

SITING AND DESIGN CRITERIA OF DOCK STRUCTURES IN THE  
MARSHALL ISLANDS

by

R.M. Noble<sup>1</sup>, K.C. Leslie<sup>2</sup> and D. O'Day<sup>3</sup>ABSTRACT

In the summer of 1978, a siting/design investigation for dock structures (Marshall Islands Dock Project) was conducted at 15 atolls within the Marshall Islands group (see Figure 1). The Marshall Islands are within the U.S. Trust Territory of the Pacific Islands (TTPI), located in the North Pacific. The Marshall Islands Dock Project is part of the Capital Improvements Program currently underway in the Marshalls. The program, aimed towards making the Marshall Islands more self-sufficient in preparation for their independence in 1981, includes the construction of low cost dock structures for use by the design vessels described in this paper to load/unload agricultural products, supplies, and passengers. This study did not include the feasibility of this approach versus other alternative loading/unloading approaches.

This investigation included site selection, development of design criteria, and the design and alignment schemes for 12 new dock structures. In addition, design criteria and plans were developed for the upgrading of three existing dock structures. The site selection was performed using a multi-disciplinary approach which considered environmental, sociological, and archaeological impacts, in addition to the usual technical site selection. This paper only discusses the technical considerations to site selection.

Overall responsibility for the project was assumed by the Pacific Ocean Division of the U.S. Army Corps of Engineers on behalf of the Government of the Trust Territory of the Pacific Islands. Our work was performed for Alfred A. Yee & Associates, Inc., the structural engineer and prime contractor for the project, and in collaboration with R. M. Towill Corporation.

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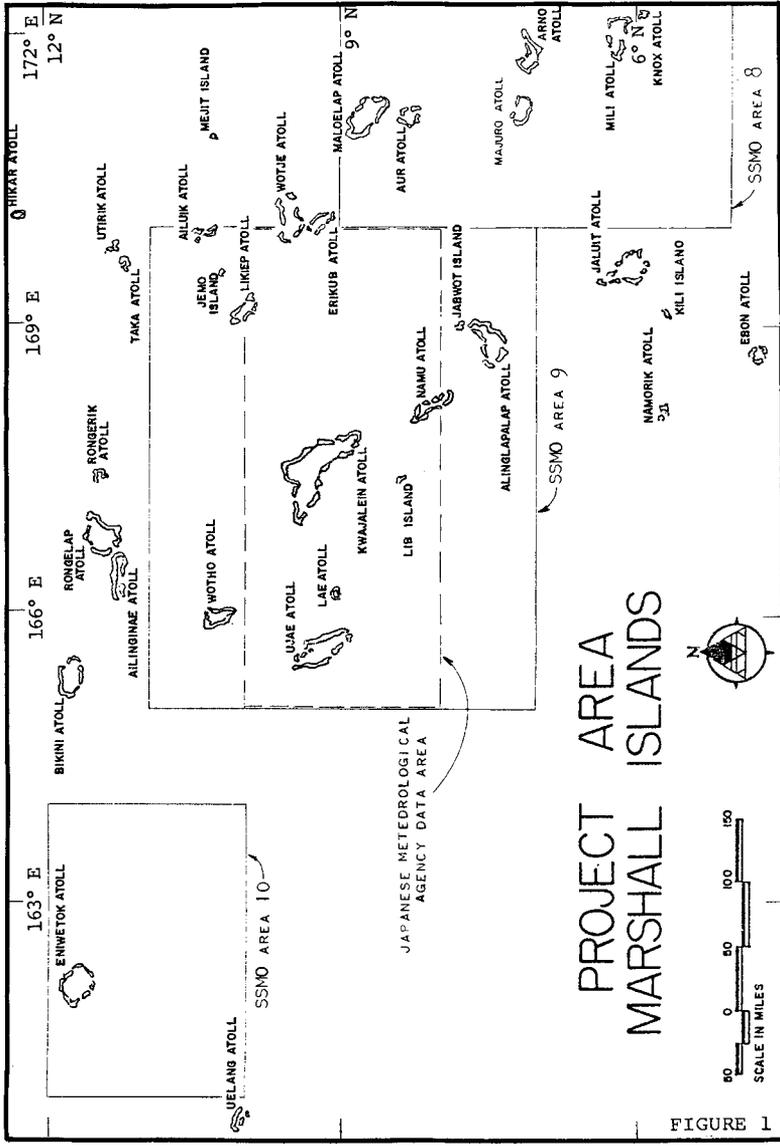


