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GUAM COMPREHENSIVE STUDY FOR WATER AND RELATED LAND RESOURCES

Agana Bay Typhoon and Storm-Surge Protection Study

TECHNICAL DOCUMENTATION

US Army Corps of Engineers
Honolulu District

January 1984

RIVERS AND HARBORS OF GUAM

COMPREHENSIVE STUDY

DRAFT

AGANA BAY TYPHOON AND STORM-SURGE

PROTECTION STUDY, GUAM

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SYNPOSIS

The purpose of this preliminary draft Survey study is to identify the water resource and related problems and needs of the Agana Bay, Guam waterfront and to develop various measures to reduce flood damage caused by storm-surge inundation in low-lying areas from Anigua to Dungca's Beach. Storm-surge flooding may be caused by local (usually typhoon-strength) storms or distant storms-probability analyses of local typhoon-generated storm surge and empirically-derived wave runup analysis found that a 50-year (2 percent) surge event could flood to an elevation of +11.4 feet (mean sea level) and a 100-year (1 percent) surge event to an elevation of +12.3 feet. This could flood large areas of coastal floodplain to depths ranging from about 2 to 4 feet. Two preliminary plans were formulated. Floodproofing was a major component of both alternatives 1A and 1B. Plan 1B also recommends a 6,750 foot-long low levee be constructed paralell to Marine Drive. Both alternatives appear economically feasible, but are dependent on other planned flood control and interior drainage projects for effectiveness in reducing flood damages. Neither alternative would have unmitigatible short-term, adverse environmental impacts, but in the long-term future, floodproofing would relocate present structures out of the waterfront zone. The adverse social impacts of relocation may be offset by improved shoreline recreational opportunities and accessibility for the general public.

A. INTRODUCTION

1. PURPOSE.

The purpose of this study is to identify the problems, needs, and various measures available to reduce flood damage caused by storm surge in low-lying coastal areas in Agana Bay. This report documents the results of the preliminary planning for use by the Government of Guam, and if feasible, further detailed studies by the Federal Government.

2. STUDY AUTHORITY.

This analysis has been undertaken under the general authority of Section 106 of the River and Harbor Act of 1970 (Public Law 91-611). This section authorizes the Secretary of the Army, through the Chief of Engineers to study navigation, flood control and related water resources purposes in the Territory of Guam. This technical documentation is part of the Rivers and Harbors of Guam Comprehensive Study. Under this Study, the Secretary of the Army may recommend to Congress solutions to the problems and the extent the Federal Government should participate in solving the problems, including implementing possible storm-surge flood protection measures.

3. SCOPE OF STUDY.

a. This particular study was initiated in response to requests from the Governor of Guam and Guam Bureau of Planning for support to the Government of Guam's Agana Bay Urban Waterfront Redevelopment (ABUWR) Plan, prepared in 1981. The Governor requested the U. S. Army Corps of Engineers conduct a comprehensive flood control study of the urban waterfront to provide more detailed mapping of existing flood hazard zones and specific plans, primarily nonstructural, for mitigation of damage due to storm surge, storm waves, and erosion (see letter, Appendix A). The Guam Bureau of Planning separately requested an assessment of the impacts of seawalls and revetments on public access, shoreline ecology, and aesthetics (see Appendix A).

b. The present study area encompasses the entire 3.5-mile Agana Bay shoreline. An earlier technical study under the Guam Comprehensive Study by Sea Engineering, Inc. (September 1981) tentatively identified a probable maximum flood level from typhoon and storm-surge of about +10 feet (mean lower low water (MLLW) datum)). This indicated that any thorough analysis of coastal storm-surge flooding would have to include all portions of the Agana Bay coastal floodplain.

c. Other Corps planning studies that address flooding, erosion and related water resources issues in Guam, and particularly, the Agana region are listed as follows:

Riverine Flooding and Interior Drainage:

U. S. Army Engineer District Honolulu. Interim Report Harbors and Rivers in the Territory of Guam. Agana River, Guam, August 1975.

U. S. Army Corps of Engineers, Honolulu District. "Flooding and Drainage on Guam: A Handbook of Basic Information." A Technical Report from the Comprehensive Study of Guam's Water and Related Land Resources. Prepared by Juan C. Tenorio & Associates, Inc., September 1980.

U. S. Army Corps of Engineers, Pacific Ocean Division. "Alternative Solutions for Flood Prone Areas in Guam." Guam Comprehensive Study. Prepared by R. M. Towill Corporation, November 1982 (Draft).

U. S. Army Corps of Engineers, Honolulu District. Tamuning Flood Control Studies (ongoing in 1983).

Coastal Flood Hazards and Erosion:

U. S. Army Engineer District, Honolulu. "Guam Comprehensive Study Shoreline Inventory." Prepared by Sea Engineering Services, Inc./R. M. Towill Corporation--A Joint Venture, September 1980.

U. S. Army Engineer District, Honolulu. "Shoreline Investigations: Agana, Guam." Prepared by Sea Engineering, Inc., September 1982.

U. S. Army Corps of Engineers, Honolulu District. "Paseo de Susana Shore Protection, Agana, Guam, Final Detailed Project Report and Environmental Assessment," October 1983.

d. None of the findings or environmental resources documented in the Paseo de Susana shore protection study will be reported in this report.

4. STUDY COORDINATION.

The work accomplished during the conduct of this study included a detailed review of existing, available documents pertinent to the study purposes and coordination with local Guam government agencies. A field trip was conducted 7-14 March 1983. Contact was made with the Bureau of Planning (Guam Coastal Management Program), Guam Housing and Urban Redevelopment Authority, Guam Visitors Bureau, Guam Environmental Protection Agency (GEPA), Department of Parks and Recreation (Parks and Planning), Department of Agriculture (Aquatic and Wildlife Resources Division), Department of Public Works (Engineering Division), and the Civil Defense Office. The library collections at the Nieve Flores Library (Guam Room), University of Guam (Micronesian Area Research Center), and University of Hawaii Library (Pacific Collection) were searched for applicable materials. Discussions with various private individuals in Guam were also made to collect information.

B. PROBLEM IDENTIFICATION

1. PURPOSE.

a. The purpose of problem identification is to define the study area and the objectives and problems to be addressed in the study. This includes describing the base conditions, identifying public concerns, establishing planning criteria and analyzing the problems. Public concerns which relate to water and related land resource problems are identified and then refined based on national and local policies and the study authority.

b. National planning objectives are provided by the Water Resources Council's Principles and Guidelines (P&G) of 1983, the National Environmental Policy Act of 1969 (PL 91-190), Section 122 of the River and Harbor and Flood Control Act of 1970 (PL 91-611), the Water Resources Development Act of 1974

(PL 93-251), the Clean Water Act of 1977 (PL 95-217), and the Corps of Engineers Policy Guidelines (Engineer Regulations). The Principles were approved by the President on February 3, 1983. The Guidelines were approved by the Secretary of the Interior, acting in his capacity of Chairman of the U. S. Water Resources Council, on March 10, 1983. The new P&G replaced the Water Resources Council's previous Principles and Standards (P&S). These P&G provide a broad policy framework for managing the nation's water and related land resources, including the conceptual basis for planning activities. The guidelines outline how the framework may be implemented by detailing uniform methods of measuring the economic and environmental beneficial or adverse effects of alternative plans. One of the most significant changes to the old P&S is the move from a two objective (NED and EQ) to a single objective (NED) system. NED is National Economic Development and EQ is Environmental Quality. Although the EQ would no longer be within the specific context of water resources planning, the P&G will not deviate from environmental planning sensitivity.

To help determine the resource management 1/ problems, the base condition of the study area is first defined. The base condition includes the existing economic, social, and environmental characteristics of the area. Future conditions are then projected and analyzed to determine the "most probable future" 2/ which would prevail over the area without any changes to existing resource management plans. This analysis describes the "without condition" criterion. Planning objectives 3/ are then formulated based on the problems and needs of the area related to the "without condition" criterion.

2. NATIONAL OBJECTIVES.

a. The P&G for Planning Water and Related Land Resources seeks promotion of one specific objective: national economic development. The national objectives provide the basis for formulation and analysis of alternative plans. The NED objective is achieved by increasing the value of the nation's output of goods and services and improving national economic efficiency.

b. Although the EQ objective has been deleted from the planning framework, this proposal will not affect the principles of maximizing the enhancement or preservation of environmental resources in developing any plan in this study. P&G also suggests that the other impacts of a proposed action

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1/ "Resource management" involves the development, conservation, enhancement, preservation, or maintenance of water and related land resources to achieve the goals of society expressed nationally and locally.

2/ "Most probable future" is the projection of basic demographic, economic, social, and environmental factors, which is used as the basis for defining the "without condition" and the planning objectives for a particular study.

3/ "Planning objectives" are the national, state, and local water and related land resource management needs (opportunities and problems) specific to a given study area that can be addressed to enhance National Economic Development or Environmental Quality.

may be measured in terms of Regional Economic Development (RED) and Other Social Effects (OSE). Contributions to the RED account are determined by establishing a proposal's effects on a region's income, employment, population, economic base, environment, and social development. Contributions to the OSE account are determined by establishing a proposal's effects on security of life, health and safety, urban and community impacts, emergency preparedness, displacement, long term productivity and energy.

3. WATER USES AND DEVELOPMENT.

Because water is a precious resource, it is important that it be utilized to the fullest extent possible. Although the primary purpose of this study is to investigate flood damage reduction or flood control measures, the other uses of water have also been considered. Sometimes, however, some of the different uses of water are not compatible with other uses, and compromises between uses may be necessary and must be identified based on needs and economic efficiency. Other primary uses or concerns for water that were considered include:

a. Shore Protection.

b. Navigation.

c. Water Contact Recreation.

d. Water Quality.

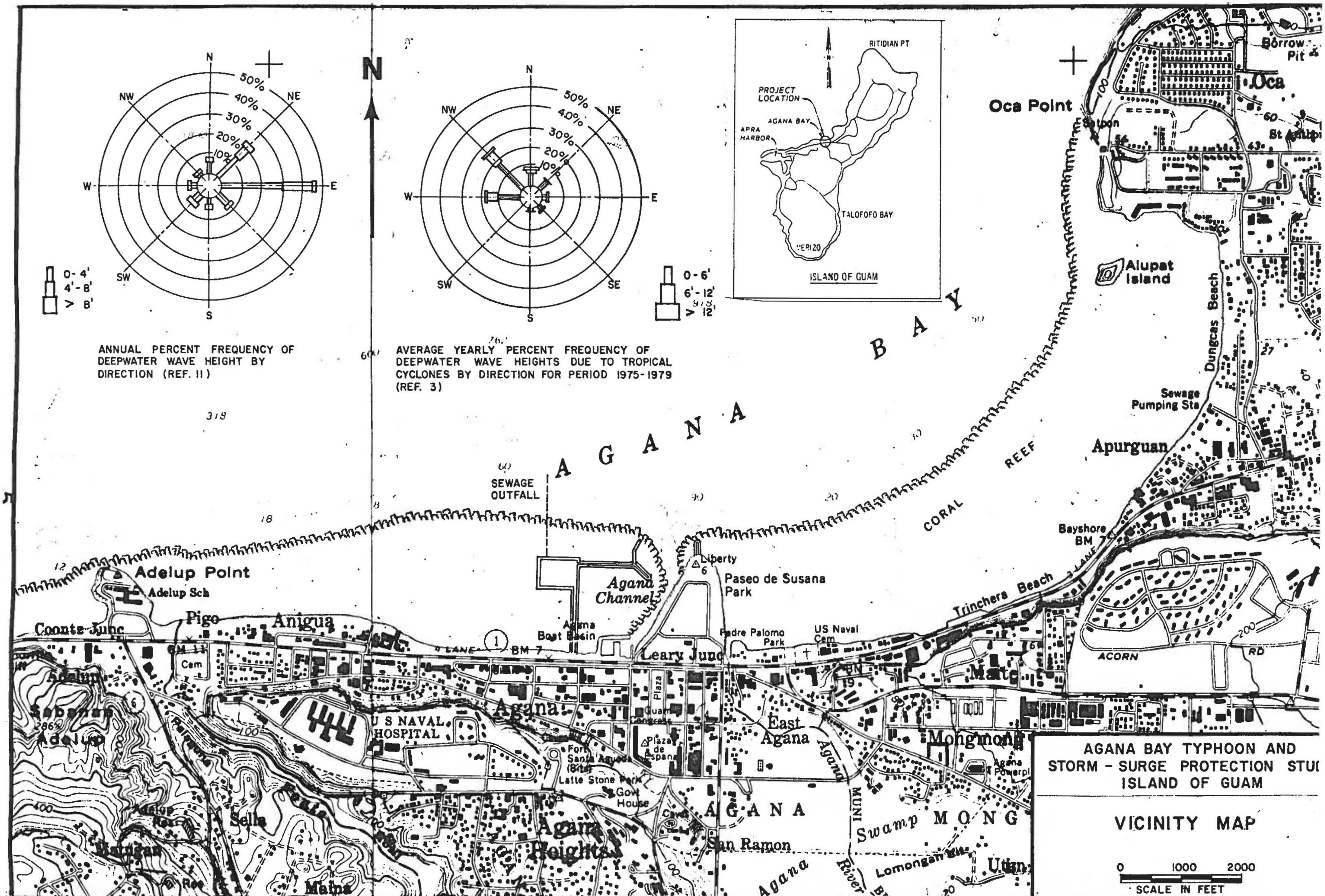
e. Fish and Wildlife Enhancement, and

f. Land Use.

4. STUDY AREA.

a. Guam is located at the southern end of the Mariana Islands at 13 degrees north latitude, 145 degrees east longitude. The island is about 31 miles long in a north to south direction and is 5 miles wide at Agana. Agana, centrally located on the west coast of the island of Guam, has been the government and commercial trade center since the beginning of Spanish occupation, over 450 years ago. The Agana Bay shoreline stretches about 3.5 miles from Adelup Point in the west to Dungca's Beach and Alupat Island in the northeast. A strip of randomly placed residential, commercial and public uses run from the community of Anigua eastward through downtown Agana and East Agana to Trinchera Beach where mostly residential uses predominate along Dungca's Beach in the old Apurguan or Tamuning areas (Figure 1). The peninsula of Paseo de Susana public park, located in the middle of the study area, was constructed in the 1940's and 1950's from the city's pre-World War II rubble. The shoreline of East Agana also consists of wartime rubble. Marine Drive (Route 2) paralleling this coastline, is the island's main traffic artery, and is itself raised up on World War II rubble. The low-lying shoreline area is bounded to the east by a 90-foot high cliff inland of Anigua and East Agana/Trinchera Beach and the Agana Marsh inland of downtown Agana.

b. Agana Bay shoreline is bordered by a wide, fringing reef flat. The reef width varies from 2,700 to 1,200 feet (810 to 360 meters), increasing slightly from north to south. A well-developed inner reef flat depression or moat impounds 1-3 feet of water during low tide MLLW at a time when the outer



AGANA BAY TYPHOON AND STORM - SURGE PROTECTION STUDY
ISLAND OF GUAM

VICINITY MAP

0 1000 2000
SCALE IN FEET

U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE 1

reef pavement is usually exposed. Two natural, shallow channels are cut through the outer reef flat offshore from Fonte River along Adelup Point and offshore from the mouth of Tamuning Stream, just west of Alupat Island. The principal natural passage through the fringing reef is via the modified channel offshore from the historical mouth of Agana River, on the west side of Paseo de Susana. This Agana channel provides passage for boats moored in Agana Marina.

5. PROFILE OF EXISTING BASE CONDITIONS.

a. Natural Forces.

(1) Climate. The warm and humid prevailing tropical conditions in Guam are due to the year-around ocean temperature of about 81 degrees (F). The mean annual air temperature is also 81 degrees. A dry season extends from January through May and a wet season from July through November. December and June are transitional months. Mean annual rainfall varies from less than 90 inches on the coastal plains to over 110 inches in the mountains.

(2) Winds. Easterly trade winds predominate throughout the year and are most pronounced in the dry season. Typical trade wind speeds fall in the 7- to 10-knot range, exceeding 17 knots only 3.6 percent of the time. Wind directions are variable with frequent calms during the main typhoon season from July to December. Agana Bay is on the west, or leeward side of the island; however, the coast faces north and is exposed to the prevailing trade winds.

(3) Typhoons. Typhoons are defined as tropical cyclonic storms with winds exceeding 65 knots (75 mph). The frequency of typhoons affecting Guam has decreased from an average of one per year between 1900 and 1946 to one every two years, between 1946 and 1976. Any typhoon passing within 75 miles north or south of Guam will directly affect the Agana Bay area. The most devastating typhoon to hit Guam in recent times was Typhoon Pamela in May 1976 which had sustained winds over Guam of 120 knots (140 mph). A study of 74 tropical storms (or cyclones) including typhoons between 1948-1975 indicates that most (54 percent) storms move toward Guam from the southeast to east quadrants (Holiday, 1975). Another 15 percent come from the southeast or south quadrants (Figure 2). High wind velocities and torrential rains from typhoons affect the island fairly uniformly, but the low-lying coastal plains may also be subject to flooding and erosion due to typhoon surge and storm surge. Generally, the most severe storm wave caused coastal inundation is generated out of the right-hand side of the storm center in the northern hemisphere. Thus, the most severe and most frequent typhoon-surge flooding occurs on the southern to eastern shores of Guam. Distant typhoon or tropical storms also affect Guam, but normally only by generating high surf or storm-surge damage. These effects are generally experienced evenly throughout the island's shorelines.

(4) Tides. Tides at Guam are semi-diurnal with a mean range of 1.6 feet and a diurnal range of 2.3 feet. Datum for the island is MLLW. Table 1 summarizes tidal data for the 19-year period between 1949 and 1967 recorded in Apra Harbor by the National Ocean Survey, National Oceanic and Atmospheric Administration.

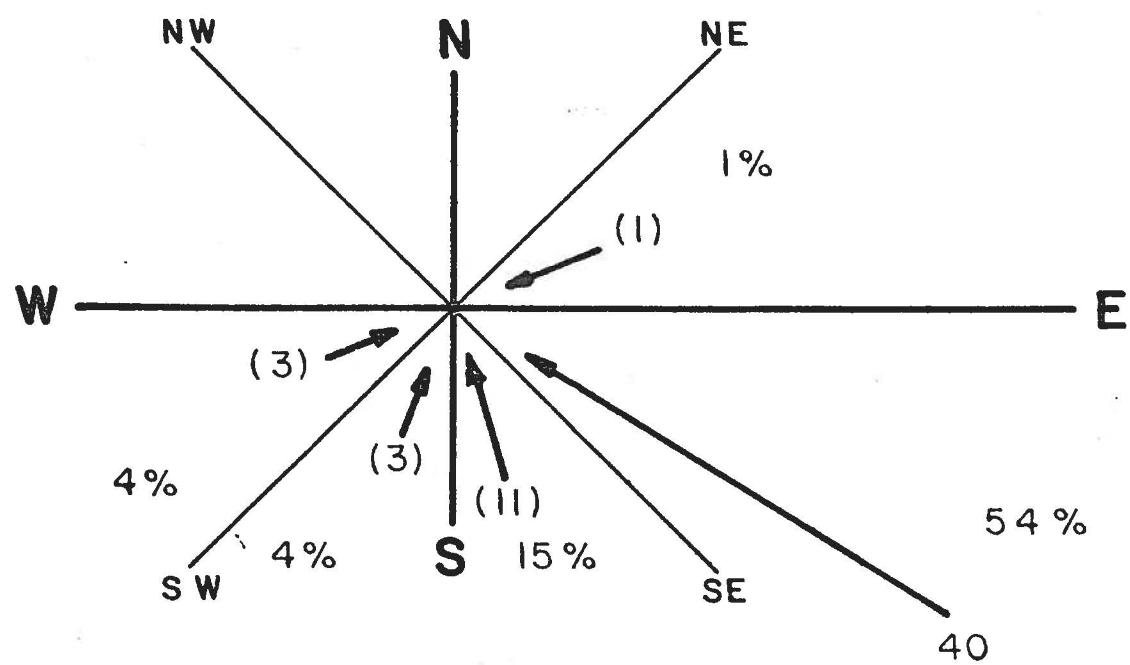


Fig. 2 - Direction of Approach of Tropical Cyclones ($\geq$ 34 kt or 39 mph) (length of each line represents number of occasions on which cyclones approached from each octant of the compass 1948-1975)

Source: Tropical Cyclones Affecting Guam, C.R. Holliday, 1975 Pg. 13

TABLE 1. GUAM TIDAL DATA

	Feet from Datum
Highest Tide (observed)	3.31
Mean Higher High Water, MHHW	2.40
Mean Sea Level, MSL	1.41
Mean Lower Low Water, MLLW	0.00
Lowest Tide (observed)	-1.89

(5) Tsunami. There has been no recorded tsunami damage in western Guam. Tsunamis are not considered a potential problem at Guam.

(6) Waves. The prevailing wave climate in the study area can be divided into two distinct wave types: (a) waves generated by the prevailing local winds; and (b) sea and swell from local and distant tropical storms and typhoons. Table 2 summarizes these data as applicable to Agana Bay, based on the "Summary of Synoptic Meteorological Observations" (SSMO), prepared by the U. S. Naval Weather Service Command. Hindcasts performed by Noda (1980) for tropical storms and typhoons in the Western Pacific (1975-1979) indicate that large, long period waves may approach from the west to north quadrants (these affect Agana Bay) more frequently than indicated by the SSMO data (see Appendix B). This information is summarized on Figure 1.

TABLE 2. ANNUAL PERCENT OF OCCURRENCE OF WAVE HEIGHTS 1/ VERSUS DIRECTION

Wave Height	Wave Direction (From Which Waves Approach)										
	S		SW		W		NW		N		
(Ft)	Sea 2/	Swell 3/	Sea	Swell	Sea	Swell	Sea	Swell	Sea	Swell	Total
0-2	2.0	0.1	1.8	0.3	1.9	6.5	1.2	9.4	2.9	2.7	28.8
2-4	1.5	0	2.1	0	0.9	3.1	0.5	4.1	2.1	1.5	15.8
4-6	0.8	0	0.8	0	0.5	2.2	0.3	3.3	1.5	2.1	11.5
6-8	0.7	0	0.9	0	0.5	1.7	0.1	2.3	0.9	1.1	8.2
8-10	0.1	0	0	0	0	1.5	0	1.7	0.1	0.8	4.2
10-12	0	0	0.1	0	0.2	1.8	0	1.7	0.1	0.4	4.3
12-14	0.1	0	0.1	0	0.1	0.4	0	0.7	0.1	0.5	2.0
14-16	0	0	0	0	0	0.9	0	0	0	0	0.9
16	0	0.5	0	0	0	0.3	0	0.3	0	0	1.1
TOTAL	5.2	0.6	5.8	0.3	4.1	18.4	2.1	23.5	7.7	9.1	
	5.8		6.1		22.5		25.6		16.8		76.8

1/ The sea and swell are assumed to be mutually exclusive. This is conserva tive, as there will be some joint occurrence.
2/ Data Source: Summary of Synoptic Meteorological Observations (SSMO), Hawaii and selected North Pacific island coastal marine areas, Volume 5, Area 15, prepared by the National Climatic Center.
3/ Data Source: Hindcasts of tropical storms and typhoons in the Western North Pacific, 1975-1979, based on data obtained from Annual Typhoon Reports published by U. S. Fleet Weather Central.

b. Environmental Conditions.

(1) Terrestrial Environment.

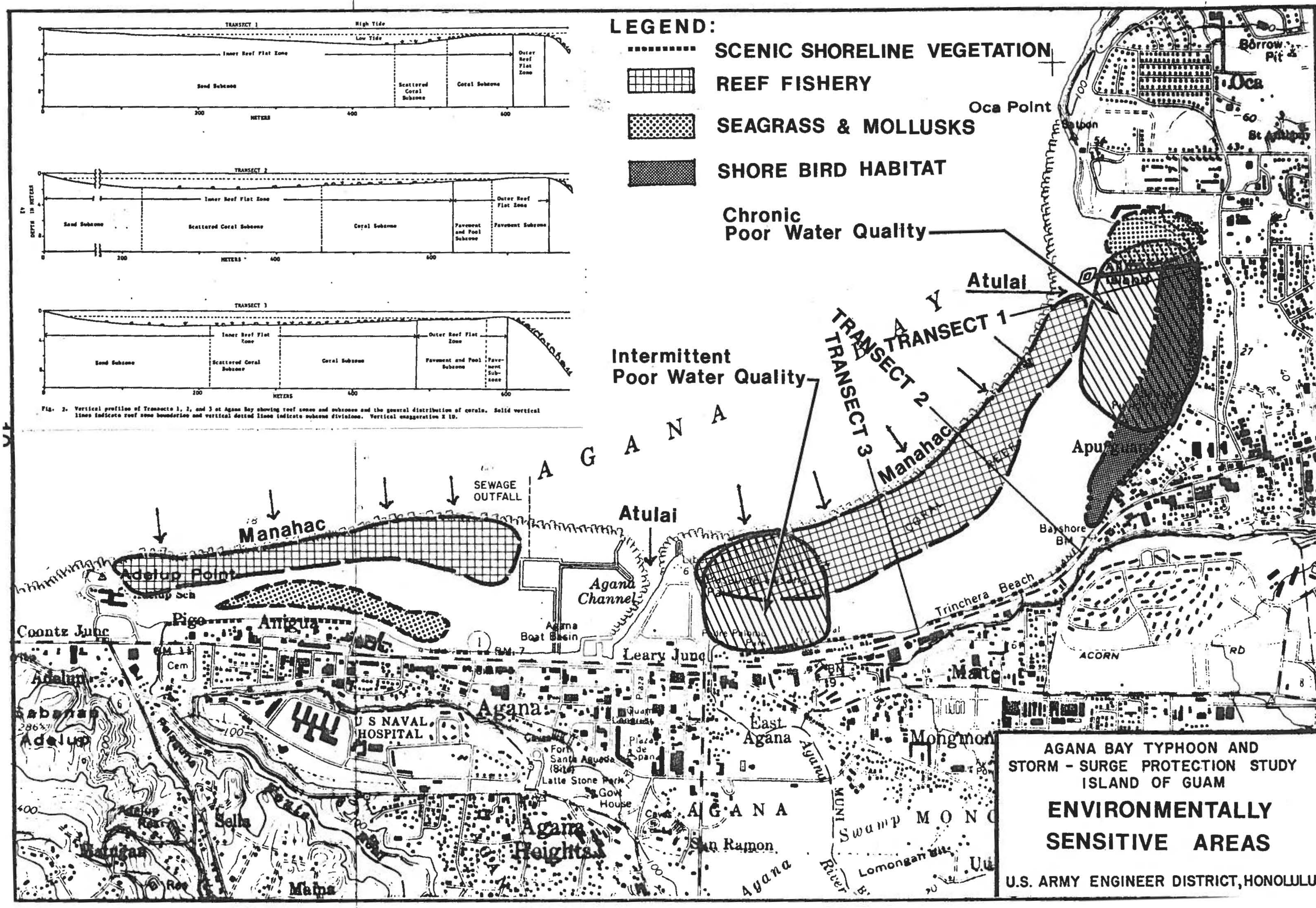
(a) Uncontrolled development of the Agana Bay waterfront and coastal floodplain has resulted in the disappearance of much of the natural vegetation and probably much of the coastal native bird population. About 45 percent of the shoreline of Agana Bay remains in the traditional dominants of the coconut palm (Cocos nucifera) and beach morning glory (Ipomoea pes-caprae). Ironwood trees (Casuarina equisetifolia) are also common, particularly at the Paseo de Susana. A wide range of native, endemic, indigenous and exotic plant species are also found planted alongside public roads and in residential gardens.

