DETAILED PROJECT REPORT
SHORE PROTECTION

TALOFOFO BEACH
TERRITORY OF GUAM

PREPARED UNDER THE AUTHORITY OF
SECTION 103a OF
THE RIVER AND HARBOR ACT OF 1962

U.S. ARMY ENGINEER DIVISION
PACIFIC OCEAN

DECEMBER 19 73

DETAILED PROJECT REPORT
SHORE PROTECTION
TALOFOFO BEACH, GUAM

PERTINENT DATA

PROJECT FEATURES	
Revetment	
Length	900 feet
Crest width	17 feet
Crest elevation	+7 feet MLLW
Side slope	1V on 2H
Armor layer	
Stone size	3,000-4,000 lb.
Layer thickness	6.6 feet
Underlayer	
Stone size	200-500 lb.
Layer thickness	3 feet
Bedding layer	
Stone size	1-50 lb.
Layer thickness	1 foot
PROJECT BENEFITS	
Total average annual benefits based on a 5-5/8 percent interest rate and a 50-year project life	$143,600
PROJECT COSTS	
Federal First Cost	$288,250
Non-Federal First Cost	236,750
Total Project First Cost	$525,000
ANNUAL CHARGES	
Total average annual charges based on a 5-5/8 percent interest rate and a 50-year project life	29,900
BENEFIT-COST RATIO	4.8

DETAILED PROJECT REPORT
SHORE PROTECTION
TALOFOFO BEACH, GUAM

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THE STUDY AND REPORT

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SECTION A

THE STUDY AND REPORT

PURPOSE AND AUTHORITY

1. The purposes of this study were to identify the causes and extent of shoreline erosion at Talofofo Bay and to develop suitable plans for stabilizing the shoreline. The economic and environmental impacts of the alternatives and the feasibility and extent of Federal participation in solution of the problem were also investigated.

2. The study and report were accomplished under the authority of Section 103a of the River and Harbor Act of 1962, as amended, which states as follows:

> "The Secretary of the Army is hereby authorized to undertake construction of small shore and beach restoration and protection projects not specifically authorized by Congress, which otherwise comply with Section 1 of this Act, when he finds that such work is advisable, and he is further authorized to allot from any appropriations hereafter made for civil works, not to exceed $25 million for any one fiscal year for the Federal share of the costs of construction of such projects: Provided, That not more than $1 million shall be allotted for this purpose for any single project and the total amount allotted shall be sufficient to complete the Federal participation in the project under this section including periodic nourishment as provided for under Section 1(c) of this Act: Provided further, That the provisions of local cooperation specified in Section 1 of this Act shall apply: And provided further, That the work shall be complete in itself and shall not commit the United States to any additional improvement to insure its successful operation, except for participation in periodic beach nourishment in accordance with Section 1(c) of this Act, and as may result from the normal procedure applying to projects authorized after submission of survey reports."

3. A reconnaissance study was initiated in November 1971 when the Governor of Guam requested the Corps of Engineers to investigate the erosion problem at Talofofo Bay. The findings and conclusions were favorable to undertaking further detailed investigations. Based on the recommendations in the reconnaissance report, a detailed project study was authorized by the Chief of Engineers in April 1972.

SCOPE OF THE STUDY

4. The depth and detail of the investigations made were commensurate with the objective of developing an effective shore protection plan within the constraints of the study authority. The study covered the entire shoreline of Talofofo Bay with particular attention devoted to the 900 feet of shoreline affected by erosion. Field and office studies consisted of site inspections, hydrographic surveys, geologic and environmental investigations, economic analyses, and field inventories of possible sources of construction material.

STUDY PARTICIPANTS AND COORDINATION

5. The Corps of Engineers was responsible for conducting and coordinating the study and the plan formulation, consolidating information from studies and other sources, and preparing the report.

6. The proposed plan of improvement and the study recommendations reflect the comments received from the following governmental agencies and citizen groups during the course of the study.

Federal Agencies

U.S. Department of the Interior
U.S. Environmental Protection Agency
U.S. Department of Health, Education, and Welfare
U.S. Coast Guard

Government of Guam Agencies

Department of Agriculture, Division of Fish and Wildlife
Department of Commerce
Department of Land Management
Department of Public Works
Bureau of Budget and Management
Department of Public Health and Social Services
Guam Environmental Protection Agency

Others

Residents
Surfers

7. Formulation of the proposed plan of improvement was also influenced by comments received during the public meeting of 31 January 1973 and informal meetings held with Government of Guam officials and interested citizens during the course of the study.

8. In compliance with the Fish and Wildlife Coordination Act of 1958, the study was coordinated with the Hawaii Area Office of the U.S. Bureau of Sport Fisheries and Wildlife's Division of River Basin Studies, and with the Division of Fish and Wildlife of the Government of Guam. No opposition to the project was received.

PRIOR REPORTS

9. The previously mentioned reconnaissance report for shore protection improvements at Talofofo Bay made by the Pacific Ocean Division is the only known prior report on the bay.

S E C T I O N B

RESOURCES AND ECONOMY OF STUDY AREA

SECTION B

RESOURCES AND ECONOMY OF STUDY AREA

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SECTION B

RESOURCES AND ECONOMY OF STUDY AREA

GENERAL DESCRIPTION

1. A general description of the resources, and the development and economy of the Territory of Guam is presented to provide some understanding of the island's physical and socio-economic developmental trends and corresponding needs. The general trends and needs for the study area essentially parallel those of the Territory. The tributary area for the proposed project is considered to be the entire island of Guam.

TERRITORY OF GUAM

2. The Mariana Islands chain, which is composed of 15 islands, forms an approximately 500-mile-long arc in the Western Pacific Ocean. The chain is part of the imaginary boundary between the Pacific Ocean and the Philippine Sea. There are four major islands in the chain; Saipan, Tinian, Rota, and Guam, the latter being the largest and most populous island in the Western Pacific between Hawaii and the Philippines. Guam is approximately 30 miles long, 4 to 8-1/2 miles wide and has an area of about 209 square miles. It is 4,120 statute miles west of Honolulu, Hawaii, 1,690 miles south of Tokyo, Japan, and 2,160 miles east of Manila, Philippines (figure 1).

3. Because of its strategic location, Guam has played an important role militarily and in the development of commerce in the Western Pacific. Ferdinand Magellan, in 1521, was the first European to discover Guam and the island was claimed by Spain in 1565. The island became a United States possession following the Spanish-American War in 1898 and was administered by the U.S. Navy. Guam continues to be a bastion for military activity. In 1961, when visitors were permitted without a military visa, the possibility of developing a budding tourist industry was envisaged. Typhoon Karen in November 1962 and Typhoon Olive in April 1963 together destroyed nearly 90 percent of the structures on the island. The widespread devastation led to declaration of Guam as a disaster area, and reconstruction was started soon after. Today, Guam can be considered to have bloomed from the aftermath of the typhoons, to the busy, bustling center of a Western Pacific mecca for visitors from Japan and the west.

STUDY AREA

4. Talofofo Bay is located on the southeast coast of Guam about midway between the southern end of the island and Pago Bay at its central waist (see figure 2). The main axis of the bay lies in an approximately east-west direction with its mouth at the east end opening into the Pacific Ocean. The bay is about three quarters of a mile long and generally less than 1,000 feet wide. The Talofofo River discharges into the west end

of the bay. The bay is a drowned river mouth and the land rises to elevations of about 150 feet on both sides, but more abruptly behind the northshore. A narrow limestone platform fringes much of the bay.

5. The project reach for the proposed shoreline protection extends from the right bank of the Talofofo River at the point where the Highway 4 bridge crosses it, 900 feet southward along the western shore of the bay to Gayloup Point (see figure 3). This reach is composed of an unstable and unconsolidated beach deposit. Its material is principally the coarse fraction of sediment carried down the river during flood conditions which is then sorted and shaped by wave action in Talofofo Bay. Route 4, the principal highway circling the island of Guam, crosses the unconsolidated beach deposit as it approaches the bridge.

6. The mouth of the Talofofo River carries the runoff from two drainage systems. The Talofofo River drains about 21 square miles of hilly savanna land in the volcanic southwestern part of Guam. About half a mile above the mouth, the Ugum River joins the Talofofo. The Ugum drains a similar hinterland of approximately 7 square miles. This combined river system is the largest on Guam, as measured both by its volume of discharge and by its drainage basin area. The combined flow varies from about 5 cubic feet per second during dry periods to flows of over 10,000 cubic feet per second during flood conditions.

7. The drainage system originates in an area of deeply weathered volcanic rocks and noncalcareous sediments and follows stream valleys floored by alluvial clays in its lower reaches. The sediment brought down to the bay is predominantly an insoluble residue of volcanic materials in the clay, silt, and sand size fractions. Most of the finer fractions are carried out to sea or the deeper parts of the bay, leaving fine sand (0.2 to 0.8 millimeter median grain diameter at low and high tide, respectively) along the shoreline or in shallow bar deposits near the river mouth.

8. A small (less than 10 percent) amount of marine materials (shell fragments and similar bioclastic materials) is mixed into the riverine sediments by wave action, and the waves shape these sands into the beach deposit. The waves also shape riverine sediments into a submerged offshore bar which shifts in position but generally extends northward from the top of Gayloup Point. It is this submerged bar which breaks the waves and forms a surfing zone during many periods of the year.

9. During periods of low flow (generally January to May) a sandbar develops on the north side of the river mouth and the principal river channel runs southeastward somewhat paralleling the shoreline along which protection is proposed. During the wet season (July to November) high flow conditions erode this bar and the main channel shifts towards the north shore of the bay.

10. The backshore area along the project reach is primarily covered with beach morning glory, Ipomea pes-caprae, and the creeper Dolichos Lablab. A few land crabs live in this area. Across the highway this zone is

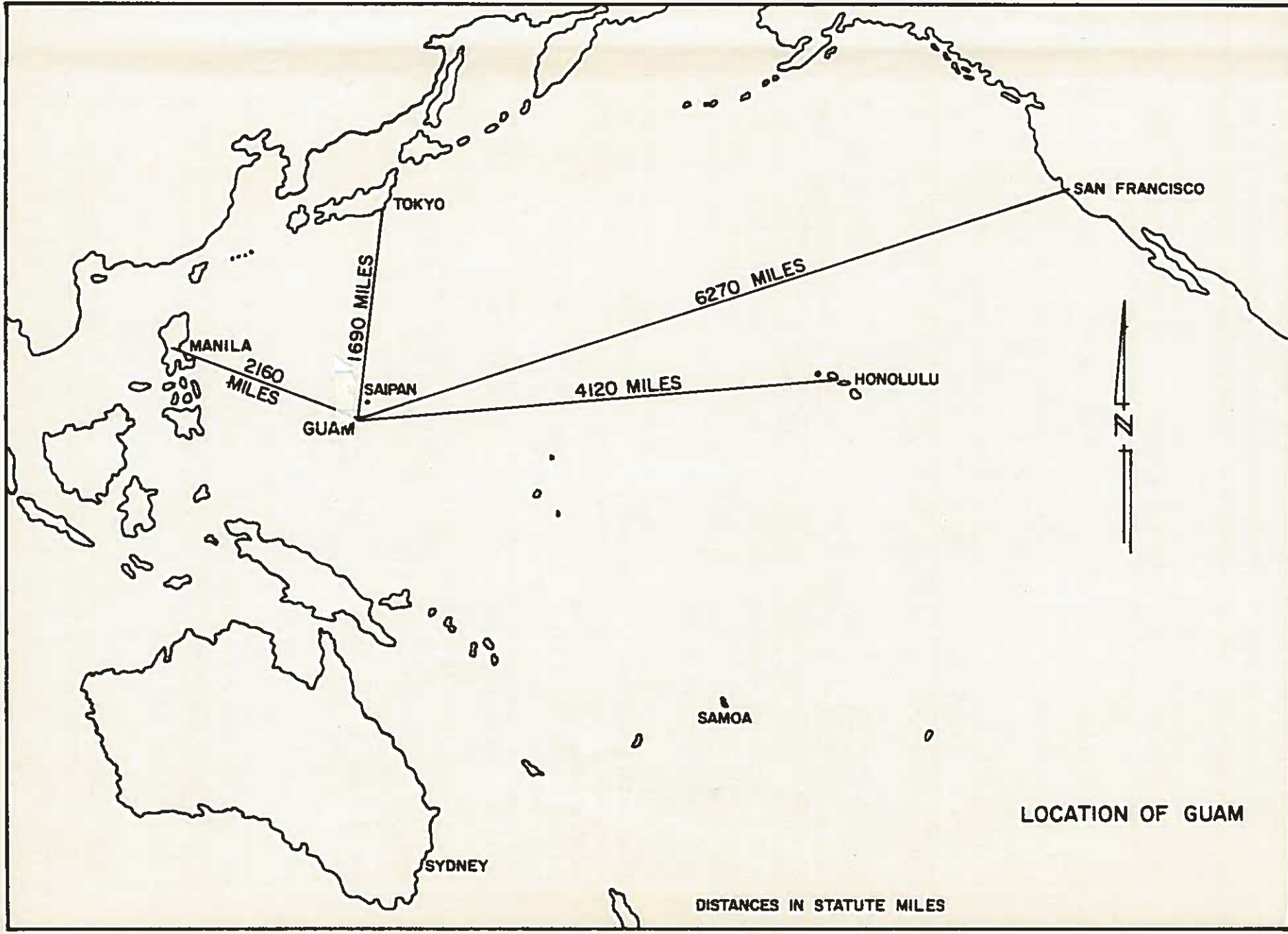
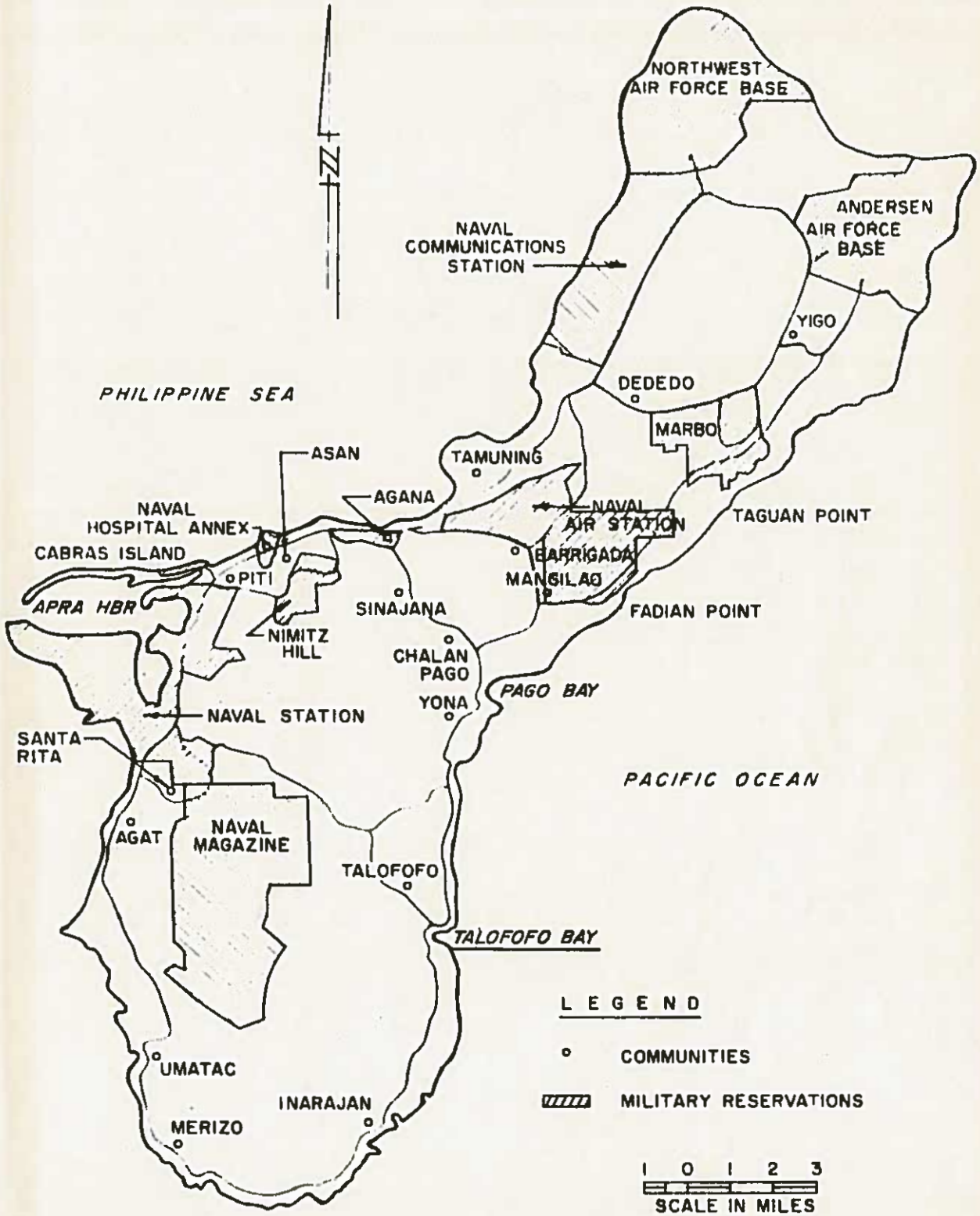