FIGURE 1

INTRODUCTION

The Marshall Islands group is composed of two roughly parallel, northwest-trending island chains approximately 500 miles long in the North Pacific. There are about 25 atolls and several islands in the Marshall Islands chain. The atolls are typically comprised of a number of elongated low lying islands and coral reef segments that enclose a lagoon.

This project involved the recommendation of sites and alignment schemes and development of design data for new docks in 12 island atolls, and recommended alignment schemes and developed design data for the upgrading of existing pier structures at three island atolls (Wotje, Jaluit and Ebeye). It is hoped that by providing centrally located dock facilities in the primary outer atolls, inter-atoll vessels could be put on a fixed schedule and copra production in the outer atolls could be increased. (Copra, the dried meat from coconuts, is a major, yet underdeveloped resource in the Marshall Islands.) In addition, one of the upgraded docks, Ebeye, was to serve for larger international vessels. The specifications of the design vessels (inter-island and international) are presented below.

	<u>M/V Eigamoiya</u> (Namu Pal Line, Melbourne, Australia)	<u>Micro Chief</u> (TTPI)
Length (feet)	368.5	185
Beam (feet)	55.0	25*
Draft (feet)	24.5	14.5
Displacement Dead Weight (tons)	5,700	800
Use	International containerized cargo	Inter-island cargo

\* Estimated

The Marshall Islands Dock Project was different than most full scale siting/design investigations due to time and budget constraints and the remoteness of the Marshall Islands. A team of individuals were asked to perform a 3-day site investigation at each atoll to select sites, develop design criteria and determine dock alignment schemes. In U.S. coastal waters, a site selection and design investigation for a project such as this would involve a site-specific data gathering effort lasting many months.

OBJECTIVES

The following objectives were undertaken to complete the assigned task within the allotted time.

- Prefield program--Existing regional data including wind and wave information and atoll bathymetric charts and aerial photographs were reviewed and assessed in order to select candidate sites for each of the atolls. Design wind and waves for return periods up to 100 years were developed from the compiled regional wind and wave information.
- Field program--During the field program, which generally lasted 3 days per atoll, the following was performed:
  - Reconnaissance of candidate sites--Usually more than one site had been pre-selected for evaluation on each island. Each was briefly examined for its coastal characteristics;
  - Meetings with residents--Meetings were held with the local officials and the probable users of the facility;
  - Site selection--Based on previously-collected data, candidate site inspections, and local input, tentative site selections and alignment determinations were made considering all major factors;
  - Site investigations--Site-specific data were then gathered for use in the design phase. A recording current meter was deployed for approximately 2 days at each site, and general reconnaissance was undertaken onshore and offshore. Limited soil sampling and jet probing were performed using SCUBA diving equipment. Wind, wave, and tidal information was collected, and on- and offshore site processes, such as littoral transport and flooding potential, were evaluated.
  - Field report preparation--Preliminary reports including the data gathered in the field were prepared with tentative alignments and preliminary design recommendations.
- Formulation of recommendations--Upon returning from the Marshall Islands, field bathymetric/topographic data were reduced and maps drawn, current meter data records were interpreted, limited soils laboratory testing was completed on bottom samples, a number of

meetings between the project participants were held, final alignments were selected, and design recommendations were formulated.

- Report preparation--A final report documenting our efforts and including the results of the literature search, field and laboratory data, and discussions and recommendations was prepared for submittal.

