAY	°/DAY	°	°	h	' "	°/DAY	°/DAY	°	°
2497854.1	2126/10/16- 9	N	61 25.2	17.068	14.809	-8.1	-8.9	0	61 25.2	17.068	14.803	-8.0	-8.9
2497883.6	2126/11/14-19	N	61 0.5	16.988	15.367	-15.2	-18.3	-23	61 9.2	16.984	15.034	-12.1	-18.1
2498046.0	2127/ 4/26-18	F	61 24.3	16.997	15.055	-10.9	13.5	6	61 25.1	16.995	15.168	-11.9	13.6
2498075.5	2127/ 5/26- 1	F	61 15.6	16.872	15.718	-16.6	21.0	-15	61 19.3	16.866	15.516	-15.1	20.9
2498238.0	2127/11/ 4-11	N	61 8.4	16.991	14.998	-11.7	-15.3	20	61 14.9	16.952	15.394	-14.5	-15.6
2498267.5	2127/12/ 3-21	N	61 28.8	17.080	15.922	-17.2	-22.1	-2	61 28.9	17.081	15.893	-17.0	-22.1
2498459.4	2128/ 6/13- 1	F	61 24.1	16.893	16.044	-18.3	23.2	7	61 24.8	16.895	16.095	-18.6	23.2
2498489.0	2128/ 7/12- 8	F	61 14.8	16.868	15.938	-18.2	21.9	-15	61 18.5	16.855	16.068	-18.7	22.0
2498651.4	2128/12/21-23	N	61 13.2	17.042	16.056	-19.1	-23.4	18	61 18.3	17.029	16.123	-19.2	-23.4
2498680.9	2129/ 1/20-10	N	61 27.1	17.128	15.932	-17.7	-20.1	-5	61 27.5	17.123	16.002	-18.1	-20.1
2498872.9	2129/ 7/31- 8	F	61 22.5	16.941	15.760	-17.3	18.2	7	61 23.2	16.940	15.643	-16.6	18.1
2498902.4	2129/ 8/29-16	F	61 13.9	16.926	14.810	-10.7	9.2	-15	61 17.7	16.936	15.124	-13.2	9.4
2499064.8	2130/ 2/ 8-13	N	61 15.6	17.094	15.405	-15.9	-15.0	14	61 19.5	17.082	15.107	-13.5	-14.8
2499094.3	2130/ 3/ 9-23	N	61 24.4	17.056	14.549	-7.4	-4.3	-7	61 25.2	17.055	14.663	-8.9	-4.4
2499286.3	2130/ 9/17-16	F	61 25.9	16.972	14.393	-6.0	2.1	6	61 26.5	16.965	14.333	-4.6	2.0
2499315.8	2130/10/17- 1	F	61 16.2	16.974	14.216	4.5	-9.1	-15	61 20.4	16.968	14.166	0.9	-8.9
2499478.2	2131/ 3/29- 0	N	61 17.8	16.989	14.079	-1.4	3.1	13	61 20.7	16.988	14.107	1.7	3.3
2499507.8	2131/ 4/27- 9	N	61 22.0	16.967	14.468	9.4	13.8	-9	61 23.2	16.954	14.329	7.4	13.6
2499699.7	2131/11/ 5- 2	F	61 28.4	17.059	14.630	11.7	-15.5	5	61 28.8	17.061	14.750	12.7	-15.6
2499729.3	2131/12/ 4-13	F	61 13.8	17.083	15.830	20.4	-22.2	-18	61 19.0	17.060	15.366	17.7	-22.1
2499891.7	2132/ 5/15- 9	N	61 15.1	16.943	15.076	16.6	19.0	13	61 17.7	16.959	15.491	18.9	19.1
2499921.2	2132/ 6/13-17	N	61 18.1	16.953	16.411	23.2	23.3	-9	61 19.5	16.948	16.205	22.3	23.2
2500113.2	2132/12/22-15	F	61 29.7	17.151	16.845	24.9	-23.4	3	61 29.8	17.150	16.076	25.0	-23.4
2500142.7	2133/ 1/21- 2	F	61 10.0	17.030	16.326	23.6	-19.9	-20	61 16.6	17.019	16.761	25.1	-20.1
2500305.1	2133/ 7/ 2-17	N	61 15.1	16.913	16.924	26.0	23.0	13	61 17.8	16.905	16.847	25.7	22.9
2500334.6	2133/ 8/ 1- 0	N	61 19.4	16.905	16.041	22.5	18.0	-9	61 20.8	16.912	16.338	23.7	18.1
2500497.0	2134/ 1/10-18	F	61 5.9	17.026	16.754	26.0	-21.9	22	61 14.2	16.983	16.234	23.8	-21.8
2500526.6	2134/ 2/ 9- 4	F	61 31.2	17.090	15.398	19.5	-14.7	0	61 31.2	17.090	15.403	19.5	-14.7
2500556.1	2134/ 3/10-14	F	61 5.6	16.944	13.731	8.0	-4.0	-22	61 13.7	16.907	14.347	13.9	-4.4
2500718.5	2134/ 8/20- 0	N	61 16.8	16.905	14.788	17.1	12.5	12	61 19.4	16.896	14.371	14.1	12.4
2500748.1	2134/ 9/18- 8	N	61 20.3	16.989	13.615	5.1	1.9	-9	61 21.8	16.989	13.765	7.7	2.0
2500910.5	2135/ 2/28- 6	F	61 8.3	17.004	13.949	11.8	-8.1	20	61 15.2	16.997	13.573	6.1	-7.8
2500940.0	2135/ 3/29-16	F	61 27.5	17.059	13.513	-1.8	3.4	-2	61 27.6	17.057	13.505	-1.2	3.4
2500969.5	2135/ 4/28- 1	F	60 58.9	16.863	14.227	-14.8	14.0	-25	61 8.4	16.844	13.622	-8.1	13.7
2501132.0	2135/10/ 7- 9	N	61 18.3	17.022	13.491	-4.9	-5.4	11	61 20.6	17.013	13.695	-8.3	-5.6
2501161.5	2135/11/ 5-18	N	61 20.5	17.069	14.786	-17.7	-15.7	-10	61 22.4	17.074	14.410	-15.2	-15.6
2501323.9	2136/ 4/16-17	F	61 8.8	16.957	13.903	-11.9	10.4	19	61 14.9	16.952	14.591	-16.9	10.7
2501353.4	2136/ 5/16- 1	F	61 25.9	16.952	15.834	-22.8	19.2	-2	61 26.0	16.952	15.709	-22.3	19.1
2501545.4	2136/11/23-20	N	61 24.1	17.063	16.338	-24.9	-20.5	10	61 25.6	17.050	16.715	-26.3	-20.6
2501574.9	2136/12/23- 7	N	61 21.4	17.069	17.322	-28.3	-23.4	-13	61 24.0	17.056	17.313	-28.2	-23.4
2501737.3	2137/ 6/ 4- 2	F	61 9.7	16.831	16.924	-27.4	22.4	18	61 15.4	16.830	17.244	-28.3	22.5
2501766.9	2137/ 7/ 3- 8	F	61 25.4	16.902	17.064	-27.4	22.9	-3	61 25.6	16.901	17.130	-27.6	22.9
2501958.8	2138/ 1/11- 9	N	61 25.8	17.107	16.499	-25.3	-21.8	7	61 26.7	17.109	16.229	-24.2	-21.8
2501988.3	2138/ 2/ 9-20	N	61 16.2	17.082	14.453	-15.6	-14.5	-15	61 20.0	17.064	15.068	-19.2	-14.7
2502150.8	2138/ 7/22- 8	F	61 8.0	16.848	15.682	-22.4	20.3	19	61 13.8	16.847	14.953	-18.5	20.1