TOKYO
SAN FRANCISCO
1690 MILES
6270 MILES
MANILA
2160 MILES
SAIPAN
4120 MILES
HONOLULU
GUAM
N
SAMOA
SYDNEY
LOCATION OF GUAM
DISTANCES IN STATUTE MILES

FIGURE 1



MAP OF GUAM

FIGURE 2

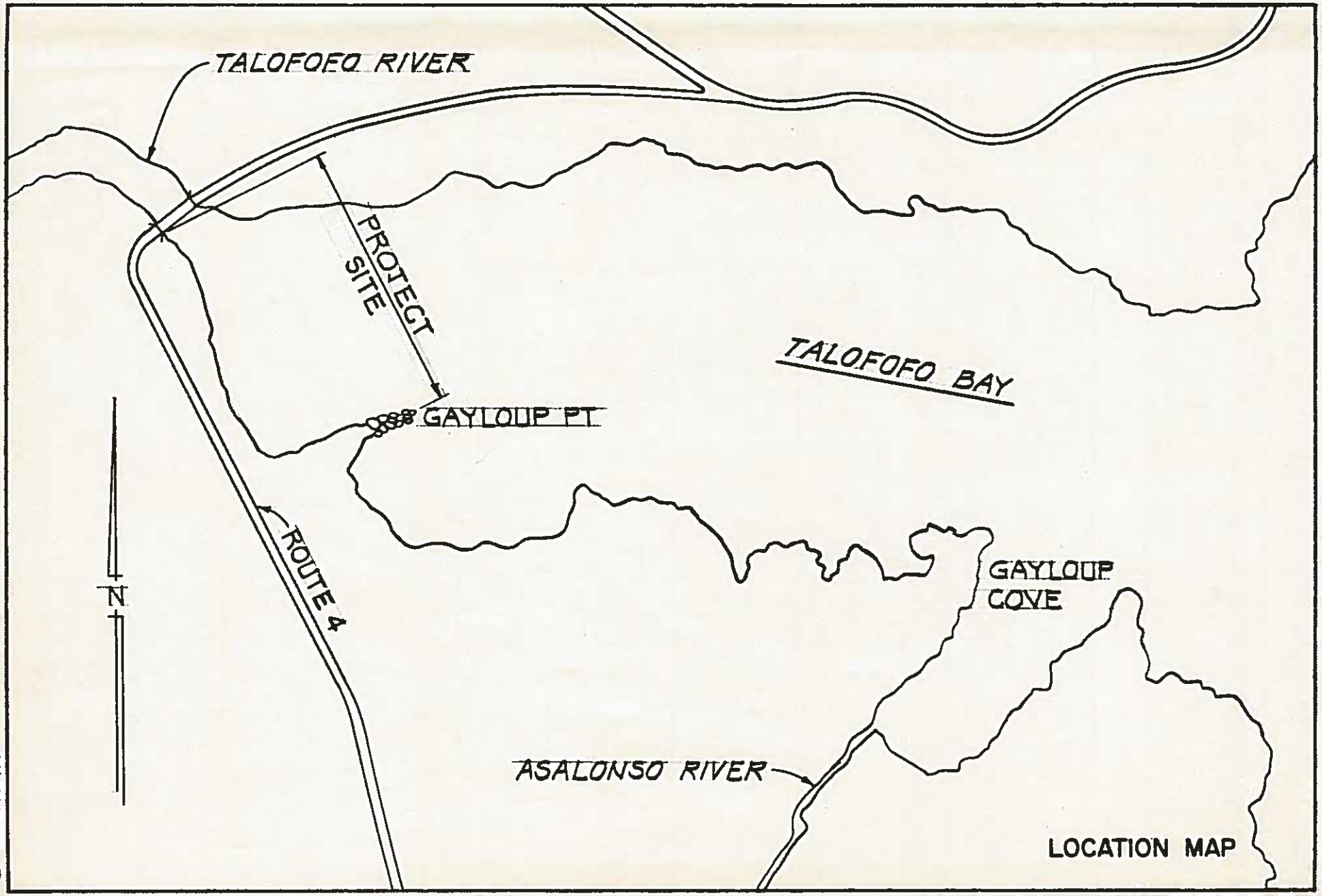


FIGURE 3

FIGURE 3

succeeded by a community of Nypa palms which approximately mark the limits of recent (as measured in geological time) stabilization of the sediment deposits brought down by the river. The foreshore area is biologically devoid of permanent elements and is used only by a few crabs, shorebirds, and sand fleas.

11. This beach area has been modified by man. During the early 1940's, the U.S. Navy used it as a landing area for small craft. Some revetment stones were placed around Gayloup Point at that time to serve the landing.

12. Offshore from the project area, the bay is floored by unconsolidated sediments and the water depth is less than 15 feet throughout the entire western half of the bay. No benthic organisms were observed, and the channel floor appears barren. There is much plant debris on the bay floor.

13. The waters of the inner portion of the bay are frequently turbid due to both river discharge and the stirring action of the waves. The fresh water from the river floats on the denser sea water beneath it for a considerable distance from the river mouth before mixing is complete. During occasional periods of high discharge the fecal coliform bacteria count in the surfing area of the bay (immediately seaward of the proposed shore protection project) has exceeded the pollution level established by the Guam Water Pollution Control Commission (200 coliform/100 MIL); but the median count is about one-tenth of this index level.

14. The proposed project reach is adjacent to a public park which is used for picnicking, swimming, surfing and other recreational activities. Expansion of the park is intended, based on information contained in the report on the Guam Outdoor Recreation Plan.

NATURAL RESOURCES

15. Guam's significant natural resources are its tropical climate, scenic beauty, and sea and reef areas. It has no known important mineral resources.

CLIMATE

16. The climate is typically tropical in character, being almost uniformly warm and humid throughout the year. Easterly trade winds are dominant throughout the year, especially from November to June. Typhoons often occur from July to October, and wind direction becomes extremely variable during this time. Trade wind speeds are generally between 4 and 12 miles per hour and rarely exceed 24 miles per hour. There are two distinct seasons on the island: a dry season from January through May, and a wet season from July to November. December and June are transitional months; they may fall in either the wet or dry season. Guam has an annual mean temperature, rainfall, and humidity of 81 degrees, 84 inches, and 81 percent, respectively.

TERRAIN

17. There are two distinct topographic features which essentially divide Guam into a northern and southern portion. The northern portion is characterized by a broad undulating limestone plateau reaching a height of almost 860 feet at Mount Santa Rosa. The plateau is fringed by steep coastal cliffs broken by patches of beach and narrow, irregular coastal plains. The southern portion of the island has broad relatively impervious volcanic rocks with mountain peaks of more than 1,000 feet. Mount Lamlam is the highest point with an elevation of 1,334 feet. The west coast is bordered by a narrow coastal plain, and the east coast by limestone cliffs 100 to 300 feet high. Because of the high permeability of the limestone plateau, no perennial streams exist in the northern portion. During heavy rain, drainage is generally downward to numerous sinkholes and fissures. Standing water occurs in the coastal lowlands during heavy or prolonged rain. The southern portion of the island is mountainous with deeply incised valley perimeters and floors. Drainage in this area is through rivers and their tributaries which carry the water to the ocean. There are more than 40 streams in the southern portion. The largest is the Talofofo River and its tributaries which drain a 28-square-mile area.

GEOLOGY

18. The small islands of the Mariana chain are the high points of submarine ridges of which Guam is one of the largest. The major soil provinces of Guam can be broadly defined by two groups, the northern limestone province and the southern volcanic province. The northern limestone plateau is permeable and contains a basal fresh water lens. The southern volcanic province is composed of relatively impermeable weathered volcanic rock whose surface has been etched and eroded by surface water runoff.

OCEAN AND REEFS

19. The ocean around Guam has a year round temperature of 81 degrees and is largely responsible for the island's tropical climate. The fringing reefs, which almost completely encircle the island, afford excellent scuba diving opportunity because of an abundance and variety of marine life. The fringing reefs range from narrow benches along parts of the limestone cliffs to broad flats over 3,000 feet wide. Small bays are numerous in the southern portion where rivers have prevented reef development.

HUMAN RESOURCES

POPULATION CHARACTERISTICS AND PROJECTIONS

20. Guam's historical population estimates reflect the combined effects of Spanish rule, natural catastrophes, and disease which reduced the population from an estimated 50,000 to as low as 1,576 in the early 18th century.[1/] Guam's population since the official census began is shown in table 1.

TABLE 1. POPULATION OF GUAM[2/]

Year	Total Population
1901	9,676
1910	11,806
1920	13,275
1930	18,509
1940	22,290
1950	59,498
1960	67,044
1970	84,996

1/ Laura Thompson, Guam and Its People, 1947; Louis de Freycinet, Voyage Autour du Monde, 1829.

2/ U.S. Department of Commerce, Bureau of Census. PC(1)-A54 Guam.

21. The population increased during the last decade at an average annual growth rate of 2.5 percent. Table 2 shows the projected population of Guam.

TABLE 2. POPULATION PROJECTION[1/]

Year	Total Population
1970	84,996
1980	154,000
2000	254,000
2020	267,000

1/ Economic Base Study, Territory of Guam, May 1973, prepared by the Pacific Ocean Division, U.S. Army Corps of Engineers.

EMPLOYMENT

22. Guam has experienced a high level of employment since World War II. However, increasing immigration and dependence on relatively cheap imported alien labor are changing the employment picture. The total paid employment of all licensed business establishments and governmental agencies during the first quarter of Fiscal Year 1971 was 25,340. Table 3 summarizes employment by industries and the percentage distribution.

TABLE 3. EMPLOYMENT BY INDUSTRIES[1/] AND PERCENT DISTRIBUTION

Industry	Total Employment	Percent Distribution
Agriculture and Mining	69	0.27
Construction	4,363	17.22
Manufacturing	935	3.69
Transportation, Communication, Electric, Gas, and Sanitary Services	1,534	6.05
Wholesale and Retail Trade	3,576	14.11
Finance, Insurance and Real Estate	542	2.14
Service	2,159	8.52
Government		
Federal	6,676	26.35
Local	5,486	21.65
TOTALS	25,340	100.00

1/ A Survey on Business and Employment, Department of Labor, Government of Guam, FY 1971.

