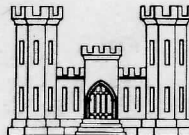


TECHNICAL REPORT ON
COOPERATIVE BEACH EROSION STUDY
OF COAST OF NORTHERN CALIFORNIA

POINT DELGADA TO
POINT AÑO NUEVO

APPENDIX VIII

CONTRACT No. W-04-193-ENG 5196



JUNE 1965

Prepared in Cooperation with
Department of Water Resources
State of California

Conducted by
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA

FINAL REPORT
ON
COOPERATIVE BEACH EROSION STUDY
PT. DELGADA TO PT. AÑO NUEVO

APPENDIX VIII

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U. S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
100 McAllister Street
San Francisco, California

SPNGP

June 1965

SUBJECT: Cooperative Beach Erosion Study of Coast of Northern California,
Point Delgada to Point Ano Nuevo (Contract No. W-04-193-Eng.-5196,
Appendix VIII, final report)

TO: Division Engineer
U. S. Army Engineer Division, South Pacific
San Francisco, California

AUTHORITY

1. CONGRESSIONAL AUTHORITY

The basic authority for this report is contained in Public Law 520, 71st Congress (River and Harbor Act of July 3, 1930), Section 2, which "authorized and directed to cause investigations and studies to be made in cooperation with the appropriate agencies of various states on the Atlantic, Pacific and Gulf coasts and on the Great Lakes, and the Territories, with a view to devising effective means of preventing erosion of shores of coastal and lake waters by waves and currents ..."

2. Formal application, dated 27 July 1946, for a continuing cooperative study of the problems of beach erosion and shore protection along the entire Pacific Coast of California was made by the Division of Beaches and Parks, Department of Natural Resources, State of California, under authority of sections 506.6 and 5015, Public Resources Code of the State of California. On 10 September 1953, beach erosion control functions were transferred to the Division of Water Resources Planning, Department of Water Resources.

3. Provision was made in the general agreement for accomplishment of the study by specific areas to be defined in appendices to the application, those appendices to be implemented from time to time upon agreement between the parties. The Chief of Engineers, on 12 September 1946, approved the application by the State of California for the continuing study. Appendix VIII to this agreement was executed on 27 March 1959 and provided for examination of the California Coast from Point Delgada to

Point Ano Nuevo over a three-year period. Funds for the study were provided on a matching basis, with the Federal Government and the State of California each contributing \$30,000.

PURPOSE AND EXTENT OF STUDY

4. PURPOSE

The purpose of this study was to examine, and to establish a basis for future examination, the coast of California from Point Delgada to Point Ano Nuevo with a view to: (a) obtaining data on shore processes and on shore problems to enable the planning and design of effective protective measures; (b) determining the possible effects of proposed shoreline developments; and (c) determining methods of maintaining stream outlets.

5. WORK ITEMS

Specific work items delineated in this study were:

a. Develop statistical wave data for selected open sea localities between the Oregon-California boundary and Cape San Martin.

b. Obtain vertical aerial photographs of the entire shoreline and oblique aerial photographs of selected locations.

c. Establish photo stations along the shoreline. Obtain two sets of ground photographs showing summer and winter conditions.

d. Initiate establishment or re-establishment of baselines on shore and reference for future use. Initiate measurement of summer profiles to 36-foot depths or to mean lower low water as specified, at the following locations:

Shelter Cove - 4 profiles to 36-foot depth
Ten Mile Beach - 4 profiles to 36-foot depth
Russian Gulch - 3 profiles to MLLW
Van Damme Beach Park - 3 profiles to MLLW
Navarro River - 3 profiles to 36-foot depth
Point Arena - 4 profiles to 36-foot depth
Gualala River - 4 profiles to 36-foot depth
Russian River - 5 profiles to 36-foot depth
Wrights Beach - 2 profiles to 36-foot depth
Bodega Bay - 7 profiles to 36-foot depth
Dillon Beach - 4 profiles to 36-foot depth
McClures Beach - 4 profiles to MLLW
Point Reyes Beach - Review studies by Parker Trask
Drakes Bay - 3 profiles to 36-foot depth
Bolin Bay - 5 profiles to 36-foot depth
Muir Beach - 2 profiles to MLLW

San Francisco Beach - 8 profiles to 36-foot depth
 Half Moon Bay - 3 profiles to 36-foot depth
 to augment navigation surveys
 San Gregorio Creek - 2 profiles to 36-foot depth
 Pescadero River - 2 profiles to 36-foot depth

(In several instances profiles to the specified 36-foot depths were not completed due to continued periods of adverse weather conditions.)

e. Obtain and analyze sand samples as follows: summer, one each from dunes, backshore, mean sea level, and three fathom depth; winter, one sample each from backshore and mean sea level. It was estimated that 200 mechanical and 50 petrographic analyses would be made.

6. PRIOR REPORTS

No prior Corps of Engineers reports have been published on the section of coastline under study. However, the following navigation and beach erosion control studies provide additional data at specific locations:

Table 1

Prior Federal Reports

<u>Title</u>	<u>Year</u>	<u>Document</u>
Noyo River and Harbor, California, Review of Reports	1962	H. Doc 121/87/2
Bodega Bay, California	1938	H. Doc 619/75/3
Fort Funston, California Beach Erosion Control Study	1940	Unpublished
Half Moon Bay Harbor	1947	H. Doc 644/80/2

7. NON-FEDERAL REPORTS

A compilation of pertinent reports and technical papers covering the section of coast studied is given in "List of References" at the end of this report. In addition, the "Bibliography of Marine Geology and Oceanography, California Coast," Special Report 44, State of California Division of Mines, California, 1955, provides a complete (to 1955) listing of available literature on the subject.

DESCRIPTION

8. GENERAL

The area under consideration covers the California Coast from Point Delgada to Point Ano Nuevo. The locations of the study sites are shown

on Plate 1. Plans, profiles and an index thereto are contained in Annex A. United States Geological Survey and United States Coast and Geodetic Survey map references giving study locations are shown in Tables 1 and 2 of Annex A. Drainage areas between Pt. Delgada and Ano Nuevo are tabulated in Table 3 of Annex A.

9. OFFSHORE HYDROGRAPHY

From point Ano Nuevo to San Francisco, the continental shelf (to the 100-fathom contour) widens from approximately 10 miles at Point Ano Nuevo to approximately 26 miles (including the Farallon Islands) off San Francisco. The continental shelf remains relatively wide to Cordell Bank, approximately 20 miles west of Point Reyes, and then narrows to approximately 5 miles offshore of Fort Ross in Sonoma County, and remains relatively narrow to approximately Point Arena. From Point Arena to Point Delgada, at the northerly limit of the study, the shelf varies in width from a minimum of 3 miles to a maximum of 13 miles. The 50-fathom contour generally parallels the 100-fathom contour, and is approximately 20 miles offshore at San Francisco, but approaches to within approximately one mile of the shore at Pt. Cabrillo. Table 2 gives the distances to the 10-, 50-, 100- and 500-fathom contours. Distances are measured from the shoreline to the nearest position of respective contours and are not necessarily measured normal to the shoreline.

10. SUBMARINE CANYONS

Along this reach of coast, numerous canyons extend from deep water through the continental shelf. The largest canyon in the study area is the Vizcaino Sea Valley, off Point Delgada, which extends from water depths greater than 1800 fathoms to within 1,000 feet of the shore approximately 5 miles north of Point Delgada. Near the head of the canyon, the 100-fathom contour reaches within one-half mile of the shore.

TABLE 2

Location of 10-, 50-, 100- and 500-fathom Contours

Study Site	Distance from shore to respective contours				Remarks
	10-fath	50-fath	100-fath	500-fath	
	(N.M.)	(N.M.)	(N.M.)	(N.M.)	
Shelter Cove	0.8	4.1	5.6	12.0	To Vizcaino Sea Valley
Ten Mile River	0.5	3.0	6.9	12.0	To Noyo Canyon
Russian Gulch	0.8	1.8	6.6	16.5	
Van Damme Beach	0.5	2.1	6.6	16.5	
Navarro River	0.5	2.3	8.7	14.8	To Navarro Canyon
Pt. Arena	0.7	4.4	10.8	16.6	To Arena Canyon
Gualala R.	0.5	4.7	9.6	15.0	
Russian R.	0.8	6.8	16.5	24.1	
Wrights Beach	0.7	7.1	16.9	24.3	
Bodega Bay	1.6	7.2	17.6	28.2	
Dillon Beach	1.2	9.7	19.5	29.1	
McClures Beach	0.5	8.6	18.5	28.0	
Pt. Reyes Beach	0.5	9.1	18.0	25.1	
Drakes Beach	0.8	13.7	21.7	24.0	
Bolinas Bay	2.3	21.7	24.5	27.4	
Muir's Beach	1.8	20.6	24.2	26.4	
San Francisco Beach	1.6	22.4	25.9	28.0	
Half Moon Bay	4.3	21.0	26.4	30.0	
San Gregorio	1.5	13.5	20.6	29.4	
Pescadero	1.0	10.0	17.8	23.0	
Point Ano Nuevo	1.0	8.3	16.1	19.9	To submarine canyon

N.M. = nautical mile.

11. DEVELOPMENT OF STATISTICAL WAVE DATA

Statistical wave data developed as a part of this study are contained in a report entitled "Wave Statistics for Seven Deep Water Stations Along the California Coast," prepared by the National Marine Consultants in December 1960. The location of the four deep water stations pertinent to this study are shown on Plate 2. Graphical summaries for these stations pertinent to this study are given on Plates 3, 4, 5 and 6. Copies of the report are on file in the offices of the U. S. Army Coastal Engineering Research Center, Washington, D. C.; the Division Engineer, U. S. Army Engineer Division, South Pacific; and the District Engineer, U. S. Army Engineer District, San Francisco, both in San Francisco, California; and the Director, California State Department of Water Resources, Sacramento, California.

12. For each of the seven stations studies, twelve monthly and one annual percent of occurrence tables were prepared for both sea and swell covering the period from January 1956 to December 1958. Each table gives a three-way distribution of significant wave heights, significant wave periods and wave direction at the deep-water station. Waves moving away from shore were neglected as such waves would have no appreciable effect on shore processes. In addition to the detailed wave statistics, a discussion is given of the meteorological aspects of the wave regime along the Pacific Coast and also a description of the hindcast methods used. The statistical wave data are summarized in Plates 3, 4, 5 and 6 for the applicable stations 1, 2, 3 and 4, respectively.