(b) Shorebird populations were likely more abundant in the past. Today, those species with large summer populations include the Gray-tailed tattler (Heteroscelus brevipes), Wandering Tattler (H. incanus), and Whimbrel (Numenius phaeopus). Shorebirds tend to congregate in the Dungca's Beach region, which is also the only area where censuses are carried out by Government of Guam wildlife biologists. That portion of the shoreline is relatively less accessible and contains suitable feeding habitat on and adjacent to storm-drain deltas. Lists of typical Agana Bay beach strand vegetation and regular migrant shorebirds are in Appendix C. Figure 3 depicts environmentally sensitive areas.

(2) Water Quality.

(a) Intermittent poor water quality in East Agana Bay is a reoccurring problem plaguing the Agana Bay waterfront. Guam Water Quality Standards designate the waters of Agana Bay as M-2, which calls for preserving a balanced, indigenous population of marine organisms, especially shellfish and corals, along with other intended uses including water-contact sports, aesthetic enjoyment and mariculture. Guam EPA records indicate moderate to heavy fecal coliform pollution continually reoccurs throughout the bay waters, but particularly off Dungca's Beach (Figure 3). These data are tabulated in Appendix C.

(b) These levels of water pollution in the bay can be mainly attributed to about 30 storm drain outfalls (GEPA, 1979 and Chan, 1977) which discharge large amounts of solids and nitrate-nitrogen and usually exhibit coliform bacteria counts exceeding water quality standards (Zolan and others, 1978). Waters off Dungca's Beach are particularly affected by storm drains that discharge runoff from the Tamuning industrial-commercial area. At low tide, obnoxious odors are produced from anaerobic conditions and algal growth on storm-drain deltas, the largest of which occur off the NAS drain along Trinchera Beach and the Tamuning drain along Dungca's Beach. Shoreline algal growth appears to be a natural phenomena caused by greatly elevated nutrient concentrations in groundwater seepage (Zolan, 1982). The reoccurring poor water quality off Dungca's Beach may also be due to a remnant causeway leading to Alupat Island which reportedly restricts the natural circulation in the northeastern-most end of the bay. Currents in East Agana Bay run easterly along the inner reef-flat moat. Currents in West Agana Bay also tend to run easterly, but are adequately flushed out through Agana Channel. Flushing is less effective in East Agana Bay.



TRANSECT 1
High Tide
Low Tide
Inner Reef Flat Zone
Outer Reef Flat Zone
Sand Subzone
Scattered Coral Subzone
Coral Subzone
METERS
TRANSECT 2
Inner Reef Flat Zone
Outer Reef Flat Zone
Sand Subzone
Scattered Coral Subzone
Coral Subzone
Pavement and Pool Subzone
Pavement Subzone
DEPTH IN METERS
TRANSECT 3
Inner Reef Flat Zone
Outer Reef Flat Zone
Sand Subzone
Scattered Coral Subzone
Coral Subzone
Pavement and Pool Subzone
Pavement Subzone
Fig. 2. Vertical profiles of Transects 1, 2, and 3 at Agana Bay showing reef zones and subzones and the general distribution of corals. Solid vertical lines indicate reef zone boundaries and vertical dotted lines indicate subzone divisions. Vertical exaggeration X 10.
LEGEND:
SCENIC SHORELINE VEGETATION
REEF FISHERY
SEAGRASS & MOLLUSKS
SHORE BIRD HABITAT
Chronic Poor Water Quality
Intermittent Poor Water Quality
Oca Point
Oca
Borrow Pit
Atulai
TRANSECT 1
TRANSECT 2
TRANSECT 3
Manahac
Apurguan
Bayshore BM
Trinchera Beach
SEWAGE OUTFALL
AGANA BAY
Manahac
Atulai
Adelup Point
Pigo
Anigua
Agana Channel
Agana Boat Basin
Coontz Junc
Leary Junc
U S NAVAL HOSPITAL
Agana
East Agana
Mongmong
Fort Santa Agueda (Site)
Latte Stone Park
Agana Heights
San Ramon
Sella
Agana River
Lomongan
ACORN
AGANA BAY TYPHOON AND STORM - SURGE PROTECTION STUDY ISLAND OF GUAM
ENVIRONMENTALLY SENSITIVE AREAS
U.S. ARMY ENGINEER DISTRICT, HONOLULU

(3) Marine Environment.

(a) The fringing reef is a gift of nature that provides a natural barrier to storm-wave attack and shoreline erosion. It is also very important resources for subsistence and recreational fishing, swimming and wading, boating and aesthetic enjoyment. Agana Bay has been extensively studied in previous Corps-sponsored research studies (Randall and Holloman, 1974 and Randall, 1976). Other studies include Randall and Eldredge (1976), Tracey et al. (1964), and Randall (1978). Live coral coverage on the reef flat grades from virtual absence on the sandy bottomed inner reef-flat moat to patchy distribution of predominantly staghorn *Acropora* clusters in a coral rubble zone about 225 meters offshore (450 meters near Alupat Island). There is relatively high diversity and abundance of the arborescent *Acropora aspera* and microatoll shaped *Porites lutea* colonies in the outer portion of the inner reef flat. These reef flat zones are depicted on Figure 3. Periodic tidal exposure of the outer reef flat precludes extensive coral coverage.

(b) The distribution of marine plants (algae and seagrasses) appear to play a significant role in determining where people focus their fishing and clamming activities. Seagrasses are found abundantly northeast of Alupat Island and immediately offshore Anigua (Figure 3). Groundwater seepage at those locations may be stimulating their growth. The green filamentous algae *Enteromorpha clathrata*, which is a primary food source of the juvenile rabbitfish (manahac) is also stimulated by elevated nutrient levels near storm-drain deltas (Tsuda and others in Randall, 1978). Bivalve mollusks mostly occur in seagrass beds. Studies by Stojkovich and Smith (1978) found six species in Alupang Cove (northeast of Alupang Island) dominated by *Quidnpagus palatum*. Numerous dead specimens of *Ctena divergens*, *Asaphis violascens* (sand clam) and *Gafrarium pectinatum* were observed on Trinchera Beach in March 1983.

(c) The most prevalent macroinvertebrate on the reef flat are the sea cucumbers (Holothurians). Sea cucumbers are very abundant throughout the reef flat, particularly in the scattered coral and coral subzones of the inner reef flat (Birkeland and Randall, 1978). Sea cucumbers are viewed as a nuisance by swimmer and waders who dislike stepping on the immobile creatures. However, they are not hazardous to swimmers and sea cucumbers perform important ecologial functions in sandy environments by keeping organic and detrital levels low, and serving as food for other organisms.

(d) The greatest species diversity and highest densities of fishes occur seaward of the scattered coral subzone of the inner reef flat. Euryhaline species are also found near groundwater seeps and storm drains. The most significant fishery resource of the Agana Bay reef flat is the springtime appearance of the juvenile rabbitfish (manahac hatang or *Siganus spinus* and manahac leso or *S. argenteus* which appear in high density schools or "balls" all across the outer reef margin and pavement subzone (Kami and Ikehara, 1976). Net fishing of the small rabbitfish is one of Guam's important cultural events of the year when one can observe groups of village fishermen concentrated on the outer reef flat and around the various green algae blooms at the NAS and Tamuning storm drains.

c. Historic and Recreational Resources.

(1) Historic Sites. The coastal plain around Agana Bay was probably settled from the earliest period of Guam occupation (c. 1500 B.C.). Most houses in the pre-war period of Agana were raised on posts with floor

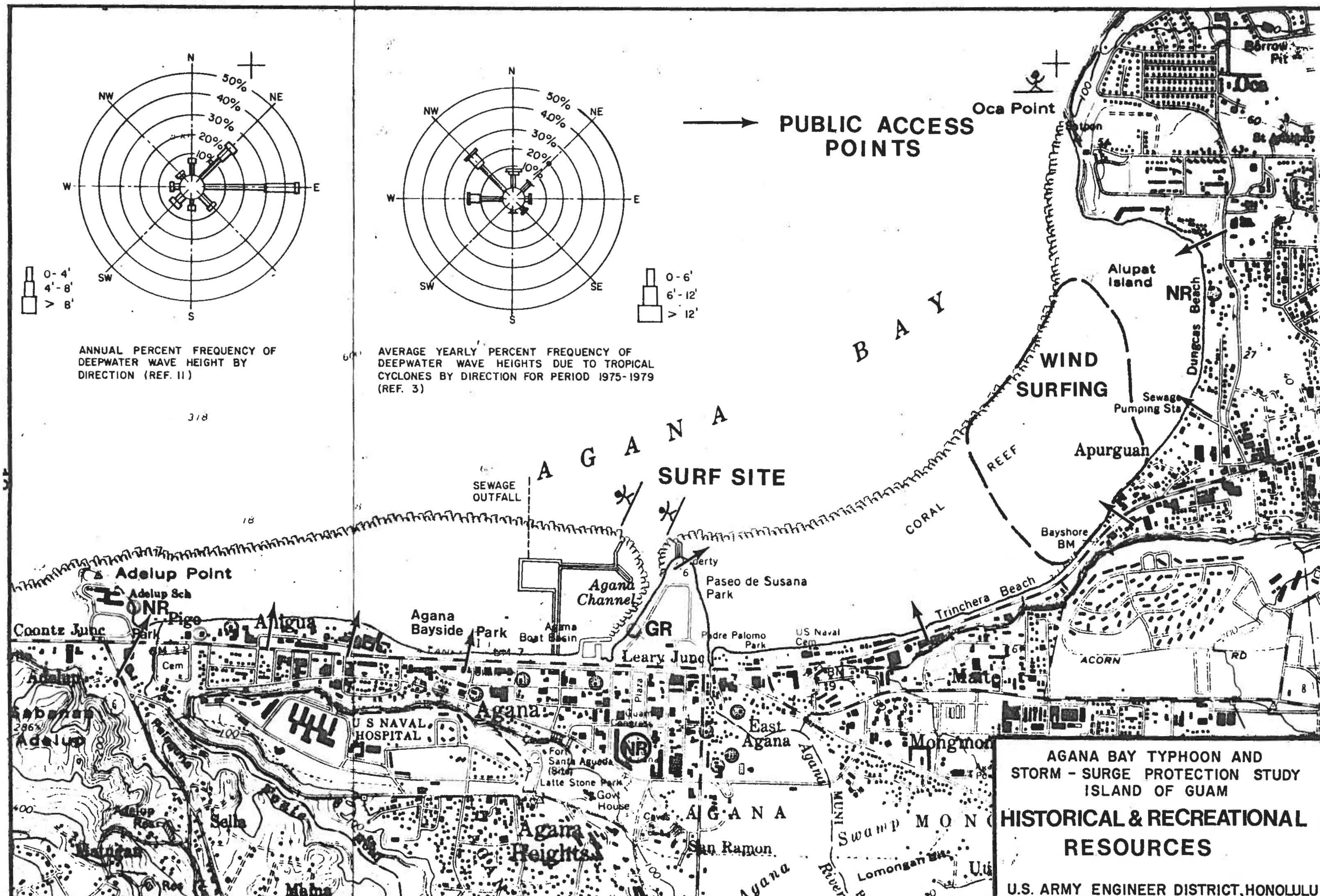
elevations of 3-6 feet aboveground. Historic Agana was destroyed by World War II bombardment in 1944 and post-war reclamation. Post-war rubble was spread over the central part of the city, as the local historical architect J. B. Jones reports that the old city was constructed on a level 1.5 to 2 feet below the present elevation. Historic sites in the Agana Bay coastal floodplain (excluding East Agana and Tamuning where no data exist) are depicted on Figure 4 and listed in Appendix C. A number of the houses in the 100-year typhoon and storm-surge flood zone are listed or considered possibly eligible for listing on the National Register of Historic Places.

(2) Recreation.

(a) Presently, three recreational activity areas in the Agana Bay study area--the waterfront and beach, the inner reef flat or moat, and the raised outer reef flat are used almost exclusively by local residents for social or family gathering, usually picnics, and for cooperative reef-flat fishing. Typical fishes caught by net or hook-and-line include rabbitfish, mackerel or atulai (Trachurops crumenopthalmus), goatfish (mullidae), jacks (carangids), surgeonfish (acanthurids), parrotfish (scarids), and snappers (lutjanids). Night fishing is particularly popular, especially at low tide. Fishing for the family table is a significant cultural tradition in Guam, and is a source of food contributed at fiestas, funerals, marriages, and christenings to repay past social debts. Other than the highly popular individual hook-and-line atulai fishing at the Agana Marina channel, aerial surveys of inshore recreational activity along Agana Bay by the Guam Aquatic and Wildlife Resources Division in 1977-1979, indicate that about 50 -ercent of all fishing techniques involved cooperative fill and surround-net activity. Non-fishing activity, however, particularly picnicking, comprised nearly 70 percent of all inshore recreational activity in 1978-1979. During the atulai and manahac fish runs, a hundred or more families camp for several days along Agaña Bay beach parks to be near to and enjoy the traditional cooperative fishing activity.

(b) Playful wading and swimming do not appear to be a significant beach activity due perhaps to the presence of many sea cucumbers, considerable litter and junk on the reef flat, and the intermittently polluted waters. Surfing is limited to "lefts" and "rights" off the Agana Marina channel, which is the most popular of all Guam surf sites (Figure 4). Twenty-five percent of Guam's population of over 105,000 reside within 2 miles of the bay and many more pass by the bay on the way to work or to shop. Based on a 1981 report, over 320,000 Japanese tourists visit Guam each year. All Japanese tourists are being subjected to intense advertising campaigns to increase their participation in Guam's ocean-oriented opportunities (Guam Department of Commerce and other sources).

(c) Two sports which are being encouraged among tourists as well as islanders are jet-skiing and wind surfing. The latter is conducted, primarily on a commercial basis in East Agana Bay, by Island Suzuki and Pacific Napu. In 1982, Island Suzuki personnel cleared about a 200-acre lagoon area of sharp objects for safe operation of their craft (Cristomo, personal communication, March 1983). Use of East Agana Bay for these activities is limited to periods of high tide because of the lagoon's generally shallow conditions. Tumon Bay, Apra Harbor, and Cocos Lagoon are more popular wind surfing areas. The jet-skiing and wind-surfing activities appear somewhat mutually exclusive with reef-flat fishing because the former relies on high tide and the latter occurs mostly during low tide.



PUBLIC ACCESS POINTS
ANNUAL PERCENT FREQUENCY OF DEEPWATER WAVE HEIGHT BY DIRECTION (REF. 11)
0-4'
4'-8'
> 8'
AVERAGE YEARLY PERCENT FREQUENCY OF DEEPWATER WAVE HEIGHTS DUE TO TROPICAL CYCLONES BY DIRECTION FOR PERIOD 1975-1979 (REF. 3)
0-6'
6'-12'
> 12'
Oca Point
AGANA BAY
WIND SURFING
SURF SITE
SEWAGE OUTFALL
CORAL REEF
Alupat Island
Apurguan
Bayshore BM
Sewage Pumping Sta
Dungcas Beach
Adelup Point
Adelup Sch
Coontz Junc
Agana Bayside Park
Agana Boat Basin
Agana Channel
Paseo de Susana Park
Padre Palomo Park
US Naval Cem
Trinchera Beach
Leary Junc
U S NAVAL HOSPITAL
Agana
East Agana
Mongmong
Latte Stone Park
Agana Heights
San Ramon
Agana River
Lomongan Bit
ACORN RD
AGANA BAY TYPHOON AND STORM - SURGE PROTECTION STUDY ISLAND OF GUAM
HISTORICAL & RECREATIONAL RESOURCES
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(d) Table 3 describes the public beaches and parks (seaward of Marine Drive) in the study area. None are fully developed with parking, public access, picnic tables and shelters, and restrooms, showers, and drinking water. All beaches and parks are accessible, at least along the beach, and most have picnic tables. The most fully developed park at Adelup Point is the smallest in beach and land area, and lacks restrooms. Restrooms, parking and vehicular accessibility seem to be the most prevailing problems.

(3) Public Access and Coastal Vistas. Public access is not only a matter of assuring a route to or along the beach, but of enhancing the urban waterfront such that it becomes a favorable destination for everyone. Horizontal access along the shoreline is guaranteed by the Guam Territorial Seashore Protection Act. However, along the Agana Bay shoreline, horizontal access is most difficult at high tide where seawalls directly abutt the beach foreshore in front of Ace Hardware in eastern Anigua, in front of SLC Motors and other commercial establishments along the East Agana strip, and in front of Island Suzuki in Tamuning. Seawalls also stimulate beach erosion and severely degrade ocean-to-shore views, such as from the Paseo de Susana park which is popular with tourists. The shore-to-sea view is also blocked by nonwater dependent strip commercial development in eastern Anigua, throughout East Agana, and along the western tip of Apurguan/Tamuning, adjacent to Island Suzuki. Perpendicular access from primary or secondary roads is primarily limited to beaches lying directly parallel to Marine Drive--Adelup Park, Bayside Beach, and Trinchera Beach. Other formal or informal access routes have been identified on Figure 4. Direct perpendicular access to the offshore reef flat across beaches does not seem to be a problem for local fishermen who gain access to the outer reef flat at Adelup Point or from the Paseo peninsula and the offshore sewage treatment plant island, west of the Paseo.

d. Land Use.

(1) Socioeconomic Characteristics. The study area covers portions of and overlaps several census units. A majority of the floodplain residents are in the Agana-Anigua District. Agana's residential population has declined significantly in the past decade from 2,119 in 1970 to 881 in 1980 as commercial structures have replaced residences. Tamuning District population rose 30 percent in the same time period, but analysis of aerial photographs reveals little apparent change in land use among the floodplain residents there or in Anigua. Most waterfront residents appear to be long-term (32-year average) residents of Guam and of the waterfront (10.5 years) according to the ABUWR Plan (ABUWR Plan, 1981). There is a concentration of extended family situations opposite 10th Street and to the east, a series of apartment buildings predominantly inhabited by transient military and alien worker tenants. Personal observations in 1983 suggest that the residents of Dungca's Beach are composed of isolated high-income families with high-value homes are interspersed with apparent moderate-income, extended family settings with lower quality residences. Dungca's Beach is sparsely settled by those believed to be mostly long-time (pre-1940) landowners.

(2) Land Use.

(a) Existing land uses in areas seaward of Marine Drive ware depicted in Sea Engineering, Inc., (September 1982) and are reproduced in Appendix C of this report. Industrial, commercial, residential, and public uses are shown, as well as the physical characteristics of the shoreline, and location of seawalls, revetments, stream mouths, and storm drains. None of the following typical uses are water dependent: new car sales, automobile servicing and

TABLE 3. SHORELINE RECREATIONAL FACILITIES ON AGANA BAY WATERFRONT

	Name	Grassed Park[1] Area (ac)	Beach[2] Length (m)	Beach[2] Width (m)	Land[3] Ownership	Inland Acess[4]	Facilities[5]	Popular Use[6]	Needs[7]
1.	Adelup Public Beach	1	213	3-12	Gov Guam	C.S parking spaces + roadside pkg.	2 concrete shelters 5 concrete tables 2 outdoor showers 5 rare cannonball trees (Xylocarpus mollucensis)	Picnicking areas/ group; fishing & softball games; strand collecting; access to reef fishing; snorkeling	Block horizontal vehicular access (Restrooms)
2.	Anigua Beach		1,619	3-16	Private	Graded & drained rd thru private property. Easement thru pkg lot between Marks Motor Park & Ace Hardware.	None	Access to nearshore seagrass beds for clamming. Motorbiking & walking.	Add facilities (incl restrooms/ landscaping and public parking.
3.	Agana Bayside Park (Anigua Public Beach)	8 ea	(see #2 above)	3-16	Gov Guam	Marine Drive Roadside Parking	1-2 Shelters Several concrete tables & benches	Access to a clamming, net fishing, picnicking on grass	
4.	Padre Paloma Park - Naval Cemetary		175	16	Private & Gov Guam	Marine Drive No park or roadside parking. Access blocked by private development.		Picnicking, swimming, snorkeling, fishing, strand collecting along East Agana shoreline; sand mining.	(Over open drainway (DPR)
5.	Trinchera Public Beach	10 ea	693	3-16	Gov Guam	Marine Drive roadside & limited offroad spaces. No pkg fac.	3 shelters numnerous concrete tables & benches	Picnicking; drinking; some swimming & wading; access to reef & shoreline fishing; launching jet skies & wind surfing.	Stop sand mining. Block horizontal vehicular access landscape. Improve picnick facilities, restrooms
6.	Apunguan Beach (Dungca's-Trinchera Gap)		1,844	3-16	Private	Through private property and along beach.	None	Walking, access to fishing, wind surfing.	
7.	Dungca's Beach		846	3-8	Private	Two dirt jeep trails from Camp Watkins Road. No pkg fac.	None	Walking, access to shoreside & reef fishing, clamming in Alupang Cove.	

1. Agana Waterfront Plan, 1981; 2. Gomez, 1977; 3. Gomez; 4. Sea Engr, 1981; Gomez; 5. 6. ; 7. Waterfront Plan

repair, machine shops, a sausage factory, grocery stores, clothing, jewelry and souvenir shops, and bars, massage parlors, and restaurants. A limited survey conducted in 1979 suggests that about 85 percent of the businesses are tenants with an average business life of only 4.2 years. Reasons cited for locating in the shoreline area were mostly "good visibility from the road." Land uses landward of Marine Drive in Anigua are a mix of residential near the cliffline, light industrial (auto repair), and predominantly commercial. The area of downtown Agana is mostly public and commercial building, with scattered old residences.

(b) Marine Drive passes through the entire Agana Bay coastal floodplain except for Dungca's Beach in Tamuning. The highway varies between 4 to 7 lanes wide and accommodates that highest volume of traffic flow on Guam, with bumper-to-bumper traffic during peak hours. The highway was designed for long, uninterrupted movement between major destinations and is, thus, generally incompatible with the needs of the commercial uses along the waterfront for parking and safe exit from and entry into the traffic stream. Lack of paved off-road parking is critical, not only for the waterfront businesses, but also the public parks.

(3) Land-Use Plans.

(a) Guam has had many land-use plans in the past, but little evidence of implementing planned land uses coming into existence. The Bureau of Planning's "Land Use Districting Plan, Guam" prepared in 1980 designates the study area is Urban and Conservation. All lands seaward of Marine Drive from Adelup Point to Tamuning are <u>Conservation</u>, as well as beach areas in Apurguan and Dungca's Beach. All other portions of the study area are <u>Urban</u>. Conservation districts include those areas needed for prevention of floods, preservation of scenic resources and beaches, and open space. Urban designation is made for areas where concentrations of people, structures, and streets have occurred traditionally and which can best accommodate future growth. Another long-term designation is the Seashore Reserve which runs in a 10-meter wide strip above the high water mark (mean higher high water) all along the waterfront. Under the local Territorial Seashore Protection Act of 1974, the seashore reserve is an open space designed to promote visual and physical access along the beach as well as wildlife preservation and shoreline continuity of land use.

(b) The 1981 ABUWR plan recommends eliminating most of the East Agana waterfront strip, similar to the official "Land-Use Plan Guam, 1977-2000." Highway improvement in Agana may be the most significant factor in stimulating urban renewal. A planned and budgeted widening of Marine Drive from Route 8 to Camp Watkins Road will eliminate nearly all parking space for most of the East Agana businesses. The planned right-of-way for the new highway would extend an easement almost 30 feet seaward for the road and a planned sidewalk with landscaping (Duenas, personal communication, March 1983). Unfortunately, it would also eliminate most off-road parking space along Trinchera Public Beach. This project was scheduled for construction in Fiscal Year 1984, but has not received funding. Associated with this project, the Guam Bureau of Planning is currently preparing an Implementation Plan for redevelopment of the East Agana waterfront strip and five structures at the western end of Apurguan/Tamuning, excluding Island Suzuki. Marine Drive in Anigua is also planned for widening from 5 to 7 lanes possibly sometime in the next decade.

(c) As early as 1966, a recreation plan for the Territory proposed dredging East Agana Bay for swimming and boating and construction of offshore islands on the edge of the reef flat. Other plans or ideas have suggested filling the reef flat near Alupat Island for government buildings, relocating Marine Drive to the outer edge of the reef flat, and construction of a hotel-condominium and small boat basin in Alupang or Sleep Hollow lagoon. In 1983, the Governor of Guam announced support for a two-phase plan which would dredge a deep-draft passenger liner terminal west of the Agana Marina with backup facilities and would dredge East Agana Bay for boating and swimming together with the construction of offshore islands on the reef front (letter of August 8, 1983). Some of the dredged material would be placed along the East Agana Bay shoreline for the construction of new beaches. This latter concept would compensate for the encroachment into Trinchera Public Beach by the planned widening of Marine Drive. This plan is depicted on Figure 5. The Corps of Engineers has provided preliminary advice upon request to the Governor of Guam and anticipates requests for additional, more detailed assistance on the deep-draft port concept. Subsequently, the Governor announced an alternative East Agana Bay plan which would fill the reef flat to create fast land for high-value resort, commercial and industrial land uses. Any more than brief analysis of these plans is beyond the scope of this report.