23. The three-industry category, government, construction, and wholesale and retail trade, employ about 79 percent of the total labor force. Government is the largest employer on the island and will continue to be a major factor in the economy of Guam. Employment by the local government is expected to increase with population and needs of an expanding economy. The Federal sector, primarily the Navy and Air Force, occupy approximately one-third of the land area on Guam. The Navy controls the central, south-central, and most of Apra Harbor, and the Air Force controls the northern portion of the island occupied by Anderson Air Force Base. Military activities are expected to continue in the foreseeable future. The return of Okinawa to Japan may result in a major change in military employment and would have a pronounced impact on the Guamanian economy.

24. The second major employer is the construction industry which employs more than 17 percent of the island's labor force. However, of the 4,363 persons employed by the construction industry, 82 percent are alien workers on contract, an indication of a critical shortage of skilled labor on Guam. Most of the contract laborers are from Korea, Japan, and the Philippines. In direct percentage of gross receipts, construction reached its peak during the aftermath of Typhoon Karen. In 1970, construction outlays reached a new high of $42.3 million; $16.8 million for commercial and residential, $20.0 million by the Federal Government, and $5.5 million by the Government of Guam. The construction industry will continue to be a major employer as the economy expands.

25. The third major employer is the wholesale and retail trade industry. Guam's natural resources for industrial development are limited, thereby making the economy service-oriented. This service is being rapidly expanded to accommodate the influx of visitors and is evident by the growing

number of new businesses. The influence of a rapidly expanding economy, provided in part by the visitors, results in an increasingly higher standard of living. These rising standards are evidenced everywhere in new housing, shopping centers, and restaurants. Increases in wholesale trade, primarily petroleum sales, are directly related to the influx of visitors to Guam.

DEVELOPMENT AND ECONOMY

ECONOMIC DEVELOPMENT

26. Economic projections for Guam envisage a continuation of the last decade's growth in the foreseeable future. The major growth areas will continue to be in Federal and local government, construction, wholesale and retail trade, and the visitor industry. It is this latter industry and related services which is expected to provide the impetus for an expanding economy.

27. Statistics on gross island product are not available for Guam. Once almost totally dependent on the military, local government, and the construction industry, the emergence of the tourist industry and related activities has broadened Guam's economic base for future growth. Table 4 shows the growth of selected industries between 1960, 1970 and 1971. Information on the visitor industry is discussed in subsequent paragraphs. The three other major industries, government, construction, and wholesale and retail trade, were described in the previous discussion of employment.

TABLE 4. GROWTH OF SELECTED INDUSTRIES, 1960, 1970, 1971

Category	1960 Earnings or Value ($ millions)	1970 Earnings or Value ($ millions)	1971 Earnings or Value ($ millions)
Gross Sales			
Retail	34.9	85.0	103.1
Wholesale	7.5	25.0	43.8
Manufacturing	3.5	4.9	6.2
Amusements	1.1	2.2	2.7
Services	42.6	93.0	112.6
Foreign Trade			
Exports	8.2	1.7	3.8
Imports	25.4	96.4	115.0
Local Government			
Revenue	16.2	57.7	68.6
Expenditure	14.2	48.9	65.2

1/ Guam 1970 - An Economy in Transition; Department of Commerce, and Guam 1971 - The Pacific Growth Leader, prepared by the Government of Guam.

TOURISM

28. Guam's tropical climate, scenic beauty, sea and reef areas, and proximity to the Far East provide the basic ingredients for a flourishing tourist industry. These attributes were only recently recognized and are now being developed into a business which is growing at a staggering rate and broadening the island's economic base. The total number of tourists and visitors to Guam from 1964 to 1970 are shown in table 5. In 1971, there were 119,200 visitors to Guam, 84,900 of whom were tourists.

TABLE 5. TOURIST AND VISITOR ARRIVALS (1964-1970)[1/]

Year	Tourist[2/]	Visitor[2/]
1964	300	2,000
1965	500	3,000
1966	1,500	3,500
1967	4,300	4,500
1968	15,100	18,000
1969	30,800	58,300
1970	44,600	73,700

1/ Economic Research Center, Department of Commerce, Government of Guam (figures rounded).

2/ Tourists are travelers arriving for pleasure. Visitors include all travelers to Guam.

29. The phenomenal growth of the visitor industry in the last 3 years is attributed to the rising Japanese economy. In 1971, almost 60 percent of all visitors and approximately 75 percent of all tourists were from Japan. The chance to visit a tropical island on an economic package tour, particularly for couples on honeymoons, and the attractiveness of business investments have resulted in the heavy influx of visitors from Japan. To accommodate the visitors, hotels are being constructed at an accelerated rate, especially at Tumon Bay, with capital provided primarily by Japanese investors. Table 6 shows the total hotel rooms available on Guam.

TABLE 6. TOTAL HOTEL ROOMS

Year[1/]	Rooms
1967	150
1968	267
1969	518
1970	680
1971	1,019

1/ As of January of the indicated year.

30. By the end of 1972, there were approximately 2,200 hotel rooms on Guam. Table 7 shows the projected visitors to Guam and the estimated rooms necessary based on an 80 percent occupancy rate, 1.75 persons per room, and an average 5-day stay per visitor.

TABLE 7. PROJECTED VISITORS[1/] AND ROOMS REQUIRED

Year	Projected Visitors[2/]	Estimated Rooms Required[2/]
1974	320,000	2,870
1975	400,000	3,590

1/ Economic Base Study, Territory of Guam, March 1973, prepared by the Pacific Ocean Division, U.S. Army Corps of Engineers

2/ As of January of the indicated year.

31. Continued development of the visitor industry will have a definite impact on related services, both in the private and public sector. This industry now appears to have the greatest potential for future growth.

S E C T I O N C

PROBLEMS AND NEEDS

SECTION C

PROBLEMS AND NEEDS

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SECTION C

PROBLEMS AND NEEDS

NATURAL FORCES

WAVES

1. As shown in figure 4, Talofofo Bay is exposed to waves approaching the island of Guam from the south to N 40° E. There are no wave gaging stations in the vicinity of Talofofo Bay. Consequently, deepwater wave data for the Guam area were obtained from the "Summary of Synoptic Meteorological Observations" prepared by the U.S. Naval Weather Service Command in June 1971. The wave rose (figure 5) developed from the data shows that waves affecting Talofofo Bay occur about 70 percent of the time. Waves 5 feet or greater occur approximately 35 percent of the time. Table 8 which compares wave height and wave period shows that Guam is affected by predominately short-period waves. Waves with periods of 9 seconds or less occur about 89 percent of the time.

TYPHOONS

2. Typhoon data specifically for Talofofo Bay is not available. However, data for Guam and the Western Pacific area were obtained from "Typhoons of Guam, 1970," prepared by Fleet Weather Central, Joint Typhoon Warning Center, Guam, Mariana Islands. During the 24-year period between 1946 and 1970, Guam has felt the effects of 12 typhoons. The closest points of approach of these typhoons, listed in table 9, range from 0 to 91 nautical miles. Typhoons listed are those with center winds known to be 64 knots or greater. Typhoon force winds have been recorded seven times on Guam and winds have exceeded 100 knots on three occasions. The most devastating typhoon to hit Guam was Typhoon Karen, which occurred on 11 November 1962 and had sustained winds of 150 knots as the eye moved directly over Guam. The 150-knot sustained winds represent a near maximum intensity for typhoons in the Guam area.

TABLE 8. PERCENT FREQUENCY OF WAVE HEIGHT VS. WAVE PERIOD
(ANNUAL) PERIOD: 1963-1970

Wave Period (Seconds)	Wave Height (Feet) <3	3-4	5-6	7	8-9	10-11	12+	Total
<8	15.5	26.8	18.1	8.1	3.2	1.3	.9	73.9
8 - 9	.5	2.0	4.5	4.9	1.7	.9	.5	15.0
9 - 11	.1	.5	1.1	.9	1.3	.5	.6	5.0
11 - 13	-	.1	.4	.2	.4	.2	.3	1.6
>13	-	-	.1	.1	.1	-	.2	.5
Total %	16.1	29.4	24.2	14.2	6.7	2.9	2.5	96.0

Indeterminate number of observations: 4 percent.
Total observations: 4,589.

TABLE 9. TYPHOONS AFFECTING GUAM (1946 TO MAY 1970)

Date	Name	CPA[1/]	Wind[2/] (knots)	CTR Wind[3/] at CPA (knots)
11 Apr 1968	Jean	91 NM NE	38	110
13 Nov 1967	Gilda	46 NM NNE	40	120
5 Sep 1964	Sally	0 NM S	70 (est)	70
25 Dec 1963	Susan	70 NM N	37	125
11 Jul 1963	Wendy	36 NM S	70 (est)	100
29 Apr 1963	Olive	23 NM W	54	125
11 Nov 1962	Karen	0 NM Central	150	150
10 Sep 1961	Nancy	85 NM SW	60 (est)	175
15 Nov 1957	Lola	25 NM S	107	145
10 Aug 1953	Nina	0 NM S	75	75
17 Nov 1949	Allyn	30 NM S	79	120
21 Sep 1946	-	0 NM N	100	100

1/ CPA - closest points of approach to Guam.
2/ Wind - maximum sustained wind speed on Guam.
3/ CTR Wind at CPA - maximum sustained wind near the center of typhoon.

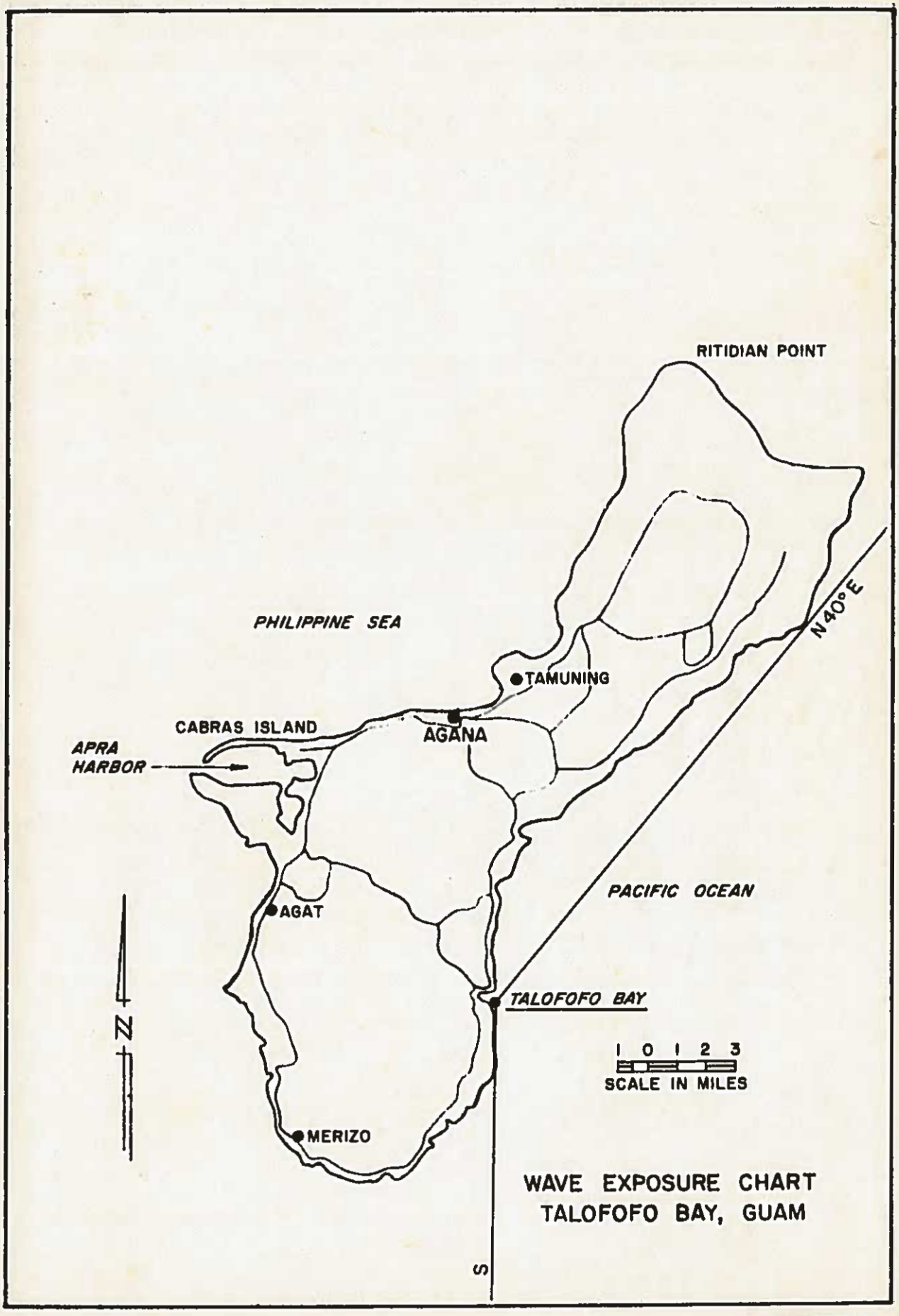
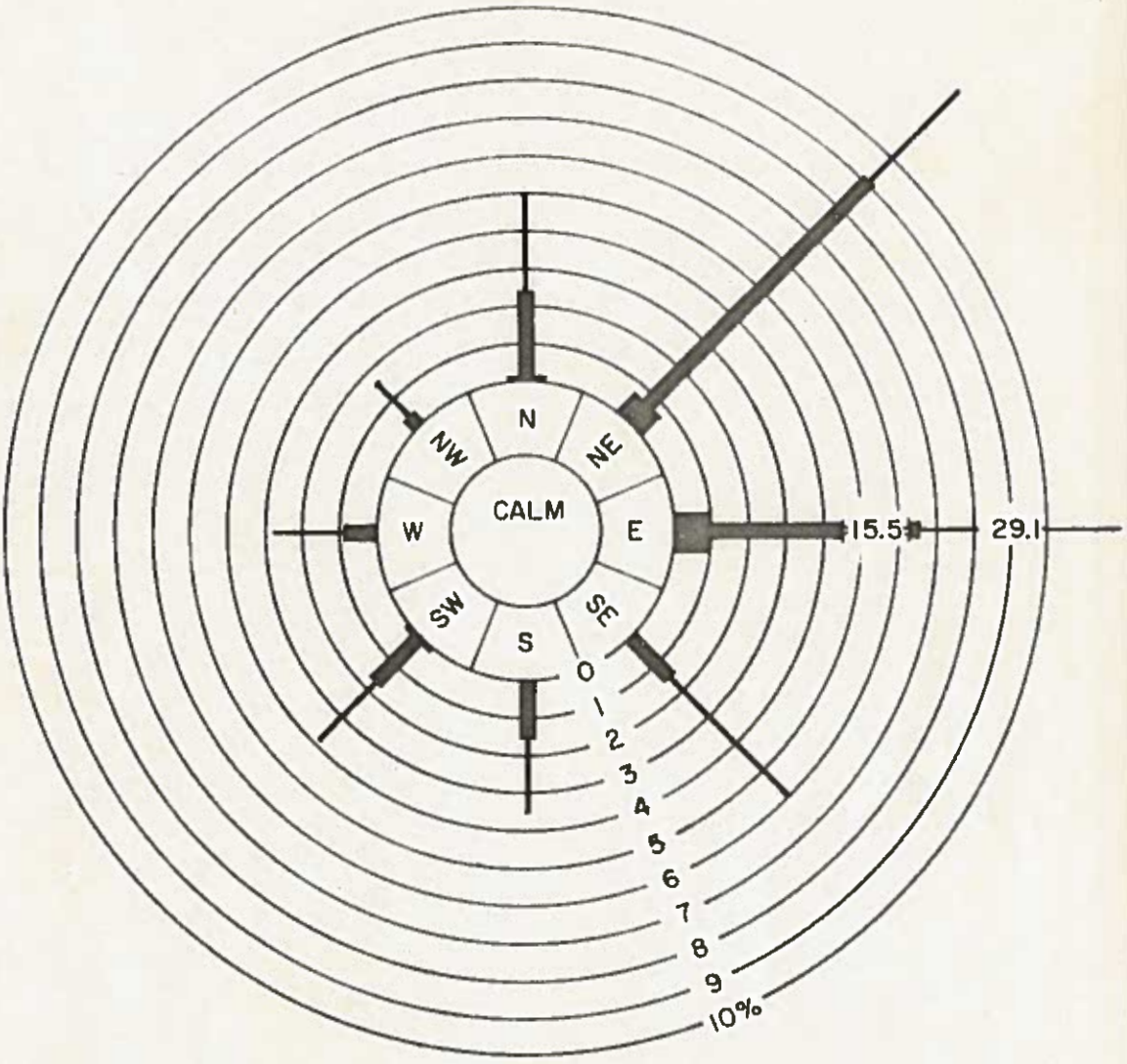
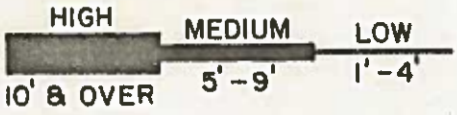