13. AERIAL PHOTOGRAPHY

During October 1959, aerial photography was obtained of the California Coastline, at a scale of 1:10,000, from a point two miles north of Point Delgada to a point one mile south of Point Ano Nuevo. The photography included coverage of Bodega Harbor and Bolinas Bay and oblique photos of each of the 20 study sites. Copies of these aerial photographs are on file in the Coastal Engineering Research Center, Department of the Army, Washington, D. C.; the District Engineer, U. S. Army Engineer District, San Francisco; and the Director, California State Department of Water Resources, Sacramento, California. Selected aerial photographs were enlarged, to a scale of 1 inch equals 400 feet, for use in laying out profiles and sampling of beach materials. An index of aerial photography taken under this contract is given on Plate 7.

14. PHOTO STATIONS

Shoreline photographs were taken in conjunction with beach sampling. However, the presence of coastal fogs during the summer and inclement weather during the winter prevented photography at a number of sites. Wherever possible, two sets of photographs were obtained at each site. Sufficient photographs were taken to serve as a basis for future comparisons of shoreline changes. Ground photographs are on file in the office of the District Engineer, U. S. Army Engineer District, San Francisco.

15. SURVEYS

Surveys of the profiles at the study sites were accomplished generally in three steps: first, monumentation; second, measurement of land sections; and third, measurement of water sections. Wherever possible, two standard Corps of Engineers monuments, set in concrete, were established on each profile. In some instances where the beach area was highly unstable and there were no suitable backshore references, it was necessary to establish offset monuments. In locations where grid coordinates were available, the monuments have been tied into the grid system, and grid intersections are shown on the plan drawings for each study site. At other locations, sufficient monuments were located to permit re-establishing the ranges

marking the profiles. However, at these locations, azimuth orientation is approximate and north arrows on site drawings are marked as such.

16. DATUM

The datum used in surveys for this study is mean lower low water (MLLW), the standard datum for Pacific Coast hydrographic surveys. When available, United States Coast and Geodetic Survey (USC&GS) tidal bench marks were used for reference elevations. In other areas, the datum was obtained by estimating the ocean still-water level or surface and measuring the elevation of this surface, making note of the time. This elevation was then converted to an estimated MLLW datum by reference to the USC&GS table of predicted tides for the time at which the measurement was made. In all instances, Corps of Engineers standard disks set in concrete were established at each site (generally on two or more ranges) in order to provide the necessary horizontal and vertical control for future remeasurements.

17. EFFECT OF FARALLON ISLANDS ON WAVE ACTION ON SAN FRANCISCO BAR

The Farallon Islands and associated shoals form a series of projections on a 15-mile long northwesterly trending ridge, about 20 miles west of the San Francisco Bar. Seaward of the Islands, the bottom drops rapidly to water depths of 1,000 feet within five miles. Toward the San Francisco Bar, the bottom remains relatively constant at 180 feet.

18. Wave retraction diagrams indicate that waves reaching the bar from the south and southwest are not affected by the Farallons. Waves reaching the bar from the west through northwest directions are partially intercepted by the Islands and broken into separate wave trains with extensive caustic areas.

19. Generally, waves from the west through northwest would be slightly reduced in height due to energy losses at the Farallons and in the landward caustic regions but there are selective directions and periods for which wave orthogonal focusing would cause wave height increases.

STUDY SITES

20. GENERAL

The following paragraphs contain brief descriptions of study sites and the data obtained. Additional detailed information about the coastal areas is given in United States Coast Pilot 7, Pacific Coast (California, Oregon, Washington, and Hawaii). Beach widths are taken from summer profiles and are measured in feet from MLLW to the toe of bluffs or dunes. Sand size classification used in this report, based on the Casagrande classification adopted by the Corps of Engineers, March 1953, is given in Table 3.

TABLE 3

Standard Size Classification

<u>Name</u>	<u>U.S. Standard Sieve Size</u>	<u>Grain size limits (diameter)</u>
Coarse Gravel	-	19mm to 76mm
Fine Gravel	No. 4 to 3/4 inch	4.76mm to 19mm
Coarse Sand	No. 10 to No. 4	2.0mm to 4.7mm
Medium Sand	No. 40 to No. 10	0.42mm to 2.0mm
Fine Sand	No. 200 to No. 40	0.074mm to 0.42mm

21. SHELTER COVE

Shelter Cove, about 20 miles west of Garberville in Humboldt County, is a crescent-shaped cove open to the south and protected from the west and north by Point Delgada. A narrow beach, approximately 100 feet wide, runs along the base of the bluffs, and is covered for the most part at high tide. This beach is composed of medium and fine sand, varying from dark to light gray in color. Point Delgada is rocky and irregular with many exposed pinnacle rocks offshore. At present, the area adjacent to Shelter Cove is relatively isolated and sparsely inhabited. The only inland connections are unpaved roads winding across the mountains from the north, south, and east. The east route, which leaves U.S. Highway 101 north of Garberville, is the main route. A small airfield is situated on the point near a small resort (Shelter Cove Inn). A privately owned boat launching area is available at the foot of the high bluffs, which extend along the shore of the cove. Four summer profiles were measured in August 1961 to MLIW. Winter profiles were measured in March 1961 to MLIW. The profiles along ranges 1, 2 and 4 indicate a generally stable beach, however, at range line 3 a loss in elevation of approximately 5 feet was noted from summer to winter. The profiles are shown on Figures A-2 and A-3 in Annex A. Sixteen mechanical and four petrographic analyses were made of sands from this site. The results of these and all succeeding analyses are given in Annexes B and C.

22. TEN MILE RIVER BEACH

Ten Mile River Beach extends from the mouth of the Ten Mile River to Laguna Point, approximately 5 miles to the south. Ten Mile River enters the ocean flowing westnorth westerly or at an angle of about 120 degrees to the coast line measured clockwise from the north. Large sand dunes begin at the mouth of the river and extend inland approximately 0.8 mile

in a southeasterly direction corresponding to the prevailing north-westerly winds. The beach is exposed over its entire length at all stages of the tide and is about 400 feet in average width. The sand is dark gray in color and generally coarse with the dunes tending to be somewhat finer than the adjacent beach. Eight summer profiles were measured in October 1960 and September 1961 to MLLW. Four winter profiles were measured to MLLW in December 1960. Due to continued periods of high waves, the profiles could not be completed to the specified depth of -36 feet MLLW. The profiles are shown on Figures A-5 and A-6 in Annex A. Thirteen mechanical and two petrographic analyses were made of sand samples from this site.

23. RUSSIAN GULCH STATE PARK

This study site is a California State Park beach located about 1.5 miles north of the town of Mendocino. A small, two-fingered cove reaches inland toward Highway 1 at this point. The sides of the cove are rugged and irregular with steep cliffs and protruding rocks extending offshore. A gulch (Russian Gulch), extending inland from the cove's northern finger, is fronted by a small pocket beach about 100 feet in width. The beach, generally consisting of a medium grained, light gray sand, slopes gently from the berm crest to slightly below MLLW with the backshore consisting of a poorly sorted material ranging from cobbles to fine sand. From MLLW to the beach toe, the sand is fairly well sorted with occasional small cobbles. Based on a number of underwater inspections, the bottom of the cove is generally rocky with small patches of sand. Three summer profiles to mean lower low water were measured in October 1960. Winter profiles were also measured to MLLW in February 1961. Profiles of ranges 1 and 2 show a 1 1/2- to 2-foot buildup of the beach during summer months; however, range 3 shows a 2 1/2-foot summer month reduction in beach elevation. The profiles are shown on Figures A-8 and A-9 in Annex A. Six mechanical analyses and one petrographic analysis were made of sands from this study site.

24. VAN DAMME BEACH STATE PARK

Van Damme Beach State Park is located at the mouth of Little River. The beach is crescent shaped, about 100 feet wide and 1500 feet long. The beach material is poorly sorted, ranging from gravel to fine sand, and is gray in color. An irregular, rocky headland protects the beach from direct westerly wave attack, while large offshore rocks to the south and southwest affect waves from these directions. Three summer and three winter profiles were measured in October 1960 and February 1961, respectively, to MLLW. The profiles are shown on Figures A-11 and A-12 in Annex A. Five mechanical analyses and one petrographic analysis were made of sands from this study site.

25. NAVARRO RIVER

Navarro River enters the Pacific Ocean through a small bight open to the southwest about 8 miles south of Mendocino Bay. The river drains 300

square miles of land area. A headland, with many offshore rocks, protrudes down from the northern end of the bight protecting the channel entrance from waves north of southwest and thus limiting the direction of wave attack at the channel entrance to southwest through south. An unstable spit approximately 600 feet in length extends from the steep bluffs on the south to the entrance channel. Landward of the spit, dune fields extend for approximately 400 feet. The beach, approximately 200 feet wide, consists of a medium grained sand, gray in color. On at least one occasion, sand mining has been observed in these dune areas. The coastline both north and south of the river mouth is very irregular with steep bluffs and numerous offshore rocks. A resort (Navarro by the Sea) is situated on the south shore about a quarter-mile from the mouth and provides facilities for small recreational boating. Three summer profiles were measured in October 1961 to the 36-foot depth. Three summer and 3 winter profiles were measured to the vicinity of MLLW in October 1960 and January 1961, respectively. The profiles are shown on Figure A-14 in Annex A. Thirteen mechanical and two petrographic analyses were made of sands from this study site.

26. POINT ARENA

Point Arena is a prominent headland located just below the mouth of Garcia Creek. Point Arena Beach, extending from the point approximately 5 miles to the north, is approximately 400 feet in width. The beach material consists of a well-sorted medium-grained sand, gray in color. Landward of Point Arena Beach, a number of migrating sand dunes extend inshore a maximum of 2,000 feet. Four summer and 4 winter profiles were measured to MLLW in October 1961 and February 1961, respectively. The profiles are shown on Figures A-17 and A-18 in Annex A. Fifteen mechanical and two petrographic analyses were made of sands from this study site.