6. FUTURE CONDITIONS WITHOUT FEDERAL ACTION.

a. The Guam Bureau of Planning "Land-Use Plan Guam, 1977-2000" is the current official projection of land use (Figure 6). It projects Open Space use for the residential-commercial area of Anigua, seaward of Marine Drive, two-thirds of the East Agana strip, and the westernmost tip of Tamuning. The remaining one-third of the East Agana strip would be for recreation. "Open Spaces" within the Seashore Reserve are designed to promote visual and public access as well as wildlife preservation and shoreline continuity. The inner coastal floodplain of Anigua, Agana, East Agana, and Tamuning (Apurguan and Dungca's Beach) would remain similar to present uses, but become more densely occupied. Agana's residential population is projected to reverse recent trends and increase to about 2,550 in the year 2000. The coastal floodplain of Dungca's Beach and the area immediately inland of the 100-year flood zone is planned for smaller lot and multiple-family unit zoning.

b. It is likely that the widening of Marine Drive will occur soon and that most of the East Agana waterfront strip businesses will be forced to relocate or close their doors. In the long term, this will be itself greatly increase the available lands for public recreational development and reconstruction of beaches. Redevelopment of Anigua seaward of Marine Drive is less likely to occur in the near-term (10-15-year) future. If a passenger ship terminal is constructed in West Agana Bay, there could be pressure to consolidate existing appropriate business establishments--as recommended in the ABUWR Plan--into a cluster at the eastern end of Anigua in the vicinity of the present Ace Hardware. Such consolidation could also occur in association with the future widening of Marine Drive in Anigua. Future urban changes in the inland portions of Anigua, based on the "Land-Use Plan Guam, 1977-2000," will likely be a change from predominantly single-family housing to multiple-family housing. The interior parcels of land currently undeveloped in downtown Agana are likely to be gradually transformed into high density commercial or government office space.

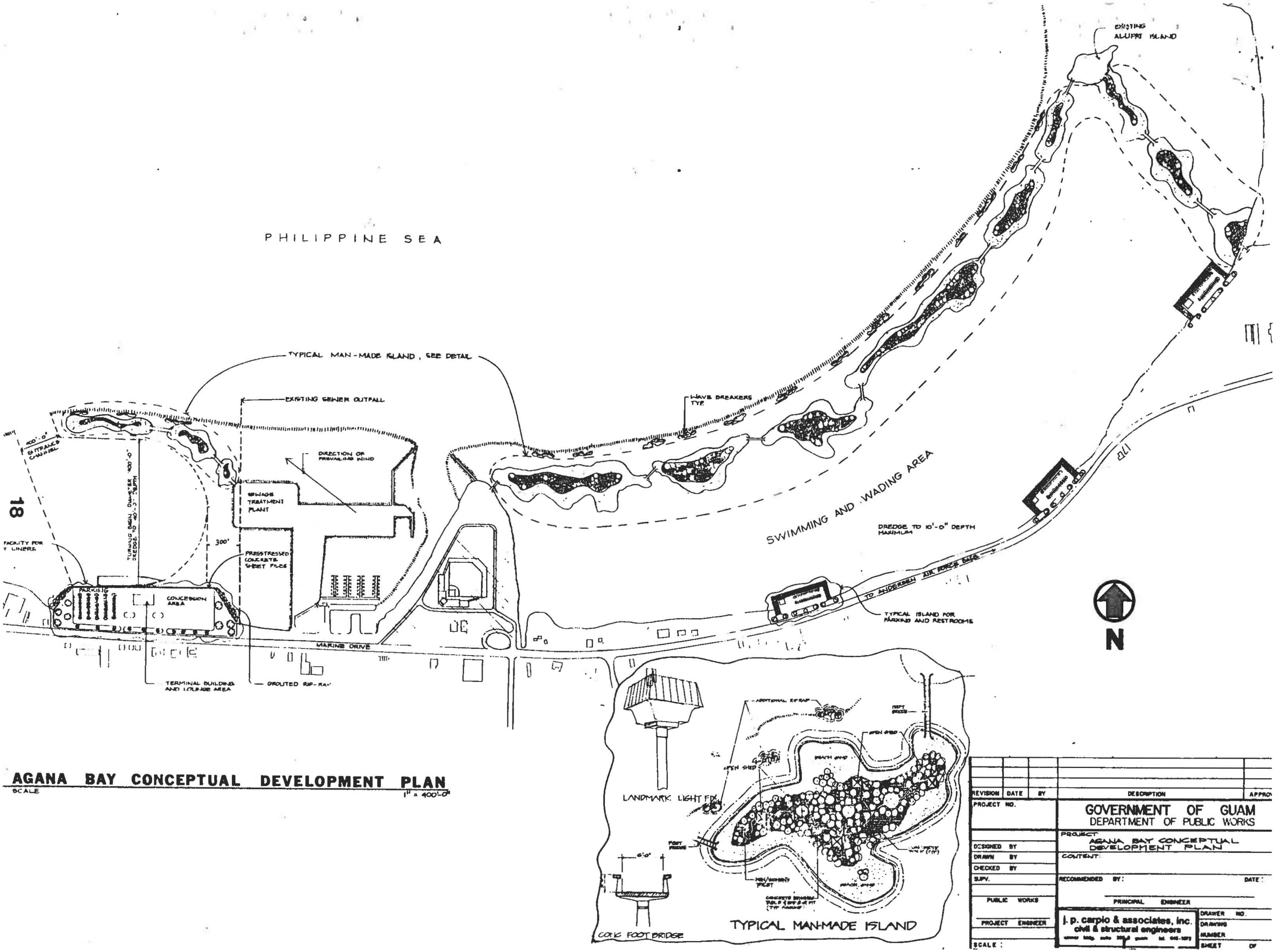
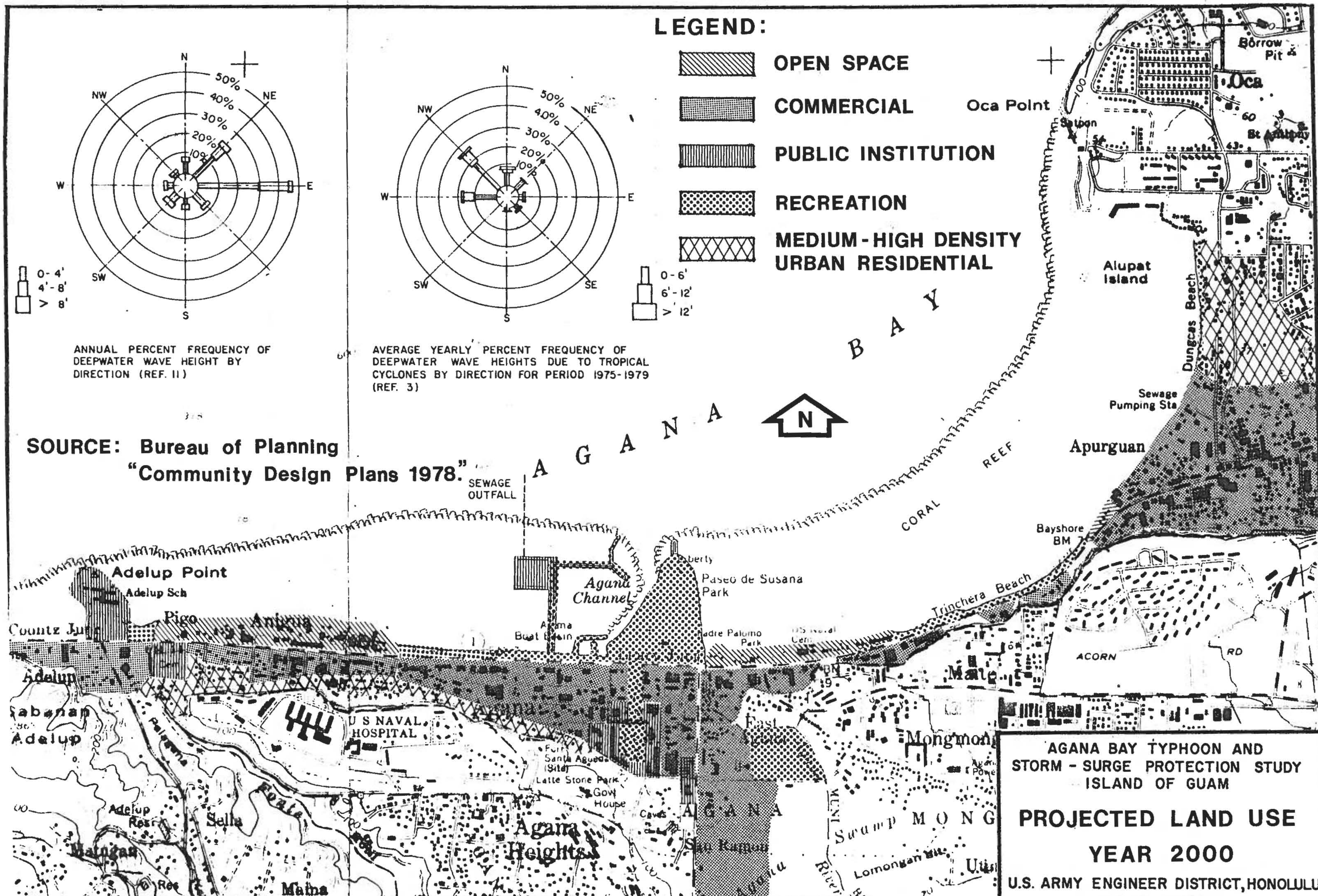

PHILIPPINE SEA
EXISTING ALUPAT ISLAND
TYPICAL MAN-MADE ISLAND, SEE DETAIL
EXISTING SEWER OUTFALL
WAVE BREAKERS TYP.
DIRECTION OF PREVAILING WIND
400'-0" ENTRANCE CHANNEL
TURNING BASIN DIAMETER 400'-0" DREDGE TO 40'-0" DEPTH
SEWAGE TREATMENT PLANT
300'
PRESTRESSED CONCRETE SHEET PILES
PARKING
CONCESSION AREA
MARINE DRIVE
TERMINAL BUILDING AND LOUNGE AREA
GROUTED RIP-RAP
SWIMMING AND WADING AREA
DREDGE TO 10'-0" DEPTH MAXIMUM
TO ANDERSEN AIR FORCE BASE
TYPICAL ISLAND FOR PARKING AND RESTROOMS
N
AGANA BAY CONCEPTUAL DEVELOPMENT PLAN
SCALE 1" = 400'-0"
ADDITIONAL RIP-RAP
OPEN SHED
BEACH SAND
LANDMARK LIGHT FIX
FOOT BRIDGE
6'-0"
MEN/WOMEN'S TOILET
CONC FOOT BRIDGE
TYPICAL MAN-MADE ISLAND
REVISION
DATE
BY
DESCRIPTION
PROJECT NO.
GOVERNMENT OF GUAM
DEPARTMENT OF PUBLIC WORKS
PROJECT
AGANA BAY CONCEPTUAL DEVELOPMENT PLAN
CONTENT
DESIGNED BY
DRAWN BY
CHECKED BY
SUPV.
RECOMMENDED BY:
DATE:
PUBLIC WORKS
PRINCIPAL ENGINEER
PROJECT ENGINEER
j. p. carpio & associates, inc.
civil & structural engineers
DRAWER NO.
DRAWING NUMBER
SHEET OF
SCALE:

FIGURE 5


LEGEND:
OPEN SPACE
COMMERCIAL
PUBLIC INSTITUTION
RECREATION
MEDIUM-HIGH DENSITY URBAN RESIDENTIAL
0-4'
4'-8'
> 8'
ANNUAL PERCENT FREQUENCY OF DEEPWATER WAVE HEIGHT BY DIRECTION (REF. 11)
0-6'
6'-12'
> 12'
AVERAGE YEARLY PERCENT FREQUENCY OF DEEPWATER WAVE HEIGHTS DUE TO TROPICAL CYCLONES BY DIRECTION FOR PERIOD 1975-1979 (REF. 3)
SOURCE: Bureau of Planning "Community Design Plans 1978."
AGANA BAY
CORAL REEF
SEWAGE OUTFALL
Oca Point
Oca
Borrow Pit
Alupat Island
Dungcas Beach
Sewage Pumping Sta
Apurguan
Bayshore BM 7
Trinchera Beach
Adelup Point
Adelup Sch
Agana Channel
Agana Boat Basin
Paseo de Susana Park
Padre Palomo Park
U S NAVAL HOSPITAL
Latte Stone Park
Gov House
Agana Heights
AGANA
San Ramon
East Agana
Mongmong
MONG
ACORN RD
Lomongan
Adelup Res
Sella
Maina
Sabanan Adelup
AGANA BAY TYPHOON AND STORM-SURGE PROTECTION STUDY ISLAND OF GUAM
PROJECTED LAND USE YEAR 2000
U.S. ARMY ENGINEER DISTRICT, HONOLULU

7. EXISTING TYPHOON OR STORM SURGE PROTECTION IMPROVEMENTS.

a. There are no existing Federal or Territorial structural improvements in place to reduce flood or erosion damage due to typhoon or storm surge. As noted on the figures in Appendix C on land use, there are several vertical concrete bulkhead fronting fastland parcels in western Anigua, East Agana and Tamuning, but these are believed to have been constructed primarily to increase the availability of fastland at the expense of the beach rather than to protect against typhoon or storm-surge. The Corps-constructed breakwaters associated with the Agana Marina were not designed to protect Agana from typhoon or storm-surge damages, but may yet provide some limited protection. This would have to be analyzed in detail by later studies.

b. The Territory of Guam has several nonstructural measures in the form of land management statutes including PL 12-200, as amended (the Seashore Reserve Act), the Zoning Law, the Seashore Protection Act, and the Subdivision Law which in various ways state that identified hazardous lands including floodplains shall be developed only to the extent that such development does not pose unreasonable risks to the health, safety, or welfare of the people of Guam.

8. EXISTING CORPS OF ENGINEERS WATER RESOURCES DEVELOPMENT.

a. Agana River Flood Control Project. In 1975, the Honolulu Engineer District, U. S. Army Corps of Engineers completed a study to reduce flood damages in the Agana River flood basin. This study, which was approved by the Chief of Engineers and the Board for Rivers and Harbors recommended the construction of 400-foot long trapazoidal riprap channel, a 1300-foot long rectangular channel, and levees totalling 4,900 feet within Agana Marsh to protect low-lying areas of downtown Agana from riverine flooding at the protection level of a 100-year flood event. The channelized portion provided for an approximately 12-foot high channel wall and levee on the westerly side of the stream. The Honolulu District is currently undertaking advance engineering and design studies beginning in Fiscal Year 1984.

b. Under the authority of Section 103 of the River and Harbor Act of 1970, as amended, the Honolulu District recently completed in October 1983 the Final Detailed Project Report and Environmental Assessment for Paseo de Susana Shore Protection, Agana, Guam. This report has not yet been approved by the Chief of Engineers. It recommends construction of two revetment sections on the northern tip and western shore of the Paseo peninsula to protect against erosion caused by high waves, including those which might produce a storm surge. However, this plan is not intended to protect against flood damage due to typhoon or storm surge.

c. Under this Guam Comprehensive Study, three other reports have been prepared which address Agana Bay shoreline erosion (Sea Engineering Services, Inc./R. M. Towill Corporation--A Joint Venture, September 1980) and (Sea Engineering, Inc., September 1982); and interior flooding, including that adjacent to the Fonte River in western Anigua and in downtown Agana (R. M. Towill Corporation, November 1982, draft). The 1980 joint venture report, "Guam Comprehensive Study Shoreline Inventory" identified severe erosion as only occurring at the Paseo de Susana, which led to the preparation of the study report mentioned above. The 1982 Sea Engineering, Inc. report, "Shoreline Investigations: Agana, Guam" revealed little chronic or ongoing erosion during normal wave conditions, except at the Paseo de Susana peninsula. The study made no recommendations for further studies or improvements except at Paseo. The 1982 R. M. Towill report, "Alternative Solutions for Flood Prone Areas in Guam," recommended a structural and a nonstructural plan of improvements for both the west Anigua and downtown Agana interior drainage basins. The structural plans called for a channelization of Fonte River for a distance of 1,000 feet above the bridge on Marine Drive and for a surface catchment and underground drainage system discharging into the lagoon west of the Marina. The nonstructural plans are similar to that discussed in this report.

d. The Tamuning Flood Control Study is currently being undertaken under this Guam Comprehensive Study. It has been examining both structural and nonstructural alternatives, but studies are still continuing to determine the economic feasibility of improvements.

9. PROBLEMS, NEEDS AND OPPORTUNITIES.

a. History of Past Floods and Erosion Caused by Typhoon and Storm Surge.

(1) Reconstructing the history of floods and shore erosion caused by typhoon and storm surge is made difficult by: different definitions of the popular term "storm surge"; discerning what damage was caused by storm surge in contrast to riverine flooding, interior drainage or the force of high-speed winds; and in recent times, the lack of one single agency assigned the responsibility for storm wave or storm-surge damage assessments. Storm wave or storm surge by itself is not usually categorized as a specific source of damage. The following chronological listing (Table 4) of typhoon and tropical storm damage reports for Agana Bay is derived mainly from the excellent summary report by Captain Charles Holliday, USAF (1975), supplemented by original secondary sources. Editorial comments on directional sources of waves are provided in parentheses.

TABLE 4. CHRONOLOGY OF TYPHOON AND TROPICAL STORM DAMAGES AT AGANA BAY, GUAM (1680-1982)

1680 11 Nov A hurricane arose on the northern side...the sea become so swollen that the people were obliged to flee to the mountains (Holliday, 1975).

1693 20 Nov The wind moved from north to south and whipped up the sea in such a manner, it seemed the island of Guam would be submerged (Holliday, 1975). The sea uprose: waves rose mountain high, broke natural limits, and swept away trees, houses, etc. Agana Fort was overthrown and burned in boiling surf (Anon., "A Typhoon in the Olden Days," Guam Recorder, 1929:87). Those who saved themselves did so by taking refuge in the hills or by swimming about all through the night (Holliday).

TABLE 4. CHRONOLOGY OF TYPHOON AND TROPICAL STORM DAMAGES AT AGANA BAY, GUAM (1680-1982) (CONT)

1817 Nov It is said that generally every 20 years, a violent storm arises in the southwest which causes the sea to run so high that the town (Agana) is overflowed and the inhabitants are obliged to flee to the mountains. Only stone houses can resist the fury of the water (Otto von Kotzebue in Carano and Sanchez, 1964).

1800's Holliday lists 21 typhoons hitting Guam in the 19th century but little descriptive data are available. At least four probably cause typhoon surge damage in Agana.

1900 13 Nov After the typhoon has passed to the west of Guam, Governor Schroeder witnessed a slow rising of the sea engulfing the low part of the town (Schroeder, 1922 in Carano and Sanchez, 1964). In Agana, the sea reached the Plaza in front of the Palace (Holliday).

1911 19 Oct The center passed between Guam and Rota (to the west). Several feet of bank along Agana beach were washed away. Some wharfs destroyed or badly damaged in Agana (Holliday).

1913 10 Nov Storm center passed over Rota (to the northwest). Storm waves washed away Agana waterfront wharf. Several sampans were sunk or beached at Agana and all low-lying areas of town were flooded.

1918 6 Jul Storm surge damage uncertain. Eye of typhoon passed directly over Agana (Holliday). Government House garden was under several feet of water for days after (Anon., "Destructive Typhoon Passes over Guam." Guam Recorder, 1935:.301-302).

1924 1 Oct Storm center passed south of Guam. Thirty-three inches of rainfall recorded in 48 hours at Agana. Agana River overflowed and flooded San Antonio barrio (Holliday). After the storm had abated (passing to the west or northwest), high waves swept over Agana beach flooding up to waist high in the beach area (Guam Recorder, 1935).

1940 3 Nov Most severe typhoon since 1918 with gusts reaching an estimated 130 knots. Eye pass at southern end of Guam (Holliday). Prior to arrival of typhoon in Agana, high waves had washed out a backyard kitchen of the Perez house on old Dr. Sargent Street along the ocean (now West Agana Bayside Beach between Fr. Duenas Avenue and Fifth Street (Chris Perez Howard, "Mariquita: A Guam Story," Guam Tribune Weekender Panorama, June 10 and 24, 1983).

1953 17 Dec A tropical storm passed 350 miles north of Guam. Large waves reportedly damaged Marine Drive and buildings in Asan, Piti, and Agana (Blumenstock, 1959). The same storm waves are also reported to have destroyed nearly all of a pure stand of tangentangen (*Leucaena glauca*) that had previously dominated almost the entire beach ridge fronting Agana (F. Raymond Fosberg, "The Vegetation of Micronesia...," Bulletin of the American Museum of Natural History, Vol 119(1), 1960).

1962 11 Nov Typhoon Karen was worst since 1900 with winds gusting to 150-160 knots. Eye passed over southern Guam. The sea inundated Marine Drive depositing boats from Agana Boat Basin as far as one block inland (Holliday). The ocean reached clear to the base of the cliff at Anigua (P. Souder, "Fortress--Guam" Guam's Postwar Military Government, Naval Government, and Civil Government--Conclusion." Guam Tribune Weekender Panorama, 24 June 1983). Recent interviews conducted in Agana in 1983 for flood insurance studies by the Corps cited flood depths of 3 feet at Mark's Department Store in east Anigua and 4 feet inland of the boat basin. The following could be describing Agana: "Before the eye passed, storm surge whipped by savage winds, rolled over reefs and thundered ashore. It tore into homes and public institutions, then retreated with furniture and other belongings" (Fritzen, The Spinning Winds: Typhoon--How to Protect Against Them. Agana: Agency Service, 1972).

1963 29 Apr Typhoon Olive's eye passed slowly near Agana 35 nautical miles to the west. Flooding by the sea was experienced in Anigua (Holliday). Six to 10-foot waves were reported inside the reef at Agana Bay.

1974 11-13 Aug Typhoon Mary passed 450 nautical miles northwest of Guam. Persistently strong southwesterly winds over a period of three days caused significant damage to ships and boats because of high seas. Some flooding by the sea was reported from Merizo to Tamuning (Holliday).

1976 21 May Typhoon Pamela's eye slowly passed over Guam with 100 knot winds for over 6 hours (Holliday). Sand and debris were deposited on Marine Drive but no storm-surge flooding was reported from Anigua to Trinchera Beach businesses.

1982 July Typhoons Andy and Bess passed simultaneously about 100 nautical miles north of Guam, but generated powerful swells that flooded about 100 feet inland among the Dungca's Beach residences (C. Crisostomo, personal communication, March 1983).

(2) There have been at least 11 instances of flooding or apparently major shoreline erosion along Agana Bay since 1900. It is highly likely that damages due to storm surge or storm waves generated by distant storms are not fully reported and when reported, the descriptions of damage are usually limited to easily accessible points along the shoreline or many shoreline residents just take it in stride and do not report the damage.

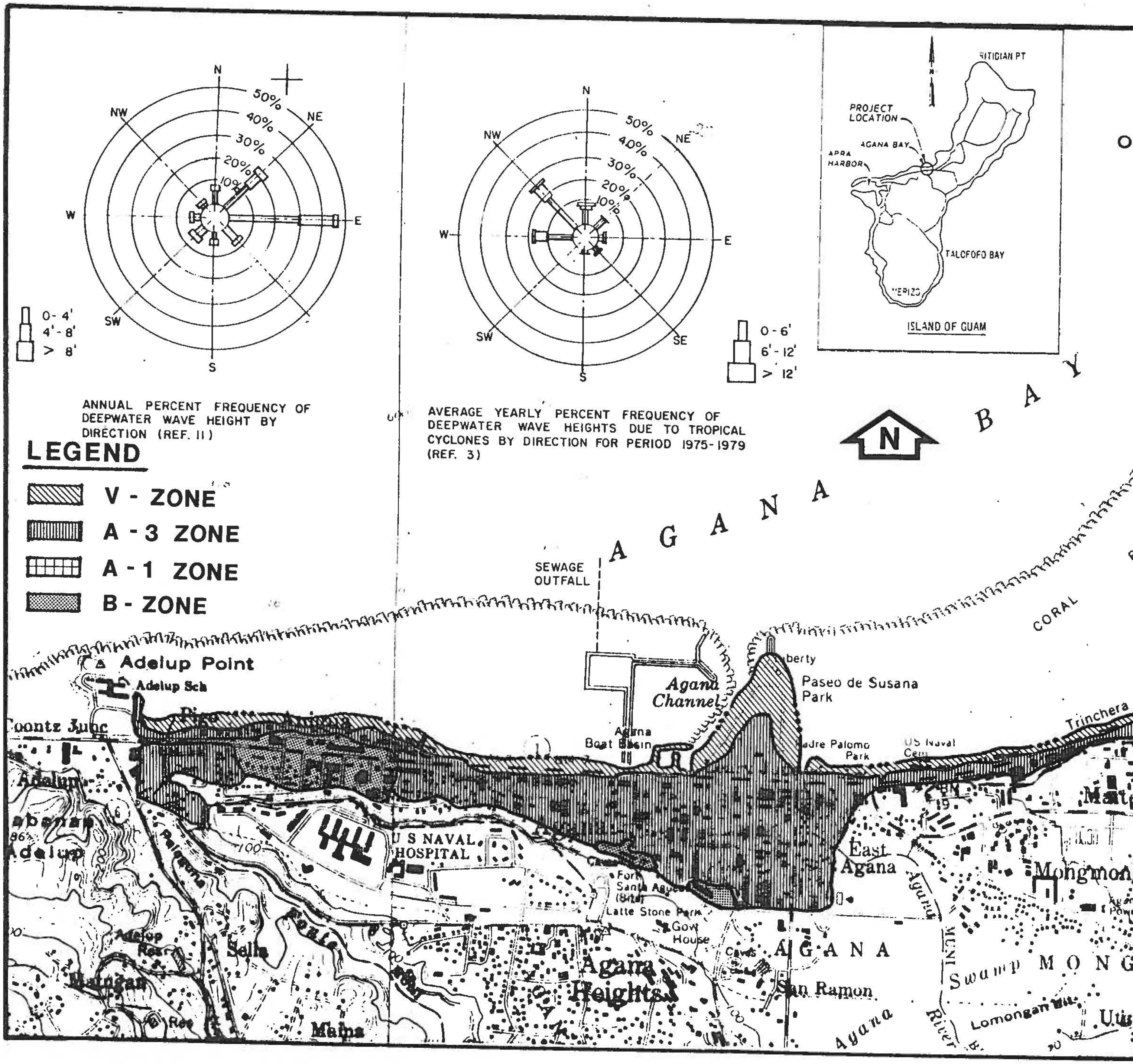
b. Storm Surge Problems.