RITIDIAN POINT
PHILIPPINE SEA
N40°E
TAMUNING
AGANA
CABRAS ISLAND
APRA HARBOR
PACIFIC OCEAN
AGAT
TALOFOFO BAY
N
1 0 1 2 3
SCALE IN MILES
MERIZO
S
WAVE EXPOSURE CHART
TALOFOFO BAY, GUAM

FIGURE 4

WAVE ROSE



LEGEND



10% = TOTAL % OF THE YEAR

PERIOD OF RECORD

1963 TO 1970

STATION LOCATION

COORDINATES 13.0 N
144.7 E

SOURCE

U. S. NAVAL WEATHER
SERVICE COMMAND

FIGURE 5

3. Severe typhoons have occurred in the Western Pacific every month of the year, but only rarely affect Guam before July. The typhoon season coincides roughly with the rainy season and is generally confined to the months of July to December. Between 1900 and 1970, a total of 65 typhoons affected Guam, 60 of which occurred in the last 6 months of the year. Table 10 shows the monthly occurrences of the typhoons affecting Guam.

TABLE 10. MONTHLY OCCURRENCES OF TYPHOONS AFFECTING GUAM (1900-1970)

Month	Occurrences	Month	Occurrences
January	1	July	9
February	0	August	13
March	1	September	13
April	2	October	10
May	1	November	11
June	0	December	4

4. Based on the 65 typhoons between 1900 and 1970, the frequency of typhoons affecting Guam is approximately one per year. However, the frequency for the period between 1946 and 1970 is one every two years. Furthermore, since 1900, winds greater than 100 knots are known to have occurred on seven occasions and the frequency of these disastrous storms is about once in every 8 or 9 years.

TIDES

5. There is no tidal station at Talofofo Bay. The nearest tidal station is at Apra Harbor, about 10 miles northwest of Talofofo Bay. Tidal data for the 19-year period 1949-1967, taken at Apra Harbor by the National Oceanic and Atmospheric Administration, National Ocean Survey, is tabulated below:

	Feet
Highest tide (observed)	3.31
Mean higher high water, MHHW	2.40
Mean high water, MHW	2.30
Mean tide level, MTL	1.45
Mean sea level, MSL	1.41
Mean low water, MLW	0.60
Mean lower low water, MLLW	0.00
Lowest tide (observed)	-1.89

THE SHORELINE EROSION PROBLEM

EXISTING SHORELINE CONDITIONS

6. The beach and backshore area which extend from the mean lower low waterline to a point about 20 feet landward of Route 4 were formed by

sediments deposited by the Talofofo River. A community of Nypa palms behind the highway is believed to mark the location and alignment of the shoreline prior to the more recent (as measured in geological time) accumulation of riverine sediments. Prior to World War II, the head of the bay was a continuous stretch of beach. Gayloup Point, a low promontory created in the 1940's by the deposition of rock for a boat landing, now divides the bay into two sectors. The approximately 1,000-foot-long sector south of Gayloup Point is stable at this time. In contrast, the 900-foot-long sector extending north from Gayloup Point to the Talofofo River has experienced periods of severe erosion and is the sector the Government of Guam seeks to stabilize.

7. The width of the beach north of Gayloup Point varies from 0 to 250 feet with an average of about 170 feet as measured from the mean lower low waterline to the edge of the backshore area about 5 to 8 feet above MLLW. Approximately 550 linear feet of the backshore is lined with coral armor stone. The area between the coral armor stone and Route 4 is grassed.

8. A hydrographic survey made in August 1972 shows the sandy beach starting about 2.5 feet below the top of the armor stones. The beach slopes at a rate of 1 to 6 percent to a scarp which drops between 1 and 3 feet to about elevation +2.0 feet MLLW, then slopes at a rate of 2 to 7 percent to the existing ocean bottom at elevation -3.0 feet.

9. Geological field investigations were conducted at Talofofo Bay during the period 2 to 6 October 1972. The material in the beach and backshore area are old flood plain deposits of alternating thin layers or bands of fine and coarse grained silt and sand. The sediments consist of 90 percent basalt fragments and 10 percent coral fragments. All particles are well rounded with smooth surfaces, free draining with no cohesion or plasticity in the upper 5 feet. Three test pits dug along the +5-foot contour of the shoreline showed a slightly plastic blue gray silty layer with vegetation and organic material at low tide level. This layer thickens from 0.5 feet to 3.0 feet in a northerly direction. The material deposited by the river is believed to have originated in a swampy, or backwater environment under conditions different from those in the area today.

SHORE PROCESS

10. Talofofo Beach changes with the seasons. During the dry seasons of the year (January through May) the volume of material deposited by the Talofofo River is very small. Because the velocity of the flow is low, a sandbar develops across the northern side of the river mouth. The bar causes the discharge from the river to flow along the shoreline south of the mouth, and the riverine material to be deposited along the sector between the mouth and Gayloup Point. In addition to material deposited by the river, the beach is also nourished by sand from offshore deposits. Sand from these sources is transported onto the beach by the large waves associated with the northeast trade winds which are prevalent during this period.

11. During the wet season of the year (July through November), the increased volume and velocity of flows on the Talofofo River remove the sandbar and the river channel shifts to a course paralleling the fringing platform which extends north from the left bank. The volume of material carried by the river increases significantly during this season. Both the riverine material and the material from the sandbar are deposited offshore in the bay. Because the trade winds are not prevalent during this season, wave energy affecting the beach is low. Consequently, the volume of material transported shoreward is very small. In addition to limited nourishment from offshore sources, the beach is vulnerable to severe erosion from storms and typhoons which usually occur during this season.

HISTORICAL SHORELINE CHANGES

12. Prior to initiation of the studies for shore protection improvements at Talofofo Bay, no hydrographic surveys had been taken at the site. Aerial photographs were made in 1962 but the scale and altitude at which the pictures were taken make them unusable for determining beach loss over a period of time. Figure 6 depicts the shoreline during the early 1940's as remembered by long-time residents of the area. They recall the backshore area being used as a cemetery and park with picnic tables. A house and a church were also situated there. All of these items have been lost to the sea, except for some human remains which were exhumed because of the danger of being washed away. Based on the shoreline shown, there has been a loss of about 1.6 acres of land since the early 1940's.

13. In addition to the losses that have occurred over the past 30 years, Talofofo Bay is subjected to severe short-term losses due to storms. In 1971, Tropical Storm Patsy and Typhoon Amy eroded the shore to within 35 feet of Route 4. This prompted the Government of Guam to dump stones along the shoreline in an effort to prevent further erosion and possible undermining of Route 4. The shoreline has since been filled in by deposits from the Talofofo River. According to one observer, severe erosion similar to that resulting from the 1971 storms occurred on three previous occasions.

ANALYSIS OF THE PROBLEM

14. Severe recession of the shoreline is attributed to wave action associated with storms and typhoons. The fact that Talofofo Bay is not protected by coral reefs makes the shoreline particularly vulnerable to erosion by storm waves. The seasonal variation of the beach width is explained in the previous section, "Shore Process."

15. The discharge from the Talofofo River has been suggested as a possible cause of the erosion problem. This factor is discounted because of the relatively low velocity of the flow that meets the ocean water at the head of the bay.

RECREATIONAL NEEDS

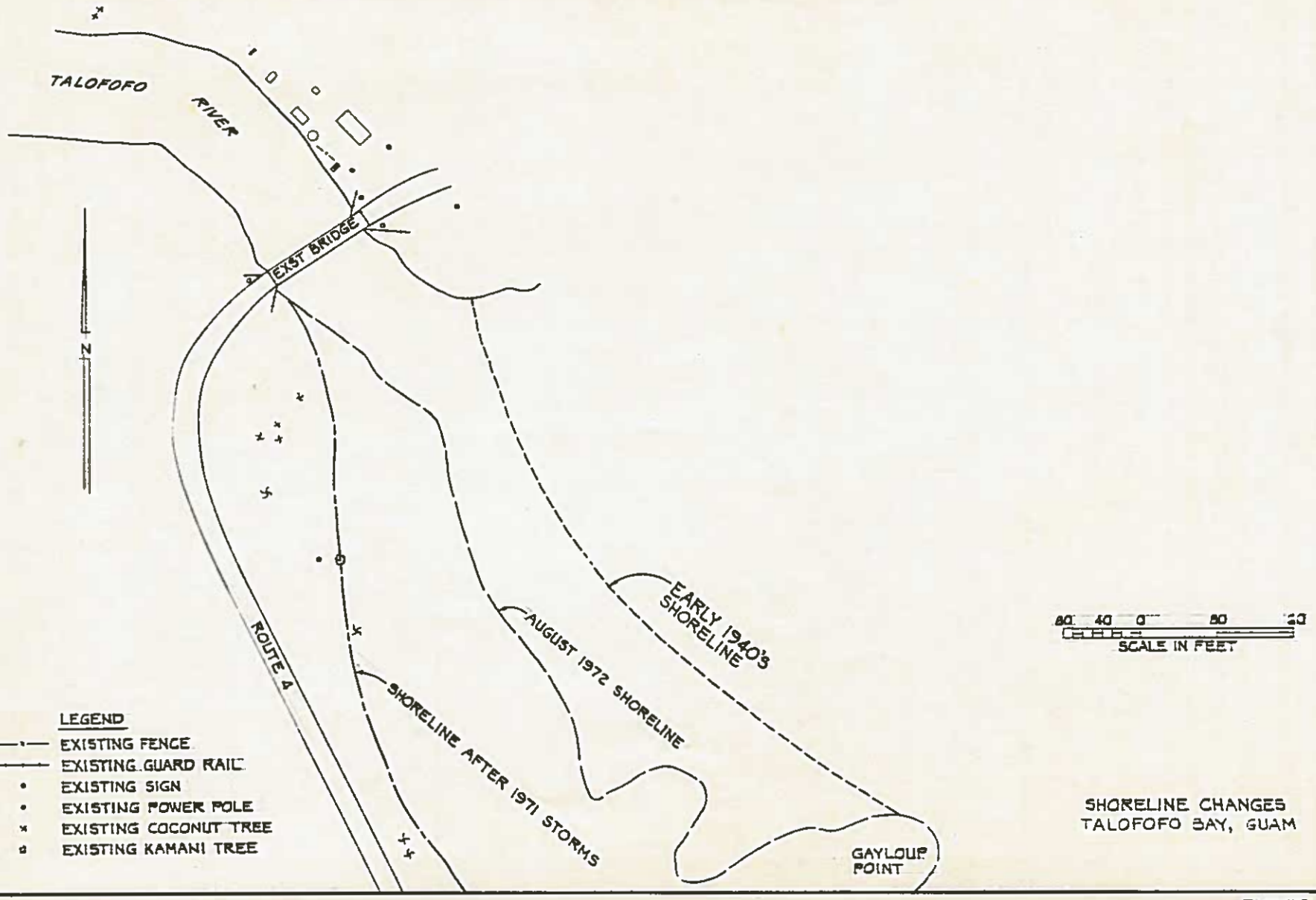
16. An outdoor recreation plan for the territory of Guam was published in 1967 and revised in 1971. Studies made during development of the plan in 1966 indicate that the people of Guam rely heavily on resource-oriented recreational activities for their leisure time pursuits. This is attributed to the favorable climate, the relatively young population, few competing activities and relatively low per capita income of the residents. A survey taken to establish interest in outdoor recreation activities resulted in the following compilation:

ACTIVITY	% OF TOTAL SURVEYED
Visiting historic sites	72
Visiting scenic sites	71
Swimming & going to beach	71
Camping	70
Picnics and outings	68
Hiking	65
Participation in competitive sports	63
Fishing	63
Attending outdoor sports	62
Horseback riding	56
Hunting	48
Shelling	33
Boating	27
Skin diving	15
Surfing	3
Water skiing	2

Source: Outdoor Recreation on Guam by Lawrence C. Johnsrud and Associates and the Planning Staff of John Carl Warnecke and Associates

17. Analysis of the survey results and the available recreational facilities showed that a critical need exists for additional facilities such as picnic grounds, campsites, developed beaches, and swimming areas. At the time of the 1966 comprehensive outdoor recreation study, the impact of the blossoming tourist industry and related population growth was unforeseen. These factors have compounded the recreational needs defined by the study. The Government of Guam is aware of the critical shortage of recreational facilities and is making every effort to improve and maintain existing facilities and to develop additional ones to meet the growing demand.