#### BASELINE DATA

The Marshall Islands, lying approximately between 4 degrees and 12 degrees north, are within the northeasterly trade wind belt. The trade winds dominate the regional wind regime in the area. They blow strongest (average wind speed of 10 to 18 knots) and most steadily from December to March, but weaker (average wind speed of 5 to 10 knots) and less steady from July to November. Maximum trade wind speeds are in the 30 knot range. A representative wind rose for the Marshall Islands is presented on Figure 2. These data are based upon eight years of observational wind data contained in the Summary of Synoptic Meteorological Observations (SSMO, 1971).

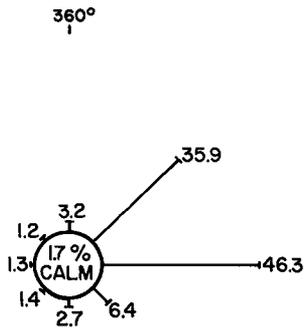
Typhoons are uncommon in the Marshall Islands, but do occur. The winds, sometimes in excess of 100 knots, and accompanying battering waves, can alter an atoll island so radically that it is not recognizable (National Ocean Survey, 1976). The typhoon season in the Marshall Islands usually extends from July to October, although typhoons have been reported throughout the year. Approach direction of the typhoons is generally east to southeast. Violent gales, sometimes severe enough to endanger shipping and cause widespread destruction on an island, occasionally occur from August through November (National Weather Records Center, 1943). The most frequent approach directions are southeast to southwest. Thunderstorms are fairly common, except during the winter months when they are relatively infrequent. Most of the thunderstorms come from the northeast, east or southwest, but a few originate in the north, south, or southwest.

Return period estimates of surface wind speeds based on observational wind data (SSMO, 1971) are presented on Figure 3. Extreme wind speeds associated with typhoons are apparently not represented in the data base. Consequently, the extreme winds for a 100 year return period (non-typhoon condition) are on the order of 40 knots and reflect primarily the trade wind condition.