(1) Local Storm Surge and Distant Storm Surge. For the purposes of this report, a local storm surge is generated by nearby storms of up to typhoon strength. It has up to five components: tidal level, still-water rise due to inverse barometric pressure (significantly only with typhoons),

wind setup, wave setup, and breaking wave runup. The component of inverse barometric pressure sucking up the water level affects the island's shoreline only when the typhoon is nearby Guam, generally within 70 miles. Distant storm surge has three components: tidal level, wave setup, and breaking wave runup. The latter type of storm surge is caused by distant storms, whether they be of typhoon, tropical or extra-tropical storm strength. The distance, which may be as much as 400-500 miles away, precludes the inverse barometric pressure and wind components affecting Guam. The effects of local storm surge, because of the added effects of inverse barometric pressure on the still-water level and wind setup, piling up the water, seems more likely to result in primarily flood damage, and only secondarily, shoreline erosion. Likewise, distant storm surge associated with deep ocean swells may be more likely to result in damage to the immediate shoreline area, due to its lower still-water levels. On the otherhand, frequency occurrence of damaging distant storm-surge in Agana Bay based on the wave roses depicted in Figure 1 and data contained in Table 2 (see those data supported by Reference 3) suggests greater likelihood of distant storm-surge damage in any one year in contrast to local storm-surge damage. For instance, wave heights of 8 feet or greater can be expected to approach Guam from the west through north sector (those affecting Agana Bay) 11 percent of the time in an average year. As indicated in the above section, storm-wave damage may be under reported, notwithstanding the findings of the two shoreline studies by Sea Engineering Services, Inc./R. M. Towill (1980) and Sea Engineering, Inc. (1982).

(2) As part of the Guam Flood Insurance Study, prepared by the Honolulu District, U. S. Army Corps of Engineers in September 1983, a joint probability analysis was conducted to compute the storm surge resulting from nearby passage of typhoons. This analysis is reproduced in Appendix B of this report. In the joint probability study, a frequency and probability analysis of the meteorological parameters of the typhoon which affect Guam was first conducted. From the analysis, a series of hypothetical but possible typhoon events were generated to represent the typhoon population in the Guam area. By use of a method which was specifically developed for that study, the surge elevations were calculated at various study areas around Guam using the hypothetical typhoon data. The surge elevations were then analyzed statistically to determine the surge-frequency relationships (10-, 50-, 100-, and 500-year events). From the probability analysis, the 100-year deep ocean wave characteristics were also determined as having a significant wave height of 50.0 feet and a significant wave period of 15.4 seconds.

(3) For the analysis of the coastal floods caused by typhoons, waves were added to the surge elevations. Coastal flood elevations at the shoreline were determined by making the crest height above the still-water level (surge) elevation of the breaking reef wave at the shoreline equal to 70 percent of the height of the transmitted wave. Inland runup was determined by using an empirically-derived relationship based on observations of the 1976 Typhoon Pamela's runup on the east coast of Guam. This relationship proved to be 1 foot drop in water surface elevation for every 115 feet of inland travel of the flood wave. The final determination of the starting flood elevation at the shoreline also relied on eye witness accounts of coastal floods in the various study areas around Guam, including Agana Bay. Table 5 summarizes the findings of this joint probability analysis. The 1 percent (or 100-year) Agana Bay local storm surge floodplain generated by typhoons is shown on Figure 7. Typhoon Flood Hazard Analysis:



AGANA BAY TYPHOON AND STORM - SURGE PROTECTION STUDY ISLAND OF GUAM

100-YR STORM-SURGE FLOOD PLAIN

U.S. ARMY ENGINEER DISTRICT, HONOLULU

TABLE 5. TYPHOON-GENERATED STORM-SURGE INUNDATION LEVELS (MSL)

Storm Frequency	Surge Level MLLW*	Surge Level MSL*	Breaking Wave Height (Ft)	Total Inundation (Ft)
10-year event (10%)	+6.7	+5.3	3.1	+8.4
50-year event (2%)	+8.8	+7.4	4.0	+11.4
100-year event (1%)	+9.4	+8.0	4.3	+12.3
500-year event (0.2%)	+10.1	+8.7	4.6	+13.3

* MLLW (Mean Lower Low Water); MSL(Mean Sea Level

(4) The significance of the inundation levels lies in the existing relatively low elevation of the study ara. The old community of Anigua lies generally between 6 and 10 feet above mean sea level (MSL) divided by Marine Drive which ranges from about 8 feet to 13 feet, east to west. Downtown Agana lies at elevations between 6.5 to 11 feet above MSL. Marine Drive fronting Agana ranges between 6.5 to 7.5 feet and 11.2 feet at Agana River bridge. The East Agana waterfront strip is about 8.5 feet (MSL) and Marine Drive about 1 foot higher. Western Tamuning or Apurguan averages about 6 to 8 feet in elevation (MSL) and the shorefront area at Dungca's Beach ranges between 3.5 to 10 feet. For the most part, there are few areas higher than 10-11 feet (MSL) in the coastal plain. Ninety-foot high cliffs are in back of Anigua and eastern Agana, and almost immediately inland of Marine Drive along the East Agana strip and Trinchera Beach. There is also an undeveloped 15-foot incline behind the Dungca's Beach residences sloping up to Camp Watkins Road. Thus, most of the Agana Bay coastal plain lies within flood levels of a 50-year storm-surge event, which could flood areas up to about 11.4 feet (MSL) according to the above calculations. Without wave runup, the surge alone would flood areas up to an elevation of 8.8 feet (MSL) (see Table 5).

(5)

(a) There are three flood zones designated on Figure 7. All indicate the areal extent of flooding from a 100-year typhoon-generated storm-surge flood event. These (and other) zones are designated under the National Flood Insurance Program to indicate degrees of flood risk, and together with other factors, are used to assign actuarial insurance rates to structures and contents insured under that program. The 100-year or 1 percent flood is the standard level of flooding used in the program..

(b) The narrow zone near the shoreline is called the "V" or Velocity Zone which is the inland extent of a 3-foot breaking wave where the effective water depth during the 100-year flood decreases to less than 4 feet. The V-zone is the Special Flood Hazard Area where velocity hazards to structures could occur. It is determined by approximate methods.

(c) The large "A" Zone is a Special Flood Hazard Area inundated by the 100-year flood. Structures in the A Zone are not subject to wave action, but residual forward movement of the breaking wave may be present. The A-zone is designated an A3 zone, which indicates that the difference in flood level between a 100-year (1%) and 10-year (10%) storm-surge flood event averages 1.5 feet. This is not an empirically derived difference in flood elevations.

The B-zones in the inland portions of Anigua and along the back (southern edge) of Agana are areas of moderate flooding, which means subject to 100-year (1%) to 500-year (0.2%) storm-surge flood events. All the flood elevations used in this draft report were determined using National Flood Insurance criteria, which are less rigorous than the methodological criteria governing hydrological analyses performed for Corps flood control projects. No hydrological analyses have yet been prepared for this report.

c. Water Resources Opportunities.

(1) Shore Protection. Separate studies of the Agana Bay shoreline have failed to identify any reaches needing remedial protection, except for at Paseo de Susana which is covered by another Corps report. Preliminary historical analyses have shown previous instances of apparent significant shoreline erosion along Agana Bay. Intensive historical studies could reveal chronic erosion occurring over a longer time period which might justify further engineering analysis of this potential problem.

(2) Flood Damage Reduction. The possibility of local storm-surge and perhaps distant storm-surge generated flood damage reduction measures, both structural and nonstructural, can be analyzed for their preliminary economic feasibility. Environmental, historic site, and land-use effects would need to be examined. The preliminary typhoon flood hazard analyses adapted in this study will directly aid the Territory of Guam in its existing floodplain and land management programs. This Technical Documentation utilizes that hydrological analyses prepared for the Corps-prepared Guam Flood Insurance Study.

(3) Navigation. The Governor of Guam has shown interest in developing West Agana Bay into a passenger liner terminal. The Corps of Engineers is available at the Governor's request to provide detailed engineering feasibility studies.

(4) Water Contact Recreation. Reef-flat fishing, as well as board and wind surfing, jet skiing, and snorkeling are very popular past-times. The fishing also plays a significant cultural role in traditional Guam society. Use of the bay's beaches for these activities and for picnicking may be threatened by what is now minor shoreline erosion combined with planned highway widening which will encroach into the public beaches.

(5) Water Quality. Agana Bay, particularly the northeastern part near Dungca's Beach is under stress due to discharge of storm-water pollutants and restricted circulation by a causeway near Alupat Island. The Guam EPA is currently investigating the effects of storm-water runoff on the bay's ecology. As applicable, its recommendations would be considered in project planning.

(6) Fish and Wildlife Enhancement. Fishery resources and the bay's limited shorebird population appear partially stimulated by the growth of algae, seagrass, and associated bivalve mollusks found at or near storm-drain deltas which also have adverse visual and odorous aesthetic effects. Any planning for structures that could affect storm-drain deltas need to be aware of these relationship. The coral reef flat is also a major recreational and subsistence fishery and shell collection area. Any measure which affects East or West Agana Bay reef flats such as proposed filling of the reef flat or deepening it must consider the very significant adverse cultural, social, and economic effects of harming these resources and associated opportunities and uses.

(7) Land Use. One of the main roles of this study is to supplement the Government of Guam's ABUWRP. The major goal of this plan is to eliminate nonwater dependent economic activities, such as the randomly sited East Agana waterfront commercial strip, which blocks visual and physical access to the shoreline, sometimes blocks horizontal physical access along the beach at high tide, pollutes nearby waters by storm-water runoff and placement of junk on the beach and in nearshore waters, and has largely obliterated any natural terrestrial landscape. In short, these nonwater dependent urban uses are generally incompatible with each other and the nature of shoreline ecology. Some ways in which these land-use activities can be controlled include floodplain management regulations, such as requirements for flood insurance and building permits.

C. PLANNING OBJECTIVES

Initial planning objectives were established by identifying specific components of the problems, needs and opportunities as well as other base conditions, that are consistent with the national objectives. These objectives are subject to review and modification during the planning process. The planning objectives were identified as follows:

1. Revive Agana's "ailing" waterfront to create an atmosphere conducive to economic growth while sustaining the natural character of the shoreline and reef flat.

2. Maintain shoreline setbacks so that damageable structures or improvements are sited sufficiently inland that flooding or erosion damages from typhoon surge or storm surge do not occur.

3. Contribute to the reduction of property damage by typhoon surge or storm-surge flooding during a 1990-2040 period of analysis.

4. Contribute to the improvement of water quality of nearshore Agana Bay; as a minimum, avoid further degradation of water quality in northeast Agana Bay.

5. Preserve all sites listed or eligible to the National Register of Historic Places.

6. Improve, or as a minimum, maintain existing water contact recreational and subsistence activities and opportunities.

7. Preserve existing seagrass beds and areas of high marine ecological diversity and abundance.

D. PLAN FORMULATION

1. RATIONALE.

Plan formulation is the process of developing a system of management and planning measures to remedy the defined problems. This process is a multi-disciplinary evaluation and assessment involving an examination of the environmental impacts, technical adequacy, economic efficiency and social acceptability of possible solutions with the framework of national and local planning objectives. Significant adverse impacts of any of the major components without an acceptable resolution may terminate further study of that alternative. Elimination of infeasible or undesirable plans will narrow the field of potential alternatives until an acceptable plan is developed. A preliminary screening of possible alternatives will eliminate obviously inappropriate plans prior to detailed analyses. Those considered to the most feasible will be carried into detailed planning and design. Greater detail may be applied during the preliminary screening stage to those plans that appear infeasible to insure that the elimination of those plans from further consideration is justified.

2. EVALUATION CRITERIA AND POLICIES.

a. Institutional Policies. The U. S. Army Corps of Engineers regulations define certain conditions for which damage reduction measures may be accomplished for damage generated by typhoons. The Federal interest in projects to protect against typhoons or abnormal tidal flood or erosion damage is not explicitly defined by legislation. Congressional authorization for Corps construction of such projects, on a case-by-case basis, has essentially established the Federal concern. Public use of the shoreline is not a condition for Federal participation in protecting against typhoons. Although project works are usually similar to beach erosion control improvements, hurricane or typhoon protection projects are viewed as being more like flood control projects. Letters of intent to support the project and comply with local assurances will be required at various planning stages for reporting and authorization procedures.

b. Design Criteria.

(1) Level of Protection. The maximum height of inundation that can be protected against by the system is the measure of level of protection. The greater the height (often interpreted in terms of storm or flood frequency), the greater the protection provided the community but the greater the cost of the improvements or measures. The level of protection is based on the type of improvements, the relative hazard, the tangible economic benefits, and the environmental or social consideratios in connection with the plan objectives. No specific levels of protection are established by regulation or guidelines for storm-surge protection studies. This report uses storm surge and wave inundation levels generated by typhoons and calculated to the equivalent levels of protection against a 10-year (10%), 50-year (2%), 100-year (1%) and 500-year (0.2%) typhoon event. No similar calculations have been performed for lesser intensity tropical storms. At the very preliminary level of this technical documentation, protection has been designed only for the 100-year (1%) typhoon event. Plans designed to the other three levels of protection would be examined in subsequent studies to evaluate which plan maximizes net benefits.

(2) Design Assumptions. The following assumptions have been made in the screening and preliminary design of structural and nonstructural alternatives:

(a) The Corps' riverine flood control project at Agana River will be constructed to include an approximately 12-foot high (MLLW) revetted channel from the mouth of the river inland to Agana Marsh where it would tie into a levee system. This would provide for protection against storm surge rushing up the stream channel.

(b) The interior drainage system for the Fonte River flood basin (West Anigua) consisting of a flood control channel designed to the 100-year level of protection as recommended by the Corps-sponsored 1982 R. M. Towill report would be constructed to protect in part against inrushing surge up the stream channel.

(c) The similarly recommended interior drainage system for downtown Agana would be constructed to protect against standing rainfall.

c. Environmental Guidelines. The following laws and their implementing regulations will be complied with in assessment of possible environmenal effects of any proposed measures:

(1) National Environmental, Policy Act of 1969 (PL 91-190). An environmental impact statement will be prepared in subsequent studies for any measures which significantly affect the quality of the human environment.

(2) Fish and Wildlife Coordination Act of 1958, as amended (PL 85-624). The Corps will consult with the US Fish and Wildlife Service in subsequent studies concerning impacts of any alternatives. No formal consultation was conducted for this preliminary-level document.

(3) Clean Water Act of 1977 (PL 95-217). Any measure requiring discharge of dredged or fill material into waters of the United States will be evaluated for its effects using Section 404(b) guidelines.

(4) National Historic Preservation Act of 1966 (PL 89-655). The Advisory Council on Historic Preservation will be consulted for the effects of any alternative on historic sites listed on or possibly eligible for inclusion on the National Register of Historic Places.

(5) Executive Order on Floodplain Management (EO 11988). The required analyses under this EO will be conducted at the appropriate planning stage.

(6) Coastal Zone Management Act of 1972 (PL 92-583). A Federal consistency statement will be prepared to assess any alternative measures in relations to the Guam Coastal Management Plan.

d. Economic.

(1) Measures for control of beach erosion and protection against typhoon flooding may include benefits from beach restoration, land loss and other physical damages prevented, emergency and business costs avoided, enhancement of property values, increased recreational usage, and prevention of lost of historic or scenic aspects of the environment. Benefits are measured as the difference in these values under conditions expected with and without any contemplated control measures (EP 1165-2-1, 30 Jun 83).

(2) It is traditional Corps policy to recommend the Federal share of typhoon protection project costs be limited to maximum of 70 percent. For multi-purpose typhoon protection and beach erosion projects, Section 208 of the 1970 Flood Control Act provides discretionary power to the Secretary of the Army acting through the Chief of Engineers to authorize a Federal share up to 70 percent of the project costs exclusive of land costs (EP 1165-2-1, 30 Jun 83).

3. CATEGORIES OF POSSIBLE MEASURES.

a. Restatement of the Problem. The inundation height of a 50-year typhoon event--one that has a 2 percent chance of occurring in any given year, in the Agana Bay area is calculated to be 11.4 feet above mean sea level. Most of the Anigua-Agana floodplain lies at elevations ranging from 7 to 10 feet above MSL, the Marine Drive area of Apurguan about 6 to 7 feet above MSL, and the residences of Dungca's Beach 4 to 7 feet above MSL. Even a 10-year storm event with maximum flood levels of about 8.4 feet (MSL) could inflict significant damage in the Tamuning shoreline area.

b. Floodplain Management. Floodplain management is an overall program of corrective and preventative measures for reducing flood damage, preserving the natural and beneficial uses of the floodplains, and minimizing the impacts of floods on human safety, health, and welfare. The program should be developed according to the nature of the flood problem to include actions or measures of several kinds: (1) structural actions to modify the flood itself by controlling the storm surge flow; (2) nonstructural actions to reduce the susceptibility of life and property to flooding by modifying individual damageable structures or their immediate setting or by otherwise regulating damageable property as a general class; and (3) actions to expedite the recovery from flood damage in the short and long term. Only structural and nonstructural measures are discussed here.

c. Range of Measures. Possible measures range from:

Structural

Flood modifications including surge diversion by breakwaters and dikes, levees or seawalls;

Nonstructural

(1) Development policies including open space, renewal and redevelopment, and relocation of sewers and utilities;

(2) Land-Use Regulation including disclosure, subdividing regulation, housing codes, building codes, and zoning;

(3) Flood Proofing including elevating structures, land fill, modifying buildings, and relocations;

(4) Flood Warning including evacuation plans, storm warning systems, and storm watches; and

(5) Disaster Plans including flood fighting and life saving, emergency shelter, and medical and health.

d. Implementability. Many of the structural measures and nonstructural floodproofing measures may be impracticable, too costly, or have unacceptable environmental impacts. Many other nonstructural measures may be difficult to implement because of local political and social constraints. The most appropriate measure, or preferably mixture of measures need not be limited to the institutional capability of the US Army Corps of Engineers. Likewise, plans should not have to be justified by the current benefit-cost ratio methodology. The nature of flood-hazard mitigation planning is to develop plans which might be entirely or mostly implemented at the local level with different sources of funding such as use of disaster funds, payment of flood insurance claims and other special Federal flood insurance programs. A preliminary screening of possible alternatives should eliminate obviously inappropriate plans prior to detailed analysis.

4. PRELIMINARY SCREENING OF ALTERNATIVES.

a. Structural Measures.

(1) Offshore Breakwaters. An offshore breakwater is a structure designed to protect an area from wave action. It is usually designed to dissipate wave energy that would normally strike the shore and cause erosion. Breakwaters are not designed to be impermeable. To be effective in meeting the planning objectives, an offshore breakwater would need to be designed to prevent overtopping under design wave and surge conditions. A 15-foot high structure could keep abnormally raised seas from flooding the Agana Bay coastal floodplain, but would cost an estimated $2,775 per linear foot (LF). This was calculated using current costs and Agana Small Boat Harbor design criteria, at the rate of $126/LF for the causeway, $255/LF for the core (100 lb spalls), $375/LF for the underlayer (0.5 to 1.0 ton stone), and $1,464/LF for the armor layer (4.0 to 6.0-ton stone), plus a contingency of 25 percent. A segmented breakwater system would not be effective in diverting storm-surge flows, although it could reduce the volume of water entering the lagoon and thus lower the still-water level near the shoreline. Such a structure, even if segmented, would severely restrict water circulation within the reef flat, thus degrading water quality there even further. The reef-flat ecosystem would be partially or nearly completely destroyed and with it, most of the lagoon's present recreational usefulness. The direct exposure of the breakwaters to the deep ocean swell on the breaking on the reef front would make them inhospitable to commercial or industrial development, without a suitable buffer zone and various floodproofing measures. Design, environmental, and cost constraints eliminate massive offshore structures from further consideration from the standpoint of likely Federal involvement. It is possible that a limited number of segmented offshore breakwaters or revetted islets could be designed and located to minimize adverse environmental effects and still contribute to the recreational enjoyment of the bay as well as providing very limited protection against storm-surge flooding.

(2) Seawalls. A seawall is a structure separating land and water areas which may be designed to prevent both erosion and storm-surge flooding, such as the famous seawall protecting Galveston, Texas. The stability of a seawall against wave and earth forces depends on its massive weight (concrete-rubble masonry). The facing is generally vertical or a steep slope. To be effective against the maximum breaking wave of 12.3 feet (MSL), a seawall fronting Agana Bay shoreline would rise 6 to 9 feet above the foreshore crest. This would be a severe aesthetic intrusion blocking most views of the bay, particularly from private residences. The near vertical face, with its poor wave energy dissipation capability, would tend to cause increased seaward and downstream erosion. Thus, seawalls are not recommended to protect individual properties within the Flood Insurance Rate Map (FIRM) V-zones. For these reasons, and its likely high cost, this alternative was not considered as a viable plan.

(3) Beach Fill or Dune Enhancement. Beach fills are quantities of sand placed on the shoreline by mechanical means. Beach fills provide some protection against erosion, but would be high enough to divert even a 10-year storm-surge event. They have relatively low initial costs, but require a regular maintenance cost of adding new fill (periodic nourishment). Short lengths of fill may also stimulate downstream erosion. Beach fill with dune enhancement or with existing high shoreline topography could also provide some protection against storm-surge flooding, as well as beautifying the shoreline landscape. Dunes provide a natural shoreline defense against storm-wave and storm-surge attack. Well vegetated dunes are surprisingly tolerant to short-term wave attack and brief overtoppig by storm surges (Woodhouse, 1978). There are no obvious backshore dunes along the Agana Bay shoreline, but the 10 to 11-foot ridge along Dulce Nobre de Maria Drive in Anigua, seaward of Marine Drive may be a remnant dune ridge. In the long-term future, with an Open Space land use designation for this area, dune enhancement may provide a viable alternative in conjunction with other measures to protect other parts of the Agana Bay floodplain. This alternative will be discussed in more detail.

(4) Levees. For the purposes of this report, levees are linear structures located inland of the foreshore beach crest. Levee structures divert the flow of water and usually protect large areas. In the Agana area, continuous levees would have lower construction costs than shoreline seawalls because of their lower height on higher topograph results in a smaller volume of materials. On the otherhand, costs of land could be higher further inland. Also to be considered are the tangible and intangible costs due to possible relocation of residents, businesses or historic sites. Levees are considered in more detail here because a partial levee system could tie into existing topography and be combined with other nonstructural flood damage reduction measures and with other planned flood control measures (see Section B8 above).

b. Nonstructural Measures.

(1) Development Policies.

(a) Development policies provide long-term, future-oriented objectives for the general distribution and location of various land uses. To minimize uneconomic risk of losses to property and life, long-range accommodations in development choices must be made in advance, and then enforced by government regulations. Guam's current floodplain management development policies are summarized in the Guam Coastal Management Program (1979) as follows:

(i) SHORE AREA DEVELOPMENT--Only those uses shall be located within the Seashore Reserve which enhance, are compatible with or do not generally detract from the surrounding coastal area's aesthetic and environmental quality and beach accessibility; or can demonstrate dependence on such a location and the lack of feasible alternative sites.

LOCAL IMPLEMENTING AUTHORITIES--PL 12-200, Territorial Seashore Protection Act, Territorial Beach Areas Act, and Zoning Law.

(ii) HAZARDOUS AREAS--Identified hazardous lands including floodplains and erosion prone areas shall be developed only to the extent that such development does not pose unreasonable risks to the health, safety, or welfare of the people of Guam, and complies with land use regulations.

LOCAL IMPLEMENTING AUTHORITIES--PL 200-12, Zoning Law, Seashore Protection Act, and Subdivision Law.

(iii) HOUSING--The government shall encourage efficient design of residential areas and restrict such development in areas highly susceptible to natural and man-made hazards.

LOCAL IMPLEMENTING AUTHORITIES--PL 12-200, Zoning Law, Seashore Protection Act, Subdivision Law, Territorial Beach Areas Act, Land-Use Districts, and Flood Hazard Area Rules and Regulations.

(b) Nearly all of the inland portions of the 100-year storm-surge floodplain is now zoned Commercial or Medium-High Density Urban Residential. None of these Urban land-use classifications contain development policies which would reduce or avoid storm-surge flood damages, except indirectly, by encouraging improved visual access and an ordered mix of high and low density uses in the urban zone, and by planning for centralized commercial areas in the Commercial zone. Any land areas in present Recreation or future Open Space will reduce potential damages, but may require specific and implementable urban renewal or redevelopment policies and programs to achieve such potential damage reductions.

(c) These nonstructural flood-damage reduction measures can only be implemented by the Government of Guam. As previously mentioned, the Guam Bureau of Planning is preparing a redevelopment plan for the East Agana waterfront businesses. Further consideration of development policy measures will be deferred at this time.

(2) Land Regulation.

(a) Zoning. The Zoning Law, Govenment of Guam (GCG) Title XVIII, is enforced by Department of Public Works building officials, and by the Territorial Planning Commission (TPC) on appeal. The Zoning Law is implemented if a building permit is needed or another Territorial Agency license. Only Urban districts are regulated. It is not related to designation of land-use zones. Section 17300(c) and (d) of the GCG prohibits the repair or reconstruction of any structure damaged by flood or other calamity which will cost more than 50 percent of its value at the time of such damage. Section 17203(b) (GCG) prohibits construction of any buildings with 35 feet (slightly over 10 meters) of the mean high watermark (mean higher high tide) bounding a beach. It also limits the height of any new buildings within 75 feet of that watermark to no more than 25 feet. The shoreline residences of Apurguan and Dungca's Beach may be exempt from that latter Section.

The Zoning land-use regulatory mechanism is supplemented by other provisions of GCG and the Governor's executive orders covering the Seashore Reserve, Flood Hazard Areas, and the Guam Coastal Management Program (GCMP).

Implementation and enforcement of the Zoning Law is under local control, but in the long term would be a component of any overall storm-surge floodplain management program. No further consideration to Zoning Law is appropriate at this time.

(b) Seashore Reserve. The Guam Territorial Seashore Protection Act of 1974, as amended (GCG Sections 13410-13420) restricts development on that land and water area seaward to the 10 fathom (60-foot) contour--the entire Agana Bay lagoon)--and currently 10 meters landward from the high water mark or to the inland edge of a public right-of-way. The V-zone under the FIRMs and shown on Figure 7 encompasses the seashore reserve. Similar to the Zoning Law, this Act prohibits reconstruction of any buildings having incurred more than 50 percent of its value from flood damages. It originally provided for a setback of 100 meters, but pressure from homeless shoreline residents after the 1976 Supertyphoon Pamela caused the Guam Legislature to drastically reduce the setback to the 10 meter limit. The amendment also exempted homeowners from the Seashore Act provisions if their homes were destroyed in any future storm event. Guam Coastal Management Program's policy proposes to locate only those uses within the Seashore Reserve which can demonstrate physical dependence on such a location and a lack of feasible alternative siters. The Act provides for a review of any development by the Territorial Seashore Protection Commission, functionally identical to the Territorial Planning Commission. It assures that access to beaches, recreational and historical areas is maintained; ocean views are not obstructed; and minimal dangers from floods, landslides and erosion are created. Implementation of this Act is a local responsibility and as originally enacted, it would have been the cornerstone of any floodplain management program designed for reducing damages from storm-surge flooding. The amendments have weakened the Act's effect in the Agana Bay shoreline area, but fortunately, many of its provisions are covered under the Flood Hazard Area regulations. Further consideration of this measure is deferred at this time.