27. GUALALA RIVER

Gualala River is the boundary between Mendocino County on the north and Sonoma County on the south, for a distance of approximately 3 miles inland from its mouth. Before emptying into the Pacific Ocean, the river turns abruptly northwestward paralleling the coastline for about a mile. The beach at this point is a long narrow sand spit, 100 to 300 feet in width, separating the river (where it parallels the coastline) from the ocean. The sand is generally well sorted, varies from coarse to fine-grained, and is dark gray in color. In the summer months, the channel from the river to the ocean is closed and the water landward of the spit forms a long, narrow lagoon. This section of coastline extends in a general northwest, southeast line with the coastline north of the river mouth rocky and irregular with steep bluffs and offshore rocks. Except for the sandspit, the shoreline to the south is similar to that to the north. State Highway 1 crosses the river near

its abrupt turn up the coast and parallels it to its mouth. The town of Gualala lies along State Highway 1 between the bridge and the river mouth. Three summer profiles were taken to the 36-foot MLIW depth and one to MLIW in September 1961. Four winter profiles were taken to MLIW in March 1961. A drop of approximately 14 feet was noted on Range 4 from summer to winter. This drop is approximately 200 feet landward of the shoreline at MLIW. The profiles are shown on Figures A-20 and A-21 in Annex A. Twelve mechanical and two petrographic analyses were made of sands from this study site.

28. RUSSIAN RIVER

This is the largest river emptying directly into the Pacific Ocean between Point Delgada and Point Ano Nuevo. The drainage area is approximately 1,500 square miles. The present river flow generally provides sufficient scouring to maintain a shallow opening in the bar at the river's mouth during the summer season. The lower six-mile reach of the river is subject to tidal action. From Goat Rock, about 4,000 feet to the south of the river mouth, a tombolo extends shoreward to the coast about 1,000 feet. Goat Rock also marks the beginning of a sand spit, with an average width of 200 feet, that extends north to a state-constructed jetty on the south side of the river's entrance channel. This beach is made up of medium grained, generally well sorted gray sand. To the west and northwest of the channel entrance are many offshore rocks that limit wave attack at the channel entrance to directions south of west. The coastline to the north is rugged and includes many steep bluffs and irregular projections. To the south, numerous offshore rocks are again found south of Goat Rock and continue down the coast. The coastline in this location, for the most part, consists of abrupt rocky cliffs with small pocket beaches found at the head of the coves. A resort area, Jenner By the Sea, is situated along the north shore of the river opposite Penny Island, a small oval shaped island about 3,000 feet upstream from the mouth. Five summer profiles were measured in September 1961 to the 36-foot depth. Five winter profiles were measured to MLIW in March 1961. The profiles are shown on Figures A-23 and A-24 in Annex A. Twenty mechanical and six petrographic analyses were made of sands from this study site.

29. WRIGHTS BEACH

Wrights Beach, located about six miles north of Bodega Bay, extends northward from Duncan Point for about one mile. The beach is approximately 250 feet in width and consists of a generally well sorted, medium grained, dark gray sand. Dunes occupy a large area of the backshore near the northern end of the beach. Cusps are a prominent feature throughout the length of the beach in late summer. A private campground is located just off Highway 1, between the Highway and the beach. A small settlement, called Ocean View School also exists just above Duncan Point

between the Highway and the beach. Two summer profiles have been measured to the 36-foot depth at MLLW in September 1961. Two winter profiles were taken to MLLW in November 1960. The profiles are shown on Figure A-26 in Annex A. Seven mechanical analyses and one petrographic analysis were made of sands from this study site.

30. BODEGA BAY

The area studied at Bodega Bay is the barrier beach, averaging 200 feet in width, which extends from the north side of the north jetty of the Corps of Engineers Bodega Harbor project to the bluff areas approximately one and three-quarter miles to the east. This section of coast, called Doran Beach, is operated as a county park. The beach here is a fine-grained, often poorly sorted light gray sand, containing moderate amounts of broken shell fragments. Landward of the active beach face is a single row of low dunes with sparse vegetation cover. At this site, seven profiles were measured to -30 MLLW in August 1961 and 7 each in November 1960 and March 1961 were measured to MLLW. The greatest fluctuation in beach elevation from summer to winter for all ranges occurs approximately 100 to 150 feet landward of the shoreline at MLLW and amounts to from 2 to 8 feet of vertical drop. The profiles are shown on Figures A-29, A-30, and A-31 in Annex A. Twenty-seven mechanical and three petrographic analyses were made of beach samples at this site.

31. DILLON BEACH

Dillon Beach is on the southern end of Bodega Bay, about 1.5 miles north of the entrance to Tomales Bay. The beach width varies from 100 to 400 feet, and extends about 4,000 feet south of Dillon Beach, a beach resort at the northern end of the beach. The beach consists of a fine, well-sorted light-gray sand. Extensive dune fields reach inland over 1 mile and cover the coast for the full beach length. Sand Point, a sandy headland, marks the entrance to Tomales Bay and is less than 1 mile from the southern tip of Dillon Beach. North of Dillon Beach, the Bodega Bay coastline is rocky and irregular and is interrupted by Estero de San Antonio, which empties into the ocean at a point about 1.5 miles north of Dillon Beach. Dillon Beach is open to wave attack from northwest through southwest. Bodega Head to the northwest and the northern tip of the Point Reyes Peninsula on the southwest assure protection from waves from the northwest to north and from the southwest to south sectors. Four profiles were measured in August 1961 to MLLW. Four winter profiles were measured in March 1960. The profiles are shown on Figures A-33 and A-34 in Annex A. Fourteen mechanical and two petrographic analyses were made of sands from this study site.

32. McCLURES BEACH

This site is located on Tomales Point, about four miles from the northern tip of the point. The 2,500-foot long beach has an average

width of 200 feet and extends in almost a straight north-south line bounded both on the north and south by small rocky headlands. The beach consists of medium-grained buff-colored sand, generally well sorted. The towns of Inverness and Point Reyes Station lie about 10 and 14 miles, respectively, south of McClures Beach and are the nearest settlements of any size. South of McClures Beach, the rocky coastline slopes away sharply to the southeast. McClures Beach is open to wave attack from SSW through NNW and is therefore slightly more exposed than the foregoing site, Dillon Beach. Four summer profiles were measured in August 1961 to MLLW. Four winter profiles to MLLW were measured in March 1961. It is noted from the profiles that ranges 1 and 2 appear to be considerably unstable. Each winter, the beach is removed to an underlying rock outcrop, a vertical distance of 10 to 12 feet. Range 3 loses approximately 7 vertical feet of beach while Range 4 appears stable. The profiles are shown on Figures A-36 and A-37 in Annex A. Twelve mechanical analyses were made of sands from this study site.

33. POINT REYES BEACH

Review of the work by Parker Trask on Point Reyes Beach (see list of references at the end of this report) indicates that Trask's work is an outstanding contribution toward the understanding of changes in beach configuration and sand size variation for Pacific Coast beaches. It appears, however, that future work at Point Reyes Beach might well include the establishment of permanent surveying monumentation to assure that the ranges used in this study can be re-established in the future. It is considered that such work should include the establishment of Lambert coordinates and Mean Lower Low Water elevations on Trask's ranges.

34. DRAKES BAY

Drakes Bay, east of Point Reyes, is a crescent-shaped bight facing south. Three range lines have been established intersecting the beach at equal intervals along the full length of the bay. Sands on this beach are generally well sorted and fine-grained and appear gray in color. The beach averages 300 feet in width and is approximately 7 miles long. Due to its orientation relative to the general coastline, waves at the beach sites are limited to those coming from the southerly directions. Cusps are often a feature of Drakes Beach and the beaches either side of Drakes Beach. Three summer profiles were measured to the 36-foot MLLW depth in August 1961. In March 1961, 3 profiles were measured to MLLW. The profiles indicate that a consistently large volume of beach sand is moved out to sea during the winter months at each of the three ranges. The profiles are shown on Figure A-39 in Annex A. Twelve mechanical and two petrographic analyses were made of sands from this study site.

35. BOLINAS BAY

Bolinas Bay is located in Marin County approximately eleven nautical miles north of San Francisco Bay. The bay is crescent-shaped and open to the south. A sand spit, Stinson Beach, extends approximately 11,000 feet from the mainland and separates Bolinas Lagoon from Bolinas Bay. Five range lines have been established along Stinson Beach, which is made up of a light gray sand, fine-grained and generally well sorted. The beach is approximately 300 feet in width. The western portion of the sand spit ends at Bolinas Channel, which in turn, is bordered by a high bluff on its western side. Duxbury Reef extends in a southeasterly direction from the western extremity of the bay and tends to disperse any wave energy coming from the north through west deep water directions. Bolinas Bay is exposed, however, to high waves or seas generated by local coastal storms, particularly from the southeast, accompanied by winds of gale force, and to high waves or swells produced by offshore, distant, Pacific Ocean storms unattended by high winds. Both types of waves generally occur during the period from November through April with the critical sector of wave approach being west through southeast. The mean diurnal tidal range in Bolinas Bay is about 5.7 feet and the extreme range approximately 10 feet. Five profiles were measured to the 36-foot MLLW depth in August 1961 and five measured to MLLW in March 1961. These profiles show a large volume of sand in the foreshore area being moved into deep water during the winter months. The profiles are shown on Figures A-42 and A-43 in Annex A. Twenty-one mechanical and three petrographic analyses were made of beach sands from this study site.

36. MUIR BEACH

Muir Beach is located on the north end of a small crescent-shaped bight open to the south and consists of a generally poorly sorted but fine-grained sand, dark gray in color. This site is only a few miles up the coast from the Golden Gate and is protected from waves at the beach from all but the southerly directions due to a prominent headland to the west. The 300-foot wide beach is privately owned and the right to use the beach is subject to payment of a fee to the owner. Four profiles were measured to MLLW, two in March 1961 and two in August 1961. These profiles indicate a five foot vertical loss of beach sand approximately 100 to 200 feet landward of the MLLW shoreline. The profiles are shown on Figure A-45 in Annex A. Seven mechanical analyses and one petrographic analysis were made of sands obtained at this site.

37. SAN FRANCISCO BEACH

Also known as Ocean Beach, this beach extends about 3 miles from the Cliff House along the Esplanade and the Great Highway to the vicinity of Fleishhacker Zoo. The beach, made up of a well sorted, generally fine-grained gray sand, increases in width from north to south. The average

width is about 300 feet. A concrete seawall extends the length of the beach along the Esplanade. Ocean Beach is open to wave attack from most, if not all, deep water storms. Sixteen profiles were measured to MLIW in March 1961 followed by eight additional profiles in October 1961. Ranges 2, 3, 6, 7 and 8 show a considerable loss of beach sand during the winter months. The profiles are shown on Figures A-49, A-50, A-51, A-52 and A-53 in Annex A. Eighteen mechanical and four petrographic analyses were made of beach samples from this study site.