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2502180.3	2138/ 8/20-16	F	61 24.5	16.972	14.131	-12.0	12.3	-3	61 24.6	16.973	14.216	-12.8	12.4
2502372.2	2139/ 2/28-22	N	61 25.6	17.099	13.724	-5.8	-7.8	5	61 26.0	17.097	13.668	-4.4	-7.8
2502401.8	2139/ 3/30- 8	N	61 11.9	16.960	13.745	7.6	3.7	-17	61 16.8	16.948	13.571	2.7	3.4
2502564.2	2139/ 9/ 8-16	F	61 11.2	16.903	13.578	-2.6	5.6	19	61 16.7	16.874	13.612	2.6	5.3
2502593.7	2139/10/ 8- 1	F	61 27.9	17.004	14.119	10.0	-5.7	-4	61 28.1	17.006	14.047	9.1	-5.6
2502785.7	2140/ 4/17- 9	N	61 25.2	16.984	14.826	15.3	10.7	3	61 25.4	16.987	14.937	16.1	10.7
2502815.2	2140/ 5/16-17	N	61 8.7	16.897	16.214	23.2	19.3	-19	61 14.2	16.865	15.679	20.6	19.1
2502977.6	2140/10/26- 2	F	61 15.3	16.965	15.067	16.9	-12.5	17	61 20.0	16.956	15.653	19.9	-12.8
2503007.1	2140/11/24-12	F	61 28.3	17.114	16.580	23.6	-20.7	-5	61 28.8	17.109	16.474	23.2	-20.6
2503199.1	2141/ 6/ 4-17	N	61 21.7	16.970	16.679	23.8	22.5	3	61 21.9	16.973	16.691	23.8	22.5
2503228.6	2141/ 7/ 4- 0	N	61 5.6	16.873	16.016	21.6	22.9	-19	61 11.3	16.878	16.439	23.3	22.9
2503391.0	2141/12/13-14	F	61 18.7	17.099	16.545	23.0	-23.2	15	61 22.3	17.090	16.442	22.4	-23.2
2503420.6	2142/ 1/12- 1	F	61 27.2	17.126	15.749	18.9	-21.7	-7	61 28.2	17.128	15.957	20.0	-21.7
2503612.5	2142/ 7/23- 0	N	61 22.6	16.934	15.349	16.2	20.1	3	61 22.8	16.931	15.270	15.7	20.1
2503642.1	2142/ 8/21- 7	N	61 7.5	16.857	14.293	7.4	12.1	-18	61 13.2	16.870	14.668	11.4	12.3
2503804.5	2143/ 1/31- 3	F	61 23.5	17.081	14.985	12.9	-17.5	12	61 26.0	17.066	14.757	10.6	-17.4
2503834.0	2143/ 3/ 1-14	F	61 25.6	17.040	14.320	3.1	-7.6	-10	61 27.2	17.032	14.413	5.3	-7.7
2504026.0	2143/ 9/ 9- 8	N	61 24.3	16.971	14.355	1.4	5.4	2	61 24.4	16.970	14.351	0.8	5.3
2504055.5	2143/10/ 8-16	N	61 7.3	16.977	14.533	-8.2	-5.9	-19	61 13.3	16.973	14.363	-4.4	-5.6
2504217.9	2144/ 3/19-15	F	61 22.6	17.046	14.442	-2.5	-0.2	10	61 24.4	17.049	14.519	-4.5	-0.1
2504247.4	2144/ 4/18- 0	F	61 20.0	16.994	14.983	-11.4	10.9	-11	61 22.3	16.986	14.805	-9.3	10.7
2504409.9	2144/ 9/27- 8	N	60 57.2	16.898	14.322	-3.5	-1.9	25	61 6.7	16.875	14.632	-8.2	-2.3
2504439.4	2144/10/26-18	N	61 25.7	17.082	15.134	-12.0	-12.8	2	61 25.8	17.081	15.168	-12.3	-12.8
2504468.9	2144/11/25- 4	N	61 5.8	17.021	15.767	-17.6	-20.8	-21	61 12.8	17.016	15.503	-15.6	-20.6
2504631.3	2145/ 5/ 7- 1	F	61 21.8	16.971	15.408	-14.2	16.8	9	61 23.3	16.968	15.576	-15.3	16.9
2504660.9	2145/ 6/ 5- 9	F	61 18.7	16.879	15.993	-18.1	22.6	-12	61 21.2	16.876	15.896	-17.5	22.5
2504823.3	2145/11/14-20	N	61 4.3	16.987	15.350	-14.8	-18.4	22	61 12.3	16.941	15.753	-17.0	-18.7
2504852.8	2145/12/14- 6	N	61 29.5	17.088	16.122	-18.3	-23.2	0	61 29.5	17.089	16.120	-18.3	-23.2
2504882.3	2146/ 1/12-16	N	61 3.3	17.011	15.679	-17.0	-21.6	-22	61 11.9	16.963	15.960	-18.2	-21.7
2505044.8	2146/ 6/24- 9	F	61 22.0	16.877	16.082	-18.5	23.4	9	61 23.3	16.877	16.072	-18.4	23.4
2505074.3	2146/ 7/23-15	F	61 18.3	16.889	15.675	-16.2	20.0	-12	61 20.8	16.880	15.863	-17.3	20.1
2505236.7	2147/ 1/ 2- 8	N	61 9.3	17.033	15.982	-18.6	-22.9	19	61 15.7	17.015	15.874	-17.7	-22.9
2505266.2	2147/ 1/31-19	N	61 27.7	17.123	15.550	-15.0	-17.3	-3	61 27.8	17.121	15.602	-15.4	-17.4
2505458.2	2147/ 8/11-16	F	61 20.8	16.939	15.347	-14.2	15.2	9	61 22.2	16.937	15.185	-12.9	15.1
2505487.7	2147/ 9/ 9-23	F	61 17.8	16.962	14.591	-6.6	5.1	-12	61 20.4	16.970	14.771	-8.9	5.3
2505650.1	2148/ 2/19-21	N	61 11.6	17.070	14.960	-12.1	-11.2	17	61 16.7	17.057	14.700	-9.1	-11.0
2505679.7	2148/ 3/20- 7	N	61 25.2	17.048	14.435	-3.0	0.1	-5	61 25.6	17.048	14.471	-4.1	-0.0
2505871.6	2148/ 9/28- 0	F	61 24.7	16.983	14.327	-1.7	-2.1	9	61 25.9	16.973	14.321	0.2	-2.3
2505901.1	2148/10/27- 9	F	61 20.2	17.008	14.550	8.3	-13.0	-13	61 23.2	17.002	14.404	5.5	-12.8
2506063.6	2149/ 4/ 8- 9	N	61 13.7	16.956	14.173	2.8	7.3	15	61 17.9	16.957	14.344	6.3	7.6
2506093.1	2149/ 5/ 7-17	N	61 23.2	16.958	14.897	12.5	17.0	-6	61 23.9	16.950	14.770	11.3	17.0
2506285.0	2149/11/15-11	F	61 27.5	17.067	15.100	14.7	-18.6	7	61 28.3	17.070	15.289	15.9	-18.7
2506314.6	2149/12/14-21	F	61 17.7	17.105	16.200	21.4	-23.3	-15	61 21.7	17.085	15.900	19.8	-23.2
2506477.0	2150/ 5/26-17	N	61 11.1	16.911	15.519	18.7	21.2	15	61 15.1	16.929	15.969	20.8	21.3
2506506.5	2150/ 6/25- 0	N	61 19.9	16.956	16.566	23.3	23.4	-6	61 20.6	16.955	16.496	23.0	23.4