(c) Flood Hazard Area Regulations. Restrictions on rebuilding flood-damaged residences are now enforced by the 1978 Executive Order 78-20 which established the Flood Hazard Area of Particular Concern (APC) under GCMP and established guidelines and standards for management of flood hazard areas. The entire 100-year storm-surge floodplain is by definition now within this Flood Hazard APC and is also delineated a Special Flood Hazard Areas on the draft FIRM. This document is incorporated by reference here. The FIRM and Flood Boundry Map (FBM) are expected to be adopted in 1984. The purpose of these regulations and a summary of their relationship to storm-surge flooding are provided in the Technical Appendix B. Some of the regulatory standards would require all approved developments within the hazard area to be floodproofed and the lowest floor of approved structures elevated above the maximum flood elevation. Seawalls cannot obstruct public access, cause shoreline erosion, or impair visual quality. Development must make as few changes as possible to the floodplains flow characteristics. Basically, these regulations must be followed for a "development" to be issued a Flood Hazard Area building permit. Current uses are defined as legal nonconforming uses and generally do not require permits. This nonstructural measure does not reduce flood hazard damages, but rather lessens the economic burden of flooding and encourages floodplain restrictions. This locally-controlled measure is most effective when complemented by other structural or nonstructural alternatives and would be an integral component of any overall storm-surge floodplain management program.

(d) Setbacks. Each of the above nonstructural measures uses the "setback" concept. There are four bases for setbacks: first, "untrammeled (public) use of beach areas beyond the high water mark" (Zoning and Seashore Reserve Acts); second, reduction of tidal water pollution (same references); third, US PL 93-435, "Guam, Virgin Island, American Samoa--Land Jurisdiction," enacted October 5 1974, which reserved to the Government of Guam all lands (now or formerly) permanently or periodically covered by tidal waters; and fourth, degree of potential flood damage. In other shoreline environments, historical records of erosion would provide a basis for delineating appropriate setback limits. Along Agana Bay waterfront, exact determination of the FIRM V-zone perhaps could be adapted for setback determination. For any particular structure, monetary and nonmonetary flood damages are likely to be greater in the V-zone, flood insurance rates are highest there, and there are more restrictive building codes for new or substantially-rebuilt structures there (see Floodproofing below). Strict enforcement of setbacks would reduce prized developable land, but long term potential economic losses to the public and government due to damages would be reduced. Development and enforcement of setback regulations are a local government responsibility, and would be a component of any overall storm-surge floodplain management program. They will be considered in later planning stages.

(e) Flood forecasting, warning, and temporary evacuation. The effectiveness of these measures are a direct function of the time to react coupled with a belief by the floodplain residents in the accuracy of the forecast or warning. While lives can be saved, little can usually be done to reduce storm-surge damage to structures unless some type of flood diversion has been provided or floodproofing has been incorporated. Flood warning would provide the maximum time to operationalize diversion structures, if appropriate, and to implement floodproofing measures to homes and other structures and then to evacuate. The "Guam Flood Hazard Mitigation Plan," prepared by the Civil Defense/Guam Emergency Services Office in August 1982, identifies flood prone areas, describes the origanization of and division of responsibilities for emergency operations, addresses inter-departmental coordination on monitoring future development with flood-prone areas, and proposes a public awareness program aimed at minimizing flood losses. These nonstructural measures would become a component of any overall storm-surge floodplain management program and will be considered in later planning stages.

(f) Floodproofing. The alteration of a structure or of conditions surrounding a structure to prevent damages by floodwaters is known as floodproofing. Typical methods are (i) raising the first floor elevation above the flood level; (ii) installing waterproof panels and sealing around opening; and (iii) providing walls or levees around the building. Different floodproofing methods apply according to the flood zone. In V-zones, National Flood Insurance Standards require that fill not be used to raise a structure above the flood elevation. In all areas, raising a structure that is built slab ongrade is usually uneconomical and structurally unpractical. Stability limits how high a structure can be raised. Sealing and waterproofing are only applicable to buildings that can sustain the hydrostatic pressure and the drag force exerted by floodwaters. The latter factor is particularly significant in the V-zone. Using walls or levees to floodproof individual properties can be unsightly and expensive due to the need to provide interior drainage. Floodproofing appears to be a viable and implementable nonstructural measure and will be considered in further detail.

(g) Summary. As a result of preliminary screening, it was found that floodproofing is effective only when complemented by incorporating long-term floodplain development policies and short-term land regulations, implementing effective forecasting and warning, and often effective in complementing structural measures. Among structural measures, no further study was warranted for seawalls or for offshore breakwaters, but further studies were deferred at this time for dune enhancement and beach fills. Inland levees will be considered further. Among nonstructural measures, all of the measures should be considered components in an overall storm-surge floodplain management program, which would become part of any possible Federal involvement. Yet all these nonstructural measures, except for floodproofing, are purely local governmental responsibilities in developing and enforcing. Floodproofing may warrant Federal Government interest.

E. PRELIMINARY ASSESSMENT AND EVALUATION

Based on the identified problems and needs, the planning objectives, and the formulation and evaluation concepts, and after preliminary screening, two plans were developed which address the total bayfront, a purely nonstructural plan and a mix of structural and nonstructural measures.

1. PRELIMINARY NONSTRUCTURAL PLAN (Alternative 1A).

a. Description. (see Appendix C).

(1)

(a) Modifications would be made to 454 structures. These modifications would include 124 structure removals, 144 structures fitted with temporary or permanent closures, 30 structure raises, 152 relocations of goods within a structure, and 4 ringwalls constructed. This plan was developed with the design storm being a typhoon having a storm surge of 6 feet (MSL) and inland flooding (runup) to the 12-foot contour (MSL). This is approximately equal to the 100-year typhoon-generated storm-surge flood event.

(b) Although the Government of Plan plans to remove or cause to be abandoned many if not all of the East Agana waterfront structures in the near-term (1-5-year) future as a result of highway widening there, this floodproofing plan includes these structures for the benefit of local planning efforts. As these floodproofed structures sustain damages to more than 50 percent of their current value or are destroyed, they should not be allowed to be rebult, in compliance with existing Guam laws and regulations. Or at a minimum, they must be rebuilt in conformance with National Flood Insurance Program construction criteria.

(2) This plan was developed using the following assumptions:

(a) Wood frame on post and beam structures can be easily raised.

(b) Wood frame on concrete slab structures can be raised, but only with special equipment and at a high cost. It is more economical to demolish the old structure and build a new structure.

(c) A poured concrete wall can withstand a high hydrostatic load, however, the concrete slab is assumed to buckle under a hydrostatic head of 2.5 feet.

(d) Metal and wood frame structures cannot be made watertight enough to use either temporary or permanent closures.

(e) Removal for this study is the demolition of the existing structure and the building of a new floodproofed structure on the same site.

(f) Any abandoned structure is removed and not rebuilt.

(g) Relocation of goods means their elevation within the structure to level above the base flood or their removal to a different location outside the floodplain.

(3) Because of expected heavy wave action in the V-zone, some special assumptions were made for the area about 200 feet inland of mean sea level. The difference between the 200-foot zone and the V-zone shown on the FIRMs will be resolved in subsequent planning. These assumptions are that removal means demolition of the structure and construction of a new floodproofed structure on a new site outside the V-zone; and that no structure will be raised in the V-zone.

(4) The tables in Appendix B present the nonstructural plan on a structure-by-structure basis. The plan is broken down into reaches only for the ease of locating a structure; it in no way implies that the plan can be enacted a part at a time, except possibly in conjunction with structural measures which provide similar protection.

b. Preliminary Cost Analysis.

(1) The cost of building certain nonstructural protection measures was based on prevailing unit construction costs in Guam as of March 1983. These costs reflect the average construction costs within the design constraints and assumptions given. Not included in the cost estimation is the purchase price of lands for removals in the V-zone. Also, the specific construction costs for any single structure may vary from the given values because of location or condition of the structure.

(a) Raised Structures. The total cost of raising a structure is based on the premise that a 2.0-foot raise costs $6.40 per square foot of structure. For each foot of raise over 1.0 feet, add $0.77 per square foot of structure.

(b) Closures. The cost of providing cover panels is based on shop fabrication of components from standard aluminum sheets and shapes. Units would be prefabricated and then fitted on the jobsite. The cost for this work is estimated to be $74 per square foot of panel surface.

(c) Removals. The cost to remove an existing structure and replace it with a new floodproofed structure is $56 per square foot of structure. Additional costs are $0.83 per square foot for moving and temporary storage of the structure's contents, and $4,000 for temporary quarters. Land costs for removals from the V-zone are not computed.

(d) Relocation of Goods. The cost to relocate goods within structures are as follows:

1,000 sq ft:.	$2,000
1,001-5,000 sq ft:	$2,000 + $1.65/sq ft over 1,000 sq ft
5,001-10,000 sq ft:	$8,000 + $1.10/sq ft over 5,000 sq ft
10,000 sq ft:	$13,000 + $0.83/sq ft over 10,000 sq ft

(2) The cost for the floodproofing elements of Alternative 1A is as follows:

TABLE 6. ALTERNATIVE 1A PROJECT FIRST COSTS

Action	Number of Structures	Costs
Ring Wall	4	$1,113,200
Closures	144	361,300
Removals	124	12,799,400
Raise Structures	30	362,200
Relocate Goods	152	1,017,400
Subtotal		$16,653,500
15% Contingency		2,348,000
Total Direct Costs		$18,002,500
15% Indirect Costs (Engrg & Design/Admin & Supervision		2,700,400
TOTAL		$20,703,000

c. Average Annual Cost. The average annual cost for the purposes of the benefit-to-cost comparisons include interest (i = 8.125%) and amortization (n = 50 years) of the project first cost. Average annual maintenance is calculated at 1/2 percent per year.

TABLE 7. ALTERNATIVE 1A AVERAGE ANNUAL COSTS

Project First Cost ($)	$20,703,000
Average Annual Cost	1,716,700
Average Annual Maintenance Costs	10,400
TOTAL ESTIMATED AVERAGE ANNUAL COSTS	$1,727,100

2. PRELIMINARY STRUCTURAL/NONSTRUCTURAL PLAN (Alternative 1B)

a. Description.

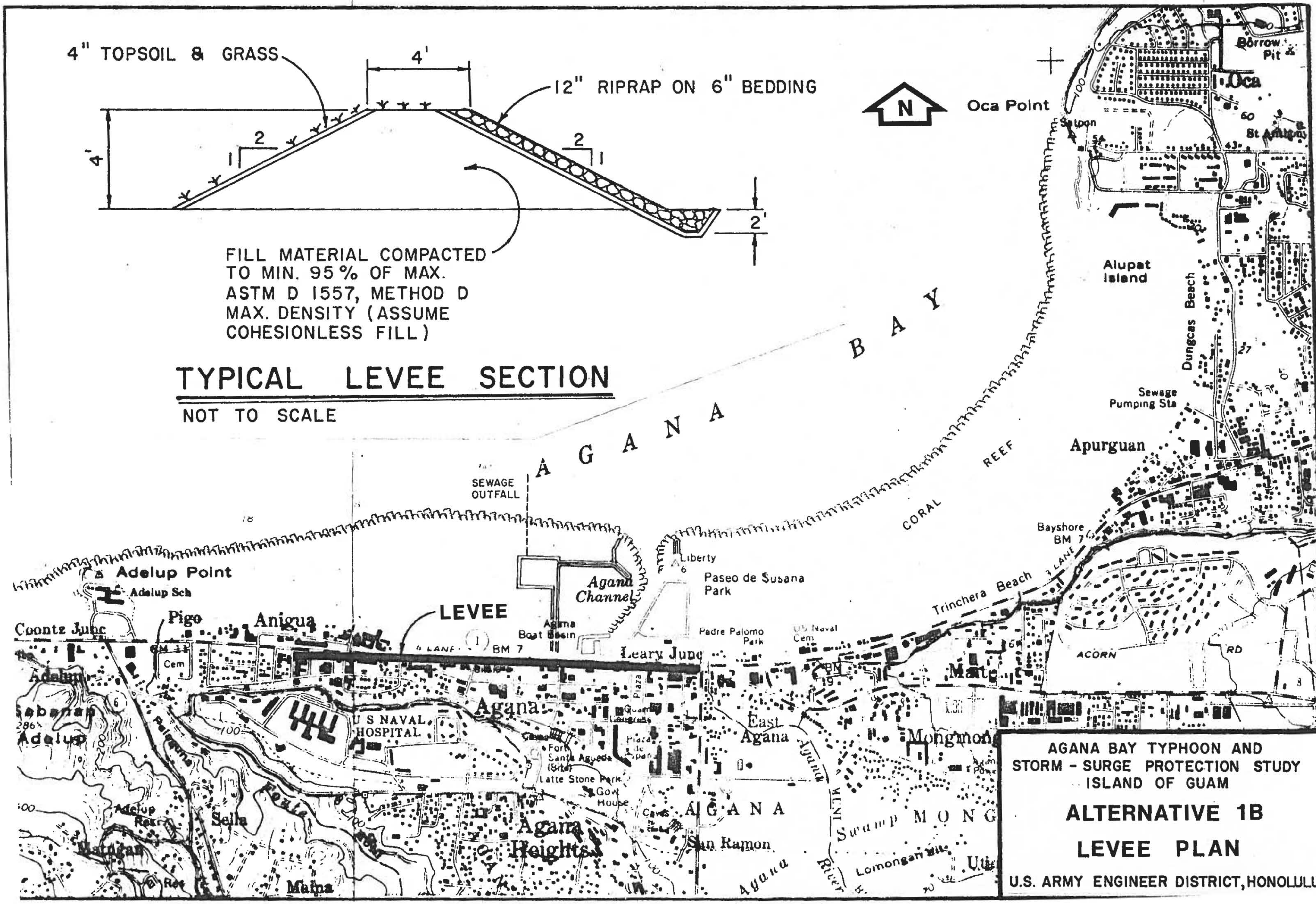
(1) This plan comprises two components, an inland levee and floodproofing, both taking advantage of existing topography to minimize the need for costly structures. This plan also assumes that Fonte River is channelized to protect Western Anigua against a 100-year riverine flood, downtown Agana is provided an interior drainage system, and the planned Agana River flood control project is constructed (see paragraphs B8 and D2b(2) above).

(2) Given the above assumptions, many of the residences and commercial structures in the A-3 and B FIRM zones of Anigua are naturally protected against storm-surge flooding by the 10 to 12-foot high Marine Drive in eastern Anigua and the approximately 10 to 11-foot high ridge or remnant sand dune running along Dulce Nobre de Maria Drive in west-central Anigua. Both these topographic features act as natural levees. Little or no floodproofing could be required for the structures south of these natural barriers. Structures seaward of Marine Drive and Dulce Nobre de Maria Drive would be floodproofed. None of those in the V-zone would be relocated immediately, but as these and all other houses in the V-zone are destroyed or heavily damaged by flooding or other causes, or otherwise abandoned, existing land-use regulations including the Zoning Act, Shoreline Reserve Act, Flood Hazard regulations, and Coastal Management Program regulations should be enforced, regarding reconstruction. This would assure that future land use in these areas is compatible with existing long-term Guam Open Space development policies, or as applicable, the ABUWR Plan.

(3) The structural component of this Alternative 1B consists of a 6,750-foot long and approximately 4-foot high trapazoidal levee. The levee would be located along the inland boundary of Marine Drive over an existing strip of green space stretching westward from the Paseo Loop and north of West Soledad Avenue. It would continue westward through a stretch of swale and parking area from Hernan Cortez Avenue to Aniceto Street (Figure 8). Design of the levee assumes minimal storm-surge velocity or wave action due to the partial protection of the 7.5 to 8.5-foot heights of Marine Drive in Agana and the 9.0 to 11.0-foot heights of Marine Drive and Dulce Nobre de Maria Drive in Anigua. More detailed engineering design will be performed in the next planning stage.

(4) Closures at through roads would be provided by timber or concrete gates which could be installed at the last moment before a storm struck Guam. The levee would be landscaped to serve as a green-space buffer park between the noisy Marine Drive and the quieter commercial areas.

(5) Alternatively, should the West Agana Bay luxury liner port area be constructed, a raised and revetted port backup area along the present Bayside Park area could provide similar protection against storm-surge flooding in Agana, making a levee unnecessary. It would need to be extended westward, perhaps through a similarly protected consolidation of businesses at the present Ace Hardware site, as envisioned by the ABUWR Plan, thus tying into the 11-foot high Dulce Nobre de Maria Drive in Anigua. This option is not costed out.



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ALTERNATIVE 1B

LEVEE PLAN

U.S. ARMY ENGINEER DISTRICT, HONOLULU

(6) The remainder of Alternative 1B consists of the floodproofing measures outlined in Alternative 1A for the structures in East Agana, Trinchera Beach, Apurguan/Tamuning, and Dungca's Beach. No barriers were formulated to protect the waterfront structures in East Agana because of Government of Guam short-term (1-5-year) plans to remove them or cause them to be abandoned in conjunction with the planned highway widening project. Under Alternative 1B, floodproofing was included for these for local planning purposes.

b. Preliminary Cost Analysis.

(1) The floodproofing costs have the same assumptions and cost elements as Alternative 1A. The levee costs do not include land acquisition or mobilization and demobilization.

(2) Project first costs for Alternative 1B are summarized in Table 8:

TABLE 8. ALTERNATIVE 1B PROJECT FIRST COSTS

Action	Unit of Cost	Costs
LEVEE (Cost per Linear Foot)		
Fill	CY/LF	$19
Bedding	CY/LF	15
Riprap	CY/LF	42
Grassing	SF/LF	2
Subtotal		$78
Contingency (25%)		20
Total Direct Levee Costs per Linear Foot		$98/LF
Total Direct Levee Costs for 6,750 Feet		$661,500
	Number of Structures	
FLOODPROOFING		
Ring Walls	4	$1,113,200
Closures	50	130,600
Removals	90	9,362,800
Structure Raises	16	210,300
Relocation of Goods	70	474,600
Subtotal		$11,291,500
15% Contingency		1,693,700
Total Direct Floodproofing Costs		$12,985,200
Total Direct Levee & Floodproofing First Costs		13,647,000
15% Indirect Costs (Engrg & Design/Admin & Supervision)		2,097,000
TOTAL FIRST COSTS FOR ALTERNATIVE 1B		$15,694,000

c. Average Annual Costs. The interest rate and amortization period is the same as Alternative 1A. Maintenance costs are calculated at the rate of 1 percent on the levee and 1/2 percent on floodproofing. These costs are summarized in Table 9 below.

TABLE 9. ALTERNATIVE 1B AVERAGE ANNUAL COSTS

Project First Costs	$15,694,000
Average Annual Costs	1,301,000
Average Annual Maintenance Costs	71,500
TOTAL ESTIMATED AVERAGE ANNUAL COSTS	$1,372,500

3. PRELIMINARY ECONOMIC EVALUATION ANALYSES.

a. Benefits are calculated as the difference in average annual damages to the structures and contents in the storm-surge floodplain between the "with-" and the "without-project" conditions. Benefits derived from emergency and business costs avoided, enhancement of property values, increased recreational usage, and prevention of loss of historical or scenic aspects of the environment have not been calculated in the preliminary stage of planning. Average content and structure values are based on those values of a similar community in Hawaii (Hilo urban center) which were surveyed in detail for the recent Alenaio Flood Damage Reduction study. These values do not include highways, streets, utilities, public parks, or the small-boat harbor facilities. The level of detailed economic analysis carried out for this preliminary study was limited to damageable units only to the +10-foot (MSL) contour, based on early study estimates to the 100-year storm-surge flood level. Thus, there may be more unaccounted damages. No residual damages were calculated.

b. Based on 10-foot flood elevations, which is equivalent to a typhoon-generated storm-surge flood event likely to occur more often than 2 percent in any given year (10-year and 50-year event), there are 465 damageable units, with first floor elevations below 10 feet (MSL). Of these 465 units, 164 (or 35 percent) are residential units and 301 (65 percent) are nonresidential commercial units. Of the residential units, 44 or 27 percent are located in the V-zone and 120 units or 74 percent are in the A, B, or C FIRM zones. A similar breakdown prevails for nonresidential commercial structures with 28 percent (85) in the V-zone and 72 percent (216) in the A, B, and C zones. For the purposes of this preliminary economic analysis, the V-zone was assumed to be anywhere seaward of Marine Drive or Camp Watkins Road. This overstates the reality. The values of these units are shown in Table 10.

TABLE 10. TOTAL MARKET VALUE OF RESIDENTIAL AND NONRESIDENTIAL UNITS (MILLIONS OF $)

	Market Value		
	Structure	Contents	Total
Residential 164 Units	$11.5	2.3	13.8
Nonresidential 301 Units	16.6	23.2	39.8
	$28.1	25.5	53.6

c. Damage Data

(1) Damage data for inundation to the +10-foot storm-surge flood elevation (MSL) were calculated for the purposes of Federal Flood Insurance studies in July 1983. They were found to exceed $10.5 million of structure damages and $19.3 million of content damages, totalling $29.8 million. These figures are spread out in Table 11. Average annual damages in the "without-a-project" condition would amount to $652,600 in structure value and $1,158,300 in content value for a total of $1,811,000.

TABLE 11. DAMAGE DATA FOR RESIDENTIAL AND NONRESIDENTIAL STRUCTURES AND CONTENTS (DAMAGE ESTIMATES IN $1,000)

Recurrence Interval	Structure Damages	Content Damages	Total Damage
10	1,745	2,642	4,387
50	9,296	16,854	26,150
100	10,538	19,296	29,834
500	11,600	20,095	31,694

(2) These damages were then broken down into two segments: Those damages which would be incurred in the "without-a-project" condition in the Anigua-Agana area proposed for levee protection and in all other areas of the Agana Bay 100-year typhoon-generated storm-surge floodplain. Damage data by frequency of a typhoon-generated storm-surge event are summarized on Table 12. Average annual damages in the "without-a-project" condition would amount to $186,400 in structure damages and $508,300 in content damages for a total of about $695,000.

TABLE 12. DAMAGE-FREQUENCY DATA FOR ANIGUA-AGANA RESIDENTIAL AND NONRESIDENTIAL STRUCTURES

Recurrence Interval	Structure Damages	Content Damages	Total Damage
10	527,000	1,263,000	1,790,000
50	2,633,000	7,358,000	9,991,000
100	2,993,000	8,353,000	11,348,000
500	3,303,000	8,593,000	11,896,000

Damage frequency data for all other areas subject to the 100-year typhoon-generated storm-surge flood is summarized in Table 13. Average annual damages to these other structures would amount to $466,200 for structure value and $650,000 for content value for a total of about $1,116,000.

TABLE 13. DAMAGE-FREQUENCY DATA FOR OTHER RESIDENTIAL AND NONRESIDENTIAL STRUCTURES

Recurrence Interval	Structure Damages	Content Damages	Total Damage
10	1,218,000	1,380,000	2,579,000
50	6,663,000	9,496,000	16,158,000
100	7,543,000	10,943,000	18,486,000
500	8,296,000	11,502,000	19,798,000

4. PRELIMINARY BENEFIT TO COST COMPARISON.

Based on these cursory-level cost and benefit analyses, taking into consideration the various limiting assumptions, the following Table 14 summarizes the benefit and cost data for the two alternatives.

TABLE 14. BENEFIT TO COST COMPARISONS (100-YEAR PROTECTION)

	Alternative 1A Floodproofing	Alternative 1B Levee/Floodproofing
First Costs		$15,694,000
Average Annual Cost (w/Maintenance) 1/	$1,727,100	1,372,500
Average Annual Benefit from Damage Prevention	1,811,000	1,811,000
Benefit/Cost Ratio	1.05	1.3
NET BENEFITS	$83,900	$438,500

1/ Average annual damages are considered equivalent to average annual benefits from damage prevention for these preliminary calculations. The residual damages have not been calculated, but are believed to be small.

5. PRELIMINARY ENVIRONMENTAL ASSESSMENT.

a. Terrestrial Environment.

(1) Neither of the two preliminary alternatives would have any direct and immediate significantly adverse effects on terrestrial flora or fauna. Some gardens and other landscaping around existing structures could require removal to construct ringwalls, install closures, or raise buildings under both alternatives. Consideration should be given to selectively landscaping around newly floodproofed buildings.

(2) Effective landscaping can retard erosion and increase ground stability to prevent undermining of foundations and new protective structures. The root systems of grasses, ground cover, shrubs and trees hold loose soil and rock together, greatly retarding erosion. When subject to inundation, certain species of ground cover can be capable of withstanding the turbulence and pounding action of storm surges and breaking waves. If the levee under Alternative 1B is landscaped appropriately with grass, shrubbery, and trees, it would replace in kind the existing landscaped buffer zone between Marine Drive and West Soledad Avenue and create a new landscaped buffer strip in eastern Anigua.

(3) In the long term, creation of open spaces along the shoreline under provisions of the floodproofing elements of both plans would significantly enhance this strand environment by allowing the natural vegetation to regrow or by creation of purposeful landscaping. New vegetation would create new habitat for shorebirds. The vegetation should preferably be carefully landscaped with salt- and wave-resistant plants to reduce erosion and reduce post-disaster vegetation debris. Wave resistant trees are usually those with characteristically low growing or shrublike forms, with deep, strong rooting habits. Multi-trunk trees and shrubs, or those having branching habits very low to the ground are desirable. Planting of shrubs and smaller tree types should be in masses or thickets, with as many rows as possible to gradually slow and remove water-borne debris from flood waters.

b. Water Quality. The floodproofing components common to both alternatives could have short-term, temporary adverse effects on water quality in nearshore waters from erosion of soil into streams, stormwater ditches, or directly over the beach resulting from construction of ringwalls, structure raises and structure removals. In the medium to long-term future, creation of open space or parks in the V-zone now occupied by damageable residences or commercial buildings should slightly reduce the volume of stormwater runoff. Nevertheless, the most severely polluted stormwater runoff is coming from upland areas outside the storm-surge floodplain.

c. Marine Environment. Neither of the alternatives would have any direct effects on the quality of the marine environment in the short- to medium-term (5- to 20-year) future. Long-term secondary effects of creation of open spaces or parks along the shoreline now occupied by damageable structures may result in more people visiting the beaches and overexploitation of the reef flat environment and declining populations of bivalve mollusks in the two seagress beds in Alupang Cove and offshore Anigua.

d. Historic Sites. Certain of the residences in Agana recognized as having historical or historically architectural value would be adversely affected by implementation of the floodproofing elements under both alternatives. Table 15 lists those houses to be affected. None of the houses recommended for nomination to the National Register of Historic Places actually have been nominated or listed yet. Closures for historic houses would need to be carefully designed to avoid unnecessary modification to the outside appearance of the structures. The removal actions proposed for the Dungca and Mr. Mesa houses, which are both recommended for National Register nomination will be reassessed for alternative, appropriate floodproofing methods. Under Alternative 1B, the Dungca House would be protected by the levee and require no modification. None of the other historic sites, including several listed on the national Register (see Appendix C), will be affected by either alternative.