38. HALF MOON BAY

Named for its crescent shape, Half Moon Bay is located on the west coast of San Mateo County about 16 miles south of San Francisco. The Bay is delimited at the north by Pillar Point. The shoreline trends easterly from Pillar Point to Princeton and then curves southeasterly to Miramontes Point. Offshore samples range from a very fine sand in the vicinity of Pillar Point to fine sand at Francis Beach. Beach samples generally consist of well-sorted fine-grained, light gray sand, with a trend of increasing grain size to the south. The floor of the Bay deepens to the general vicinity of the opening in the breakwater that encloses the harbor and then rises to a reef that extends southerly from Pillar Point. The Bay is rimmed by a half-mile wide, wave-cut terrace that is bounded by 50-foot sea cliffs along the Bay shore and terminates against the steep slope of Montara Mountain. The Bay is floored with fine to very fine sand that ranges in thickness from about 20 feet along the beach to 160 feet in the deepest portion of the Bay and thins to a few feet along the reef at the west. Thirty-one mechanical and ten petrographic analyses were made of beach sands from this study site. Poorly sorted samples are believed to be the result of construction activity during the sampling program. The town of Half Moon Bay with a population of about 2,000, is the largest town in the immediate vicinity and is located on the east side of Half Moon Bay. Princeton, a community of about 100 residents, is at the northern end of the Bay. The principal activities of the area are commercial fishing, agriculture, sport fishing and recreation. The mean tidal range for Half Moon Bay is 5.5 feet. A reef extending southeasterly from Pillar Point protects the Bay from northwesterly and west waves leaving the area open to wave attack from the southwest. Thirteen range lines have been established along Half Moon Bay as follows:

Coast Guard Beach - 2	Naples Beach - 3
Princeton Beach - 2	Francis Beach - 2
El Granada Beach - 3	Vallejo Beach - 1

a. Coast Guard Beach. Along the 300 foot wide Coast Guard Beach (2 range lines) four summer profiles have been measured to the approximate 20 foot MLLW depth, two in June 1959 and two in July 1960. Two winter profiles were measured in April 1963. The profiles are shown on Figure A-57 in Annex A.

b. Princeton Beach. The Princeton Beach (2 range lines) location has four profiles to the approximate 25 foot MLLW depth, two in June 1959 and two additional profiles measured in July 1960. Two more were measured in April 1963. The beach averages 200 feet in width. The profiles are shown on Figure A-58 in Annex A.

c. El Granada Beach. Three profiles were measured to the 36-foot MLLW depth in July 1960 along El Granada Beach (3 range lines). Previously, 2 were measured to the 30-foot MLLW depth and one to MLLW in June 1959. In January 1961, three profiles were measured to MLLW. Two additional profiles were measured to the 20-foot MLLW depth and one to MLLW in April 1963. The beach is approximately 150 feet wide. The profiles are shown on Figure A-59 in Annex A.

d. Vallejo Beach. Along 200 foot wide Vallejo Beach (1 range line) two summer profiles were measured to the 30-foot MLLW depth, one in June 1959, the other in July 1960. One profile was measured to MLLW in January 1961. The profiles are shown on Figures A-60 in Annex A.

e. Naples Beach. At Naples Beach (3 range lines and 150 feet wide) six profiles were measured to the 30-foot MLLW depth, 3 in June 1959 and 3 in July 1960. Three profiles were measured to MLLW in January 1961. The profiles are shown on Figures A-61 in Annex A.

f. Francis Beach. Two profiles were measured to the 36-foot MLLW depth along Francis Beach (2 range lines) in July 1960. Two additional profiles were measured to the 30-foot MLLW depth in June 1959. In January 1961, two profiles were measured to MLLW on this 200 foot wide beach. The profiles are shown on Figure A-62 in Annex A.

39. SAN GREGORIO CREEK

San Gregorio Creek empties into the Pacific Ocean about 35 miles south of San Francisco. State Highway 1 crosses the mouth of the creek. In summer months, the flow in the creek may be reduced sufficiently to allow a sizeable pocket beach, with a maximum width of about 500 feet to form between the creek and the ocean. This beach is composed of fine-grained, well sorted light gray sand. The coastline near San Gregorio Creek extends approximately north and south and consists of steep bluffs fronted by a narrow expanse of beach. This area has no natural protection from deep water waves or local wind generated waves. Other than the town of La Honda about 9 miles to the east, the area is made up of small farms

and sparsely located country residences. Four profiles were measured to MLLW, two in July 1960 and two in January 1961. About 4 feet of vertical beach loss is evident during the winter months. The profiles are shown on Figure A-64 and A-65 in Annex A. Six mechanical analyses and one petrographic analysis were made of sand samples from this study site.

40. PESCADERO CREEK

Pescadero Creek joins Butano Creek about one-quarter mile from the ocean. The area near the junction of the two streams forms a marsh with several isolated pools and sloughs. The seaward several hundred feet of the creek's south shore follows the base of a steep bluff, which ends in an abrupt headland protruding northwest. The shoreline to the south is very irregular with many offshore rocks. From the mouth of Pescadero Creek, a fairly wide expanse of beach, varying in width from 200 to 400 feet, extends 3,000 feet to the north. The sand on this beach is medium-fine, generally well sorted and light gray in color. Due to the rocky point which marks the entrance on the south, the creek empties into the ocean in a northwest direction. Waves from west through northwest break directly in the entrance to the creek. Waves from south of west would be broken up by the offshore rocks and protruding point. This site is approximately 4 miles south of the previous study site, San Gregorio Creek. Highway 1 crosses the mouth of Pescadero Creek and proceeds to Santa Cruz, about 34 miles to the south. Two profiles were measured to the 40-foot MLLW depth (excluding the area between MLLW and -10 MLLW) in July 1960. In January 1961, two profiles were measured to MLLW. There are indications of a large volume of sand being carried to sea during the winter months in the vicinity of range line 2. The profiles are shown on Figure A-67 in Annex A. Seven mechanical analyses and one petrographic analysis were made of sands from this study site.

41. BEACH SAND GRADATION

Generally, an increase in grain size was observed in beach samples taken toward the end of the winter season as compared with those taken toward the end of the summer season (August - September). This trend was least noticeable on exposed beaches such as the Ten Mile River beach which tended to have highly variable median grain sizes. The more protected beaches, (typically found in hook shaped bays such as Bodega Bay) tended to have the finest material in the most protected or northwesterly portion of the beach and the coarsest material on the open or more exposed portion of the beach. These beaches tended to have consistently finer sands than the exposed beaches.

42. SEASONAL BEACH CHANGES

Although the small number of measurements (two) on most beaches appears insufficient to make any general conclusions, the foreshore portion of most beaches appears to have been lower toward the end of

the winter season than toward the end of the summer season. At locations such as Range 1, Francis Beach, a reverse action was noted. On numerous occasions (not indicated on profiles) the beach foreshore was observed to be considerably higher during the late winter months than during the summer months. This action is not understood but may be associated with an increase in supply of littoral material to this beach from the adjacent coast during the winter months.

43. SHORE INSTABILITY

The only beach where a pronounced shoreline instability was observed was at El Granada Beach in Half Moon Bay, where progressive erosion occurred. The profile measurements taken at the Half Moon Bay beaches have been continued in the Survey Report on Beach Erosion (El Granada Beach, California). Recent measurements (1965) show a continuing trend of shoreline instability.

44. CONCLUSION

As shown in the detailed study material presented in the annexes to this report, the coastline has been examined at specified study areas. It is concluded that the measurements reported in this study will provide a basis for future examination of the Coast of California from Point Delgada to Point Ano Nuevo.