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			′ ″	°/DAY	°/DAY	°	°	h	′ ″	°/DAY	°/DAY	°	°
2510803.2	2162/ 3/31- 0	F	61 19.3	17.014	14.525	-6.8	4.1	12	61 22.0	17.019	14.724	-9.3	4.3
2510832.8	2162/ 4/29- 8	F	61 22.0	16.989	15.383	-15.0	14.5	-9	61 23.4	16.983	15.201	-13.6	14.4
2511024.7	2162/11/ 7- 2	N	61 25.7	17.094	15.533	-15.5	-16.2	4	61 25.9	17.092	15.614	-16.0	-16.3
2511054.2	2162/12/ 6-12	N	61 10.4	17.048	16.059	-19.3	-22.5	-18	61 16.1	17.042	15.937	-18.4	-22.4
2511216.7	2163/ 5/18- 9	F	61 18.7	16.942	15.756	-16.9	19.6	12	61 21.2	16.939	15.936	-17.9	19.7
2511246.2	2163/ 6/16-16	F	61 21.3	16.886	16.119	-18.9	23.4	-9	61 22.8	16.886	16.125	-18.9	23.3
2511408.6	2163/11/26- 4	N	60 59.8	16.981	15.667	-17.2	-20.9	25	61 9.4	16.926	15.969	-18.5	-21.1
2511438.1	2163/12/25-15	N	61 29.5	17.093	16.137	-18.5	-23.4	1	61 29.6	17.092	16.128	-18.4	-23.4
2511467.7	2164/ 1/24- 1	N	61 7.9	17.022	15.373	-14.8	-19.4	-20	61 14.9	16.982	15.755	-17.0	-19.6
2511630.1	2164/ 7/ 4-16	F	61 19.2	16.860	15.950	-17.8	22.8	12	61 21.5	16.858	15.841	-17.1	22.7
2511659.6	2164/ 8/ 2-23	F	61 21.3	16.909	15.338	-13.7	17.4	-9	61 22.8	16.904	15.512	-14.9	17.5

TABLE 16a

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			' "	°/DAY	°/DAY	°	°	h	' "	°/DAY	°/DAY	°	°
2506698.5	2151/ 1/ 3- 0	F	61 29.0	17.152	16.818	24.4	-22.9	4	61 29.4	17.149	16.810	24.3	-22.9
2506728.0	2151/ 2/ 1-11	F	61 14.0	17.037	15.827	20.8	-17.1	-18	61 19.3	17.031	16.350	22.9	-17.3
2506890.4	2151/ 7/14- 1	N	61 11.7	16.897	16.650	24.7	21.7	15	61 15.6	16.884	16.378	23.5	21.6
2506920.0	2151/ 8/12- 7	N	61 21.7	16.924	15.514	19.4	15.0	-6	61 22.4	16.930	15.727	20.4	15.1
2507111.9	2152/ 2/20-13	F	61 30.6	17.078	14.844	15.7	-11.0	2	61 30.7	17.077	14.782	15.2	-11.0
2507141.4	2152/ 3/20-23	F	61 9.9	16.947	13.638	3.6	0.3	20	61 16.5	16.916	13.974	9.1	-0.0
2507303.8	2152/ 8/30- 8	N	61 13.8	16.901	14.313	13.3	8.8	15	61 17.6	16.888	13.949	9.4	8.5
2507333.4	2152/ 9/28-16	N	61 22.8	17.013	13.602	0.9	-2.4	-7	61 23.6	17.013	13.636	2.7	2.3
2507495.8	2153/ 3/10-15	F	61 3.0	16.966	13.626	7.5	-3.9	22	61 11.5	16.961	13.464	1.0	-3.5
2507525.3	2153/ 4/ 9- 0	F	61 27.1	17.041	13.707	-5.9	7.6	0	61 27.1	17.041	13.712	-6.0	7.6
2507554.9	2153/ 5/ 8- 8	F	61 3.9	16.876	14.810	-18.0	17.2	-21	61 11.5	16.861	14.110	-12.6	17.0
2507717.3	2153/10/17-17	N	61 15.9	17.025	13.757	-9.0	-9.5	14	61 19.2	17.014	14.144	-12.9	-9.7
2507746.8	2153/11/16- 3	N	61 23.2	17.091	15.427	-20.8	-18.8	-8	61 24.4	17.095	15.101	-19.1	-18.7
2507909.2	2154/ 4/28- 1	F	61 3.5	16.910	14.336	-15.6	14.1	22	61 11.3	16.908	15.261	-20.7	14.4
2507938.8	2154/ 5/27- 9	F	61 25.9	16.942	16.401	-25.0	21.3	0	61 25.9	16.942	16.390	-24.9	21.3
2507968.3	2154/ 6/25-16	F	61 3.4	16.781	17.133	-28.2	23.4	-22	61 11.2	16.772	16.990	-27.5	23.4
2508130.7	2154/12/ 5- 5	N	61 22.1	17.066	16.849	-26.8	-22.4	12	61 24.4	17.049	17.169	-27.8	-22.4
2508160.2	2155/ 1/ 3-16	N	61 24.0	17.078	17.150	-27.7	-22.8	-11	61 25.9	17.068	17.324	-28.2	-22.8
2508322.7	2155/ 6/15- 9	F	61 4.5	16.795	17.131	-28.3	23.3	21	61 12.0	16.791	17.151	-28.1	23.3
2508352.2	2155/ 7/14-16	F	61 25.8	16.903	16.669	-26.1	21.6	0	61 25.8	16.903	16.675	-26.1	21.5
2508381.7	2155/ 8/12-23	F	61 2.9	16.840	14.599	-17.6	14.8	-22	61 10.8	16.832	15.595	-22.4	15.1
2508544.1	2156/ 1/22-18	N	61 23.8	17.098	15.890	-23.1	-19.7	9	61 25.3	17.099	15.501	21.3	-19.6
2508573.7	2156/ 2/21- 4	N	61 18.9	17.082	13.972	-11.8	-10.8	-12	61 21.7	17.068	14.410	-15.3	-10.9
2508736.1	2156/ 8/ 1-16	F	61 3.2	16.826	15.068	-20.0	17.7	21	61 10.8	16.822	14.280	-14.7	17.5
2508765.6	2156/ 8/30-23	F	61 25.3	16.988	13.751	-8.3	8.5	0	61 25.3	16.968	13.756	-8.4	8.5
2508795.1	2156/ 9/29- 8	F	61 2.2	16.913	13.410	5.2	-2.7	-23	61 10.5	16.925	13.374	-1.4	-2.3
2508957.6	2157/ 3/11- 7	N	61 23.7	17.082	13.511	-1.5	-3.6	7	61 24.6	17.079	13.509	0.5	-3.5
2508987.1	2157/ 4/ 9-16	N	61 15.1	16.961	14.046	11.8	7.9	-15	61 18.7	16.951	13.728	7.7	7.6
2509149.5	2157/ 9/19- 0	F	61 7.1	16.896	13.449	1.6	1.4	21	61 14.1	16.862	13.717	7.5	1.1
2509179.0	2157/10/18- 9	F	61 29.1	17.026	14.486	14.2	-9.8	-1	61 29.1	17.026	14.453	13.9	-9.7
2509208.6	2157/11/16-18	F	61 2.6	16.973	16.045	23.6	-18.9	-23	61 11.7	16.940	15.230	19.5	-18.7
2509371.0	2158/ 4/28-17	N	61 23.4	16.963	15.321	19.0	14.3	6	61 24.0	16.967	15.546	20.2	14.4
2509400.5	2158/ 5/28- 0	N	61 12.5	16.904	16.702	25.4	21.4	-15	61 16.5	16.879	16.332	23.9	21.3
2509562.9	2158/11/ 6-10	F	61 11.7	16.964	15.581	20.5	-16.0	19	61 17.7	16.953	16.258	23.3	-16.3
2509592.5	2158/12/ 5-20	F	61 29.6	17.127	16.947	25.4	-22.4	-3	61 29.8	17.124	16.917	25.3	-22.4
2509784.4	2159/ 6/16- 1	N	61 20.3	16.955	16.768	24.7	23.3	5	61 20.9	16.960	16.712	24.5	23.3
2509813.9	2159/ 7/15- 8	N	61 9.9	16.898	15.666	20.4	21.5	-16	61 14.0	16.905	16.170	22.6	21.6
2509976.4	2159/12/24-23	F	61 15.5	17.094	16.448	23.2	-23.4	17	61 20.2	17.080	16.125	21.7	-23.4
2510005.9	2160/ 1/23-10	F	61 28.6	17.128	15.271	16.8	-19.5	-6	61 29.1	17.130	15.446	17.6	19.6
2510197.8	2160/ 8/ 2- 8	N	61 21.7	16.937	14.886	13.8	17.6	6	61 22.3	16.930	14.744	12.6	17.5
2510227.4	2160/ 8/31-15	N	61 12.2	16.893	14.043	3.7	8.3	-16	61 16.3	16.905	14.257	7.4	6.5
2510389.8	2161/ 2/10-12	F	61 20.3	17.062	14.526	9.6	-14.2	14	61 23.7	17.044	14.328	6.5	-14.0
2510419.3	2161/ 3/11-22	F	61 27.1	17.032	14.204	-1.1	-3.3	8	61 28.1	17.027	14.208	0.7	3.4
2510611.3	2161/ 9/19-15	N	61 23.8	16.980	14.295	-2.8	1.2	6	61 24.3	16.978	14.335	-4.0	1.1
2510640.8	2161/10/19- 0	N	61 12.0	17.015	14.869	-12.4	-10.0	-16	61 16.6	17.009	14.593	-9.2	-9.8