TABLE 15. EFFECTS OF FLOODPROOFING ON HISTORIC SITES

Structure No.[1]	Site Description[2]	Historic Site No.	Significance Recommendation	Type of Structure	Depth of Flooding	Proposed Action
A-3	Toves House	66-01-1134	National & Guam Registers	Concrete	1.0 ft	Closures
A-9	Garrido House	66-01-1135	National & Guam Registers	Concrete	0.5	Closures
B-36	Ungacta House	66-01-1132	National & Guam Registers	Concrete	2.1	Closures
B-48	Gumataotao House	66-01-1133	Staff Files	Concrete	2.0	Closures
C-1	Shimuzu House	66-01-1033	National & Guam Registers	Concrete	2.5	Closures
C-9	L. D. Flores House	66-01-1138	Staff Files	Concrete	0.4	Closures
	Dungca House	66-01-1130	National & Guam Registers	Concrete	Abandoned	Remove
D-3	Cruz House	66-01-1142	Staff Files	Concrete	2.5	Closures
D-6	Dr. Mesa House	66-01-1141	National & Guam Registers	Wood	Abandoned	Remove
D-11	Duenas House	66-01-1139	Staff Files	Concrete	0.5	Closures
D-22	White House	66-01-1136	Staff Files	Concrete	Abandoned	Remove

1 See Figures in Appendix B

2 J. B. Jones, Architect, AIA letter, September 4, 1980, subject: Agana Historic Residences (provided by Guam Historic Preservation Officer staff, Department of Parks & Recreation)

d. Recreational Activities.

(1) Neither of the alternatives would have any direct and immediate impact on existing recreational resources or activities. The one exception is the change in character of the existing green strip running from Paseo Loop to Hernan Cortez Avenue along West Soledad Avenue. A new green strip would be created extending westward to the vicinity of Aniceto Street, which would provide new open space for noon-day picnics or siestas as well as a relaxing vista for office workers and shoppers.

(2) Strict enforcement of the Guam Zoning Law and Flood Hazard Area regulations regarding reconstruction of damaged or abandoned structures in the Seashore Reserve, and under these two alternatives, in the larger V-zone of particularly severe damage (see Figure 7) will assure the gradual creation of pockets or strips of open space in East Agana and Anigua. In these areas, the "Land-Use Plan, Guam, 1977-2000" projects Open Space and Recreation uses. Under this scenario, all existing recreational patterns including picnicking, reef fishing, jet skiing and wind surfing would continue unaffected and in the very long term, likely increase due to easier accessibility to the shoreline. For the East Agana waterfront strip area, this increase of activity could occur in the near-term future. All new Open Space and Recreation areas should be landscaped by the local government with the suggestions in paragraph 5a(2) above in mind. The local government may wish to consider enhancing existing or constructing new dunes or ridges in these areas to create an aesthetically pleasing seascape, variety in recreational opportunities, and a partial buffer to storm-surge or wave erosion. With adequate local enforcement, the overall and long-term effect of floodproofing under both alternatives would be to greatly enhance recreational opportunities, public access, and coastal vistas.

e. Socioeconomic Characteristics.

(1) An opinion survey conducted in January 1977 of local attitudes toward land use management (Bureau of Planning, 1977) found a majority of respondents feeling that residential, business and industrial development should be strictly limited along the shoreline. About 25 percent of northern residents supported changing the Shoreline Reserve from 30 feet to 300 feet (which it was originally). Coastal flooding was not mentioned, but the survey was conducted only 7 months following Supertyphoon Pamela. Thus, one could view, with reservation, these opinion as reflecting attitudes influenced by memories of major waterfront damages.

(2) Nonetheless, those residents, tenants and landowners occupying the V-zone will certainly view any attempts to relocate them, even in the indefinite future, as undesirable. Enforcement of the local Zoning Law and Flood Hazard Area regulations restricting reconstruction of buildings receiving 50 percent or more damage (than current values) will result in hardship to long-time Guamanian families who cannot readily afford to rebuild elsewhere. Small-area statistics are unavailable to determine whether those residing in the V-zone are predominantly of a lower income status or predominantly of a particular ethnic group. It is believed that many do have lower than average incomes particularly in Anigua. Redevelopment of that area, however, is only likely in the long-term future. Many of the residences proposed for eventual relocation in the Dungca's Beach region are large, slab-on-grade structures giving the appearance of relatively high-income owners. Relocation of these property owners will be just as undesirable, but comparatively less of an economic burden.

(3) Land and structure values of those homes and commercial buildings receiving floodproofing should rise in comparison to other shoreline structures without floodproofing. The softer real estate values in the V-zone that one might envision occurring because of projected downzoning may not in fact soon come about because of their perceived low probability of occurring in the near future, given the political realities of Guam.

(4) A recent research study, "Relocation as Process: A Social Psychological Perspective," was completed by Dr. Annabelle Motz for the Corps of Engineers' Institute of Water Resources (January 1983). A long series of possible effects of the planning for relocation, the move, and post-move adjustment are posited. In later planning stages, an examination of this study in relation to Agana will be conducted in order that a socially and economically equitable relocation program can eventually be developed.

f. Land Use.

(1) There would be effects on land usage as a result of implementation of floodproofing under both alternative plans, however, the effects in regards to land use in the shoreline V-zone will be diffused by time and perhaps weakened by political realities. The long-term relocations or abandoning of shorefront properties is mainly dependent on local implementation and enforcement of the existing Zoning Law (GCG, Section 17300) and Flood Hazard Area regulations (EO 78-20). Any near-term changes in land use in the East Agana Bay waterfront strip are more likely to occur because of the Government of Guam's highway widening project than as a result of storm-surge floodplain management measures. Nevertheless, these studies may provide the local government with some of the justification needed to implement separate redevelopment plans in that region. Whatever other uses these and the other V-zone lands are put to in the future will depend on the local government to determine through the political and planning process.

(2) Under certain circumstances, for specific buildings, it is possible that the proposed floodproofing measure could adversely affect the ability of the occupant or occupants of that building to efficiently conduct business. Such cases would have to be assessed on an individual, case-by-case basis.

(3) The future creation of new open space or park-recreation lands where their previously existing buildings and/or seawalls could result in an increase of storm-surge runup or an expansion of the V-zone of damaging wave action. Detailed studies in subsequent planning efforts will examine this possibility.

(4) Construction of the levee under Alternative 1B would use space on the southern side of Marine Drive between Hernan Cortez Avenue and Eighth Street now used for parking and a drainage swale. Alternative drainage would be needed to be provided unless drainage was built into the levee structure. Alternative sites for parking would be necessary. The siting of the levee here could also impact the proposed plans to widening Marine Drive from 5 to 7 lanes in Anigua.

g. Land-Use Plans.

(1) Both alternatives are generally compatible with the "Land-Use Plan, Guam, 1977-2000" and the "Land Use Districting Plan, Guam," except that floodproofing under both alternatives would eventually result in a strip of

open space to the 12-foot contour (MSL) inland of Dungca's Beach, where these plans now project Medium-High Density Urban Residential uses. Both alternative plans are also compatible with and complement the ABUWR Plan. Both alternatives appear compatible with the planned widening of Marine Drive between Route 8 near Paseo Loop and Camp Watkins Road, but the actual plans for that project have not been examined.

(2) Neither of the proposed alternatives are compatible with the Governor of Guam's proposed East Agana Bay project which would either dredge the bay and construct a series of offshore islands at the reef front or would fill all or most of the bay to create fastland for tourist, commercial and industrial uses (see Figure 5).

(a) The present shallow reef flat is an excellent wave energy dissipator which prevent large swell or distant storm surge from significantly impinging on the shoreline. Increasing water depth over the reef flat by dredging would increase the amount of wave or storm-surge energy that could cross the reef flat under local or distant storm conditions. A change in direction of wave approach or refraction could also occur. A combination of the two factors has the chance of increasing the frequency of shoreline change due to differing rates of erosion or accretion which may now be confined only to periods of significant local or distant storm surge. Increased wave energy reaching the shoreline during local storm conditions could also change the currently projected patterns of typhoon-generated storm-surge inundation due to changed breaking wave runup characteristics. The series of proposed offshore islands could reduce these effects, but as proposed would not significantly affect overall flooding characteristics.

(b) Filling all or most of East Agana Bay would eliminate the threat of storm-surge flooding from East Agana to Dungca's Beach, depending on the characteristics of the filled area. This same threat would be transferred to the fill area itself unless a massive seawall was constructed across the entire ocean face of the fill or the fill was elevated above the calculated storm-surge level near the reef front. This would be a different figure than the one calculated for the present shoreline region. Partially filling the East Agana Bay reef flat could result in a continuing threat of storm-surge flooding in unprotected inland areas as well as possible shoreline erosion problems.

(c) Channelizing either the East Agana Bay for recreational purposes or the West Agana Bay for construction of a deep-draft port for luxury liners would likely increase the threat of storm-surge flooding or shoreline erosion in areas immediately inland of channels. Historical analysis of storm-surge damages (Table 4) suggests this phenomena as well as the reasoning above in paragraph 5g(2)(a). Thus, the pattern of inundation in West Agana between Fifth and Sixth Avenues could change without increase shoreline protection such as an adequately designed revetted mole providing port backup facilities or a differently designed levee section.

F. SUMMARY

1. In response to requests from the Government of Guam for a comprehensive flood control study of the Agana Bay waterfront, this preliminary analysis was conducted. A current and historical review of the natural forces affecting

the Agana Bay region and its social and environmental resources found that the most significant water-resources related problem affecting the entire waterfront to be the threat of storm-surge flooding. Based on very short-term studies, shoreline erosion was found not to be a significant problem except at the Paseo de Susana Park which has been addressed by a separate report. The reef flat is very popular with local residents for recreational and subsistence fishing and clamming. It is growing in popularity among residents and tourist for jet skiing and wind surfing. Significant water quality problems exist, particularly in East Agana Bay due to excessive discharges of polluted stormwater runoff from upland industrial areas and limited circulation in the northeast part of East Agana Bay. The stormwater discharges also stimulate the growth of food sources for popular eating fish. Non-water dependent uses of the waterfront block visual and physical access to the shoreline, are unsightly and degrade the terrestrial and nearshore marine environment. They also lie in storm-surge flood zones where destructive wave action and flooding can inflict severe economic losses.

2. A joint probability computer analysis was conducted to determine typhoon-generated storm-surge flood levels. Based on the 10-, 50-, 100-, and 500-year frequency flood events and present conditions in the study area, a series of structural and nonstructural measures were screened for appropriateness in resolving the identified problems and needs. Two alternatives were developed: both involved floodproofing and one had an additional element of a levee tying into existing topography. Each plan also would depend on local enforcement of the Guam zoning law and flood hazard area regulations as well as other nonstructural measures for complete effectiveness. The purely nonstructural (primarily floodproofing) Alternative 1A was calculated to yield a benefit-to-cost ratio of 1.05. The mixed nonstructural and structural (levee) Alternative 1B yielded a benefit-to-cost ratio of 1.3.

3. Neither alternative would have significant, near-term effects on the quality of the terrestrial or marine environment, or on water quality, except for possible temporary erosion during construction of floodproofing actions. Likewise, there would be no significant near-term effects on recreational activities including public access, socioeconomic characteristics or land use characteristics, nor on land use plans. Building closures, raises and removals could adversely affect, in the near-term, six historic residences recommended for nomination to the National Register of Historic Places. The levee under Alternative 1B would be visually intrusive but would replace a green strip in kind and create new a green strip providing new, although limited recreational opportunities. Some current parking space would be lost by the levee construction. The floodproofing element common to both alternatives would have significant long-term beneficial effects on recreational activities, public access and aesthetics of the waterfront while helping achieve the goals of local land-use plans for new open space and recreation land uses along the Agana Bay shoreline. There could be long-term future pressure on reef-flat shellfish resources. Relocation of residences or other buildings from the V-(wave action)zone over a long period of time would not be popular among waterfront residents or property owners. Neither alternative would be compatible with recent Governor of Guam proposals to develop East Agana Bay.

APPENDIX A: PUBLIC INVOLVEMENT

APPENDIX A: PUBLIC INVOLVEMENT

1. There has been limited public involvement to date in identification of the problems and formulation and assessment of the alternative plans. The initial interest in a typhoon and storm-surge protection study came in the Governor of Guam's (Governor Paul Calvo) letter of July 11, 1979, reviewing the Corps Draft Stage 1 Report for the Guam Comprehensive Study. The Governor identified that stormwave damage along the Agana Bay urban waterfront "primarily involves structural damage to shoreline homes and businesses," beside the shoreline erosion problem mentioned in the draft Corps report. He also requested in a separate comment more study of flood hazard areas, including more detailed mapping, with emphasis on non-structural management measures of flood control. To support the Agana Bay Urban Waterfront Redevelopment Plan, the Governor sought the Corps' assistance in assessing seawalls, revetments, etc. within the urban waterfront to determine their impact on public access, shoreline ecology and aesthetics. He also hoped that the Corps study of seawalls would identify methods of mitigating their adverse impacts.

2. In March 1981, Corps planning staff met with Guam Bureau of Planning officials to present, in part, results of the draft Sea Engineering, Inc. report on "Shoreline Investigations: Agana, Guam," in relation to the Agana Bay Urban Waterfront Redevelopment Plan. The Guam planners reiterated earlier Bureau of Planning desires for the Corps' "participation in baseline data and planning/evaluation efforts to define the erosion and flooding concerns for the coastal area between Adelup Point and Dungcas Beach (PODED-PJ "Trip Report, 10-13 March 1981, Saipan/Guam," 18 March 1981).

3. Subsequently, on July 16, 1981, the Bureau of Planning provided review comments on a scope of work provided by the Corps for an Agana Waterfront Redevelopment Baseline and Planning Evaluation (precursor to the present analysis). They requested the following:

a. Recommendations be made for minimum setback limits from the high water line within the study area;

b. Silitation be examined for sources, seriousness of the problem, and recommended remedial actions;

c. Sleep Lagoon (Alupang Cove) be included in the study area;

d. Tidal flow impedence caused by the Alupang Island causeway be examined and options discussed;

e. Cost estimated be provided for any projects recommended;

f. Recommendations for the following erosion problem areas mentioned by the agencies be formulated:

(1) the area west of the Agana River mouth,

(2) the area around the access channel to the Agana Boat Basis; and

(3) the east coastal margin of the Paseo de Susana Park.

4. Setbacks are examined in this report and preliminary costs were provided for the two preliminary alternative plans. . The area of Sleepy Hollow is also addressed, but no detailed study of the Alupang Island causeway was conducted. The impact of siltation from storm drains is being investigated by the Guam Environmental Protection Agency. The erosion problems have been addressed in the Detailed Project Report and Final Environmental Assessment for Paseo de Susana (October 1983).

5. Government of Guam Agencies and random members of the public were consulted by the study manager in March 1983 during a field investigation conducted to gather information for this report.

6. Results of the Preliminary Draft Agana Bay Typhoon and Storm-Surge Protection Study will be presented at a public workshop held January 27, 1984 at the Guam Civil Defense Conference Room.

APPENDIX B: TECHNICAL ANALYSES

TABLE 1

ANNUAL PERCENT FREQUENCY OF DEEP WATER
WAVE HEIGHT BY DIRECTION

HEIGHT (ft)	N	NE	E	SE	S	SW	W	NW	TOTAL PCT
1	0.6	0.9	2.3	0.5	0.4	0.7	0.5	0.4	6.3
1-2	2.3	4.6	11.3	3.1	1.6	1.1	1.4	0.8	26.2
3-4	2.1	7.4	15.5	2.4	1.5	2.1	0.9	0.5	32.4
5-6	1.5	4.4	10.4	0.7	0.8	0.8	0.5	0.3	19.4
7	0.6	2.6	4.1	0.7	0.6	0.7	0.4	0.1	9.8
8-9	0.3	2.1	1.0	0.1	0.1	0.2	0.1	0.0	3.9
10-11	0.1	0.5	0.7	0.1	0.1	0.1	0.1	0 0	1.5
12	0.1	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.4
13-16	0.1	0.1	0.2	0.0	0.1	0.1	0.1	0.0	0.5
TOTAL PCT	7.6	22.8	45.6	7.6	5.1	5.8	3.9	2.1	100.4

TOTAL OBSERVATIONS 2,529

TABLE 2

ANNUAL PERCENT FREQUENCY OF DEEP WATER
WAVE HEIGHT VERSUS WAVE PERIOD

HEIGHT (ft)	PERIOD (SECONDS)							TOTAL PCT
	6	6-7	8-9	10-11	12-13	13	INDET	
1	1.6	0.1	0.0	0.0	0.0	0.0	2.4	4.1
1-2	12.0	1.8	0.5	0.1	*	0.0	0.4	14.9
3-4	17.2	9.6	2.0	0.5	0.1	0.0	0.6	30.0
5-6	7.0	11.1	4.5	1.1	0.4	0.4	0.4	14.4
7	2.4	5.7	4.9	0.9	0.2	0.1	0.2	14.4
8-9	1.1	2.1	1.7	1.3	0.4	0.1	0.1	6.8
10-11	0.5	0.8	0.9	0.5	0.2	*	0.1	3.1
12	0.2	0.3	0.3	0.3	0.1	0.1	*	1.4
13-16	0.1	0.3	0.2	0.2	0.3	0.1	0.1	1.2
17-19	0.0	0.0	0.0	*	*	0.0	0.0	0.1
20-22	0.0	*	0.0	0.1	0.0	0.5	0.0	0.7
23-25	0.0	0.0	0.0	0.0	0.0	*	0.0	0.1
TOTAL PCT	42.1	31.9	15.0	5.1	1.7	1.4	4.4	101.5

TOTAL OBSERVATIONS 4,589

TABLE 3

GUAM, MARIANA ISLANDS DEEP WATER SIGNIFICANT WAVE HEIGHT STATISTICS DUE TO WESTERN NORTH PACIFIC TROPICAL CYCLONES

AVERAGE YEARLY CONDITIONS FOR THE PERIOD 1975-1979

Percent of Time Occurrence of Wave Height Versus Wave Direction

HEIGHT (ft) (=H)	Wave Direction Class (From Which Waves Approach) N	NE	E	SE	S	SW	W	NW	TOTAL
0-2	2.7	1.9	0.4	0.8	0.1	0.3	6.5	9.4	22.1
2-4	1.5	1.4	0.1	0.2	0.0	0.0	3.1	4.1	10.4
4-6	2.1	1.0	0.1	0.1	0.0	0.0	2.2	3.3	8.8
6-8	1.1	0.4	0.1	0.1	0.0	0.0	1.8	2.3	5.8
8-10	0.8	0.0	0.1	0.1	0.0	0.0	1.5	1.7	4.2
10-12	0.4	0.0	0.1	0.1	0.0	0.0	1.8	1.7	4.1
12-14	0.5	0.0	0.1	0.0	0.0	0.0	0.4	0.7	1.8
14-16	0.0	0.0	0.1	0.1	0.0	0.0	0.9	0.0	1.1
= 16	0.0	0.0	1.2	1.1	0.5	0.0	0.3	0.3	3.3
TOTAL	9.0	4.7	2.3	2.6	0.7	0.3	18.4	23.6	

GUAM, MARIANA ISLANDS DEEP WATER SIGNIFICANT WAVE PERIOD STATISTICS DUE TO WESTERN NORTH PACIFIC TROPICAL CYCLONES

AVERAGE YEARLY CONDITIONS FOR THE PERIOD 1975-1979

Percent of Time Occurrence of Wave Period Versus Wave Direction

HEIGHT (ft) (=T)	Wave Direction Class (From Which Waves Approach) N	NE	E	SE	S	SW	W	NW	TOTAL
0-6	6.9	4.8	0.0	0.4	0.0	0.3	11.4	18.0	41.7
6-8	1.6	0.9	0.1	0.1	0.0	0.0	3.1	4.5	10.3
8-10	2.1	0.7	0.0	0.0	0.0	0.0	1.8	4.0	8.8
10-12	2.1	1.6	0.0	0.1	0.0	0.0	2.4	3.8	10.1
12-14	1.8	0.7	0.0	0.1	0.0	0.0	4.0	5.2	11.7
14-16	1.4	0.6	0.0	0.2	0.0	0.0	2.4	2.9	7.4
16-18	0.8	0.2	0.8	0.0	0.0	0.0	1.1	1.8	4.8
= 18	0.8	0.0	0.2	0.3	0.0	0.2	2.4	2.3	6.2
TOTAL	17.6	9.5	1.1	1.3	0.0	0.5	28.6	42.4	

FLOOD INSURANCE STUDY

TERRITORY OF GUAM

DRAFT REPORT

SEPTEMBER 1983

~~In the hydrologic analysis of Harmon Sink, only the volume of runoff flowing into the depresion was considered since Harmon Sink has no outlet structure. The storage capacity of Harmon Sink is 496 acre-feet at its overflow elevation of 93 feet. A 1,000-foot section of Ypao Road serves as the overflow crest. Harmon Sink's overall drainage area extends to the Yigo area and encompasses an area of 17.1 square miles. However, numerous depressions in the Yigo area and the large Mogfog depression will intercept overland flows. The effective drainage area for Harmon Sink extends to the Mogfog depression and equals 5.78 square miles. Rainfall data and infiltration loss rates were obtained from the Guam Storm Drainage Manual, September 1980. In the selection of the infiltration loss rate, the flood history of the Harmon Sink was taken into account. The 10-, 50-, 100-, and 500-year floods will generate runoff volumes of 62, 370, 463, and 647 acre-feet respectively which will fill Harmon Sink to elevations 80, 90.4, 93, and 93 feet respectively.~~

~~For areas of approximate study, the regional equations were also used to determine the peak discharge for the 100-year flood.~~

Coastal Surge Analyses

A joint probability analysis was conducted to analyze the coastal surge. In the joint probability study, a frequency and probability analysis of the meteorological parameters of the typhoons which affect Guam was first conducted. From the analysis, a series of hypothetical but possible typhoon events were generated to represent the typhoon population in the Guam area. By use of a method which was specifically developed for this study, the surge elevations were calculated at the study area using the hypothetical typhoon data. The surge elevations were then analyzed statistically to determine the surge-frequency relationship. For this Flood Insurance Study, surge is defined as the stillwater elevation within the reef which is caused by tidal, wind, breaking wave and interactive effects.

Typhoon meteorological data were obtained from the "Tropical Cyclones Affecting Guam" report and the "Annual Typhoon Report" series (Reference 17). Meteorological data were available for the years 1946 to 1982, a 37-year period of record.

The typhoon meteorological data for the region between 9°N and 17°N latitude in the Western North Pacific area were investigated to develop relationships between the meteorological parameters (central pressure versus maximum windspeeds, and central pressure versus radius of maximum wind). The regional investigation was made to provide better definitions of the meteorological relationships for the typhoon events affecting Guam. Data from 151 typhoons were analyzed.

A circular area with a radius of 180 nautical miles from Guam was selected for the investigation of the central pressure for typhoons affecting Guam. In the "Tropical Cyclones Affecting Guam" report, it was noted that typhoons passing outside of the 180-nautical mile radius generally did not significantly affect Guam, while those passing within the distance had a significant impact on Guam. Data from 34 events which had typhoon strength within the 180-nautical mile area were analyzed.

The "Tropical Cylcones Affecting Guam" report also noted that significant surge was normally generated only by typhoons passing within 60 nautical miles of Guam. Thus the distance of 60 nautical miles was selected as the outer typhoon passing distance for the surge computations. The frequency curve of the typhoon central pressure for the 180-nautical mile radius area was modified for the 60-nautical mile radius area.

The method by which the surge elevations in a reef were calculated from the meteorological parameters was developed by the Coastal Engineering Research Center (CERC), US Army Corps of Engineers for this Flood Insurance Study. The method was developed by the usage of laboratory wave model results together with a numerical model. The laboratory reef model was built to the configurations of a typical reef on Guam. The numerical model used by CERC was originally developed by the Danish Hydraulics Institute (DHI) of Horsholm, Denmark. The results of the CERC study have been placed in a POD computer program titled GINT which was used to compute the surge elevations for this Flood Insurance Study.

Table 2 shows the parameters used in the joint probability analysis. The central pressure of the typhoon, the most critical meteorological characteristic which governs typhoon intensity, was selected as the primary variable and is associated with an annual exceedence frequency. The other parameters were given equal probabilities of occurrence (for 2 cases of occurrence - each case given a 0.5 probability of occurrence; 3 cases - each case 0.333; and 4 cases - each case 0.25).

To develop the surge-frequency curve, the various cases of the 5-, 10-, 20-, 50-, 100-, and 500-year typhoon events were generated and were made to represent 400, 200, 120, 40, 32, and 8 surge events respectively. The surge elevations, representing a population of 800 events during a 4,000-year span, were plotted on probability graph paper by the use of a plotting position formula to determine the surge-frequency curve (Reference 18). Results of the surge-frequency analysis are shown in Table 3. The astronomic tide elevation was kept constant at 0.99 feet (the mean higher high water) for the joint probability analysis.

From the joint probability analysis, the 100-year deep ocean wave characteristics were also determined. The 100-year deep ocean wave has a significant wave height of 50.0 feet and a significant wave period of 15.4 seconds.

TABLE 2. Typhoon Parameters Used in the Surge Analysis

Central Pressure of Typhoon (Millibars)	Annual Exceedence Frequency
962	0.20 (5-yr event)
935	0.10 (10-yr event)
917	0.05 (20-yr event)
903	0.02 (50-yr event)
895	0.01 (100-yr event)
884	0.002 (500-yr event)

Typhoon Event	Radius of Maximum Wind (Kilometers)	Typhoon Passing Distance from Study Area (Kilometers)	Wind Direction (Degrees)
962 mb	10.2	10.2	45
(5-year)	18.0	42.0	225
	28.7	70.0	
	59.3	97.0	
935 mb	11.5	11.5	45
(10-year)	24.1	42.0	225
	45.4	70.0	
		97.0	
917 mb	8.5	8.5	45
(20-year)	18.0	42.0	225
	34.8	70.0	
		97.0	
903 mb	7.4	7.4	45
(50-year)	18.5	42.0	225
		70.0	
		97.0	
895 mb	7.0	7.0	45
(100-year)	16.0	42.0	225
		70.0	
		97.0	
884 mb	7.0	7.0	45
(500-year)	16.0	42.0	225
		70.0	
		97.0	

NOTES:

1) The values for the radius of maximum wind were obtained from the regional (9°N to 17°N latitude) analysis.