18. As part of their effort, the Government of Guam has programmed Talofofo Bay for development as a major beach and park, and destination area for tourists and residents. The bay is already a popular scenic site,



SHORELINE CHANGES
TALOFOFO BAY, GUAM

FIGURE 6

FIGURE 6

swimming beach, picnic ground, and surfing site. Based on the outdoor recreation survey, Talofofo Bay contributes toward satisfying 3 of the 6 more popular activities. Although the survey showed a relatively small interest in surfing, the importance of the surfing site at Talofofo Bay is that it is the better of the two most popular sites on Guam. In fact, the 1967 Outdoor Recreation Plan for Guam lists Talofofo Bay as the only natural surfing area on Guam and has designated it as a surfing beach.

19. At the time of the 1966 study, the Government of Guam was in the process of acquiring the backshore beach area at Talofofo Bay. The outdoor recreation plan recommended that the project be given the highest priority for both acquisition and development of the site. Since that time, the site for the park has been acquired and development of the park has been given the second priority island-wide in the 1971 revision to the outdoor recreation plan.

20. Although emphasis has been placed on development of the bay, full implementation of the Talofofo Bay recreation master plan is hampered by the erosion problem along the north shore between Gayloup Point and the Talofofo River. Erosion has already severely limited the recreational usefulness of this area, and it now serves primarily as a buffer between the Route 4 Highway and the sea. Because the north bay is an integral part of the recreational master plan for the bay, the eroded reach must be restored and protected before the following park improvements proposed by the master plan for this reach can be implemented:

a. Picnic areas with a total of about 15 tables

b. Two beach pavilions

c. Parking for 21 cars

d. Beach area for sunbathing

e. Rest area for surfers

21. Although the reach south of Gayloup Point could be developed in accordance with the master plan regardless of the condition of the north shore, the total effectiveness and intent of the recreational development for the bay would not be achieved without the complementary development of the north bay. Not only would the recreation facilities be limited, but the continued erosion would also mar the attractiveness of the area and create hazardous conditions.

IMPROVEMENTS DESIRED

22. In November 1971, the Government of Guam formally requested the Corps of Engineers to investigate the feasibility of Federal participation in shore protection improvements for Talofofo Bay. The request came after two storms during the year had caused severe erosion of the shoreline

which reduced the recreational usefulness of the bay and threatened to undermine Route 4. In his letter, the Governor of Guam described Talofofo Bay as a major public recreation area and tourist destination area popular for picnicking and surfing. He cited the high usage of Route 4 and the fact that the Government of Guam had spent $3,000 in an effort to temporarily stop the erosion and maintain the shoreline.

23. During initial investigation of the problem and discussions with Government of Guam officials, it became clear that shore protection was desired to enable implementation of the recreational master plan for the bay. Emphasis was placed on shoreline protection rather than beach restoration because it was felt that the beach which is expected to form seaward of the structure through sediment deposition from the Talofofo River would be sufficient for the intended park use. Local interests stressed the importance of attaining the project objectives without destroying surfing and seriously detracting from the natural beauty of the bay.

24. In addition to facilitating implementation of the recreational master plan, local interests recognized that shore protection would also satisfy their desire for a more permanent solution for protecting Route 4 which is the primary highway around the island and the major link between communities along the southeast coast and the capital and business center on the central west coast of the island.

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SECTION D

FORMULATING A PLAN

POSSIBLE SOLUTIONS

1. Formulation of the proposed plan of improvement was based on the study objective of providing an engineeringly efficient, economical, and environmentally acceptable plan for controlling shoreline erosion at Talofofo Bay. The possible solutions to the problem were first divided into two broad categories, nonstructural and structural alternatives.

NONSTRUCTURAL MEASURES

2. A basic nonstructural alternative is that of doing nothing about the problem. Although this alternative would have the least impact on the existing environment, it would preclude the development of the backshore area for park purposes. In addition, portions of Route 4 would still be subject to undermining due to storm waves. For these reasons, it would not satisfy the study objectives, and therefore was not selected.

3. A nonstructural measure often considered for areas subject to inundation by storm waves is the implementation of zoning and building codes to control development. This alternative is intended to minimize the hazard to life and property in these areas. It is therefore not applicable to the situation at Talofofo Bay where the objective is to control erosion of the shoreline fronting a section of a Government owned park which will be used for recreation purposes.

4. The relocation of Route 4 farther inland would be a solution to the problem of protecting the highway. This course of action is not desirable, however, because it would not deter erosion and, consequently, development plans for the park in the project reach could not be implemented.

5. At the 31 January 1973 public meeting, the nonstructural approach of planting the backshore area was proposed as a solution to the erosion problem. While this measure may be effective in certain instances, wave action at Talofofo Bay, particularly during storm conditions, is too severe for it to be effective. Ground cover existent during previous storms have been of little value in deterring erosion.

6. Although nonstructural measures have merit, they are not applicable to the Talofofo Bay shoreline erosion problem primarily because they would not provide a complete solution compatible with the overall development plans for the area.

STRUCTURAL MEASURES

7. Basically, there are two approaches to controlling shoreline erosion through structural means. One of these is to protect the shoreline with

a structure such as a revetment built along the coastline. The other approach is to build offshore structures to reduce the wave energy reaching the shoreline. Variations of these two schemes are numerous and many would satisfy the study objectives for Talofofo Bay. Their usage is dependent on the physical and environmental constraints of the study area.

SELECTING A PLAN

8. In accordance with the guidelines of Section 122 of the River and Harbor and Flood Control Act of 1970, the two structural alternatives and the no-action alternative were compared in terms of their social, economic and environmental impacts. The comparison of alternatives is shown in table 11.

9. Table 11 shows that the no action and offshore breakwater plans are not viable alternatives in terms of satisfaction of the stated needs of the area. The no action alternative would not prevent erosion of the shoreline and serious consequences would result from the failure to correct the situation. The offshore breakwater plan is undesirable because it eliminates surfing in the bay. The shortage of surfing sites on Guam makes it imperative that surfing be continued at Talofofo Bay.

10. The alternative of protecting the shoreline through the use of a revetment structure has a few undesirable effects but satisfies all of the project objectives. This approach to the problem is explained in the next section.

TABLE 11

EFFECTS OF ALTERNATIVE ACTIONS

CONSIDERATION	NO ACTION	REVETMENT PLAN	OFFSHORE BREAKWATER PLAN
SOCIAL			
1. Noise	No Impact	Temporary increase in noise level at project and borrow sites due to operation of equipment.	Same as Revetment Plan
2. Displacement of People.	No Impact	No Impact	No Impact
3. Aesthetic Value	Deterioration of the site will continue, particularly after storms. No structural alteration to the shoreline.	Exposure of rock revetment along the shoreline. Backshore area can be landscaped.	Exposure of rock breakwater offshore. Backshore area can be landscaped.
4. Transportation	Possibility of section of Route 4 being undermined requiring rerouting of traffic and inconveniences to motorists.	Assures continued transit along Route 4.	Same as Revetment Plan
5. Leisure Opportunities	Prohibits development of park in backshore area.	Allows development of park in backshore area. Limits erosion, thereby limits expansion of board recovery zone for surfing. Impairs access to the beach.	Allows development of park in backshore area. Eliminates surfing.
6. Community Cohesion	No Impact	No Impact	No Impact

TABLE 11 - CONTINUED

CONSIDERATION	NO ACTION	REVETMENT PLAN	OFFSHORE BREAKWATER PLAN
7. Community and Regional Growth	If Route 4 is breached, community growth in this and other adjacent communities could be impaired due to the increase in travel distance.	No Impact	No Impact
ECONOMIC			
1. Local Government Finance	Continued expenditure of funds to protect Route 4 from being undermined due to shoreline recession.	Minimizes local costs for protection of the highway against erosion. The project site is Government-owned land so there would be no meaningful increase in property values or tax. Local interests would be required to share in the cost of the project.	Same as Revetment Plan
2. Public Facilities and Services	Loss of use of the project reach as a public park.	Increased park space in protected backshore area.	Same as Revetment Plan
3. Employment	No Impact	Creates work for construction industry.	Same as Revetment Plan
4. Business and Industrial Activity	No Impact	Some material will be purchased from commercial firm.	Same as Revetment Plan
5. Displacement of Farms	No Impact	No Impact	No Impact

TABLE 11 - CONTINUED

CONSIDERATION	NO ACTION	REVETMENT PLAN	OFFSHORE BREAKWATER PLAN
ENVIRONMENTAL			
1. Man-made Resources	No Impact	Allows park to be developed.	Same as Revetment Plan
2. Natural Resources	Loss of use of the site as a public park. Deterioration of the site.	Enhances recreational usefulness of the site. 11,000 cubic yards of rocks of varying sizes will be required for construction of the structure.	Same as Revetment Plan
3. Pollution Aspects			
a. Air	No Impact	Slight increase in air pollution at project and borrow sites due to equipment operation, excavation and placement of rock.	Same as Revetment Plan
b. Water	No Impact	Slight increase in turbidity due to disposal of excavated material seaward of the revetment.	Increase in turbidity due to placement of breakwater materials and disturbance to ocean bottom.
4. Plants	Loss of plants due to erosion.	Change in ground cover from beach morning glory to grass chosen for use in park.	Same as Revetment Plan
5. Erosion	Continual erosion of the shoreline.	Prevents continued erosion of the shoreline.	Same as Revetment Plan

S E C T I O N E

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THE SELECTED PLAN

DEVELOPING A PLAN

1. The determination of a revetment plan as the appropriate alternative for Talofofo Bay leaves decisions concerning the specific design features and alignment of the revetment. These aspects of the plan are discussed in this section.

ALIGNMENT

2. The revetment structure can be constructed in many locations and with various alignments. These factors are guided, however, by the desire to have a picnic area and a surfing site. Consequently, the revetment would be constructed about 120 feet from the edge of Route 4. The northern end of the revetment would be indented shoreward to induce the accretion of sediments from the Talofofo River on the seaward side of the structure. The center portion would be aligned parallel to Route 4 which is roughly parallel to the existing shoreline. The southern end of the revetment would be curved seaward to meet the existing revetment at Gayloup Point and provide a transition from the larger park area south of the point. This location and alignment of the revetment about halves the distance between the edge of Route 4 and the existing shoreline. It allows a sufficient area for a sandy beach on the seaward side of the structure while still maintaining a suitable area on the landward side for park development. Consequently, this location and alignment best serves the interests of both surfers and picnickers.

REVETMENT FEATURES

3. Computations made to determine the wave runup on the revetment under the conditions of water fronting the structure and the occurrence of a typhoon showed that waves would run up to an elevation of +15.4 feet MLLW. Although construction of the revetment with an elevation higher than this value would prevent overtopping, it would result in a massive structure along the shoreline. The top of the revetment would be 10 feet higher than portions of Route 4 and would be unacceptable from the visual standpoint. Consequently, a top elevation of +7.0 feet MLLW was chosen for the revetment. This elevation matches the elevation of the shoreline existent after the 1971 storms and is more responsive to the project objective of shore protection without seriously detracting from the natural beauty of the bay.

4. Consideration was given to constructing the revetment of clayey soil rather than rock. The clay could be overlaid with topsoil and planted

to present a very pleasing appearance. However, this alternative is not considered feasible for Talofofo Bay because of the relatively high water elevation at the bay.

5. The revetment section would consist of two layers of 3,000- to 4,000-pound armor stones, an underlayer consisting of two layers of 200- to 500-pound stone, a 1-foot bedding layer of 1- to 50-pound stone, and a layer of plastic filter cloth. The front slope of the revetment would be 1V on 2H and the top width of the revetment would be 17 feet to allow for dissipation of the wave energy overtopping the structure. About 16,000 cubic yards of beach sand would be excavated to construct the revetment. About 10,000 cubic yards would be used to backfill the seaward side of the structure and grade the area landward of the revetment. The remaining 6,000 cubic yards would be used to build up the beach along the shoreline.