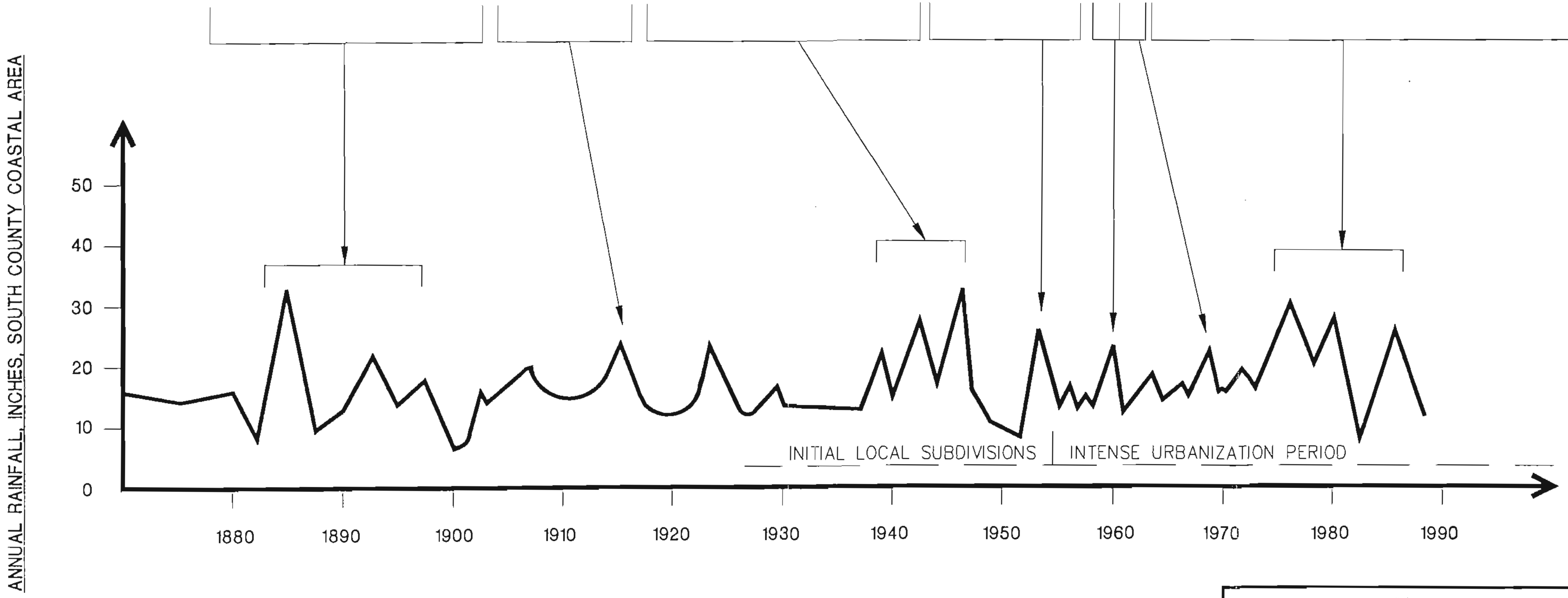
Base Map from Orange County EMA / Public Works Division

PLATE 4
CONSTRAINTS SEVERITY MAP
CITY of DANA POINT
COASTAL DEVELOPMENT DISTRICT

ZEISER
GEOTECHNICAL, INC.
DATE 6-29-90 PN 89312-2
]

HISTORIC COASTAL EROSION EVENTS

CITY OF DANA POINT



1884-1891 Storm Periods:
- 100' + Seacliff erosion and retreat, Dana Point Headlands, western face. Large Deep-seated Landslides.
- 75' ± Blufftop and Bluff face retreat, Dana Point Headlands(southern face).
- Very Large Delta Forms, San Juan Creek Outfall
- Bluff Failures and Blufftop Retreat, Dana Bluffs (North Doheny Palisades
- 30' Blufftop retreat, Central Capistrano Bluffs

1916 Storm
- Large Bedrock Landslide with 80' + Blufftop retreat, Cannòns Restaurant area, Dana Cove Subunit
- Delta Progrades 800' Seaward, San Juan Creek

1938-1941 Storms:
- 40' Beach Erosion, Capistrano Beach
- 20' Blufftop recession, North Doheny Palisades
- 25-40' Waves, 1939 Southern (El Nino) Storm
- Large Bedrock Landslides, Monarch Bay Seacliff
- 150' Terrace erosion and retreat of Blufftop, south Niguel Shores
- Locally 100' + bluff face retreat, Dana Point Headlands

1952 storm:
- Terrace (Blufftop) Landslides, Nothern Nigual Shores (Dana Strand)
- Up to 30 feet Blufftop Retreat, Dana Cove and old Golden Lantern Areas
- 70-80' Talus cones removed, Dana Cove and Headlands Subunits