2) The typhoon passing distance is the distance to the center of 4 incremental sections (each 15 nautical miles in length) which comprise the 60-nautical mile limit for surge effects on Guam. Typhoons passing within

the first incremental section were considered direct hits and therefore, the passing distance was made equal to the radius of maximum wind. For the cases where the radius of maximum wind exceeded the passing distance, the value of the radius of maximum wind was used.

3) Wind direction is measured in a counterclock direction. The zero degree wind direction is parallel to the coastline and travels from left to right (looking from the sea towards the coastline). From their experience in developing the surge program, CERC recommended the use of a 45 degree wind direction to produce the highest possible surge elevations. The 225-degree direction represents the non-maximum conditions.

TABLE 3. Summary of Stillwater Elevations

Flooding Source and Location	Stillwater Elevation (Feet) 10-Year	50-Year	100-Year	500-Year
Agana Bay	5.3	7.3	8.0	8.7
Asan Bay	6.0	7.9	8.3	9.0
Piti Bay	5.4	7.5	8.1	8.8
Agat Bay	6.0	8.0	8.4	9.1
Umatac Bay	6.8	8.4	8.8	9.3
Cocos Lagoon	5.1	7.2	7.7	8.5
Inarajan Bay	6.8	8.5	8.8	9.4

3.2 HYDRAULIC ANALYSES.

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

The existing bridge and culvert crossings at Umatac River (Route 4) and Geus River (Route 4 and Espinosa Avenue) are planned to be replaced in the near future (the Geus River culverts are under construction). For the hydraulic analyses, the new (planned) bridge, culverts and approaches were used instead of the existing conditions.

Water surface elevations for floods of the selected recurrence intervals were computed by use of the COE HEC-2 "Water Surface Profiles" computer program (Reference 19).

Flood profiles were drawn showing the computed water surface elevations for the selected recurrence intervals. The higher of either the mean high tide elevation or the critical depth elevation

Coastal Inundation Analyses

For the analysis of the coastal floods caused by typhoons, waves were added to the surge elevations. From an interpolation of the charts developed in a CERC report, a transmitted wave height through the reef equaling 0.65 times the stillwater depth was used. The report summarized the results of the laboratory wave-reef modeling task which was conducted for this Flood Insurance Study by CERC (Reference 31).

The crest height above the stillwater (surge) elevation of the breaking reef wave at the shoreline was selected to equal 70 percent of the height of the transmitted wave (a percentage recommended by the National Academy of Sciences). Using these wave relationships together with the surge elevations, the coastal flood elevations at the shoreline were determined.

After a search was made to find an appropriate method for the inland runup analysis (a method which would provide water surface elevations and also account for the shore conditions of Guam), it was found that an empirical relationship was the most appropriate. The empirical relationship was based on observations of typhoon Pamela's (1976) runup and was developed in a report made by the Scripps Institution of Oceanography, University of California (Reference 32). The empirical relationship for the determination of the runup profile is a one-foot drop in water surface elevation for every 115 feet of inland travel of the flood wave.

For coastal areas with reefs less than 100 meters wide, the deep ocean waves were used in the flood analysis instead of the surge elevations. From the 100-year deep ocean wave height (50.0 feet) and open ocean surge elevation (2.4 feet), a 28-foot crest elevation for the breaking wave near the reef edge was determined for the 100-year event. A simplified method for determining the water surface profile of the breaking wave was developed. The development was based on the method described in the US Army Shore Protection Manual (Reference 33) which determines the breaking wave's travel distance, the linear relationship of energy dissipation to wave travel distance described in the Scripps Institution of Oceanography report on Typhoon Pamela, and the observations made by CERC on the effects of the reef widths on runup values in their report on the laboratory modeling task. The method developed for the breaking wave profile uses a starting flood elevation of 28 feet near the reef edge and decreases it by a one-foot drop in elevation for every 20 feet of wave travel.

The historical accounts of coastal floods were given some consideration in the final determination of the starting flood elevation at the shoreline. Besides the coastal flood descriptions tabulated in the "Tropical Cyclones Affecting Guam" report, Government of Guam officials, village commissioners and the elderly residents of the community had also provided information (eye witness accounts) on coastal floods in Guam. Table 4 shows the surge elevations, the calculated wave crest elevations, and the starting flood elevations used at the shoreline for the areas studied in detail. The starting flood elevations are based on the calculated wave crest elevations with slight modifications made in consideration for the historic accounts of the study area's vulnerability to coastal floods.

For the areas studied in detail, the V zone (area with velocity wave action) was terminated at the 3-foot inundation depth.

TABLE 4. Summary of Starting Flood Elevations at the Shoreline

	Elevation (Feet)		
Location	Stillwater	Wave Crest	Starting Flood Elevation
Agana Bay	8.0	12.3	12
Asan Bay	8.3	12.7	12
Piti Bay	8.1	12.4	12
Agat Bay	8.4	12.7	12
Umatac Bay	8.8	13.4	13
Cocos Lagoon	7.7	10.3	10
Inarajan Bay	8.8	13.4	14

. Hazard Areas Rules and Regulations, promulgated under Executive Order 78-20, include all areas which have a one percent or greater chance of flooding in any given year. This flooding may be due to either abnormally high coastal water, overflow of streams, rivers and wetlands or excessive rainfall drainage into sinkholes or low lying basins. These Special Flood Hazard Areas are delineated on official provisional Flood Hazard Boundary Maps prepared in August 1978. These areas have been redefined into specific zones based on recent detailed studies (see Section B3g above) and the information from the draft Flood Insurance Rate Map (FIRM) and Flood Boundary Map (FBM) documents for Agana are incorporated in this report. The FIRM and FBM maps are expected to be formally adopted in 1984.

The major intent of these regulations was to qualify for the federally-subsidized National Flood Insurance Program. The procedures and standards for the management of flood harzard areas must be followed in order to be issued a Flood Hazard Area Building Permit for a proposed development. A "development" includes erection or placement of any solid material or structure, disposal of dredged material, grading, change in land or water use intensity, and removal of significant vegetation. Any expansion of an approved development project, which exceed 50% of the physical value of the original structure or development, is required to submit application for a new building permit for development within the flood hazard area. Current uses not adhering to these rules and regulations will not require a Flood Hazard Area Building Permit and are classified as legal non-conforming uses, unless declared to be a hazard to public health, safety and welfare by the Department of Public Health and Social Services, at which time they will be subject to conformance with these rules and regulations.

Emergency repairs of existing flood-damaged structures shall not require application for a Flood Hazard Area Building Permit if completed within a period of six months after a flood event and do not involve major structural or developmental expansion. After the above- stated time period, major

There are twenty-three specific regulatory standards. Those which are particularly applicable to coastal water inundation include the following:

-- An approved seawall for stormwave protection shall not impair public access, contribute to shoreline erosion or significantly disturb scenic vistas or visual quality and shall be sufficiently storm-resistant and structurally safe so as not to create a health or safety hazard.

-- Flood hazard areas shall not be graded, dredged or filled such that natural topographic drainways are altered unless issued a Flood Hazard Area Permit by the Department of Public Works.

-- Approved developments shall be designed to the maximum extent practicable to maintain the natural flow during flood conditions, nor create backwater effects or expand a flood hazard area into previously non-flood prone areas.

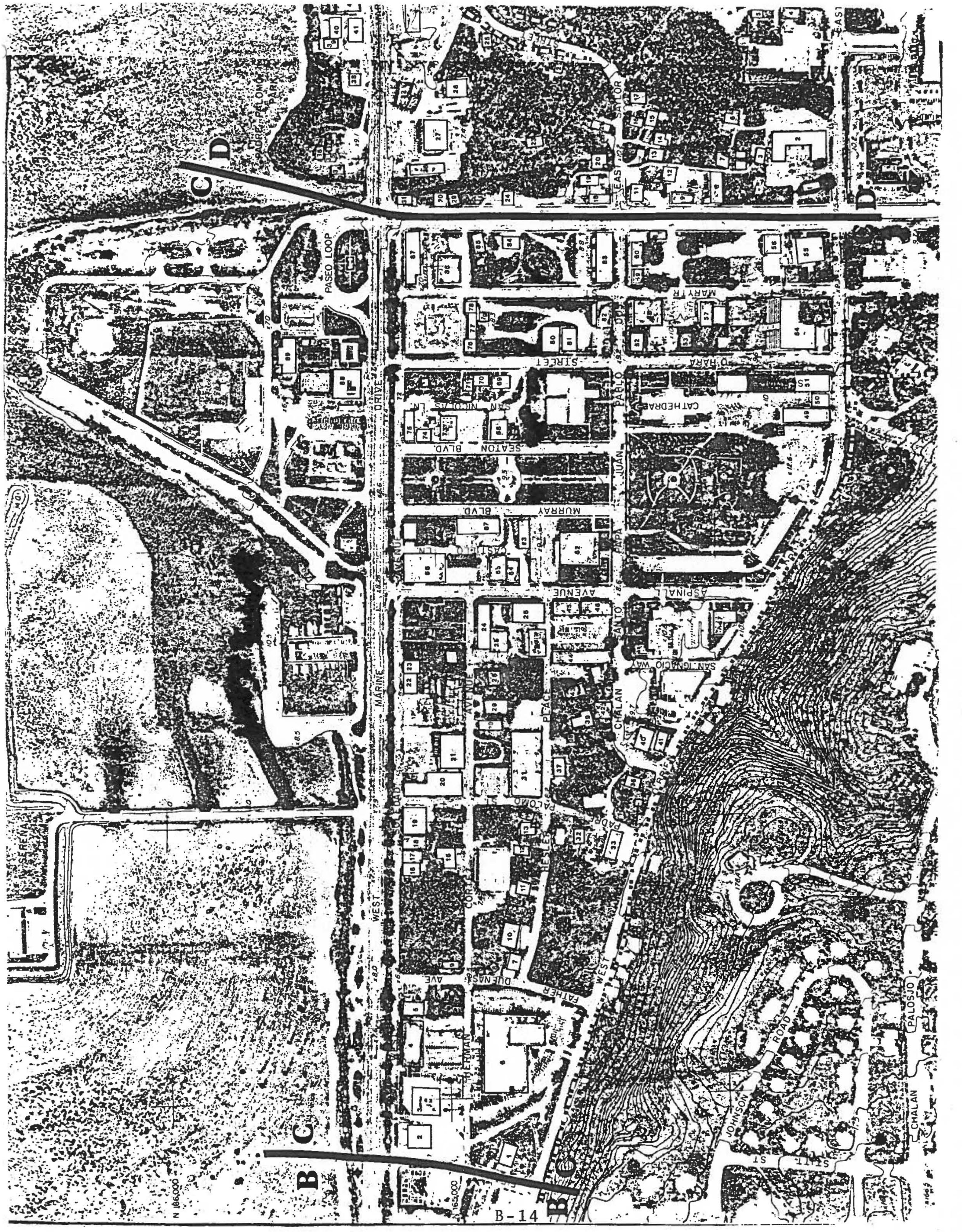
-- All approved developments within flood hazard areas shall be floodproofed to the maximum extent practicable.

-- All electrical equipment and the lowest floor of approved structures shall be elevated above the maximum flood elevation.

-- Approved structures shall be planned for construction with the longitudinal axis parallel to the direction of flood flow or wave assault whenever possible and additional or adjoining structures shall be planned for placement on the same flood-flow lines as the established structures.

The Federal flood insurance program has not been in place long enough in Guam to evaluate its institutional acceptance. In general, however, this non-structural measure does not reduce flood hazard damages but rather lessens the economic burden of flooding and encourages floodplain restrictions.


AGANA WATERFRONT STUDY
GUAM M.I.
REACHES A&B
Honolulu
INUNDATION LEVEL
MARINE DRIVE
SEVENTH ST
O'BRIEN
ANICETO ST
NINTH ST
DULCE
MARIA DR
CRANDALL
DRIVE
CHALAN
PALOSJO
WEST



B
C
D
WEST
MARINE
DRIVE
PASEO LOOP
SAN NICOLAS LN
SEATON BLVD.
MURRAY BLVD.
AVENUE
ASPINALL
SAN IGNACIO WAY
CHALAN
SANTO
PAPA
JUAN
PABLO
STREET
O'HARA
MARTYR
CATHEDRAL
PALOMO ST
PADRE
FATHER
DUENAS
AVE
HERMAN
CORTES
AVENUE
PLACE
JOHNSON
ROAD
CHALAN
SERENA
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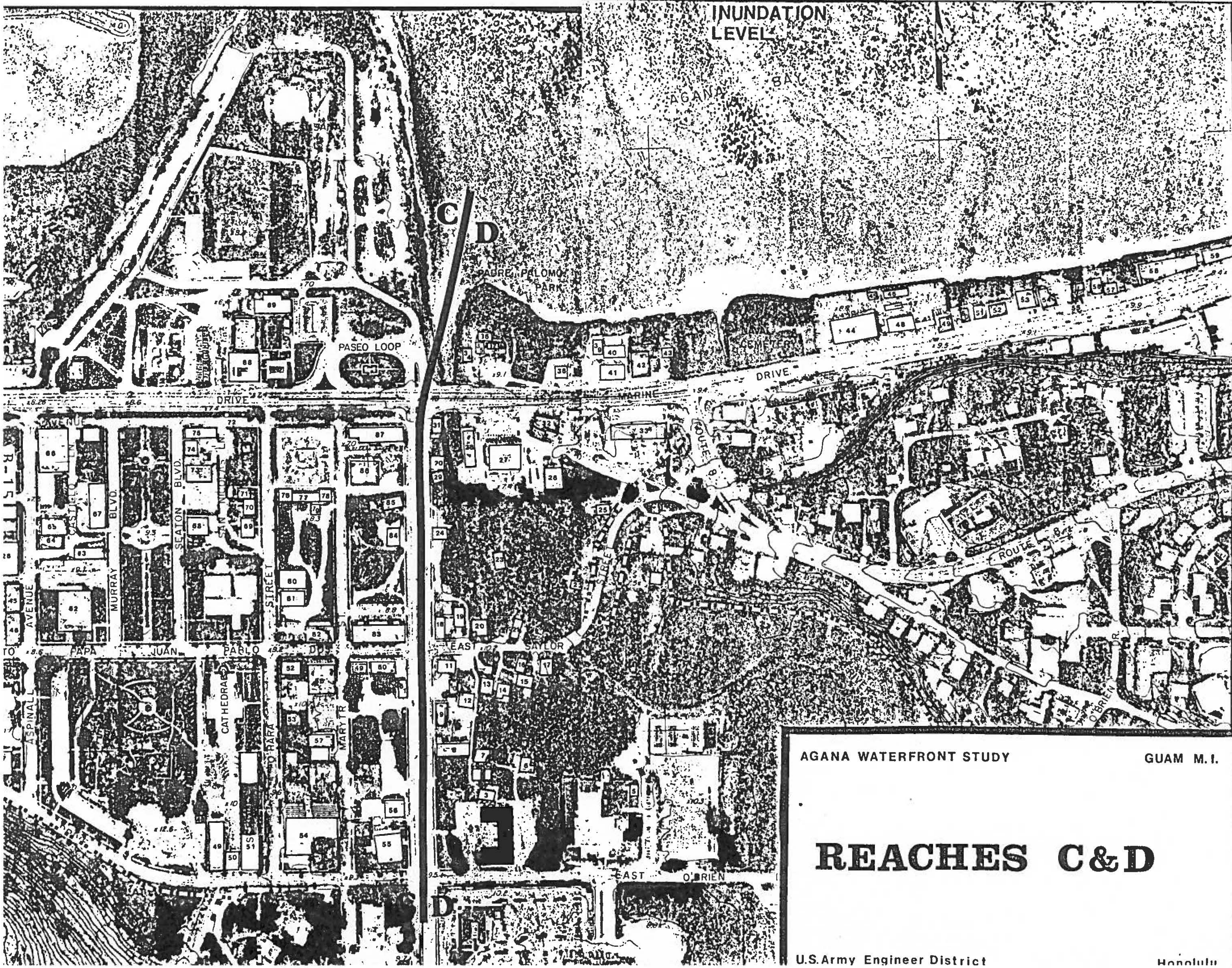
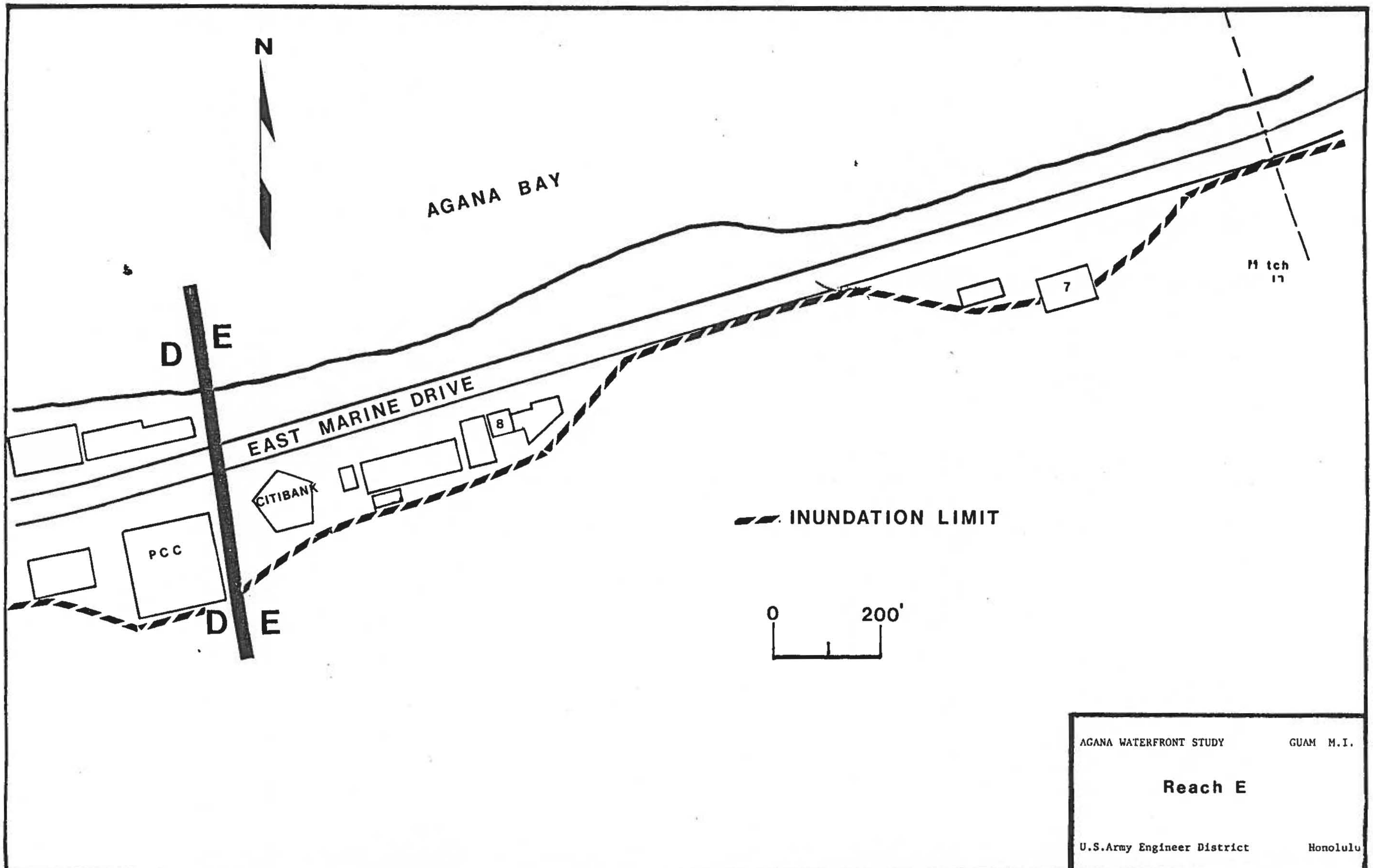


AGANA WATERFRONT STUDY GUAM M.I.

REACHES C&D

U.S.Army Engineer District Honolulu


N
AGANA BAY
D
E
EAST MARINE DRIVE
CITIBANK
PCC
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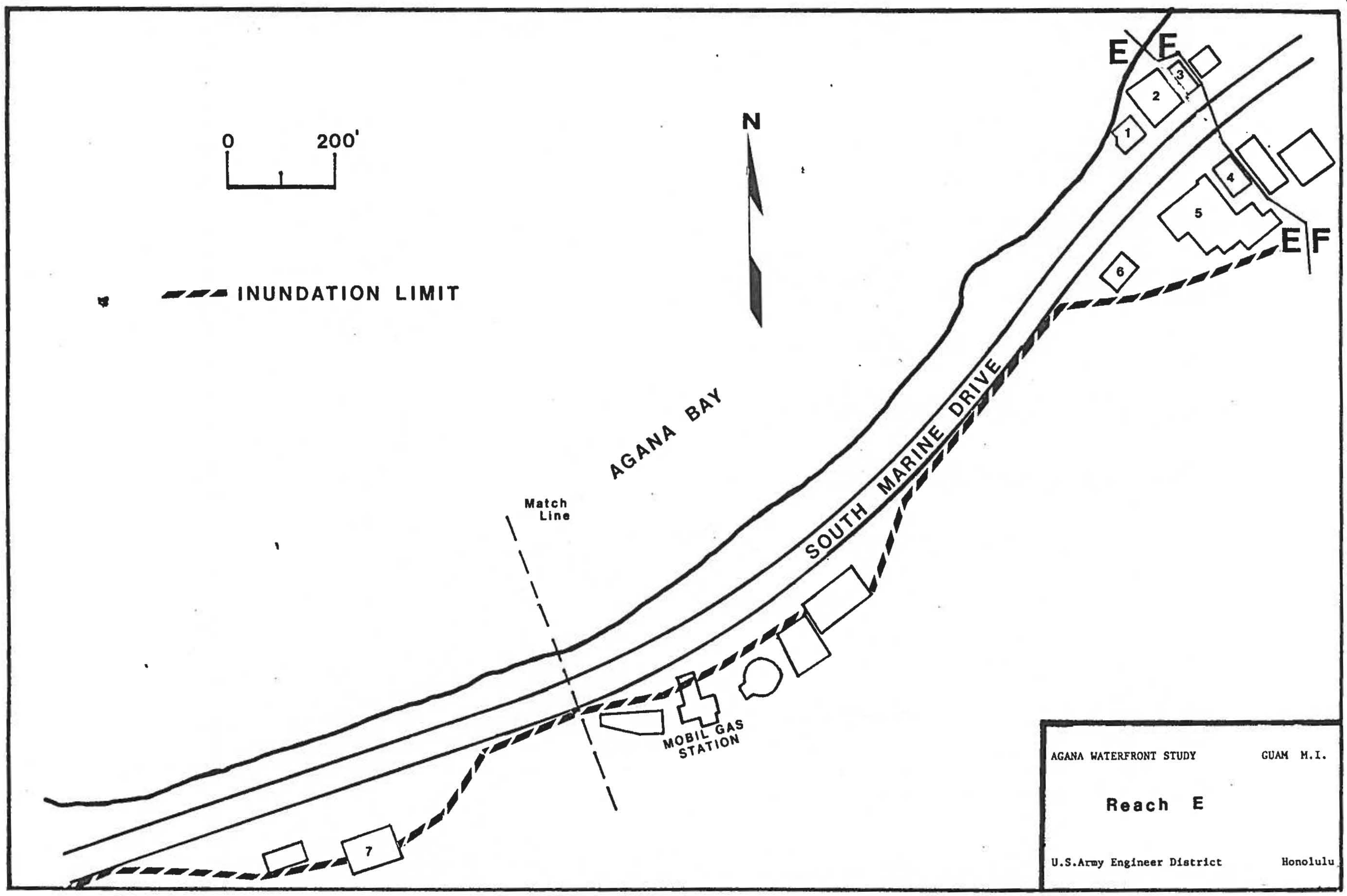
7
INUNDATION LIMIT
0
200'
AGANA WATERFRONT STUDY
GUAM M.I.
Reach E
U.S.Army Engineer District
Honolulu