OTHER PLAN FEATURES

6. At the public meeting in January 1973, concern was expressed over access to the beach from the park, the contention being that the crest width and the foreslope of the revetment would be difficult to negotiate. As a result of this concern, three concrete walkways with stairs and handrails leading down the revetment slope were incorporated into the plan of improvement.

7. The land shoreward of the revetment would be graded as required to provide adequate drainage of the backshore area between the revetment and Route 4. It would also be grassed to conform with the ground cover used in the existing park.

8. The proposed plan of improvement is shown on plate 1.

PLAN ACCOMPLISHMENTS

9. The proposed plan of improvement would curtail erosion of the shoreline, thereby protecting the Route 4 Highway and allowing the area shoreward of the revetment to be developed for park use. Implementation of the proposed plan would be consistent with the outdoor recreation plan for Guam.

EFFECTS OF THE PLAN ON THE ENVIRONMENT

10. By the nature of its objectives, the plan of shoreline erosion control could be considered an environmental project. Its implementation would prevent further erosion and allow 2.2 acres of land to be developed for park use. The plan would also assure continued transit of vehicles along Route 4. These positive results, however, are not accomplished without some sacrifices to the existing environment.

11. The revetment stones would replace a strip of the existing backbeach area and add an artificial structure to the shoreline. The visual impact would be most pronounced during the periods when there would be no accumulation of sand in front of the revetment.

12. The 17-foot-wide crest and 20-foot front slope of the revetment would impair access to the beach to some extent. Although the rock size and the slope of the structure should not make negotiating the revetment difficult, three walkways with stairs leading down the revetment slope would be provided for easy access to the beach.

13. By preventing shoreline recession, the proposed plan of improvement would limit the board recovery zone for surfers which, under existing conditions, expands when the shoreline recedes. The proposed plan would present the danger of surfboards running up the revetment slope when there is no sand in front of the structure. This impact would be greatest at the southern end of the project area where the revetment is flared to provide a transition to the existing park and revetment at Gayloup Point.

14. Approximately 11,000 cubic yards of rock of various sizes would be required for initial construction of the project. Additional rock would be required for periodic maintenance of the structure. The rock would be obtained from existing commercial and government sources and would not entail the opening of a new source.

15. Grading and planting of the area between the revetment and Route 4 would result in a change of vegetation from creepers such as the beach morning glory to grasses chosen for use as ground cover in the expanded park.

16. Temporary disturbances to the environment anticipated during the construction period include increased turbidity of the water, noise, dust, and increased traffic. These impacts would not be lasting and would be controlled through strict enforcement of the contract specifications.

17. There are no known historical or archaeological sites in the project area which would be endangered by the proposed plan of improvement. No rare or endangered botanical or zoological species are known to exist in the project area.

DESIGN

DESIGN WAVE HEIGHT

18. Calculation of the design wave height was based on the solitary wave theory which describes the maximum wave height which can reasonably be expected at the revetment. The design wave height, H_b, is equal to 0.78 times the depth of water, d_b, approximately 7 wave heights seaward of the

toe of the proposed structure. The depth of water was calculated on the basis of the occurrence of a typhoon with the properties of Typhoon Karen which passed over the island in 1962. A depth of 3.0 feet of water below MLLW was chosen on the assumption that the beach would be eroded prior to the arrival of the design wave. A high tide and storm surge of 6.4 feet added to the 3.0-foot of water resulted in a d_b equal to 9.4 feet. The design wave height was then computed to be 7.3 feet. The design stillwater level of +6.4 MLLW is about a foot lower than has previously been used for other projects on Guam. The difference results from a decrease in the rise of the water level due to the winds of the typhoon. In most areas of Guam, the shoreline is fronted by coral reefs with shallow depths of water. The typhoon winds, under this condition, cause a significant rise in the water level. At Talofofo Bay, there is no coral reef within the central section of the bay, and water depths are relatively large resulting in a decrease in the effect of the winds on water elevations.

WEIGHT AND THICKNESS OF ARMOR STONES

19. The rubblemound stability formulas were used to determine the weight and thickness of the armor units. The equation for the weight of stone is:

$$W = \frac{W_r H^3}{K_D (S_r - 1)^3 \cot \alpha}$$

While the equation used to determine the layer thickness is:

$$r = nK_\Delta \left(\frac{W}{W_r}\right)^{1/3}$$

The following constants were used in the computations:

W_r = 150 pounds per cubic foot

K_D = 3.0

S_r = 2.3

$\cot \alpha$ = 2.0

n = 2

K_Δ = 1.15

The computations showed that the revetment should be constructed of 3,000-pound minimum stones, and that the armor layer should be 6.6 feet thick. Based on the results, 3,000- to 4,000-pound stones would be specified in the construction contract.

CREST ELEVATION

20. Computations were made to determine the height of wave runup on the revetment structure. The computations showed that water would reach an elevation of +15.4 feet MLLW under the design conditions. However, a crest elevation of +7.0 was chosen for aesthetic reasons as explained earlier in the paragraph, REVETMENT FEATURES.

CREST WIDTH

21. The width of the crest was computed by the following equation:

$$B = nK \left(\frac{W}{W_r}\right)$$

Where: $n = 3$

$K = 1.15$

$W = 3{,}500$ pounds

$W_r = 150$ pounds per cubic foot

The required crest width was calculated to be 9.9 feet. However, because the design of the revetment allows wave overtopping, a width of 17 feet was chosen to provide for dissipation of the wave energy.

CONSTRUCTION

SOURCES OF STONE

22. Stones for shoreline revetment can be obtained through the process of segregation and accumulation at various borrow pits ("quarries") which are operated primarily as sources of fill material. Possible sources of stone for the project are described below:

a. Malolos borrow pit (quarry): The pit is located 1.8 miles south of Talofofo Bay and was opened during World War II for construction of the Route 4 Highway around the south end of the island. The pit is about 600 feet long and 300 feet wide with a circular ramp leading down to the pit floor 200 feet below the ground surface. The rock now being excavated by the Guam Department of Public Works contains 65 to 75 percent weathered, loose, argillaceous, or chalky coral limestone with a bulk specific gravity of 2.2. Scattered ledges or lenses of fairly compact hard coral limestone constitute the remaining 25 to 35 percent of the deposit. The argillaceous particles range in size from

angular fragments 1/4 inch across through cobble and boulder sizes 10 feet in diameter. Most of the rubble pieces are between 4 and 10 inches in diameter. The fine sandy detritus exposed in the walls of the pit show evidence of surficial crusting or self-cementation. The walls of the older excavations are covered with a dark gray algae coating. Materials in the pit can be excavated with a front end loader. Little drilling and blasting is required to remove the rock. This borrow pit is capable of supplying rock for the underlayer and bedding layer of the revetment structure.

b. Fadian Point quarry. This quarry, owned by the Government of Guam, is located approximately 12 miles from the project site. The quarry is open at three levels, and accessibility and operating conditions are excellent. The rock is compact, recrystallized, massive coral limestone with bulk specific gravity ranging between 2.5 and 2.6.

c. Cabras Island quarry. The Cabras Island quarry face is 6,400 feet long. The quarry has a reserve of about 1 million cubic yards of rock. It is approximately 15 miles from the proposed project. The surface of the quarry varies in elevation from 91 feet at the east end to 20 feet at the west end. The seaward side of the quarry now stands as a fairly vertical face 200 to 400 feet back from the ocean. Over 3 million cubic yards of limestone rock were quarried between 1941 and 1947. The rock is massive, compact, recrystallized, white- to light-brown limestone with numerous coral heads well cemented in a hard, fine-grained algae matrix. All rock in the deposit will require blasting. The blasted material will be in the shape of angular blocks 0.5 to 10 feet across. The number of armor stone pieces recoverable would probably be more than 50 percent depending on the drilling and blasting methods used. Joints are spaced 0.5 to 15 feet apart with an average of 5 feet. Jointing decreases to the east. Bulk specific gravity of the rock generally ranges between 2.4 and 2.6.

d. Hawaiian Rock Products quarry. This quarry is located off Highway 15 at Taguan Point in Barrigada, approximately 14 miles from the proposed project. The quarry operates primarily for asphalt and concrete products. The crusher system is limited to 36-inch pieces, and larger pieces are segregated and pushed over the edge of the berm to get them out of the way since secondary shooting is not economical. The quarry has been in operation for 10 years, and several thousand pieces of stone have accumulated on the berm face and on the hillside below the quarry. The company plans to open a haul road to the lower slope to provide access to the boulders. The rock is compact, recrystallized massive and similar to the Cabras Island rock. The rock breaks in angular blocks up to 20-ton pieces. Blasting is required. The face is 800 feet long and 20- to 100-feet high, and the quarry is about 300 feet above the ocean. The bulk specific gravity ranges from 2.3 to 2.5.

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ECONOMICS OF SELECTED PLAN

METHODOLOGY

1. The tangible economic justification of the proposed improvements was ascertained by comparing the equivalent average annual charges (i.e., interest, amortization, and maintenance costs) with an estimate of the equivalent average annual benefits anticipated to accrue over the 50-year project life. The average annual benefits should equal or exceed the annual costs if the Federal Government is to participate in the project.

2. The value given to benefits and costs at their time of accrual is made comparable by conversion to an equivalent time basis using an appropriate interest rate. An interest rate of 5-5/8 percent was used in this report. The net effect of converting benefits and costs in this manner is to develop equivalent average annual values.

3. A number of economic and physical forces such as physical depreciation, obsolescence, changing requirements for project services, and inaccuracies in making overly long projections, limit the economic life of the project. Based on these factors, an economic life of 50 years was used for project analysis.

4. The development of project costs and benefits follows standard Corps of Engineers practice. The value of all goods and services used in the project is estimated on the cost side. Benefits which would accrue from shore protection improvements at Talofofo Bay essentially consist of recreational enhancement.

COSTS

PROJECT FIRST COST

5. The estimated first cost for the Talofofo Bay Shore Protection Plan of Improvement is $525,000. Table 12 shows a breakdown of this amount into the various items of work. The cost estimates are based on:

a. A 6-month construction period for the project.

b. December 1973 price levels in the territory of Guam. The unit costs for all items reflect in-place costs.

c. Stones for the construction of the revetment to be obtained from field sources within 15 miles of the project site.

TABLE 12. ESTIMATE OF PROJECT FIRST COST

ITEM	UNIT	QUANTITY	UNIT COST	ITEM COST	TOTAL COST
Excavate and Backfill	CY	16,300	$ 4.50	$ 73,400	
Construct Revetment	LF	900	298.80	268,900	
Grade Backshore	CY	3,600	2.50	9,000	
Drainage	SY	2,800	1.00	2,800	
Walkways	EA	3	4,900.00	14,700	$368,800
Contingency, 15% ±					55,300
Direct Cost					$424,100
Engineering and Design					
Plans and Specifications				$ 18,300	
Engineering During Construction				3,400	
Study Costs				51,500	$ 73,200
Supervision and Administration					$ 27,700
TOTAL PROJECT FIRST COST					$525,000

APPORTIONMENT OF PROJECT FIRST COST

6. The apportionment of costs between Federal and Non-Federal interests is shown in table 13. The apportionment is in accordance with Section 103 of Public Law 87-874 which prescribes the basis for Federal aid toward the cost of restoration and protection of Federal, Non-Federal, public and private shores. The apportionment of costs applicable to the Talofofo Bay project is a 50-50 sharing excluding study costs which are borne by the Federal Government.

TABLE 13. APPORTIONMENT OF PROJECT FIRST COST

TOTAL FIRST COST	FEDERAL SHARE (50%)	NON-FEDERAL SHARE (50%)
$525,000	$288,250*	$236,750

* Includes $51,500 study costs borne solely by the Federal Government.

ANNUAL COSTS

7. The average annual costs for the proposed plan of improvement is $29,900 with $28,500 attributable to interest and amortization and $1,400 attributable to maintenance cost. The maintenance cost is based on replacement of 1 percent of the revetment armor stone every year. The estimate for interest and amortization is based on a 5-5/8 percent interest rate and a 50-year economic life. Interest during construction is not included since the construction period is relatively short.

BENEFITS

GENERAL

8. The tangible benefits which would accrue from the proposed shore protection improvements at Talofofo Bay are based on expected conditions with and without the project and the following criteria: (1) base year assumed to be 1975; (2) 50-year project life; and (3) 5-5/8 percent interest rate. The latest available estimated use of the Talofofo Bay beach and park for various activities is summarized on table 14.

TABLE 14. ANNUAL USE OF TALOFOFO BAY

Activity	Annual Use
Swimming	4,000
Surfing	5,000
Visiting scenic site	17,000
Picnicking	4,000
Horseback riding	1,000
Total	31,000

Horseback riding is limited to the outer periphery of the park on a strip adjacent to the road and will not be affected with or without the proposed improvement. Consequently, no benefits were evaluated for this activity. One of the two most popular surfing sites on Guam is in Agana bay at the entrance to the existing small boat harbor. The other, considered to be the better of the sites, is at Talofofo Bay. The proposed plan will neither improve nor interfere with, surfing conditions in the bay. Surfing benefits, adverse or beneficial, are therefore not evaluated. Tangible recreation benefits are evaluated for swimming, visiting scenic site, and picnicking collectively. Although swimming conditions will not be changed, the overall increase in attendance resulting from the proposed improvements is expected to result in increased swimming and picnicking activities.

9. Interviews with the Guam Department of Parks and Recreation personnel revealed that records of attendance at government controlled recreational facilities are not kept. The best available data are estimates provided by personnel familiar with the site. Information on instantaneous peak and non-peak day use and use between residents and tourists are also not available. For planning purposes, it was estimated by the parks personnel that more than 50 percent of the visitors who stop at Talofofo Bay to view it as a scenic site are tourists. Most tours, however, by-pass Talofofo Bay without stopping because of its eroded condition and lack of facilities.