1958: Pines Peak Landslides

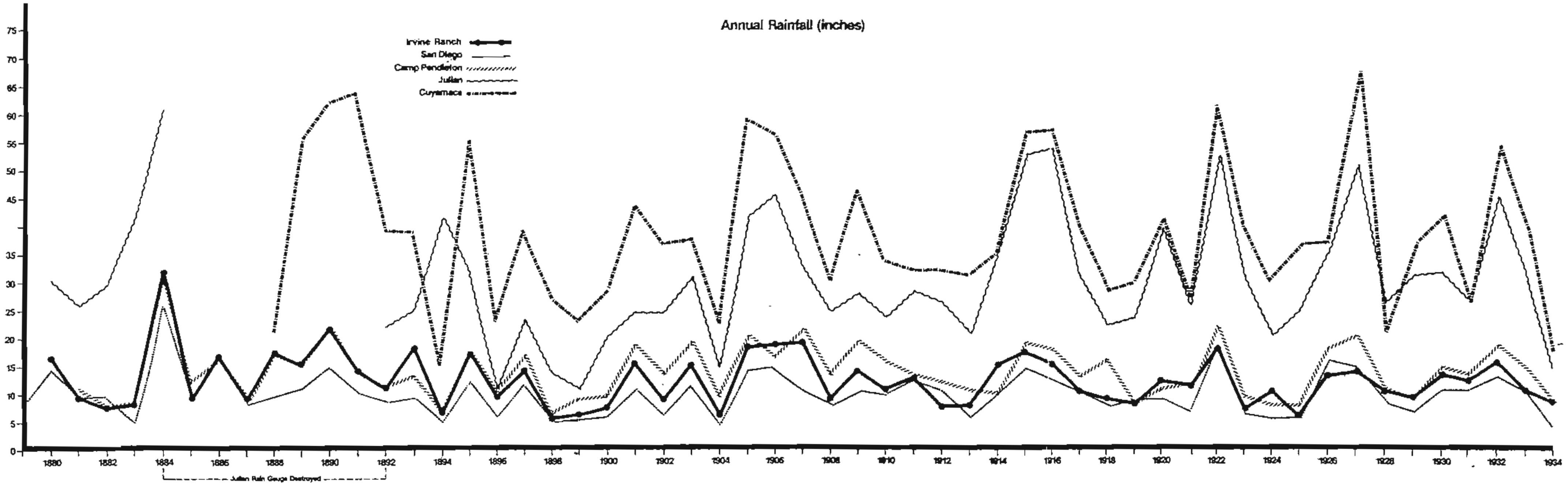
1968-69: Blockfalls, Dana Harbor Park

1978-1983 Storms:
- 15-20' Blufftop (Terrace) erosion seaward of Crown Coast Road, Monarch Bay
- Sea Caves form, Dana Point Headlands(western face)
- Revetment destruction, Dana Strand Beach (1983) (Southern El Nino Storm)
- 20-30' retreat of Blufftop (Terrace Sands), Southern end of Dana Strand Road
- Surficial Failures, Cove Road Fill
- Cannons Restaurant Landslide (1980)
- Large Blockfalls, Dana Harbor Park(1978)
- 50-60' Beach erosion, Southern Capistrano Beach
- Estrella Stairs Landslides(1978)
- 20' Blufftop retreat due to Blockfalls, Dana Bluffs (Doheny Palisades)

PLATE 5
HISTORICAL COASTAL EROSION
VERSUS
HISTORIC RAINFALL PERIODS,
DANA POINT COASTAL ZONE

ZEISER
GEOTECHNICAL, INC.

PN: 89312-2 DATE: 6/29/90



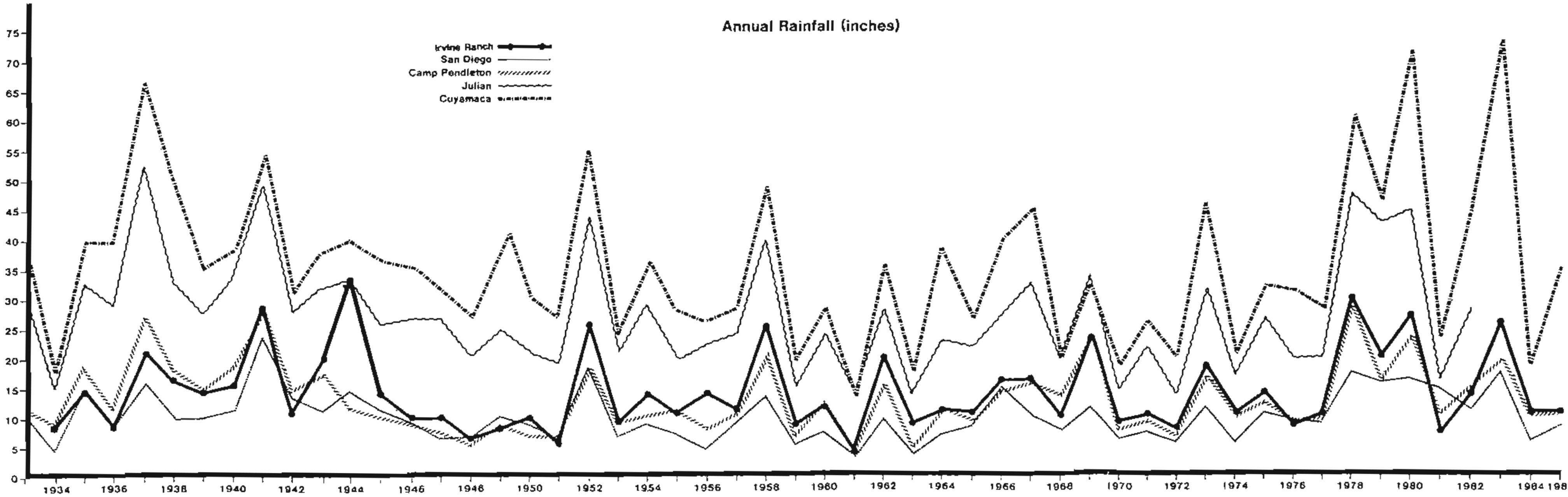
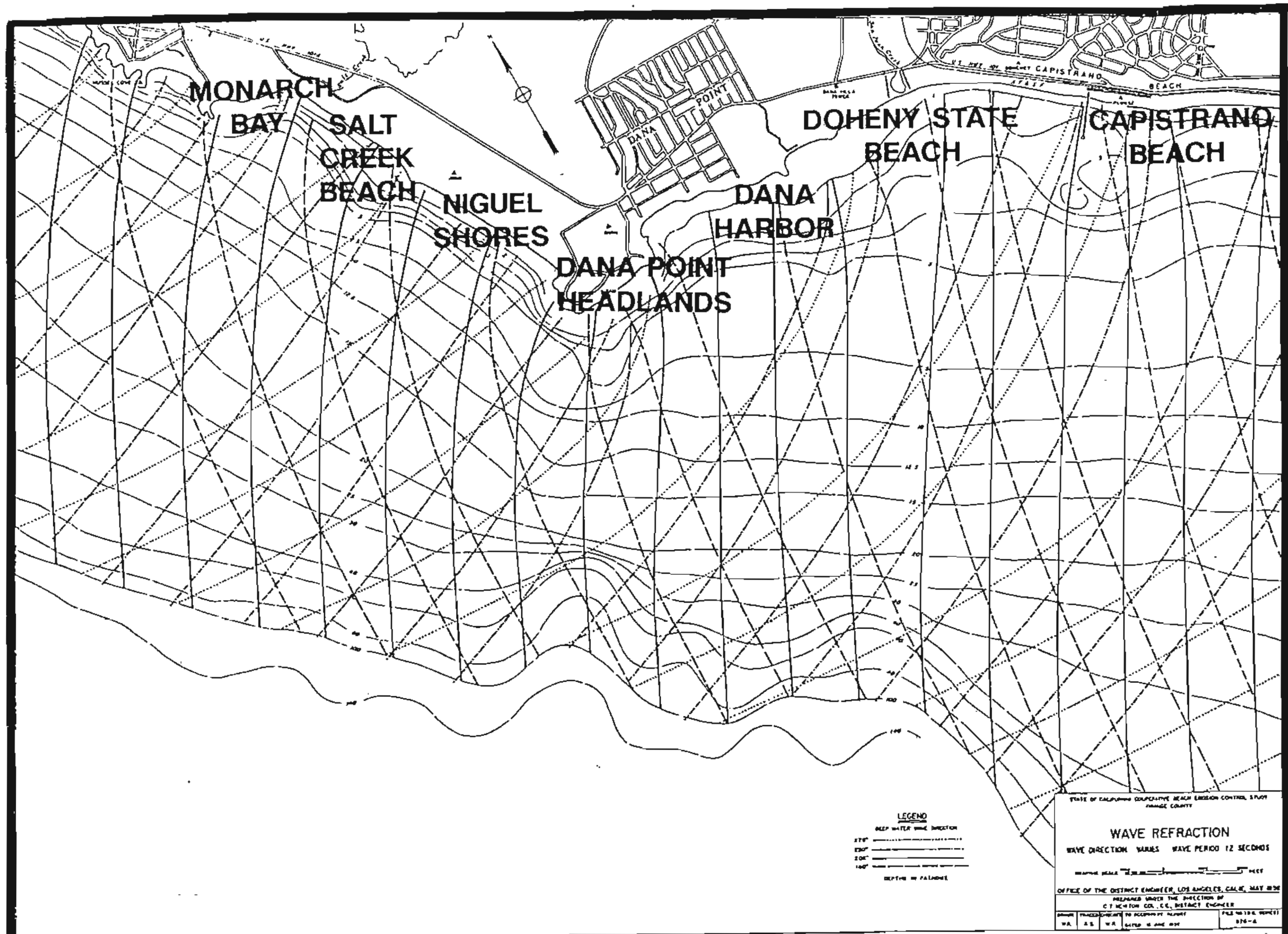