0
200'
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INUNDATION LIMIT
AGANA BAY
SOUTH MARINE DRIVE
Match Line
MOBIL GAS STATION
E
F
E
F
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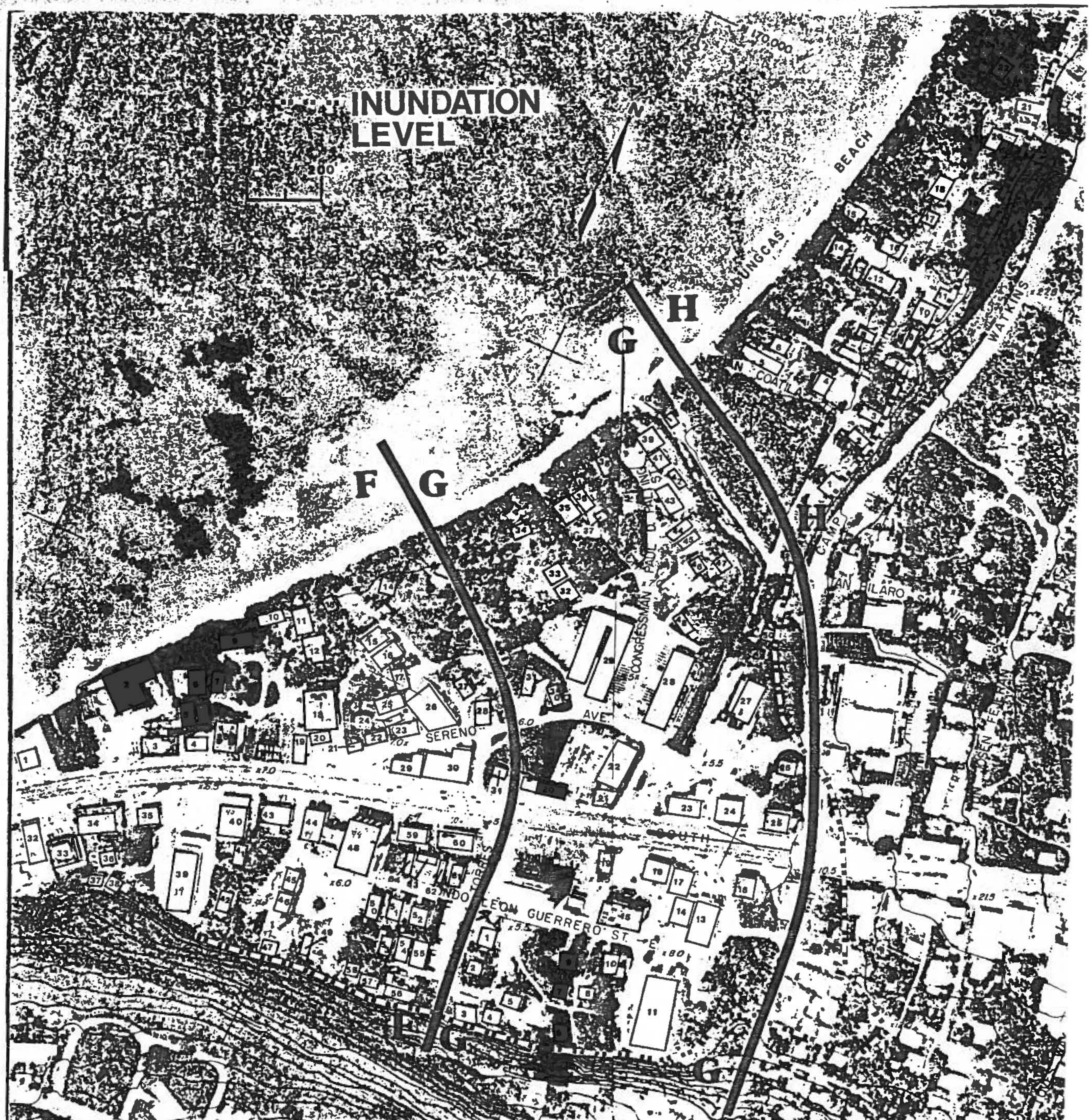
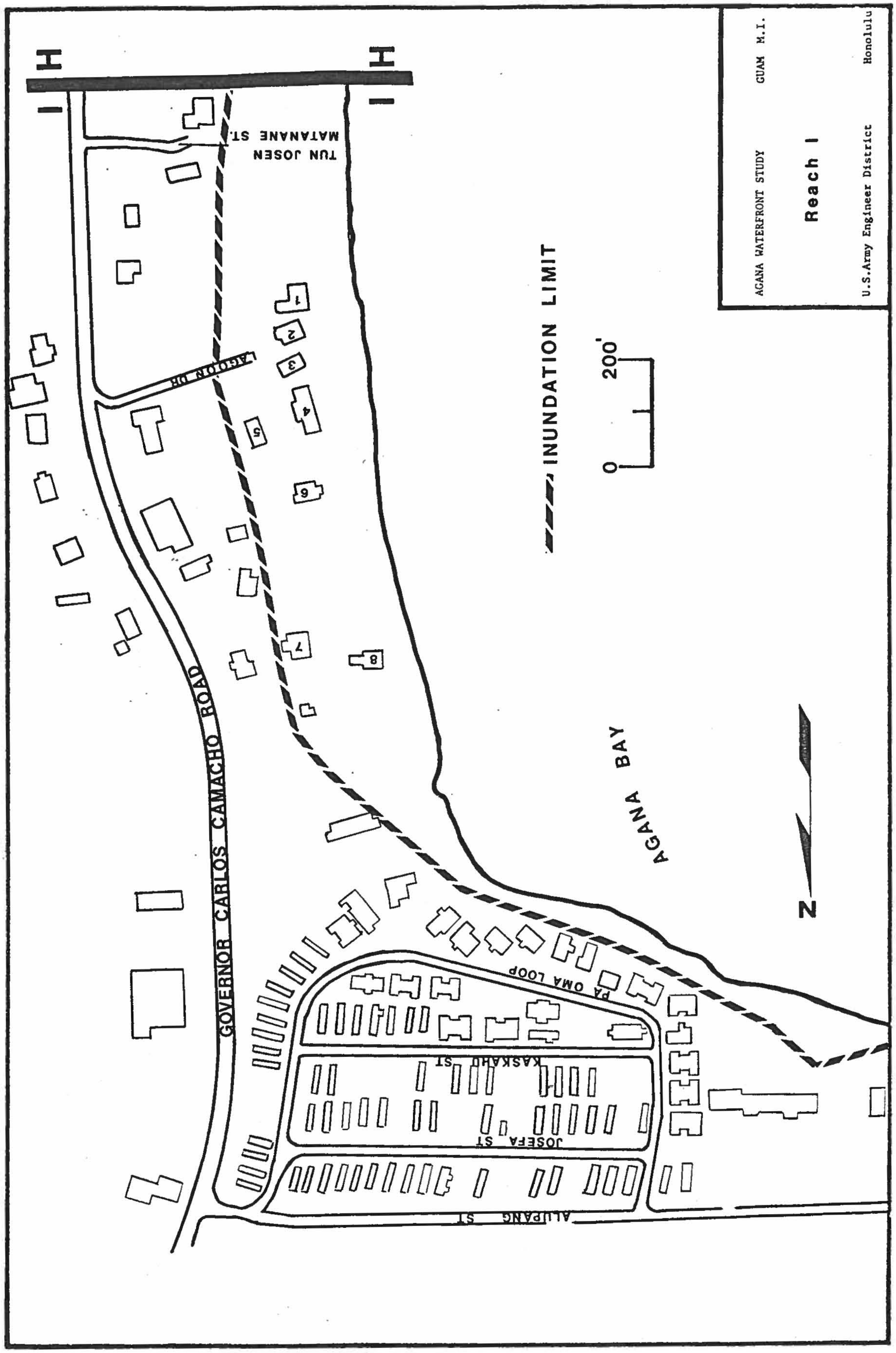
AGANA WATERFRONT STUDY
GUAM M.I.
Reach E
U.S.Army Engineer District
Honolulu



AGANA WATERFRONT STUDY GUAM M.I.

REACHES F,G&H

U.S.Army Engineer District Honolulu


AGANA WATERFRONT STUDY
GUAM M.I.
Reach I
U.S.Army Engineer District
Honolulu
INUNDATION LIMIT
0
200'
AGANA BAY
N
GOVERNOR CARLOS CAMACHO ROAD
TUN JOSEN MATANANE ST.
LAGOON DR
PA OMA LOOP
KASKAHO ST
JOSEFA ST
ALUPANG ST
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8

TABLE 1 REACH A

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	concrete	1.5	closures	40	Metal	2.7	Relocate Goods
2	wood	3.0	Remove	41	wood	2.0	Raise
3	concrete	4.0	Relocate Goods	42	concrete	3.3	Remove
4	concrete	3.0	Ring Wall	43	concrete	1.5	closures
5	Metal	3.0	Remove	44	Metal	3.5	Relocate Goods
6	concrete	2.5	closures	45	concrete	3.5	Relocate Goods
7	Metal	1.5	Remove	46	concrete	3.6	Relocate Goods
8	Metal	4.0	Remove	47	concrete	3.5	Remove
9	Metal	2.0	Remove	48	concrete	3.3	Remove
10	Metal	2.0	Relocate Goods	49	concrete	3.5	Relocate Goods
11	Metal	2.0	Relocate Goods	50	concrete	2.5	closures
12	concrete	1.5	closures	51	concrete	2.5	closures
13	Metal	2.0	closures	52	concrete	2.5	closures
14	concrete	2.0	closures	53			
15	concrete	2.5	closures	54	concrete	3.0	Relocate Goods
16	concrete	2.5	closures	55	concrete	2.5	closures
17	concrete	2.5	closures	56	concrete	3.6	Relocate Goods
18	Metal	3.0	Relocate Goods	57	concrete	3.6	Relocate Goods
19	concrete	2.5	closures	58	concrete	1.0	closures
20	concrete	2.5	closures	59	concrete	3.0	Relocate Goods
21	concrete	5.0	Remove	60	concrete	3.0	Relocate Goods
22	concrete	5.5	Remove	61	concrete	3.0	Relocate Goods
23	wood	3.5	Remove	62	concrete	3.0	Relocate Goods
24	concrete	2.5	closures	63	concrete	3.0	Relocate Goods
25	concrete	2.5	closures	64	concrete	1.0	closures
26	concrete	5.5	Remove	65	concrete	0.5	closures
27	Metal	4.0	Relocate Goods	66	concrete	0.5	closures
28	Metal	3.3	Relocate Goods	67	concrete	0.5	closures
29	concrete	3.3	Relocate Goods	68	concrete	1.0	closures
30	Metal	3.3	Relocate Goods	69	concrete	1.0	closures
31	Metal	3.6	Relocate Goods	70	wood	1.0	Raise
32	Metal	3.5	Relocate Goods	71	concrete	1.0	closures
33	Metal	3.3	Relocate Goods	72	concrete	2.5	closures
34	Metal	3.0	Relocate Goods	73	concrete	1.0	closures
35	concrete	3.5	Relocate Goods	74	concrete	3.0	Relocate Goods
36	Metal	3.5	Relocate Goods	75	concrete	2.5	closures
37	concrete	3.5	Relocate Goods	76	wood	0.6	Raise
38	concrete	3.5	Remove	77	concrete	2.0	closures

Table 2 Reach B

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	concrete	4.5	Remove	37	concrete	4.1	Relocate Goods
2	concrete	3.0	Remove	38	concrete	4.2	Relocate Goods
3	concrete	3.0	Relocate Goods	39	concrete	4.2	Relocate Goods
4	Metal	2.0	Remove	40	concrete	4.0	Relocate Goods
5	concrete	3.0	Relocate Goods	41	concrete	4.2	Relocate Goods
6	concrete	4.0	Remove	42	concrete	4.2	Relocate Goods
7	concrete	4.0	Relocate Goods	43	concrete	3.8	Relocate Goods
8	concrete	3.5	Relocate Goods	44	concrete	3.7	Relocate Goods
9	Metal	4.0	Remove	45	concrete	1.7	closures
10	concrete	3.5	Relocate Goods	46	concrete	1.5	closures
11	concrete	4.0	Relocate Goods	47	concrete	2.5	closures
12	concrete	0.5	closures	48	concrete	3.3	Remove
13	concrete	4.5	Relocate Goods	49	concrete	3.7	Remove
14	concrete	3.5	Relocate Goods	50	concrete	4.0	Remove
15	concrete	3.7	Relocate Goods	51	concrete	4.0	Remove
16	concrete	3.8	Relocate Goods	52	concrete	2.0	closures
17	concrete	5.0	Remove	53	concrete	2.0	closures
18	wood	2.8	Raise	54	concrete	4.0	Relocate Goods
19	concrete	3.8	Remove	55	concrete	5.0	Remove
20	concrete	5.2	Remove	56	concrete	5.0	Remove
21	concrete	5.0	Remove	57	concrete	2.5	closures
22	concrete	3.5	Relocate Goods	58	concrete	4.7	Remove
23	concrete	5.0	Remove	59	concrete	4.0	Relocate Goods
24	concrete	2.5	Closures	60	concrete	2.5	closures
25	concrete	2.5	closures	61	Metal	2.5	Relocate Goods
26	concrete	2.5	closures	62	concrete	2.5	closures
27	concrete	2.5	closures	63	concrete	4.5	Remove
28	concrete	4.0	Relocate Goods	64	concrete	2.5	closures
29	concrete	5.0	Remove	65	wood	0.5	Raise
30	concrete	5.0	Remove	66	wood	1.0	Raise
31	concrete	4.5	Relocate Goods	67	concrete	2.0	closures
32	concrete	5.2	Remove	68	Metal	2.5	Relocate Goods
33	concrete	5.0	Remove	69	concrete	2.5	closures
34	Metal	4.5	Relocate Goods	70	concrete	2.5	closures
35	concrete	4.4	Relocate Goods	71	concrete	2.5	closures
36	concrete	4.3	Relocate Goods	72	concrete	3.5	Relocate Goods

TABLE 3 Reach C

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	concrete	4.5	Relocate Goods	46	concrete	3.2	Relocate Goods
2	Metal	4.0	Relocate Goods	47	concrete	1.3	closures
3	concrete	4.5	Relocate Goods	48	concrete	0.3	closures
4	concrete	4.0	Relocate Goods	49	concrete	0.5	closures
5	concrete	4.0	Relocate Goods	50	concrete	1.0	closures
6	concrete	2.0	closures	51	concrete	1.5	closures
7	concrete	2.3	closures	52	concrete	1.8	closures
8	concrete	2.4	closures	53	concrete	1.5	closures
9	concrete	2.0	closures	54	concrete	2.0	closures
10	concrete	1.5	closures	55	concrete	2.5	closures
11	concrete	2.5	closures	56	concrete	2.5	closures
12	concrete	4.0	Remove	57	concrete	1.5	closures
13	Wood	2.0	Raise	58	concrete	0.5	closures
14	Wood	2.0	Raise	59	concrete	2.5	closures
15	concrete	4.5	Relocate Goods	60	concrete	2.5	closures
16	concrete	2.5	closures	61	wood	1.0	Raise
17	concrete	4.5	Relocate Goods	62	concrete	3.2	Relocate Goods
18	concrete	4.5	Relocate Goods	63	concrete	3.0	Relocate Goods
19	concrete	4.4	Relocate Goods	64	concrete	3.0	Relocate Goods
20	Metal	4.5	Relocate Goods	65	concrete	3.0	Relocate Goods
21	Metal	4.0	Relocate Goods	66	concrete	2.5	closures
22	Metal	4.0	Relocate Goods	67	concrete	2.5	closures
23	concrete	4.0	Relocate Goods	68	concrete	0.5	closures
24	Metal	4.5	Relocate Goods	69	concrete	2.5	closures
25	concrete	4.5	Relocate Goods	70	concrete	2.5	closures
26	concrete	0.5	closures	71	concrete	2.5	closures
27	concrete	1.0	closures	72	concrete	3.4	Relocate Goods
28	concrete	4.5	Remove	73	concrete	1.5	closures
29	concrete	2.0	closures	74	concrete	2.0	closures
30	concrete	4.5	Relocate Goods	75	concrete	2.0	closures
31	concrete	4.0	Relocate Goods	76	concrete	4.0	Relocate Goods
32	concrete	2.0	closures	77	concrete	4.0	Relocate Goods
33	concrete	1.8	closures	78	concrete	4.0	Relocate Goods
34	Metal	1.5	Relocate Goods	79	wood	2.7	Raise
35	Not used			80	concrete	3.2	Relocate Goods
36	concrete	2.0	closures	81	concrete	3.7	Relocate goods
37	concrete	3.5	Relocate Goods	82	concrete	1.4	closures
38	concrete	2.0	closures	83	concrete	1.0	closures

TABLE 3 Reach C

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Actio
39	concrete	2.0	closures	84	concrete	3.5	Relocat Goods
40	concrete	1.5	closures	85	concrete	2.5	Closur
41	concrete	1.5	Closures	86	concrete	4.5	Relocat Goods
42	concrete	1.5	closures	87	concrete	4.5	Relocate Goods
43	Wood	0.5	Raise	88	wood	4.5	Relocate Goods
44	concrete	2.5	closures	89	concrete	4.5	Relocat Goods
45	concrete	3.2	Relocate Goods	90	concrete	4.5	Relocat Good
46	concrete	3.0	Relocate Goods				

TABLE 4 Reach D

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	wood	0.5	Raise	32	Concrete	3.0	Relocate Goods
2	concrete	2.5	closures	33	Concrete	3.0	Relocate Goods
3	wood	2.0	Raise	34	Concrete	5.0	Remove
4	Metal	3.8	Relocate Goods	35	wood	3.5	Remove
5	Wood	1.5	Raise	36	wood	3.5	Remove
6	Concrete	4.5	Remove	37	wood	3.5	Remove
7	Wood	2.5	closures	38	Concrete	2.5	closures
8	Concrete	4.0	Relocate Goods	39	concrete	3.5	Relocate Goods
9	Concrete	3.0	Relocate Goods	40	Metal	4.0	Relocate Goods
10	Concrete	2.5	closures	41	concrete	3.5	Relocate Goods
11	Concrete	2.0	closures	42	concrete	4.0	Relocate Goods
12	Concrete	2.5	Closures	43	Concrete	4.0	Relocate Goods
13	Concrete	2.5	Closures	44	Concrete	2.5	Closures
14	Concrete	2.5	Closures	45	Metal	3.5	Relocate Goods
15	Concrete	2.5	Closures	46	Metal	3.5	Relocate Goods
16	Concrete	2.0	Closures	47	Metal	3.5	Relocate Goods
17	Concrete	2.0	closures	48	concrete	3.5	Relocate Goods
18	concrete	2.0	Closures	49	concrete	3.5	Relocate Goods
19	Concrete	2.0	Closures	50	concrete	3.5	Relocate Goods
20	Concrete	2.0	closures	51	concrete	3.5	Relocate Goods
21	Concrete	2.0	Closures	52	concrete	3.5	Relocate Goods
22	Metal	2.5	Remove	53	concrete	3.5	Relocate Goods
23	Metal	3.0	Remove	54	concrete	3.5	Relocate Goods
24	Concrete	0.7	closures	55	concrete	3.5	Relocate Goods
25	Concrete	2.5	closures	56	concrete	3.5	Relocate Goods
26	Concrete	2.5	closures	57	concrete	3.5	Relocate Goods
27	Concrete	4.5	Relocate Goods	58	concrete	3.5	Relocate Goods
28	Concrete	3.5	Relocate Goods	59	concrete	4.0	Relocate Goods
29	Concrete	1.0	closures	60	concrete	0.5	closures
30	Concrete	2.0	closures	61	Concrete	2.0	closures
31	Concrete	2.0	closures	62	Concrete	2.0	closures

TABLE 5 Reach E

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	Metal	3.1	Relocate Goods	7	Concrete	1.0	Closures
2	Metal	3.7	Relocate Goods	8	Concrete	1.0	closure
3	Concrete	3.2	Relocate Goods	9	Concrete	2.0	closures
4	Concrete	0.3	Closures	10	Concrete	4.5	Relocate Goods
5	Concrete	2.3	Closures	11	Concrete	1.0	closure
6	Concrete	2.5	Closures				

TABLE 6 Reach F

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	Concrete	2.3	Concrete	33	concrete	2.2	closures
2	Concrete	3.3	Relocate Goods	34	concrete	2.5	closures
3	Concrete	2.5	closures	35	concrete	4.5	Relocate Goods
4	Metal	3.1	Relocate Goods	36	concrete	4.5	Remove
5	Concrete	3.0	Relocate Goods	37	Wood	0.8	Brick Veneer + Closures
6	Concrete	2.5	Closures	38	Wood	2.2	Raise
7	Concrete	2.5	closures	39	concrete	3.8	Relocate Goods
8	Concrete	0.7	closures	40	Metal	3.5	Relocate Goods
9	Concrete	5.0	Remove	41	Metal	5.5	Remove
10	Concrete	5.8	Remove	42	Concrete	5.0	Remove
11	concrete	5.3	Remove	43	Concrete	5.0	Remove
12	concrete	5.0	Remove	44	concrete	5.2	Remove
13	Metal	5.0	Remove	45	concrete	5.0	Remove
14	wood	5.0	Remove	46	Concrete	5.1	Remove
15	Metal	3.5	Remove	47	concrete	3.5	Remove
16	Metal	3.5	Remove	48	concrete	3.7	Relocate Goods
17	Concrete	2.5	Closures	49	Metal	5.9	Remove
18	concrete	1.4	Closures	50	concrete	5.8	Remove
19	wood	1.4	Raise	51	concrete	4.6	Remove
20	Concrete	1.3	closures	52	concrete	4.8	Remove
21	Concrete	3.3	Relocate Goods	53	wood	4.2	Raise
22	concrete	5.0	Remove	54	concrete	5.6	Remove
23	concrete	3.1	Relocate Goods	55	concrete	5.3	Remove
24	Metal	3.8	Relocate Goods	56	Wood	3.4	Raise
25	Metal	3.2	Remove	57	wood	3.4	Remove
26	Concrete	3.3	Relocate Goods	58	wood	4.5	Raise
27	Metal	3.9	Remove	59	concrete	4.5	Relocate Goods
28	Concrete	3.3	Relocate Goods	60	concrete	3.6	Relocate Goods
29	concrete	3.2	Relocate Goods	61	concrete	3.9	Remove
30	concrete	3.3	Relocate Goods	62	Wood	3.6	Raise
31	concrete	4.5	Remove	63	Wood	3.6	Remove
32	Metal	5.0	Remove	64	Wood	3.7	Raise

TABLE 7 Reach G

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	concrete	4.4	Remove	26	concrete	3.5	Remove
2	wood	6.0	Remove	27	wood	5.2	Ring Wa
3	concrete	2.5	closures	28	Metal	5.2	Ring Wa
4	Metal	4.0	Remove	29	Metal	5.4	Ring Wa
5	Wood	6.1	Remove	30	Metal	3.0	Raise
6	Metal	4.2	Remove	31	concrete	3.5	Relocate Goods
7	Wood	4.2	Remove	32	wood	3.3	Remove
8	wood	4.0	Raise	33	wood	3.0	Remove
9	Wood	4.2	Raise	34	Wood	4.0	Remove
10	Wood	5.3	Remove	35	concrete	5.0	Remove
11	Metal	1.6	Relocate Goods	36	wood	3.7	Remove
12	wood	2.4	Brick Veneer + Closures	37	concrete	3.7	Relocate Goods
13	Metal	4.4	Relocate Goods	38	wood	3.7	Remove
14	concrete	2.5	Closures	39	Wood	3.2	Remove
15	concrete	1.0	closures	40	wood	4.0	Remove
16	concrete	0.2	closures	41	wood	4.0	Remove
17	concrete	2.1	Closures	42	wood	4.0	Raise
18	concrete	4.0	Relocate Goods	43	wood	3.2	Raise
19	concrete	4.0	Relocate Goods	44	Metal	3.3	Remove
20	wood	0.5	Raise	45	wood	3.4	Raise
21	concrete	4.3	Relocate Goods	46	Metal	6.5	Remove
22	wood	5.4	Remove	47	Metal	6.0	Remove
23	concrete	3.1	Relocate Goods	48	Metal	4.0	Remove
24	concrete	3.1	Relocate Goods	49	wood	2.1	Raise
25	concrete	0.4	closures	50	wood	2.6	Remove

TABLE 8 Reach H

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	concrete	4-1	Relocate Goods	12	concrete	3-3	Relocate Goods
2	concrete	4-7	Remove	13	concrete	5-0	Remove
3	concrete	2-5	Closures	14	concrete	4-5	Relocate Goods
4	concrete	4-5	Remove	15	concrete	2-5	closures
5	concrete	4-0	Relocate Goods	16	concrete	5-1	Remove
6	concrete	3-9	Relocate Goods	17	concrete	3-9	Relocate Goods
7	wood	1-3	Raise	18	wood	1-0	Raise
8	concrete	2-4	Closures	19	concrete	3-3	Remove
9	concrete	3-4	Relocate Goods	20	concrete	2-5	Closures
10	Metal	3.0	Remove	21	concrete	2-3	Closures
11	concrete	3-9	Remove	22	concrete	1-1	closures

TABLE 9 Reach I

Structure Number	Type of Structure	Depth of Flooding (Feet)	Action	Structure Number	Type of Structure	Depth of Flooding (Feet)	Action
1	concrete	5-0	Remove	5	concrete	4-2	Remove
2	concrete	4-7	Remove	6	concrete	5-1	Remove
3	concrete	5-2	Remove	7	concrete	4-0	Remove
4	concrete	5-2	Remove	8	concrete	4-8	Remove

APPENDIX C: ENVIRONMENTAL DATA

Table 1. Typical Agana Bay Beach Strand Vegetation

Common Name	Chamorro Name	Scientific Name
Beach morning glory	Alahai tasi	Ipomoea pes-caprae
Begger's stock		Bidens pilosa
Beach sunflower		Wedelia spp
Beach magnolia	Nasaso	Scaevola frutescens
Beach heliotrope	Hunik	Messerschmidia argentea
Ironwood	Gago	Casuarina equisetifolia
Coconut palm	Niyuk	Cocos nucifera
Milo	Binalo	Thespesia polulnea

Source: U.S. Fish and Wildlife Service. Letter, 26 Apr 1983, "Coordination Act Report, Paseo de Susana Shore Protection Study;" and Moore, Philip H., "An Ecological Survey of Pristine Terrestrial Communities on Guam" (August 1977), in Guam Coastal Management Program Technical Reports, Volume I, October 1977, Agana: Guam Bureau of Planning.

Table 2. Regular Migrant Shorebirds at Agana Bay

Common Name	Scientific Name	Large-summering Populations
American golden plover	Pluvialis dominica	
Gray-tailed tattler	Heteroscelus brevipes	X
Wandering tattler	H. incanus	X
Mongolian plover	Charadrius mongolus	
Ruddy turnstone	Arenaria interpes	
Whimbrel	Numenius phaeopus	X

Source: Jenkins, 1978.

Table 3. Incidence of Moderate to Heavy Pollution in Water of Agana Bay (Percent of Total[1]

Year	Alupang Cove (AGMS)	Dungca's Beach (AGMD)	LOCATION East Agana NAS S-D (AGMT)	Padre Paloma (AGMP)	Agana Bt Basin (AGML)	Bayside Park (AGMB)
1976[2]	21%	-	7%	-	0%	16%
1977	10%	-	4%	-	2%	19%
1980[3]	14%	41%	10%	18%	16%	21%
1981	16%	33%	14%	11%	14%	9%

Source: 1. Heavily Polluted: (1,000FC/100ml); Moderately Polluted (500-1000FC/100ml)
2. Guam Environmental Protection Agency. Fifth Annual Report, April 1977-March 1978, Table 2.
3. Ms. Christie Anderson, GEPA, Personal Communication, March 1983.

TABLE 4. HISTORIC SITES IN STUDY AREA

Guam Site No.	Site Name	Historic Era	Status
66-01-1070	Plaza de Espana	Spanish	Nat'l Register
66-01-1069	Agana Spanish Bridge	Spanish	Nat'l Register
66-01-1035	US Naval Cemetary	Pre-WWII	Marginal
66-01-1039	SMS Cormoran Monument	Pre-WWII	Guam Register
66-01-1055	Adelup Pt Gun Emplacmnt	WWII	Nat'l Register
66-01-1105	Dungca's Bch Defense Gun	WWII	Nat'l Register
66-01-??	Paseo de Susana Pillbox	WWII	Guam Register
66-01-1033	Shimizu House	Pre-WWII	Recommd'd NR/GR
66-01-1130	Dungca House	Pre-WWII	Recommd'd NR/GR
66-01-1132	Ungacta House	Pre-WWII	Recommd'd NR/GR
66-01-1133	Gumataotao House	Pre-WWII	Staff Files
66-01-1134	Toves House	Post-WWII	Recommd'd NR/GR
66-01-1135	Garrido House	Post-WWII	Recommd'd NR/GR
66-01-1136	White House	Pre-WWII	Staff Files
66-01-1138	L.D. Flores House	Pre-WWII	Staff Files
66-01-1139	Duenas Houses	Post-WWII	Staff Files
66-01-1141	Dr. Mesa House	Pre-WWII	Recommd'd NR/GR
66-01-1142	Cruz House	Post-War	No Recommend'tn