# WIND ROSE- MARSHALL ISLANDS

## Percent Frequency by Direction (8 pt. Compass Direction)

### SSMO AREA 9

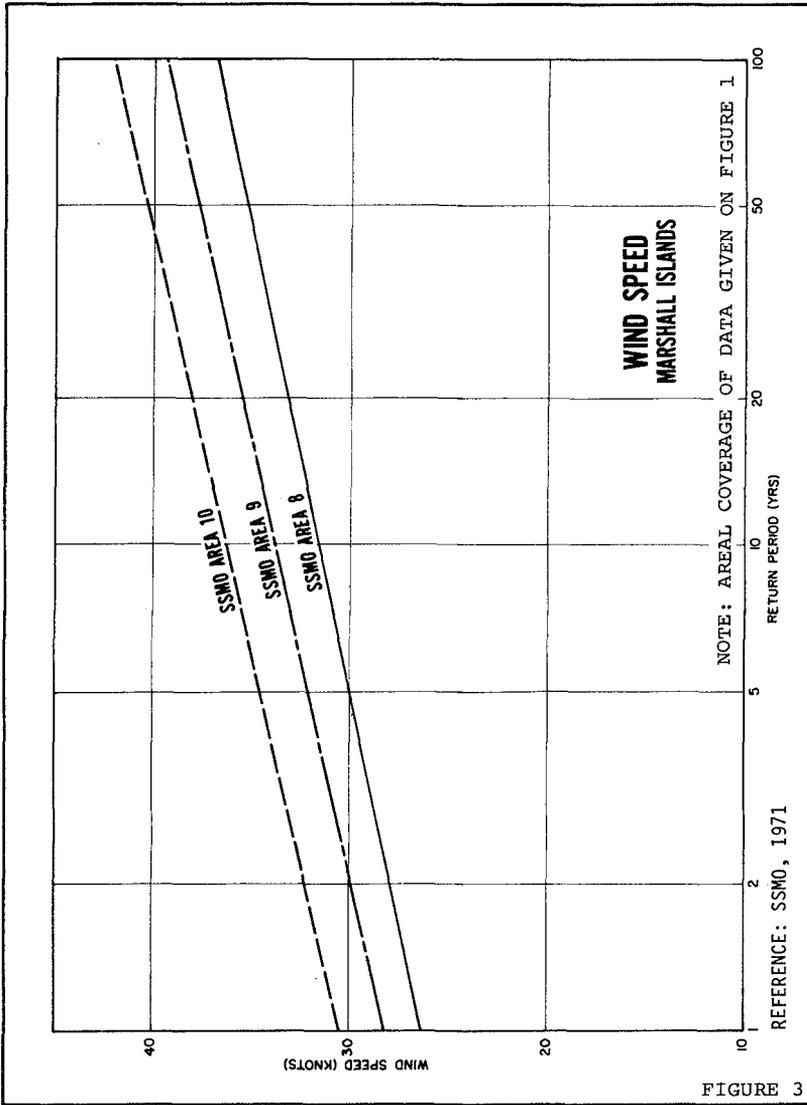


NOTE: AREAL COVERAGE OF DATA  
GIVEN ON FIGURE 1

180°

REFERENCE: SSMO, 1971.

FIGURE 2



The predominant wave approach directions within the Marshall Islands area are northeast to east, which is a consequence of the persistent northeast trade winds. Wave data based upon wave observations made aboard ship over an eight- to ten-year period and compiled in SSMO (1971) and Japanese Meteorological Agency (1971-1978) are presented on Figure 4. These data indicated that less than two percent of the waves observed in the Marshall Islands area have heights exceeding 12 feet. The maximum wave height observed in either of the two data bases was a long period, 22-foot-high wave, directed from the northeast. Return period estimates of wave heights based on observational wave data (SSMO, 1971 and Japanese Meteorological Agency, 1971-78) are shown on Figure 5.

The protection afforded by the encircling islands and reef segments forming the atoll rim shelter the lagoon from incoming oceanic waves. Wave heights were calculated within the lagoons along critical approach directions using a 20-knot wind speed and the wind speed associated with a 50-year return period. The wave heights calculated using the 50-year return period wind speed ranged from 3.0 to 7.8 feet, depending primarily upon fetch length and degree of exposure, and were in close agreement with the maximum wave height observed by atoll residents.

Currents within the lagoons of the Marshall Islands atolls are generally wind dominated. The wind generated currents have speeds generally less than 0.5 knots. Tidal current speeds as great as 5 to 10 knots have been reported in some of the passes of the atolls.

Seiching was observed in several of the lagoons where a reference, such as the face of an existing pier, was available. It is likely that the seiching occurs as a result of lagoon excitation produced by incoming wave trains passing through the channels and passes.

The Marshall Islands are, in essence, coral atolls. Fringing reefs, sometimes rising above sea level to form islands, encircle the atoll, creating a protected lagoon. Deep drilling studies indicate the coral atolls are underlain at depth by basaltic bedrock (Emery and others, 1954). It is generally accepted that the volcanic masses once reached a near- or above-sea level elevation, and that during subsidence, upward growth of the coral has kept pace with the subsidence, thus preserving the near-sea level feature.

The reefs forming the atoll rim have adjusted to the prevailing wind, wave and current forces. Emery and others (1954) investigated the marginal reefs of Bikini and nearby atolls, and were able to correlate reef type with prevailing