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District Engineer

COOPERATIVE
BEACH EROSION STUDY

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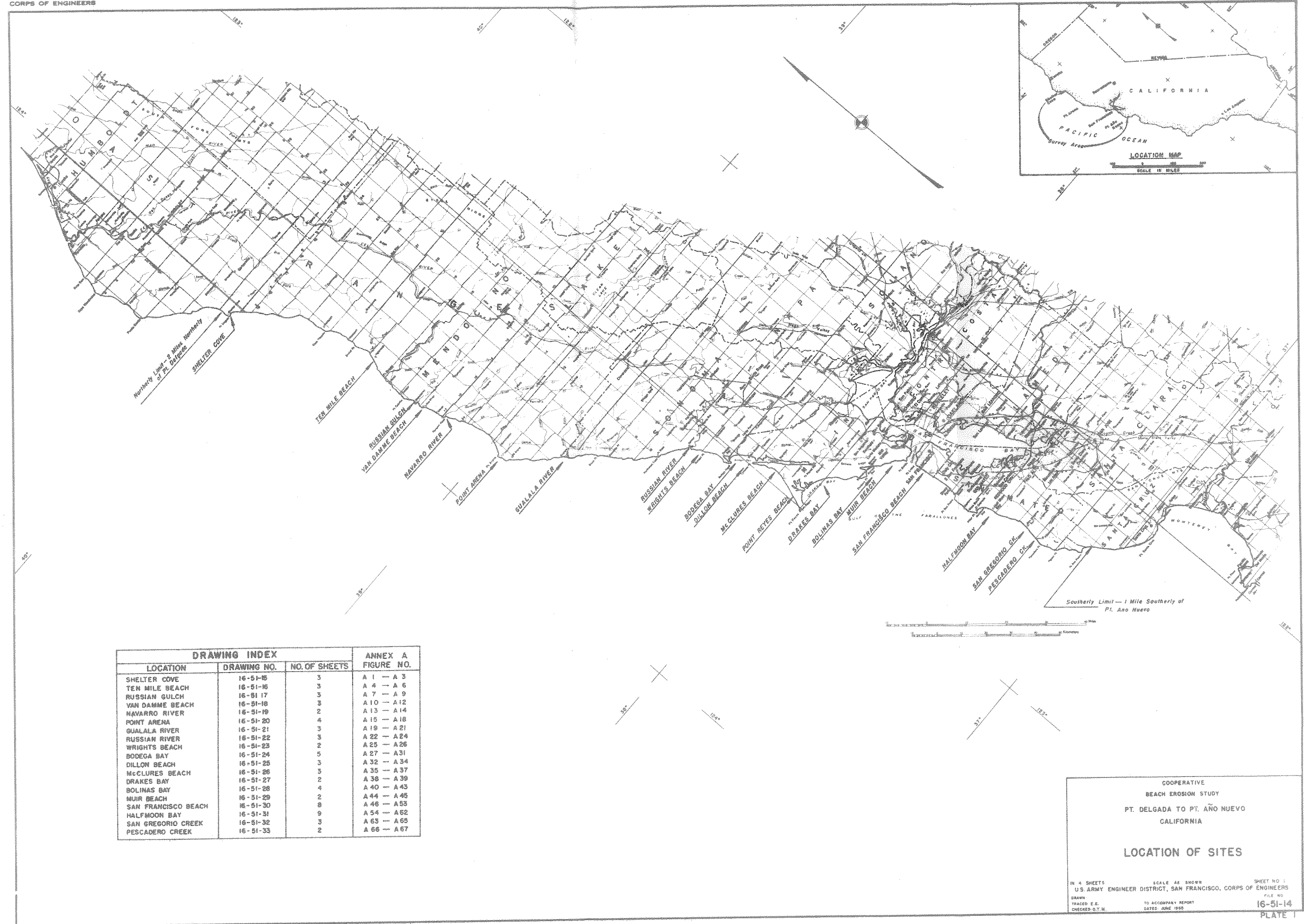
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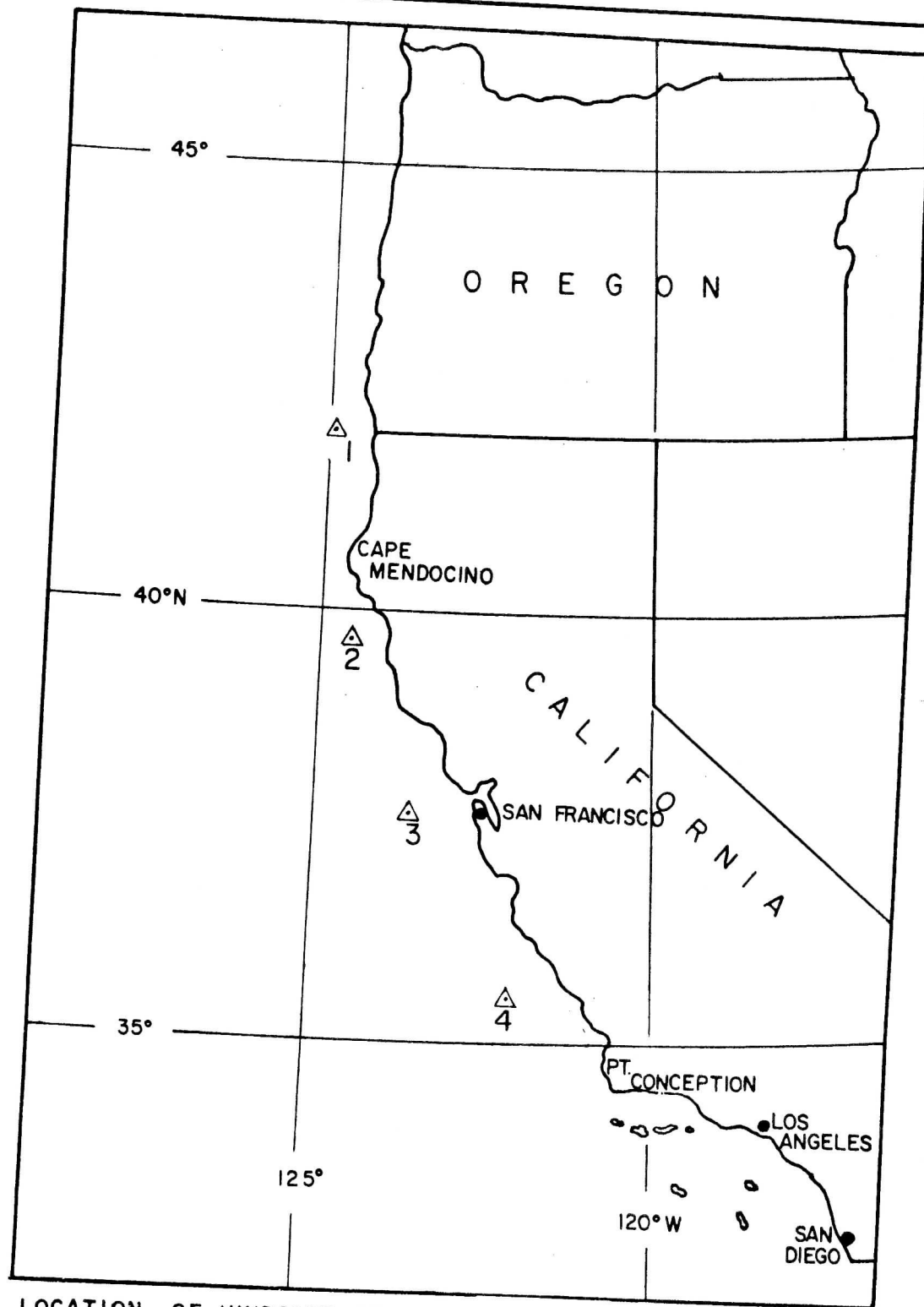
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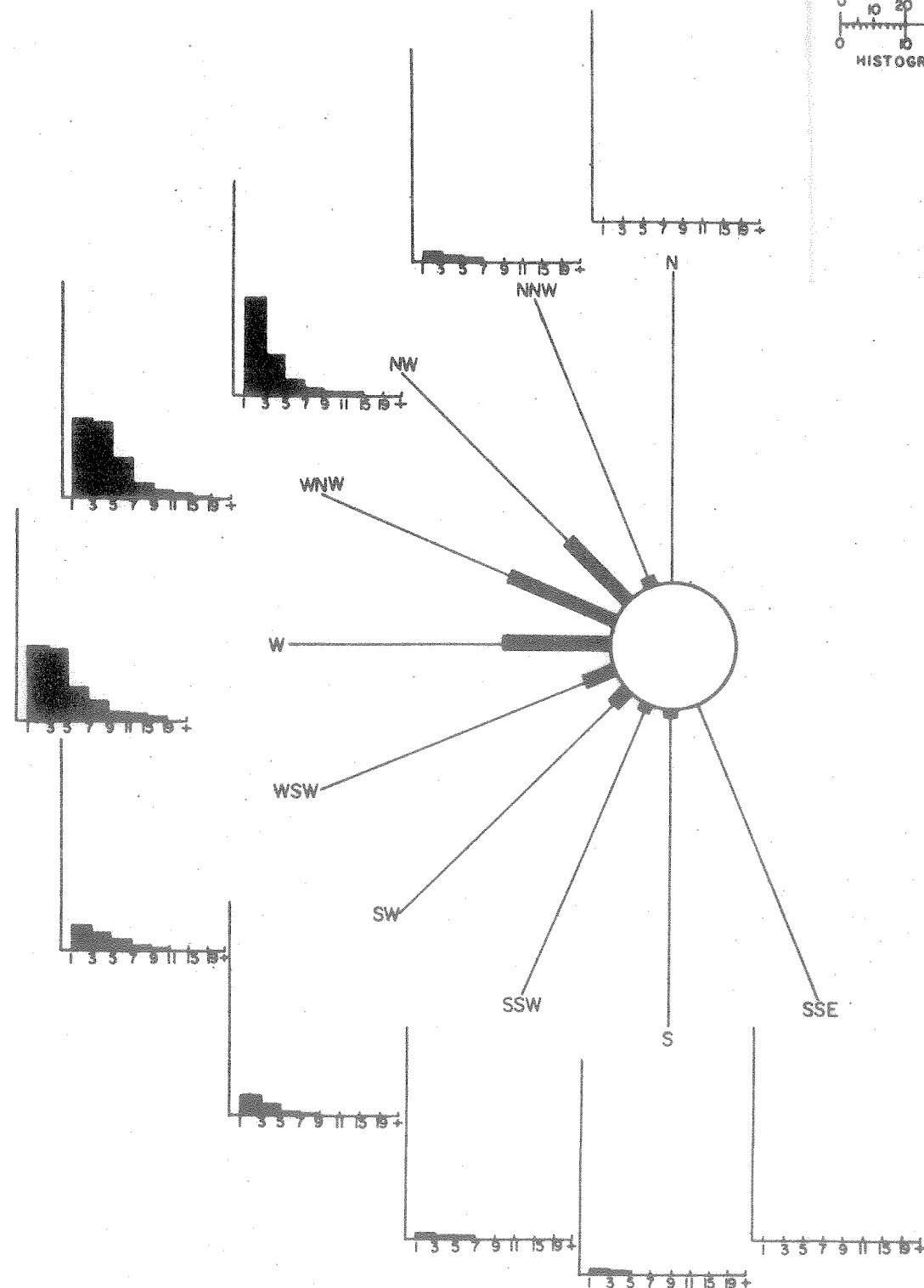
LOCATION OF HINDCAST STATIONS