10. A major resort area less than two miles north of Talofofo Bay will contribute to the use of the beach and park. Although the resort will have most of the conveniences to meet the recreational needs of the tourists, there will be no opportunity for ocean swimming, surfing, or outdoor strolling and relaxation at a scenic tropical site such as Talofofo Bay. Maximum utilization of the bay is dependent upon restoration and prevention of further erosion of the north shore between Gayloup Point and the Talofofo River. Funds have been allotted by the Government of Guam for park improvements for the area south of Gayloup Point. Additional park improvement funds are contingent upon protection provided for the north bay.

11. In computing the average annual benefits which would accrue from the proposed improvements, it was assumed that limited shoreside facilities will be constructed in the park area back of the south bay by 1975. This is expected to result in an increase in visits to the beach and park with or without improvements to the north bay. However, without improvements, the maximum use of the beach and park will not be realized. Without improvements, it was assumed that (1) resident use would increase at 30 percent of the projected population growth, (2) visitor use and tour stops would increase at a rate approximated by 20 percent of the projected visitor growth, and (3) benefits to users without the proposed improvements would be 75 percent of the maximum under ideal conditions (i.e., the remaining 25% would accrue if the proposed project is implemented). With the proposed plan of improvement, it was assumed that resident use will at least increase at a rate equal to the projected average annual growth of the population. It was further assumed that at least 25 percent of all

visitors will stop at Talofofo Bay as part of the scenic tour and use the facilities as part of their tropical outdoor recreational experience. The value per recreation day with improvements is $0.50. The data used in computing the benefits are derived from table 14 and differentiated between tourists and residents in table 15. Table 16 shows resident and tourist use with and without the proposed improvements.

TABLE 15. EXISTING USE OF TALOFOFO BAY (1,000's)

	Resident	Tourist	Total
Swimming	4	-	4
Visiting scenic site	8	9	17
Picnicking	4	-	4
Total	16	9	25

TABLE 16. PROJECTED RESIDENT & TOURIST USE OF TALOFOFO BAY (1,000's)

	Resident Use		Tourist Use	
Year	With Improvement	Without Improvement	With Improvement	Without Improvement
1972	16.0	16.0	9.0	9.0
1975	19.2	17.0	100.0	55.0
1990	37.7	22.5	880.0	680.0
2020	42.6	23.9	880.0	680.0

12. Table 17 shows the derivation of the average annual benefits which would accrue as a result of the proposed project. The total average annual benefits are $143,600.

JUSTIFICATION

13. The average annual benefit for the proposed plan is $143,600. The average annual charge is $29,900. The resulting benefit-cost ratio is 4.8.

TABLE 17. AVERAGE ANNUAL BENEFITS

1. Residents

a. Existing (without improvements)

Year	No. of visitors	Benefit at 25 percent of $0.50/visit
1975	17,000	$2,100
1990	22,500	2,800
2020	23,900	3,000

Equivalent average annual benefit $2,600

b. New (additional visits with improvement)

No. of visitors	Benefit at $0.50/visit
2,200	$ 1,100
15,200	7,600
18,700	9,400

Equivalent average annual benefit $5,800

2. Tourists

a. Existing (without improvements)

Year	No. of visitors	Benefit at 25 percent of $0.50/visit
1975	55,000	$ 6,900
1990	680,000	85,000
2020	680,000	85,000

Equivalent average annual benefit $60,000

b. New (additional visits with improvement)

No. of visitors	Benefits at $0.50/visit
45,000	$ 22,500
200,000	100,000
200,000	100,000

Equivalent average annual benefit $75,200

S E C T I O N G

PLAN IMPLEMENTATION, FINDINGS, AND RECOMMENDATIONS

SECTION G

PLAN IMPLEMENTATION, FINDINGS, AND RECOMMENDATIONS

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SECTION G

PLAN IMPLEMENTATION, FINDINGS, AND RECOMMENDATIONS

PLAN IMPLEMENTATION

LOCAL COOPERATION

1. Federal participation in construction of the proposed project is subject to the conditions that local interests will:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project.

b. Hold and save the United States free from claims for damages due to the construction work and subsequent maintenance of the project.

c. Assure maintenance and repair during the useful life of the project as may be required to serve the intended purpose.

d. Provide a cash contribution presently estimated at $236,750, or 50 percent of the total construction costs of the project, the final amount to be determined at the time of project construction in accordance with cost-sharing procedures for shoreline erosion control defined in the report.

e. Assure continued public ownership of the shore upon which the amount of Federal participation is based, and its administration for public use during the economic life of the project.

f. Assure that water pollution that would endanger the health of bathers will not be permitted.

g. Provide and maintain necessary access roads, parking areas and other public use facilities open and available to all on equal terms.

2. By letter, a copy of which is included as Exhibit A, the Government of Guam, the local cooperating agency, has given its approval of the proposed project and has agreed to fulfill the necessary requirements of local cooperation. The Government of Guam has the financial capability to participate in the construction of the project and formal assurances of its intent to comply with the local cooperating requirements will be obtained prior to advertising for construction.

WORK SCHEDULE

3. The work schedule for the preparation of plans and specifications and construction of the Talofofo Bay Shore Protection Project is shown in Figure 7. Construction would be accomplished by contract and would take approximately six months to complete.

STATEMENT OF FINDINGS

4. In light of the overall public interest, the District Engineer has reviewed the documents concerning the proposed plan of improvement, as well as the stated views of other interested agencies and the concerned public, relative to the various practical alternatives for protecting the shore at Talofofo Bay. This shore protection study was accomplished under the authority of Section 103a of the River and Harbor Act of 1962.

5. The possible consequences of alternative solutions were studied for environmental, social well-being, and economic effects, including regional and national economic development and engineering feasibility, in accordance with the guidelines of Section 122 of the River and Harbor and Flood Control Act of 1970. Other factors bearing on the review included the expressed desires that the shore protection improvements allow usage of the backshore area as part of a park, preserve surfing, and not seriously detract from the natural beauty of the bay.

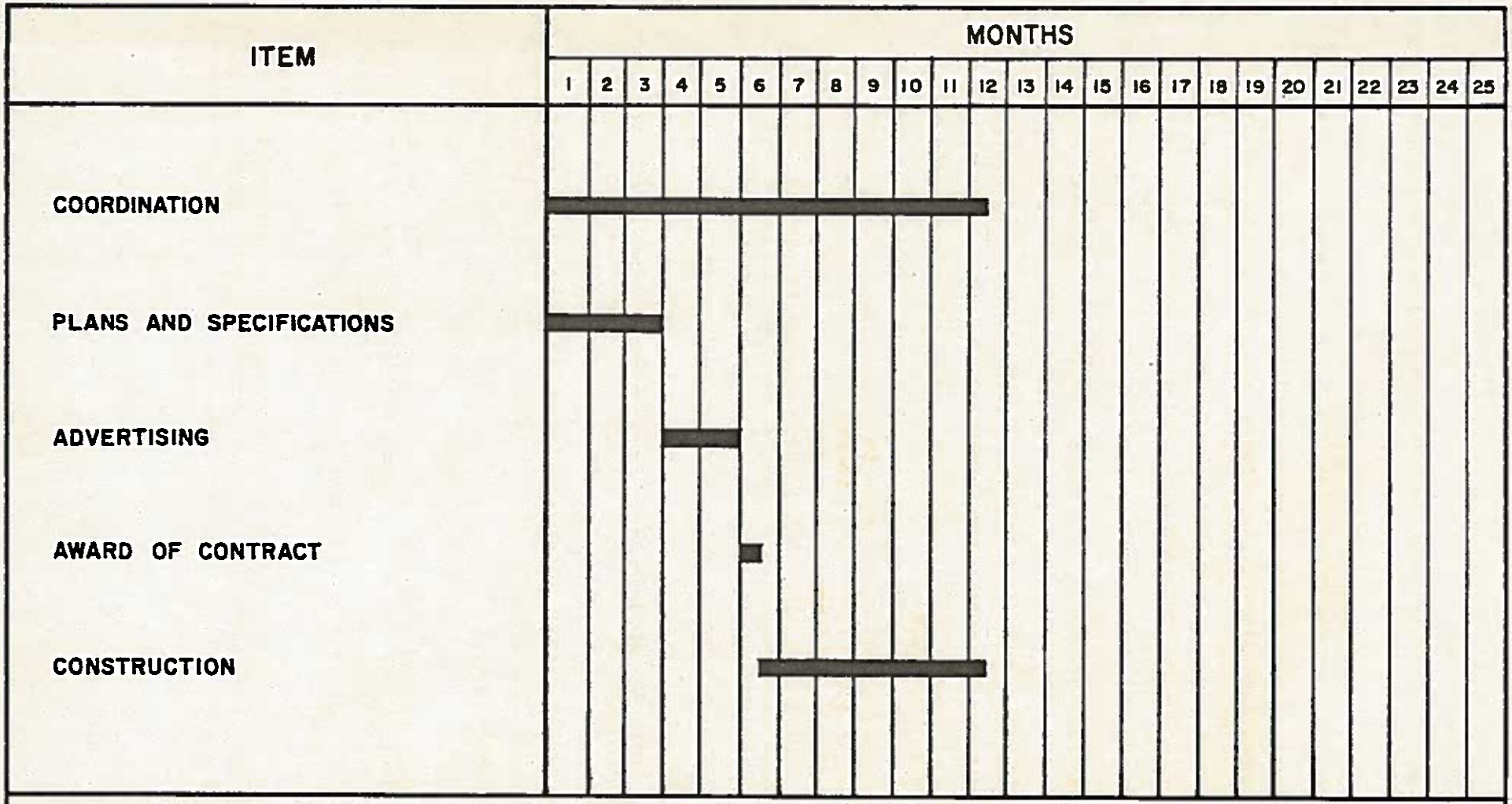
6. During the course of the study, on-site investigations were made independently and in cooperation with others, and discussions were held with Government of Guam officials and interested citizens. The possible consequences of alternative plans which included both structural and non-structural measures were studied and analyzed in the decision-making process. The alternatives considered are briefly described below:

a. No Action. This approach would not prevent further erosion of the shoreline. Consequently, Route 4, the primary highway circling the island of Guam, would continue to be vulnerable to undermining by storm waves. The erosion problem would also prevent development of the backshore area for park use.

b. Relocation of the Highway further inland. Although this alternative would prevent undermining of the highway, it would not deter shoreline erosion. Consequently, it would prevent development of the backshore area for park use.

c. Offshore breakwater and beach restoration. This alternative would satisfy the project objectives at the expense of eliminating surfing in the bay. Because Talofofo Bay is the better of the two most popular surfing sites on the island, elimination of surfing in the bay would be unacceptable to the people of Guam.

d. Shoreline revetment. This alternative would also satisfy the project objectives. Undesirable effects essentially consist of the visual impact of the revetment and the limitation imposed on the surfboard recovery area which, under existing conditions, expands when the shoreline erodes.



TALOFOFO BAY, GUAM

WORK SCHEDULE

FIGURE 7

7. The alternatives were coordinated with Government of Guam agencies, other Federal agencies, and interested citizens. Comments received through this coordination effort, during the 31 January 1973 public meeting, and in response to the draft environmental statement, were considered in the decision-making process. Because it is impossible to satisfy all human desires, a system of trade-offs was used to evaluate the comments. In so doing, the no action and highway relocation plans were eliminated because they do not satisfy the basic project objective of preventing erosion. Although the offshore breakwater plan satisfies the objective, it was eliminated in the interest of retaining surfing in the bay. The revetment plan is considered to reflect the best balancing of all factors pertinent to the physical problem and to the socio-economic environment of the study area and the territory of Guam. This plan has therefore been selected for implementation.

8. As a result of the comments received during the public meeting, the selected plan was revised to include three walkways with steps leading down the revetment slope for easier access to the beach. Some objections were raised at the public meeting by surfers who were concerned that the revetment might increase backwash and offshore currents at the southern end of the project. The District Engineer explained why the revetment should have little effect on offshore currents and backwash.

9. Most of the comments received on the draft environmental statement concerned the inclusion of additional information and more detailed substantiation and description of project features. There were no objections to the proposed plan of improvement.

10. The District Engineer believes that all necessary investigations commensurate with the scope of this detailed project study have been made, and sufficient data and information on the engineering, economic, and environmental aspects of the alternatives considered have been reviewed to facilitate making a sound decision. He therefore finds that the proposed action is based on thorough analysis and evaluation of various practical alternative courses of action for achieving the project objectives; that wherever adverse effects are found to be involved they cannot be avoided by following reasonable alternative courses of action which would achieve the specified purposes; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations of national policy; that the recommended action is consonant with national policy, statutes, and administrative directives; and that on balance the total public interest should best be served by implementation of the proposed plan.