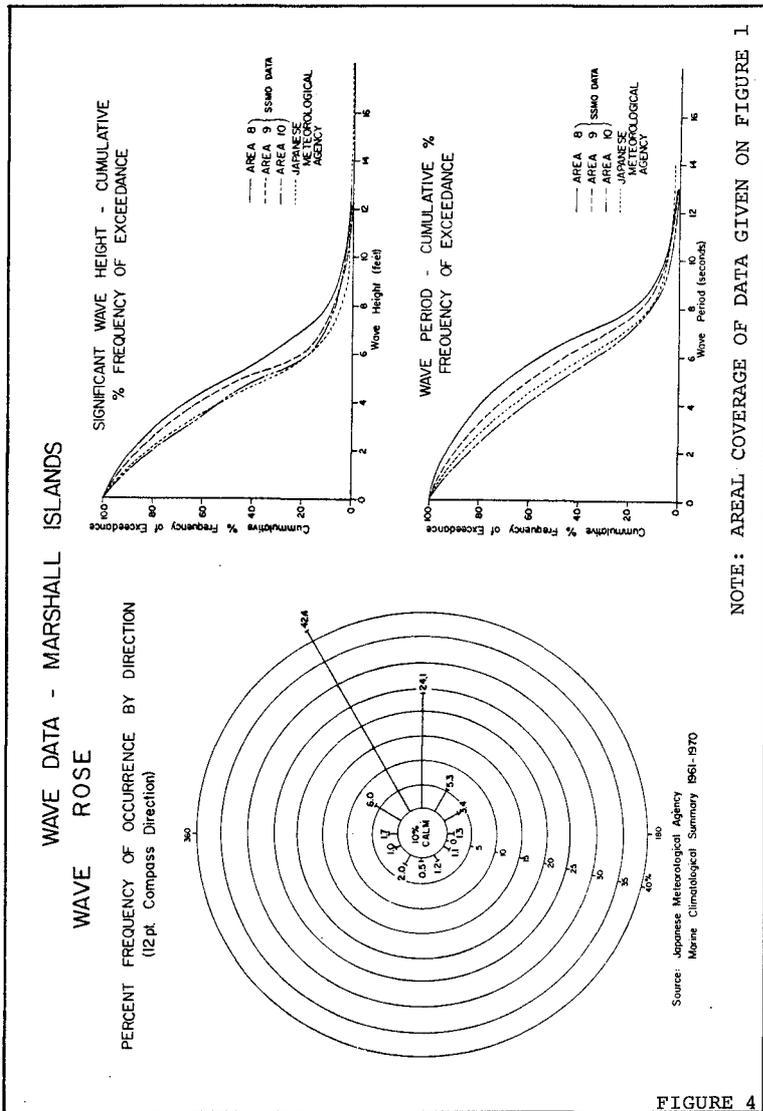
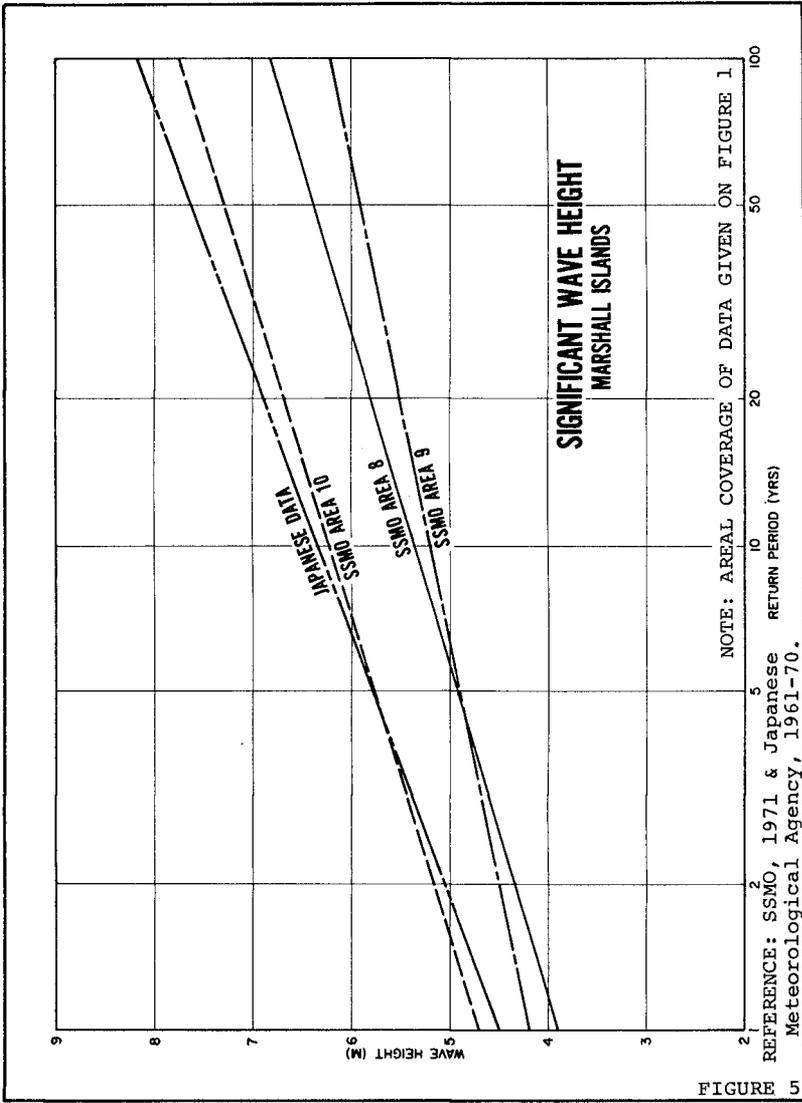