COOPERATIVE
BEACH EROSION STUDY
PT. DELGADO TO PT. AÑO NUEVO
CALIFORNIA

FILE NO. 16-51-34

PLATE 2

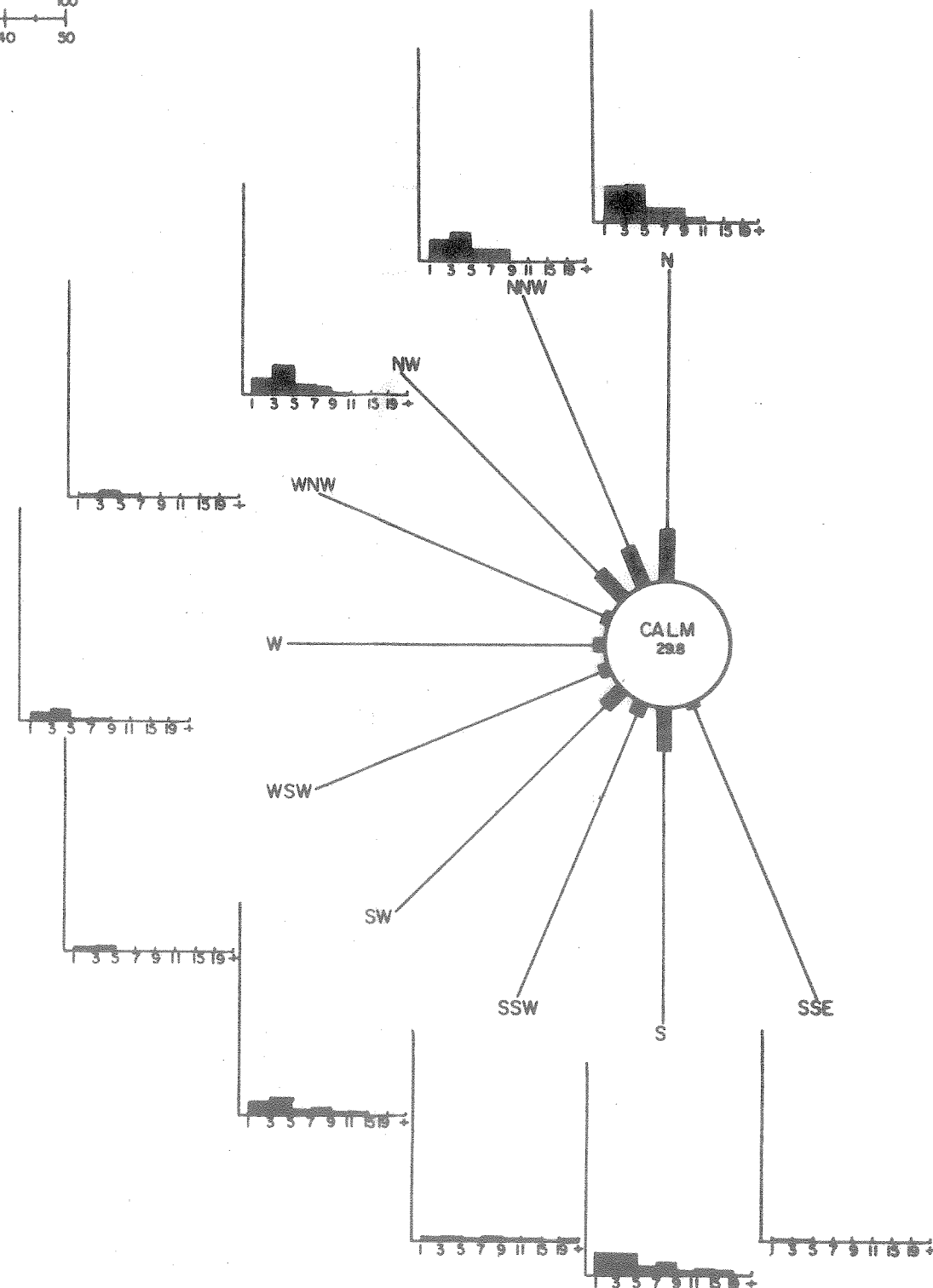
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ROSE (% Occurrence, θ)
HISTOGRAM (% Occurrence, H)

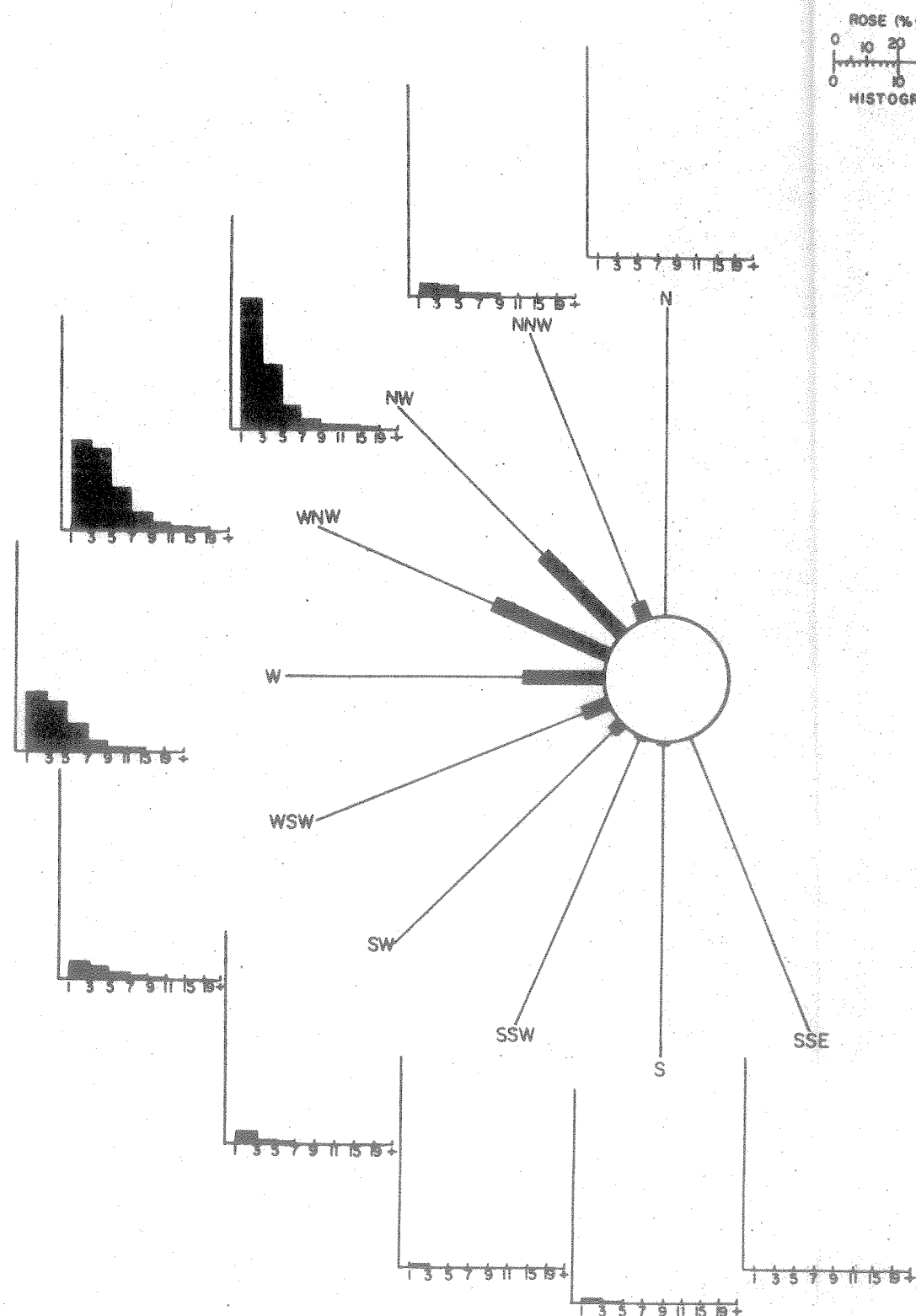
SCALE

AVERAGE ANNUAL SEA ROSE FOR STATION 1



COOPERATIVE
BEACH EROSION STUDY
PT. DELGADO TO PT. AÑO NUEVO
CALIFORNIA

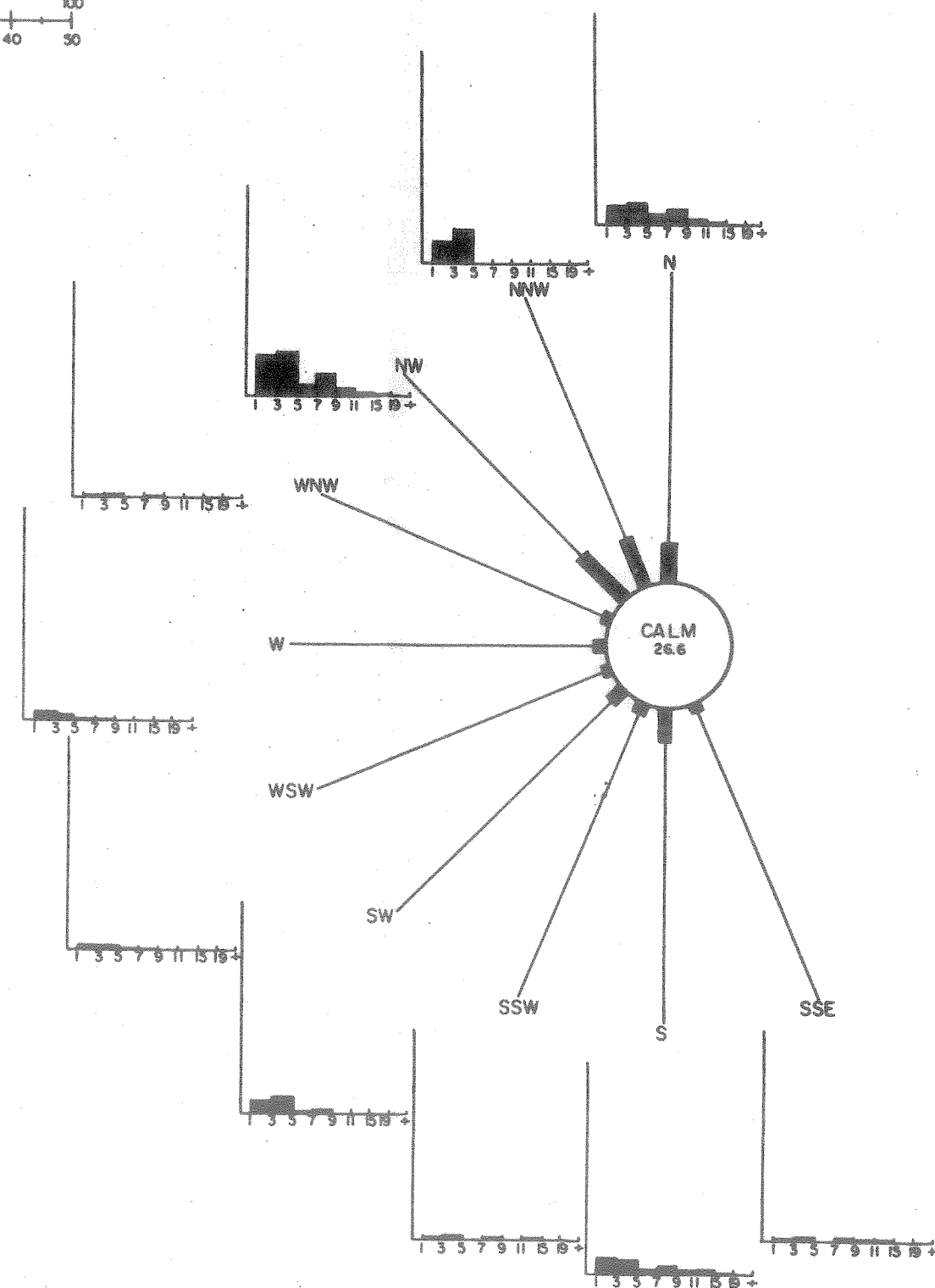
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ROSE (% Occurrence, θ)
HISTOGRAM (% Occurrence, H)