CONCLUSIONS

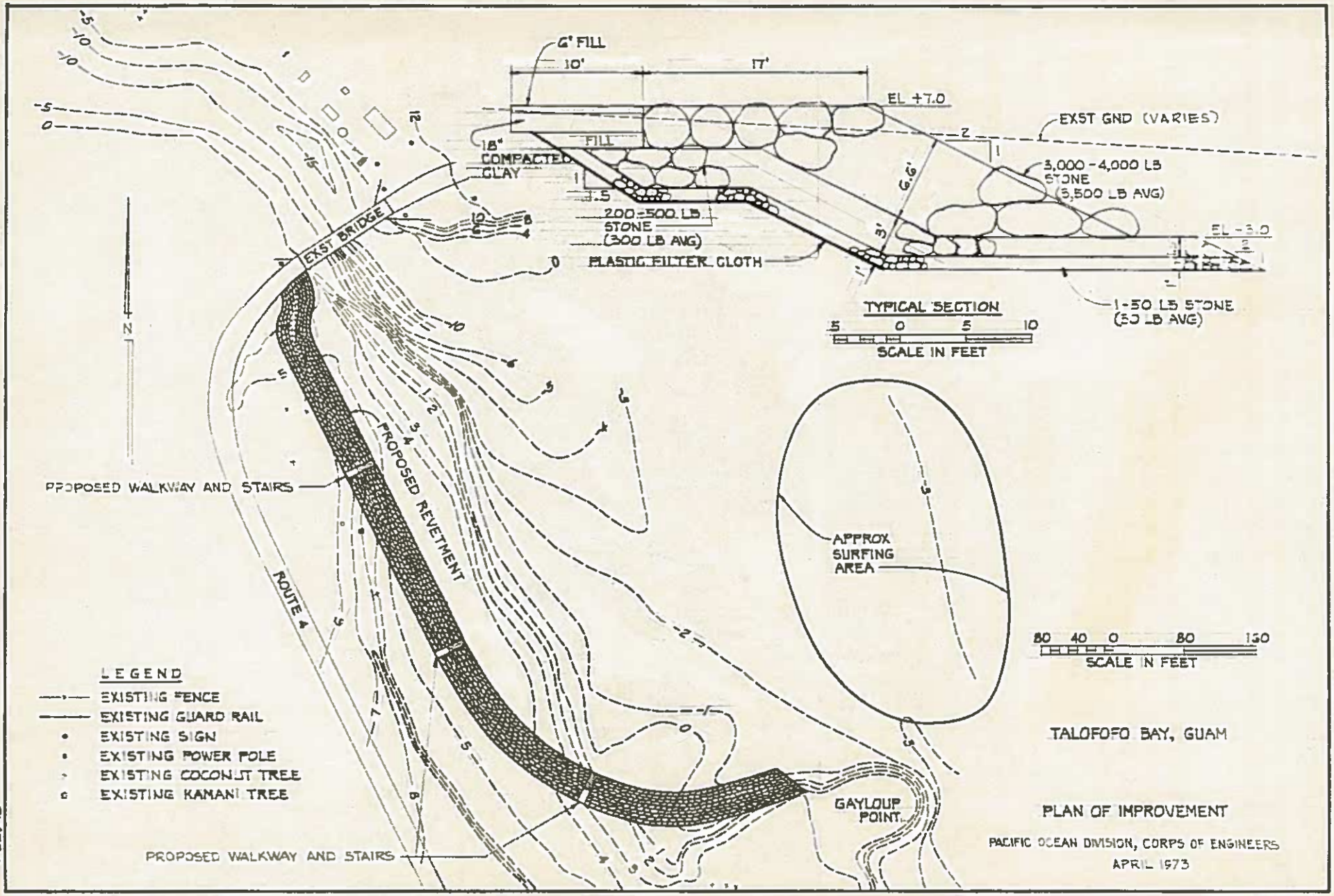
11. The proposed plan of improvement is economically justified. The plan was developed by evaluating alternative shore protection measures for

Talofofo Bay against formulation and evaluation criteria discussed previously and summarized in the Statement of Findings. The Government of Guam supports the project and has agreed to furnish the required local cooperation.

RECOMMENDATIONS

12. The District Engineer recommends that the proposed plan of improvement for Talofofo Bay be approved and constructed, provided that the Government of Guam furnishes the assurances satisfactory to the Secretary of the Army that they will comply with the local cooperation requirements outlined previously. The estimated first cost of the proposed project is $525,000, of which $288,250 would be Federal cost and $236,750 would be Non-Federal.

LEONARD EDELSTEIN
Colonel, Corps of Engineers
District Engineer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10'
17'
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1.5
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PLASTIC FILTER CLOTH
6.6'
3'
3,000 - 4,000 LB STONE (3,500 LB AVG)
EL -3.0
2
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1-50 LB STONE (50 LB AVG)
TYPICAL SECTION
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SCALE IN FEET
EXST BRIDGE
N
PROPOSED WALKWAY AND STAIRS
PROPOSED REVETMENT
ROUTE 4
APPROX SURFING AREA
80 40 0 80 160
SCALE IN FEET
LEGEND
EXISTING FENCE
EXISTING GUARD RAIL
EXISTING SIGN
EXISTING POWER POLE
EXISTING COCONUT TREE
EXISTING KAMANI TREE
PROPOSED WALKWAY AND STAIRS
GAYLOUP POINT
TALOFOFO BAY, GUAM
PLAN OF IMPROVEMENT
PACIFIC OCEAN DIVISION, CORPS OF ENGINEERS
APRIL 1973
PLATE 1

TERRITORY OF GUAM
OFFICE OF THE GOVERNOR
AGAÑA, GUAM 96910
U.S.A.

CARLOS G. CAMACHO
GOVERNOR

NOV 28 1973

Colonel Leonard Edelstein
Honolulu District, Corps of Engineers
Building 96, Fort Armstrong
Honolulu, Hawaii 96813

Dear Colonel Edelstein:

Please be assured that the Government of Guam intends to comply in full to the following specific conditions in regard to the proposed improvements at Talofofo Bay.

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project.

b. Hold and save the United States free from claims for damages due to the construction work and subsequent maintenance of the project.

c. Assure maintenance and repair during the useful life of the project as may be required to serve the intended purpose.

d. Provide a cash contribution presently estimated at $236,750, or 50 percent of the total construction costs of the project, the final amount to be determined at the time of project construction in accordance with cost-sharing procedures for shoreline erosion control defined in the report.

e. Assure continued public ownership of the shore upon which the amount of Federal participation is based, and its administration for public use during the economic life of the project.

f. Assure that water pollution that would endanger the health of bathers will not be permitted.

g. Provide and maintain necessary access roads, parking areas, and other public use facilities open and available to all on equal terms.

I understand that this is only a preliminary agreement and that construction can begin only when the final cooperation agreement is signed and funds are available from both parties.

Please keep me informed of any further action on this project.

Sincerely yours,

Carlos G. Camacho

EXHIBIT A

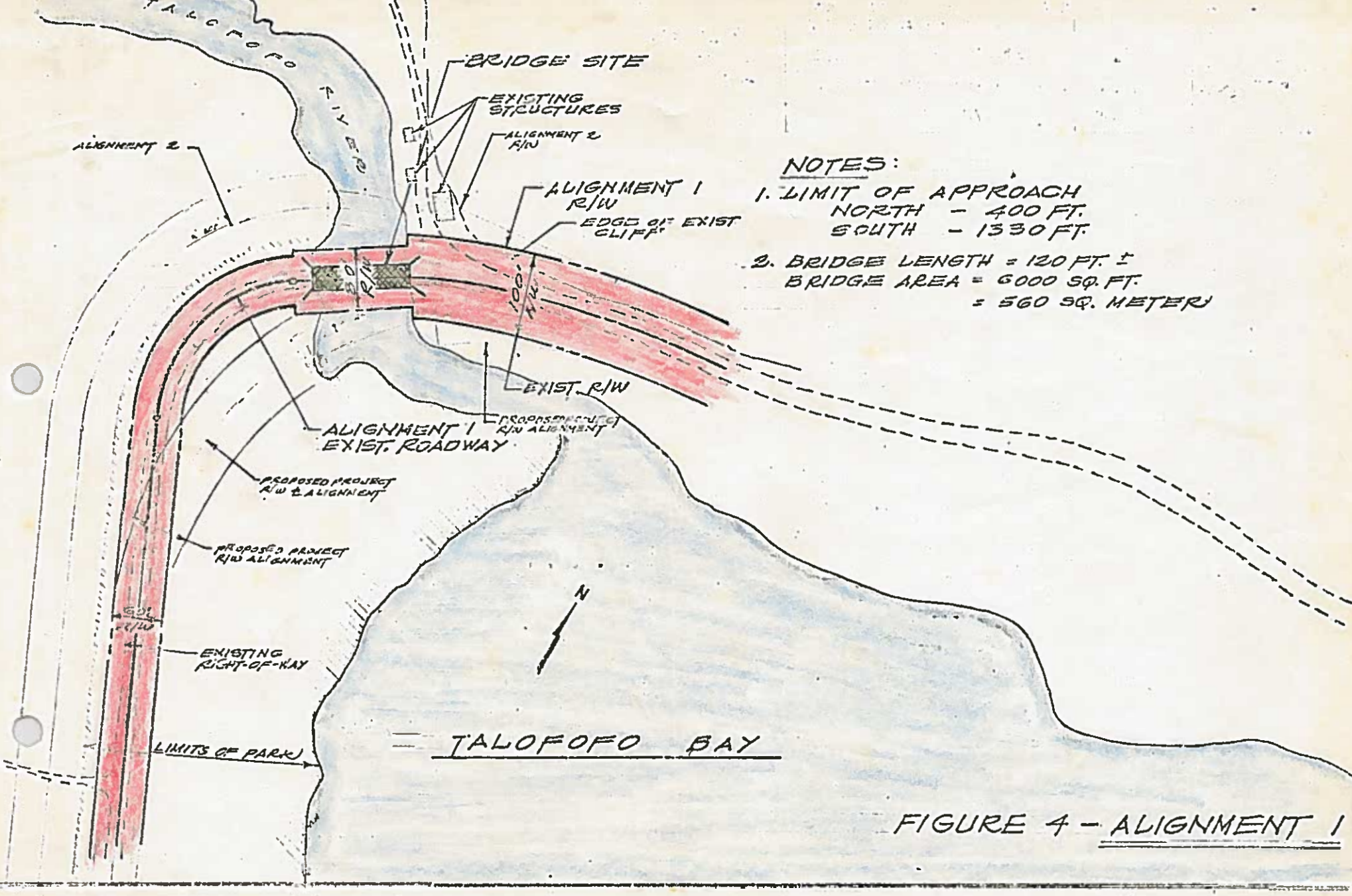

FIGURE 4 - ALIGNMENT 1

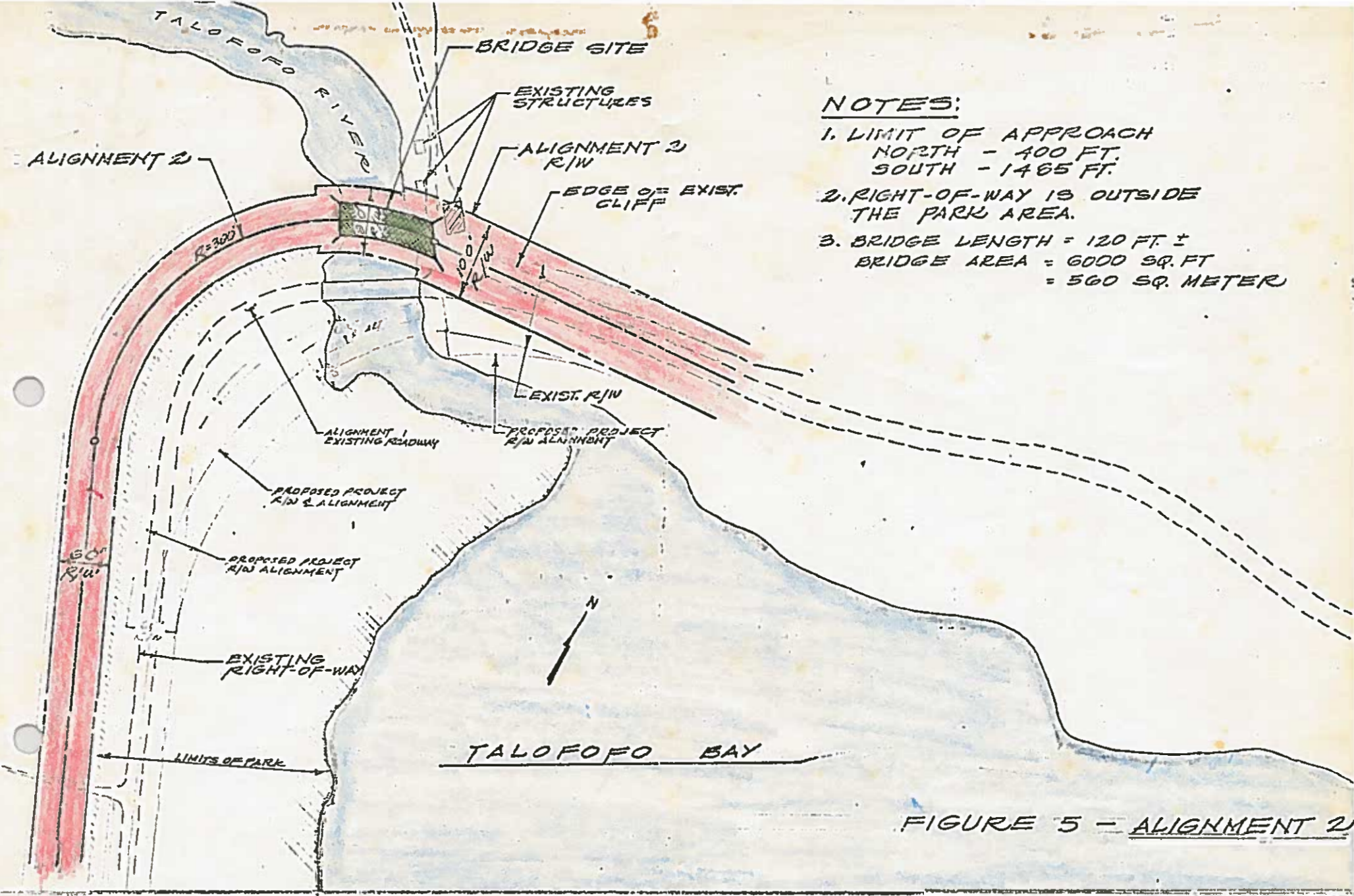

FIGURE 5 – ALIGNMENT 2