FIGURE 4



oceanographic conditions. In general, the windward reefs, the more vigorous of the reefs investigated, had characteristic well-developed algal growth (Lithothamnion ridge) that appeared to be a consequence of an adjustment to strong, steady surf. The leeward reefs generally lacked this prominent ridge, were slower growing, wide, and had steeper seaward slopes. The reefs on the southern shore are adapted to weak surf conditions, as this is the lee shore, but are subject to severe damage during periods of southern storms (Emery and others, 1954). Large blocks of coral torn from the reef edge during storms litter the reef flat.

Between the reef segments are passes or channels that link the lagoon to the open ocean. The passes are characteristically deeper, and have flatter sea floor bottoms than the channels. Tidal currents maintain these passageways.

Shallow lagoons lie within the encircling reefs. The maximum depth of the lagoons is generally less than 200 feet. Beach or near-beach deposits are often present around the outside margin of the lagoon. Coral knolls and pinnacles rising near- or above-sea level are common features within the lagoons.

#### SITE INVESTIGATION

The site investigation team consisted of six professionals from Dames & Moore, Alfred A. Yee & Associates, Inc. and R. M. Towill Corp. Represented were experts in coastal/ocean engineering, geotechnical engineering, environmental/oceanographical sciences, surveying and structural/construction engineering. Also traveling with this team were one or two representatives of the U.S. Army Corps of Engineers and one or two representatives of the TTPI.

Key siting criteria were established for use in both pre-site and final site selection. Due to the short duration (average of 3 days per atoll) site visits, it was extremely critical to rapidly perform final site selection at each atoll where a docking facility was to be established. Therefore, all pertinent data, including navigational charts and aerial photographs, were thoroughly reviewed in advance of the site investigations to pre-select the most desirable sites. Siting criteria considered were as follows:

- Exposure
- Navigation
- Water depths near shore
- Bottom conditions
- Location/access within atoll
- Available landside area
- Environmental considerations

Of prime consideration in pre-site selection were: site exposure to or protection from oceanographic/meteorological conditions such as waves, winds, surge, currents, sediment transport, etc.; navigational approach to the site, sufficient water depths along approach, potential navigational hazards, transit through inlet passes for lagoon sites, vessel exposure to currents, waves, winds, etc.; and, proximity of deep water nearshore for more economical dock facilities.

Whenever possible, lagoon sites were selected over open ocean sites due to their usual better protection from wave conditions which resulted in lower design conditions, safer navigational approach, and longer duration of operational time during the year.

Just prior to the site investigations, a quick reconnaissance was performed to assess pre-selected sites. In addition, meetings were held with the local Marshallese to confirm preferred site locations. Preliminary diving and land surveys were then performed to select a final site and a possible alternative. This involved consideration of such added factors as: offshore bottom conditions from design, construction and environmental viewpoints; available landside area for storage and dock facilities; and, the site location relative to the atoll's population, copra production, and roads.