SCALE

AVERAGE ANNUAL SEA ROSE FOR STATION 2

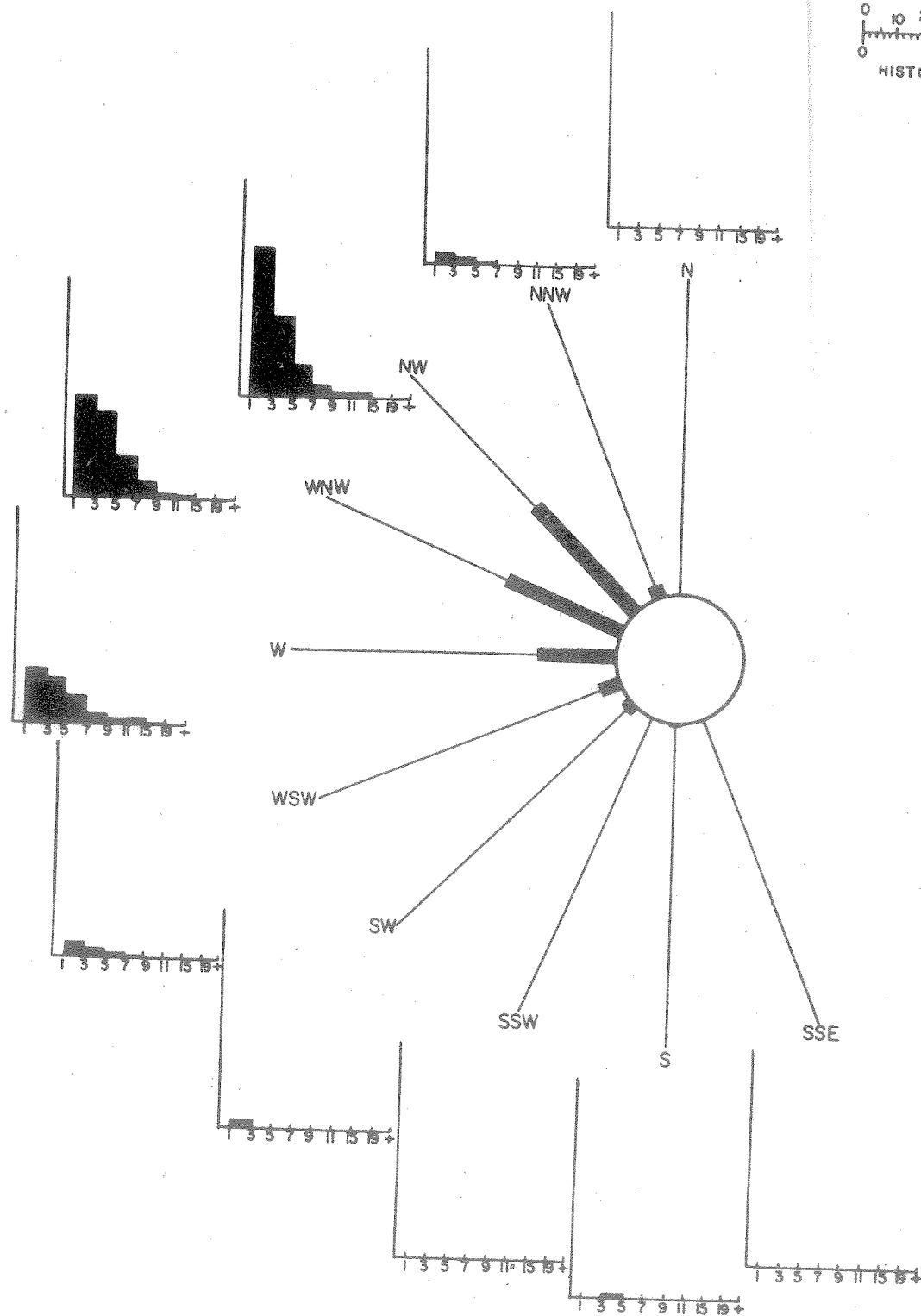


COOPERATIVE
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PT. DELGADO TO PT. AÑO NUEVO
CALIFORNIA

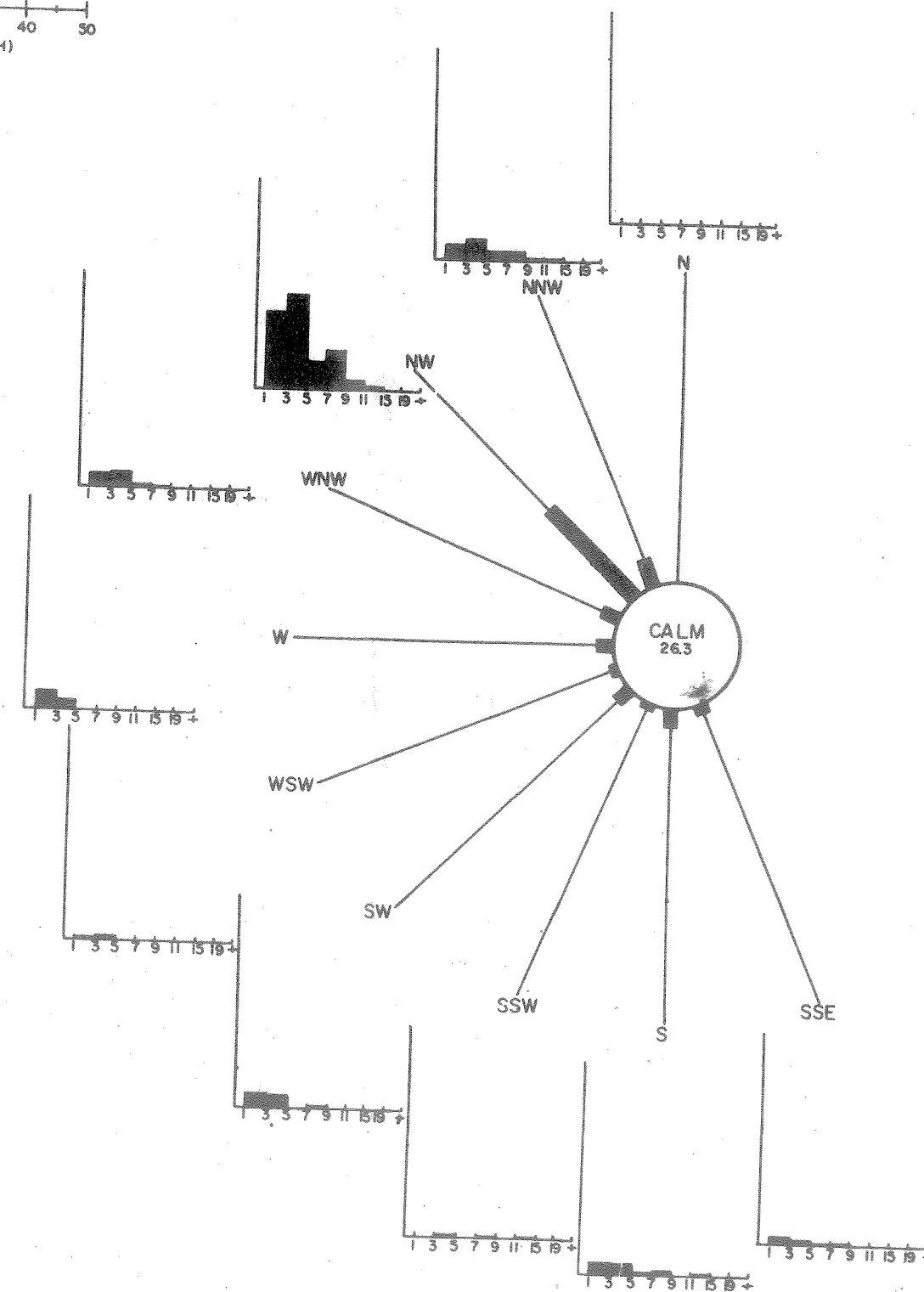
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PLATE 4

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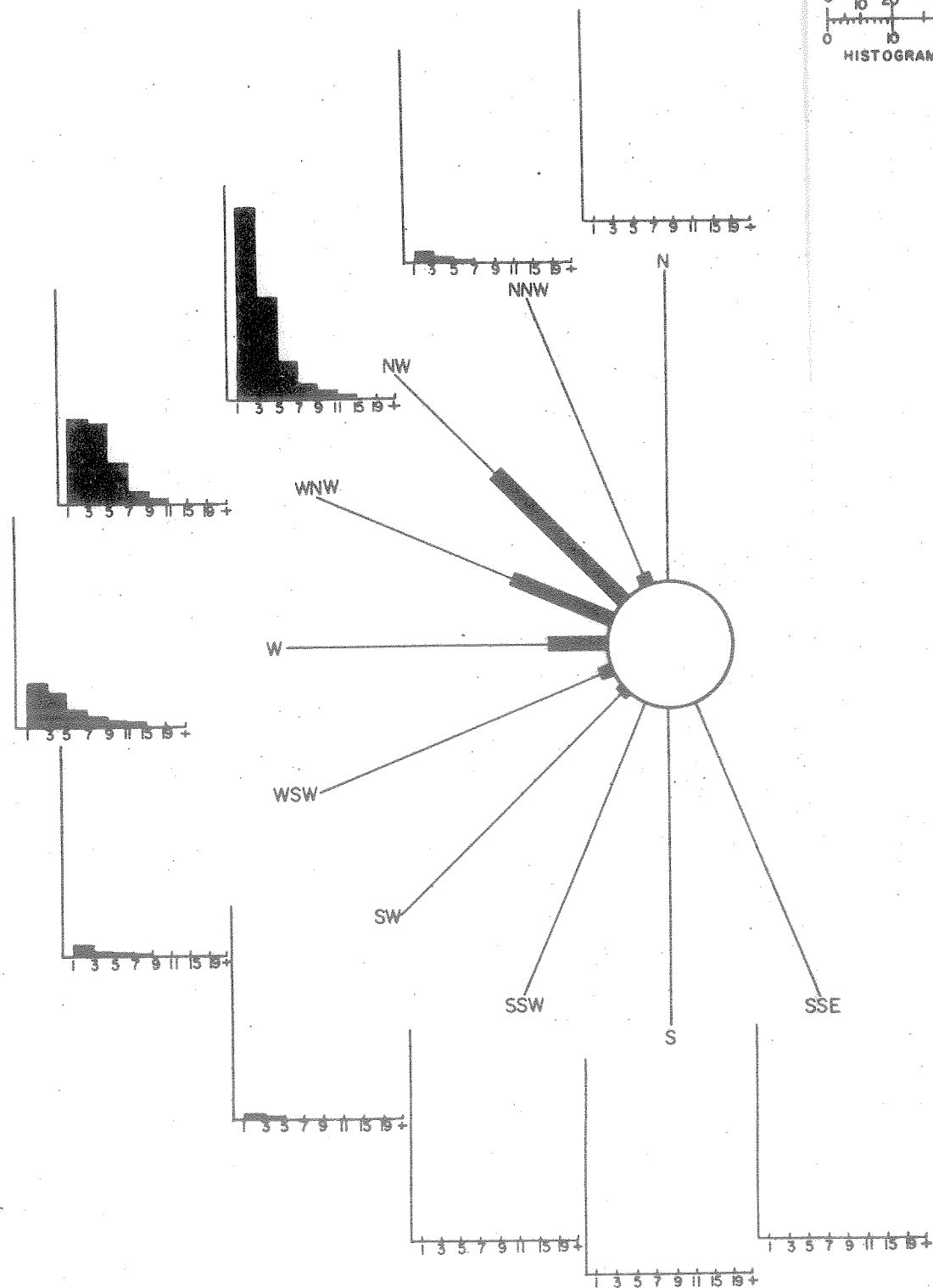