PLATE 6

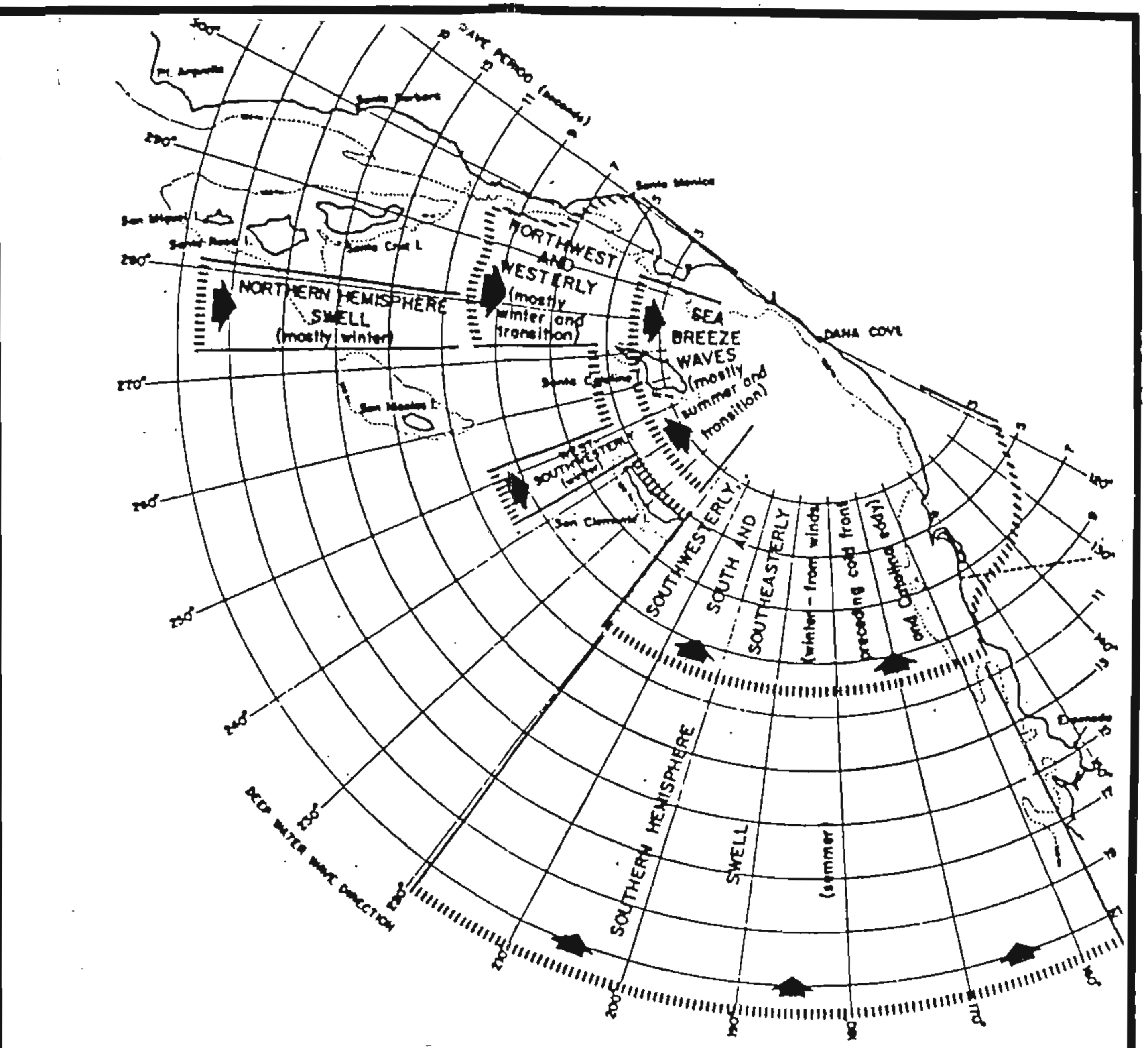
HISTORICAL SOUTH COASTAL RAINFALL,
ANNUAL PEAKS
DANA POINT COASTAL INVESTIGATION

ZEISER
GEOTECHNICAL, INC.

PN: 89312-2 **DATE:** 6-29-90



A WAVE REFRACTIONS WAVE PERIOD (Ts) EQUALS 12 SECONDS



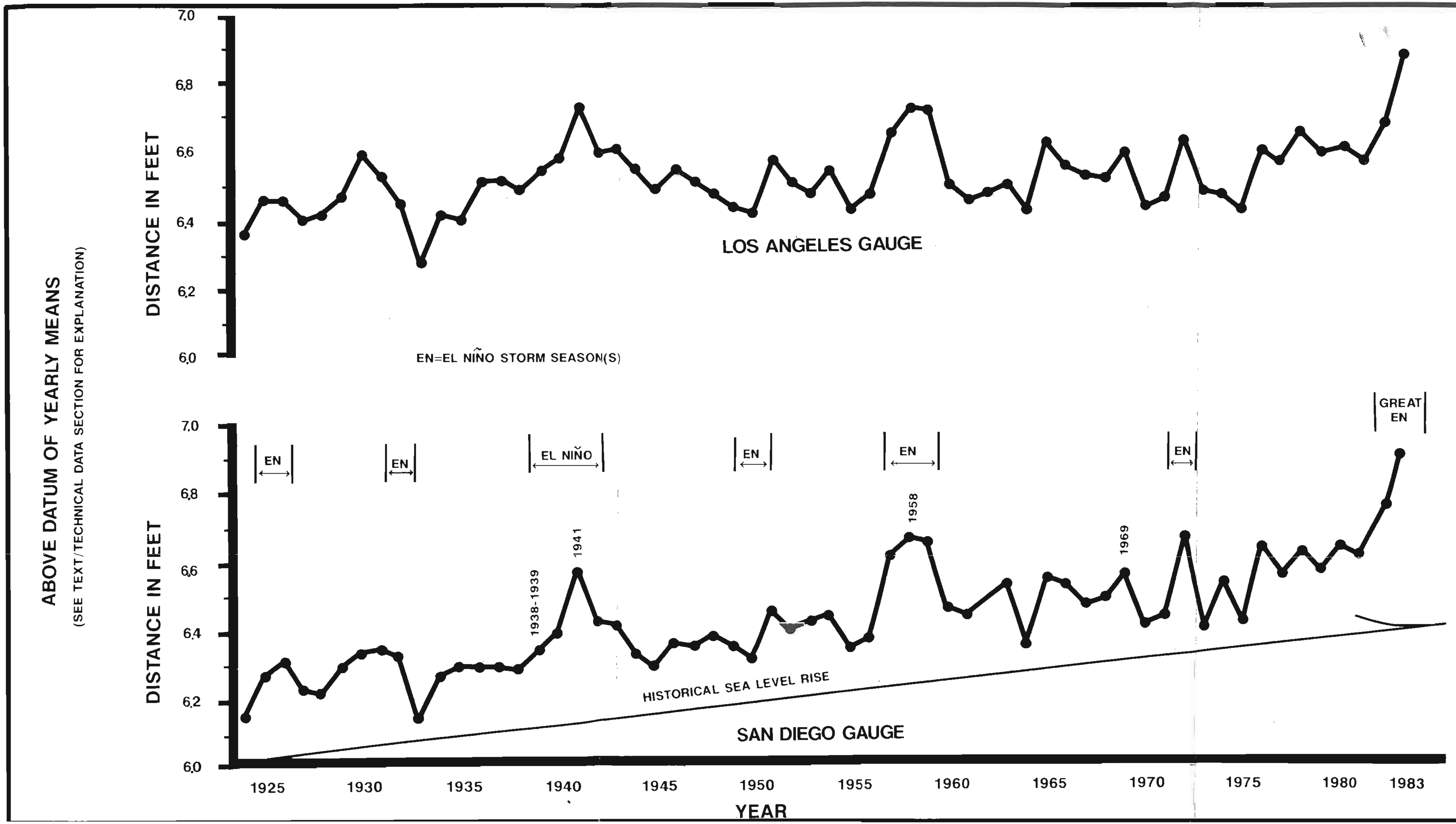
B DEEP WATER WAVE DIRECTIONS

SOURCE: ARMY CORPS OF ENGINEERS, 1959
MARINE ADVISERS, 1960

PLATE 8
WAVE DIRECTION AND REFRACTION DIAGRAMS
DANA POINT COASTAL ZONE

ZEISER
GEOTECHNICAL, INC.