The means for performing physical site investigations were kept as simple as possible due to time, budget, weight, and maintenance constraints. On several occasions, we were left on atolls where we were totally self-sufficient by transporting all living supplies and field equipment (approximately 3,000 pounds) across several hundred feet of coral reef to a camp location. Field equipment consisted of such items as SCUBA gear, tanks, compressor, boat, outboard engines, gasoline, survey instruments, current meters, jet probe and pump, fathometer, weights, floats, etc. Field equipment had to be dependable as we could only handle a limited number of spares and selected maintenance equipment.

Site surveys consisted of both onshore surveys and offshore diver reconnaissance surveys. Offshore surveys consisted of a bathymetric survey, installation of an in situ current meter, jet probing into bottom sediments along the proposed pier alignment, mapping of bottom conditions including extent of coral, mapping of existing structures, and an environmental inventory. Onshore surveys consisted of a topographic survey, shoreline conditions, site exposure, onshore geologic structure, available land area and access, socioeconomic considerations, availability of construction materials, etc.

RECOMMENDATIONS

Site field data were reduced and assessed along with the analysis of available historical data to develop appropriate design criteria for the design and construction of dock structures. Design criteria consisted of the following:

- Water levels--deck height
- Wave/wind conditions--pier alignment
- Wind/impact loads
- Wave uplift forces
- Setback
- Pier support

A pile-supported trestle/pier structure with mooring dolphins was recommended. Gravity structures, such as landfills or permanent cofferdams, were ruled out for economic and environmental reasons. The basic pier design adopted consists of a 16-foot-wide approach trestle terminating at a 24- by 80-foot loading/unloading platform at the pier head. A dolphin off each end of the pier head was recommended to provide proper mooring, while minimizing the length of the pier head required to handle cargo and passengers. Preliminary vertical pile loads were estimated at 20 tons per trestle pile and 40 tons per pier head pile. The approach trestle was recommended for extension landward of the intertidal zone beyond the upper limits of wave uprush. This was recommended to reduce environmental and construction concerns if a landfill causeway had crossed the beach area to connect with the trestle. A pier deck height of +10 to +12 feet (chart datum) was recommended to account for the effects of tide, storm surge, wave, and wave runoff.

The following recommendations were of major importance in the final design and construction of dock facilities:

- Minimize
  - Dock lengths
  - Dredging
  - Maintenance
- Standardize
  - Dock configurations
  - Construction materials
  - Construction techniques
- Maximize
  - Precast concrete

It is recommended that standardized concrete modular units be prefabricated elsewhere and then transported to the sites. By use of a construction barge with a crane and pile driver and use of standard construction techniques, docks

would be assembled on location with minimum on-site construction. The above are recommended due to the remoteness of the sites, the unavailability of supplies and laborers, and to keep construction costs to a minimum. Concrete is recommended from a corrosion maintenance standpoint.

Due to the high cost of mobilization to the sites, additional field work to gather supplementary data was not economically feasible. Therefore, it is expected that some changes to the designs may be required in the field.

#### BIBLIOGRAPHY

- Emery, K. O., and others, 1954. Geology of Bikini and Nearby Atolls, in Bikini and Nearby Atolls, Part 1, Geology, U.S. Geological Survey Prof. Paper 260-A.
- Japanese Meteorological Agency, 1971-1978. Marine Climatological Summary - Marshall Islands area, 8°-10° north latitude, 165°-170° east longitude. Covers period 1961-1970.
- National Ocean Survey, 1976. Sailing Directions for the Pacific Islands. Publ. 82, Vol I (revised from first edition, 1964), published by the Defense Mapping Agency, Hydrographic Center.
- National Weather Records Center, 1943. Meteorology of the Marshall Islands. Strategic Bulletins of Oceania, No. 2, compiled by the Cross-Cultural Survey, Institute of Human Relations, Yale University.
- U.S. Naval Weather Service Command, 1971. Summary of Synoptic Meteorological Observations, Vol. 3, Area 8 - Majuro, Area 9 - Kwajalein, Area 10 - Eniwetok.