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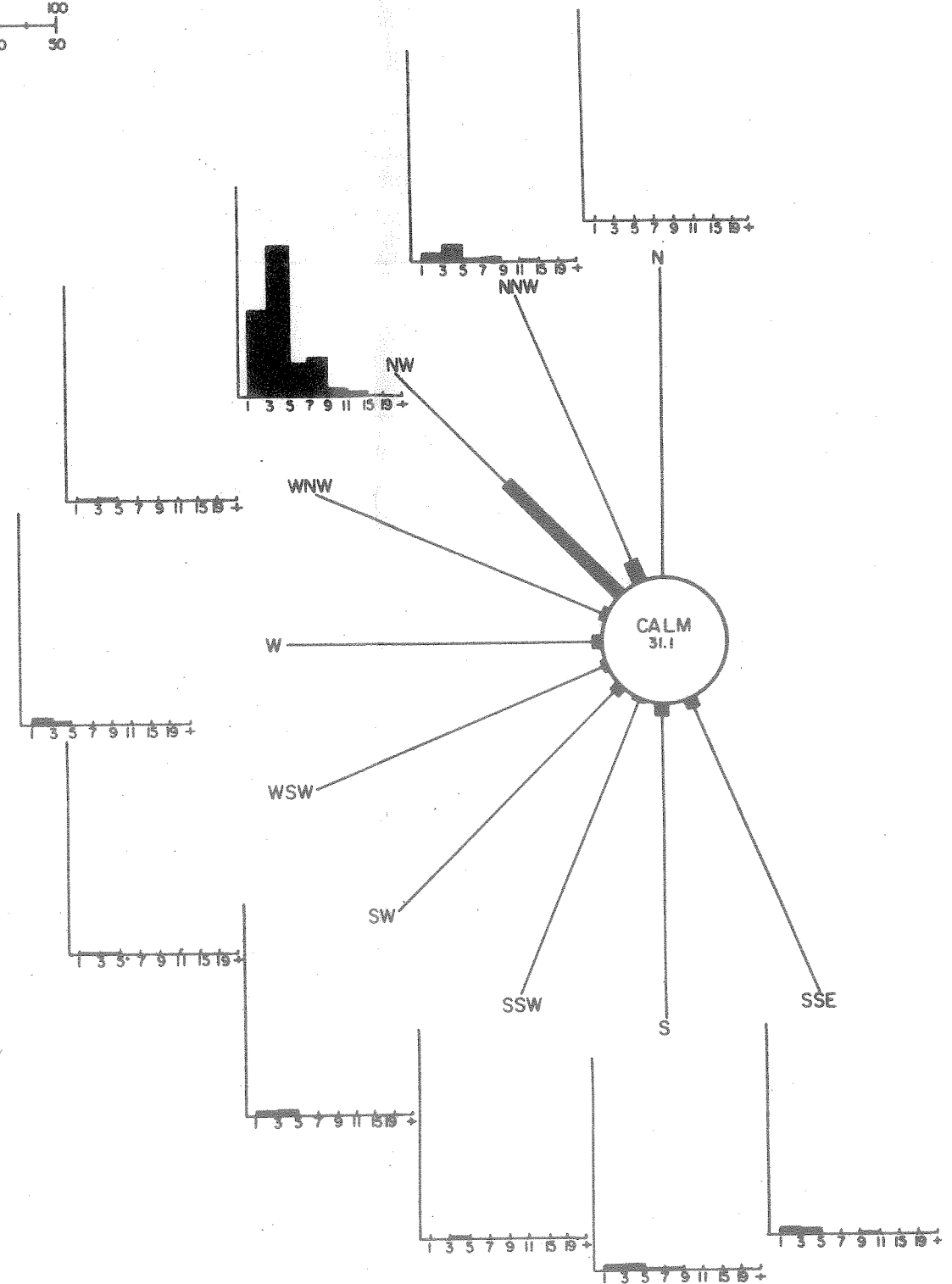


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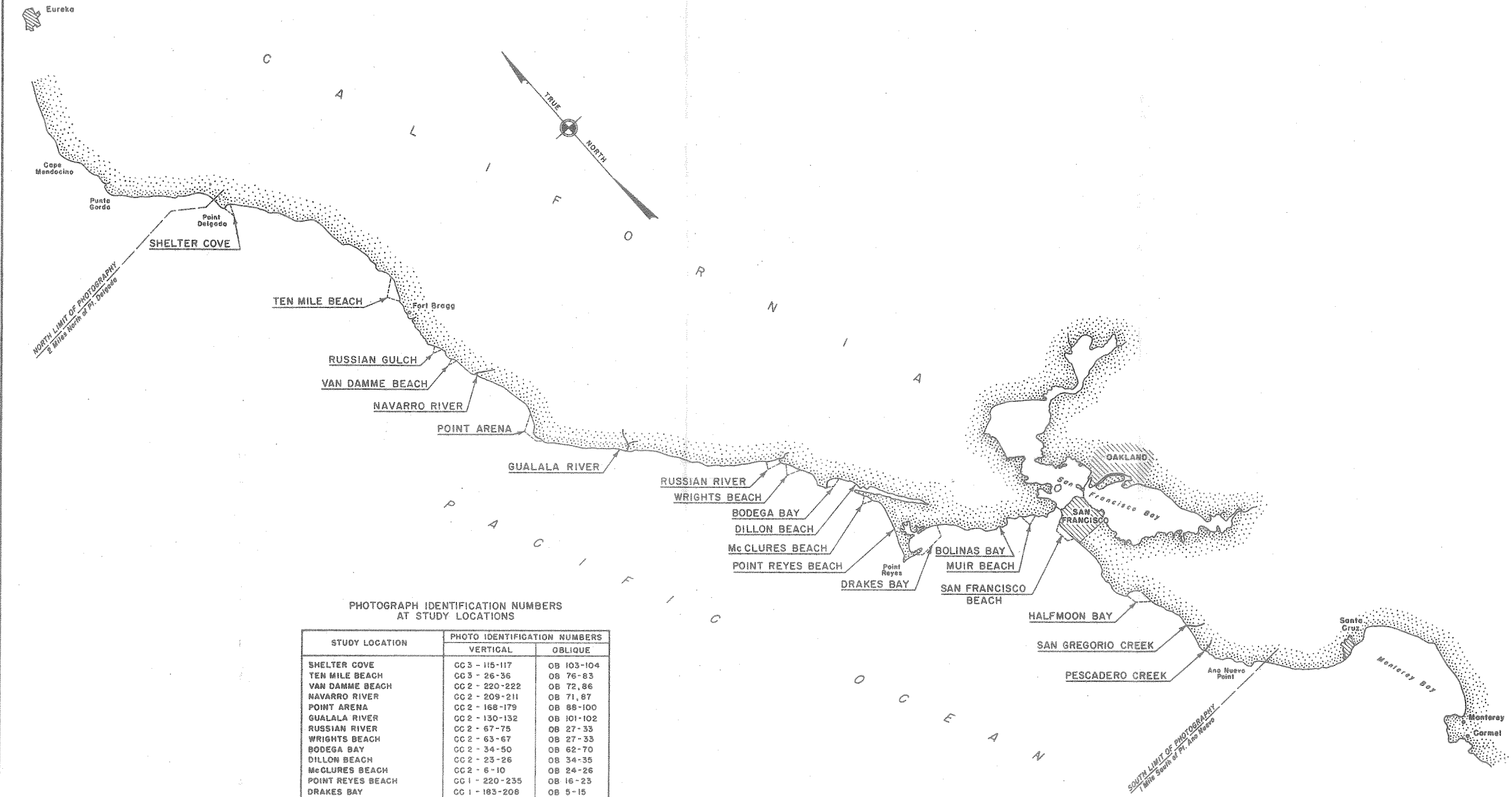
AVERAGE ANNUAL SWELL ROSE FOR STATION 4



AVERAGE ANNUAL SEA ROSE FOR STATION 4



COOPERATIVE
BEACH EROSION STUDY
PT. DELGADO TO PT. AÑO NUEVO
CALIFORNIA



PHOTOGRAPH IDENTIFICATION NUMBERS
AT STUDY LOCATIONS

STUDY LOCATION	PHOTO IDENTIFICATION NUMBERS	
	VERTICAL	OBLIQUE
SHELTER COVE	CC 3 - 115-117	OB 103-104
TEN MILE BEACH	CC 3 - 26-36	OB 76-83
VAN DAMME BEACH	CC 2 - 220-222	OB 72, 86
NAVARRO RIVER	CC 2 - 209-211	OB 71, 87
POINT ARENA	CC 2 - 168-179	OB 88-100
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COOPERATIVE
BEACH EROSION STUDY
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CALIFORNIA

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U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO, CORPS OF ENGINEERS

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