DATE 6-29-90 PN 89312-2



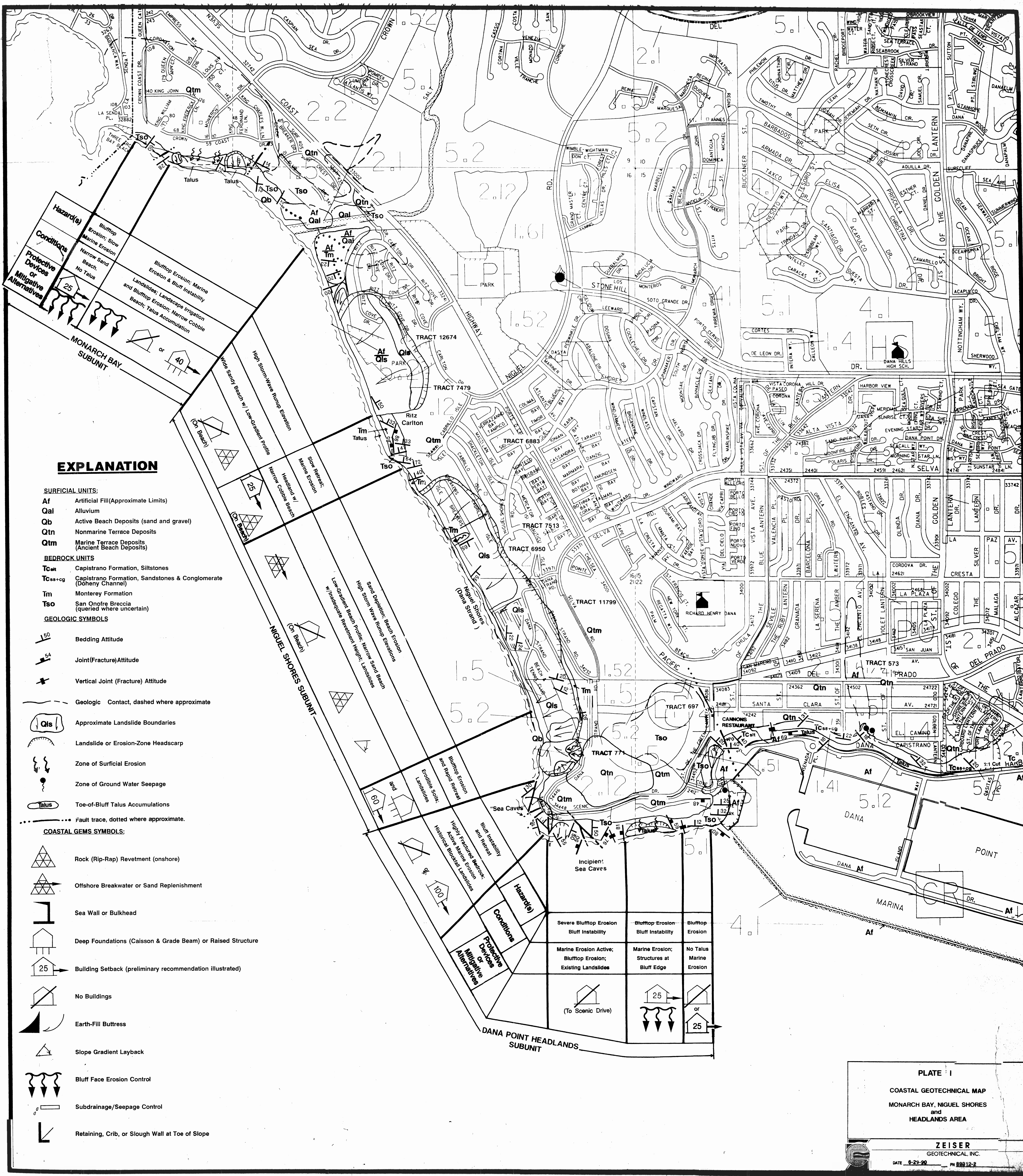
Source: NOS (National Ocean Survey)/NOAA

PLATE 7

HISTORICAL TIDE GAUGE RECORDS
SOUTHERN CALIFORNIA COASTAL REGION
1924 TO 1983
DANA POINT COASTAL INVESTIGATION

ZEISER
GEOTECHNICAL, INC.

DATE 6-29-90 PN 89312-2



EXPLANATION

SURFICIAL UNITS:

Af	Artificial Fill(Approximate Limits)
Qal	Alluvium
Qb	Active Beach Deposits (sand and gravel)
Qtn	Nonmarine Terrace Deposits
Qtm	Marine Terrace Deposits (Ancient Beach Deposits)

BEDROCK UNITS

Tcslt	Capistrano Formation, Siltstones
Tcss+cg	Capistrano Formation, Sandstones & Conglomerate (Doheny Channel)
Tm	Monterey Formation
Tso	San Onofre Breccia (queried where uncertain)

GEOLOGIC SYMBOLS

Bedding Attitude

Joint(Fracture)Attitude

Vertical Joint (Fracture) Attitude

Geologic Contact, dashed where approximate

Approximate Landslide Boundaries

Landslide or Erosion-Zone Headscarp

Zone of Surficial Erosion

Zone of Ground Water Seepage

Toe-of-Bluff Talus Accumulations

Fault trace, dotted where approximate.

COASTAL GEMS SYMBOLS:

Rock (Rip-Rap) Revetment (onshore)

Offshore Breakwater or Sand Replenishment

Sea Wall or Bulkhead

Deep Foundations (Caisson & Grade Beam) or Raised Structure

25 Building Setback (preliminary recommendation illustrated)

No Buildings

Earth-Fill Buttress

Slope Gradient Layback

Bluff Face Erosion Control

Subdrainage/Seepage Control

Retaining, Crib, or Slough Wall at Toe of Slope

PLATE I

COASTAL GEOTECHNICAL MAP

MONARCH BAY, NIGUEL SHORES
and
HEADLANDS AREA

ZEISER
GEOTECHNICAL, INC.

DATE 6-29-90 PN 89312-2

Hazard(s)	Bluff Instability; Slope Erosion	Bluff Top Erosion Bluff Face Instability	Bluff Erosion; Seepage; Bluff Face Instability	Bluff Top Erosion and Retreat; Bluff Face Instability	Slopeface Erosion and Siltation	Flooding; Storm Wave Runup	Sand Depletion Storm Wave Runup
Conditions	Landslides in Bedrock & Fill; Bluff Face Erosion	Talus at Toe; Adverse Structure, Local Severe Blufftop Erosion Rockfalls Along Bluff Face	Storm Drain Outlet; Blockfalls; Inadequate Setbacks	Talus at Toe Adverse Bedrock Structure. Inadequate Bluff Top Protection	Bedrock with Favorable Bedding Orientations; Siltstones & Sandstones Locally Subject to Rilling in 1:1 Graded Cut Slopes	Wide Sandy Beach Subject to Periodic Flood Replenishment & Direct Southerly Wave Attack	Wide Sandy Beach with Shallow Gradient and Low Runup Elevation; Existing Revetment
Protective Devices or Mitigative Alternatives	40	25	25	40		or	or

DANA COVE AND HARBOR SUBUNIT

DOHENY BEACH / CAPISTRANO BEACH SUBUNIT

EXPLANATION

SURFICIAL UNITS:

Af	Artificial Fill(Approximate Limits)
Qal	Alluvium
Qb	Active Beach Deposits (sand and gravel)
Qtn	Nonmarine Terrace Deposits
Qtm	Marine Terrace Deposits (Ancient Beach Deposits)

BEDROCK UNITS

Tcslt	Capistrano Formation, Siltstones
Tcss+cg	Capistrano Formation, Sandstones & Conglomerate (Doheny Channel)
Tm	Monterey Formation
Tso	San Onofre Breccia (queried where uncertain)

GEOLOGIC SYMBOLS

24 Bedding Attitude

75 Joint Fracture Attitude

GEOLOGIC SYMBOLS (CONT):

Vertical Joint (Fracture) Attitude

Fault trace, dotted where approximate

Geological Contact, dashed where approximate

Qls Approximate Landslide Boundaries

Landslide or Erosion-Zone Headscarp

Zone of Surficial Erosion

Zone of Ground Water Seepage

Talus Toe-of-Bluff Talus Accumulations

COASTAL GEMS SYMBOLS:

Rock (Rip-Rap) Revetment (onshore)

Offshore Breakwater or Sand Replenishment

Sea Wall or Bulkhead

Deep Foundations (Caisson & Grade Beam) or Raised Structure

25 Building Setback (preliminary recommendation illustrated)

No Buildings

COASTAL GEMS SYMBOLS (CONT):

Earth-Fill Buttress

Slope Gradient Layback

Bluff Face Erosion Control

Subdrainage/Seepage Control

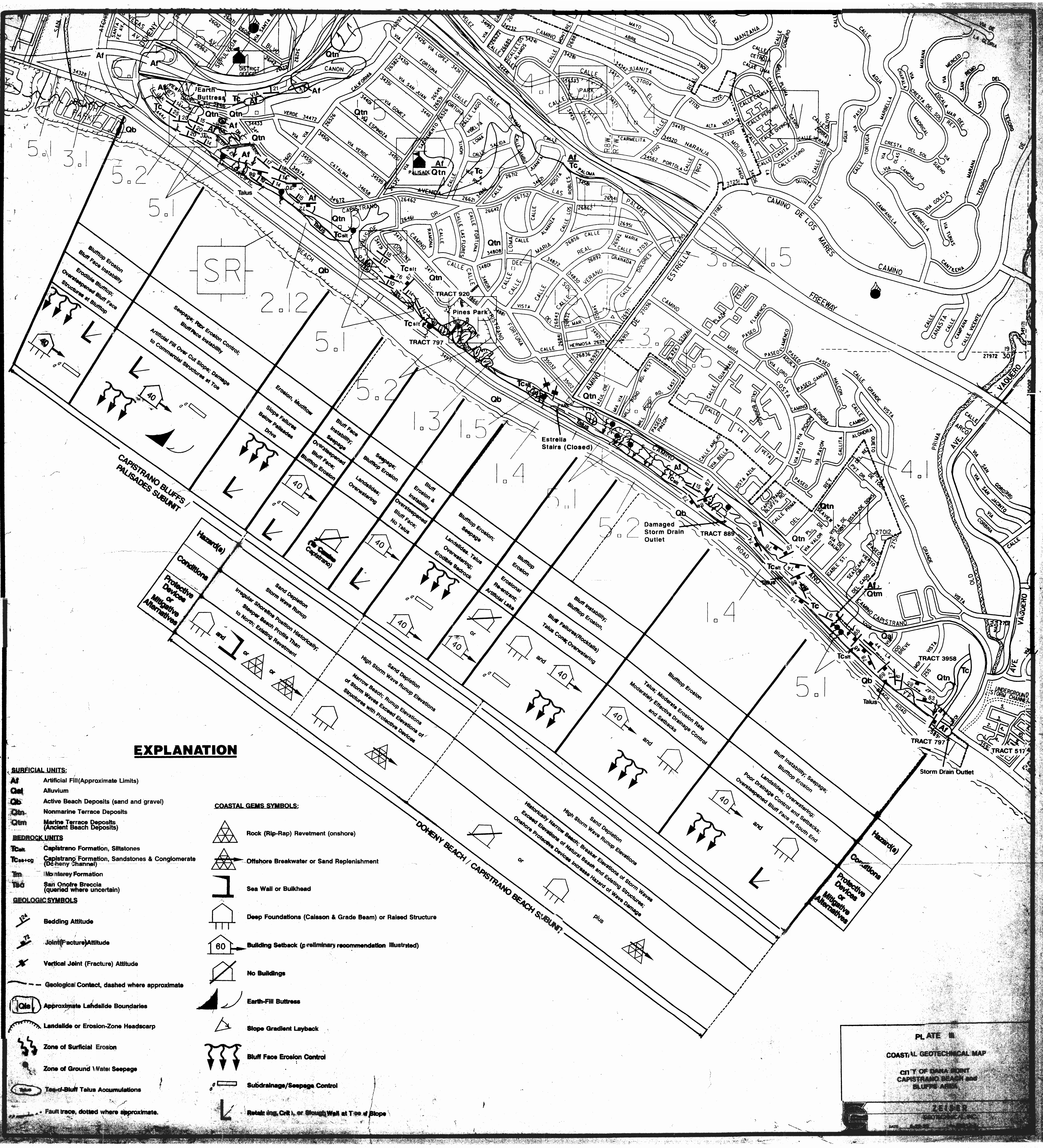
Retaining, Crib, or Slough Wall at Toe of Slope

PLATE II

COASTAL GEOTECHNICAL MAP

DANA POINT HARBOR
and
DOHENY BEACH AREAS

ZEISER
GEOTECHNICAL, INC.
DATE 6-29-90 PN 89312-2



EXPLANATION

SURFICIAL UNITS:

Af	Artificial Fill(Approximate Limits)
Qal	Alluvium
Qb	Active Beach Deposits (sand and gravel)
Qtn	Nonmarine Terrace Deposits
Qtm	Marine Terrace Deposits (Ancient Beach Deposits)

BEDROCK UNITS

Tcslt	Capistrano Formation, Siltstones
Tcss+cg	Capistrano Formation, Sandstones & Conglomerate (Doheny Channel)
Tm	Monterey Formation
Tsd	San Onofre Breccia (queried where uncertain)

GEOLOGIC SYMBOLS

- Bedding Attitude
- Joint(Fracture)Attitude
- Vertical Joint (Fracture) Attitude
- Geological Contact, dashed where approximate
- Approximate Landslide Boundaries
- Landslide or Erosion-Zone Headscarp
- Zone of Surficial Erosion
- Zone of Ground Water Seepage
- Toe-of-Bluff Talus Accumulations
- Fault trace, dotted where approximate.

COASTAL GEMS SYMBOLS:

- Rock (Rip-Rap) Revetment (onshore)
- Offshore Breakwater or Sand Replenishment
- Sea Wall or Bulkhead
- Deep Foundations (Caisson & Grade Beam) or Raised Structure
- 60 Building Setback (preliminary recommendation illustrated)
- No Buildings
- Earth-Fill Buttress
- Slope Gradient Layback
- Bluff Face Erosion Control
- Subdrainage/Seepage Control
- Retaining, Crib, or Slough Wall at Toe of Slope

PLATE III

COASTAL GEOTECHNICAL MAP

CITY OF DANA POINT
CAPISTRANO BEACH and
BLUFFS AREA

ZEISER
GEOTECHNICAL INC.

DATE