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Coastal Erosion and Management of Majuro Atoll, Marshall Islands

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ABSTRACT

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About fifty kilometers of lagoon coast in Majuro Atoll is suffering erosion, which is induced by human activities including aggregate excavating and building causeways, artificial channels, landfill and other constructions. The west longshore sediment transportation on lagoon coast is significant for stability of lagoon shore of the west atoll. The lagoon coast erosion on the west atoll is induced by development on the east atoll. Distribution of beachrock demonstrates former existence of a continuous land on the south rim. The causeway has not caused sea level rising in lagoon. Openings on the south rim should not be made, as these will induce severe erosion. Reforming lagoon coastal constructions is proposed.

ADDITIONAL INDEX WORDS: *Erosion, longshore sediment transport, coastal construction, artificial channel.*

INTRODUCTION

Majuro Atoll, located at 171°12′ E and 7° 09′ N, is elongate in shape, extending 40 km from east to west and 9.7 km from north to south. The lagoon is enclosed by an almost continuous reef flat with some passages on the middle west of north rim, in which a 3.2 km wide and 9.1–18.3 m deep passage is located to the west of Calalin Islet. Most islets are on the east half of north rim, east, south and southwest rims. The islets on the south rim have been connected by causeways. The lagoon has a surface area of about 324 km^2 and an average depth of about 46 m, descending to a maximum depth of 67 m (MANOA MAPWORKS, 1989; WILSON *et al.,* 1990; HOLTHUS *et al.,* 1992; Figure 1).

The prevailing winds at Majuro Atoll are east-northeast trade winds. During the period 1938–1970, the east-northeast winds account for 81.3% (east, 45.2%, northeast, 36.1%) of the time. The tides at Majuro Atoll are semi-diurnal with pronounced diurnal inequalities. Predicted mean range and mean spring range at Majuro Atoll are 1.13 and 1.62 m respectively. A highest tidal level observed at Majuro was 1.10 m above mean sea level in 1977 (HOLTHUS *et al.,* 1992).

The present study was undertaken by South Pacific Applied Geoscience Commission (SOPAC) as part of its technical assistance program to the Republic of the Marshall Islands, to provide advice on coastal erosion and management issues. The study areas are the lagoon and ocean coasts along the east, south and southwest rims *i.e.* from Djarrit to Laura. Half day geological trip was conducted in Bok-aitoktok Islet on the north rim. The field survey was undertaken from 28 January to 15 March 1997.

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COASTAL GEOLOGY

The reef flat is continuous in most parts of the atoll. The ocean reef flat is commonly tens to 200 m wide and exposed in low tide. It is occupied by pavement-bare coral reef rock with some rubble and blocks dispersed on the pavement. Some living or dead branch corals exist in a narrow belt close to the edge in some areas. Gravel beach is distributed along most of the ocean shore and sand beach in a few areas. This indicates that the main sediment supply is from the rubble tossed by exceptional storm waves.

The lagoon reef flat is 150–750 m wide. On the north rim, most sections of east rim and the east section (from south Delap to the southernmost turning point) of south rim except the westernmost 1.5 km, there is no break or evident edge on the outer boundary of the lagoon reef flat. The lagoon reef flat gradually becomes deeper. The reef flat is occupied by sand and patch reef, or with pavement, sand or rubble in the inner part. Living corals are still luxuriant in most areas. Even at low tide, most of the reef flat is covered by shallow water. This type is distributed in the coast with moderate waves and currents. There is a 2–3 m high break or cliff at the edge of lagoon reef flat on the west section (from the southernmost turning point to east to Laura) of south rim (R. MISTRY-resident UNDP coastal manager, personal communication). The break extends to the westernmost 1.5 km of the east section of south rim and the southwest rim (the triangular land-Laura). From the reef flat edge to land, there is a coral zone with a width of 10–20 m, sand and patch coral zone, and loose sediment zone (sand or rubble). The reef flat is exposed in low tide. Sand beach is found along most of the shore. Gravel beach occurs in very limited areas. This type is distributed on the coast with relatively strong wave and current, which encourage growth of corals along the edge of the reef flat. On the north end of Djarrit on east rim, there is no

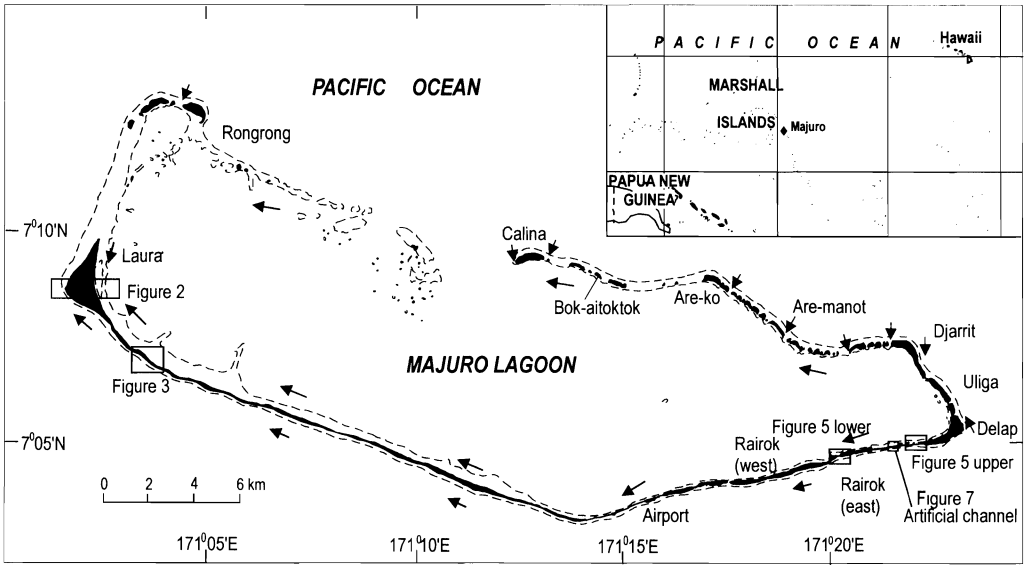

Figure 1. The Majuro Atoll showing longshore sediment transportation and location of some figures in this paper.

evident reef flat. Gradually deeper lagoon with sand cover is at front of sand beach. This is contributed by lagoonward migration of the entire islet with erosion on the ocean side and progradation on lagoon side. The historical lagoon reef flat has been covered by present land and beach.

The lagoon beach sediment is supplied from the reef flat and lagoon. On the east section of south rim, the lagoon sand is relatively easily moved onto the reef flat. However, on the west section of south rim and the southwest rim, it is more difficult to move the lagoon sand onto the reef flat because of existence of the break. The longshore sediment transports on the lagoon and ocean sides of the south rim are westward, since the dominant winds are east-northeast (Figure 1). This is demonstrated by measurement of currents in the lagoon (Rosti, 1990) and difference in sedimentation on both sides of many groins. Historically and at present the westward sediment transport is very important for stability and progradation of lagoon shores on the west section of south rim and southwest rim (Laura). Along these shores almost all of the beaches are sandy. On land in the west section of south rim, the width of surface sand ranges from a few to one hundred meters along the lagoon shore. In Laura, rubble is only distributed along the ocean beaches and a narrow belt on the south and middle ocean shores. Most of the land is covered by sand (Spennemann, 1990). At present a big reef hole with more than 9 m maximum water depth exists in front of Laura, on the lagoon side. This hole was much bigger and deeper in history. Most of the original reef hole has been filled by thick sand, which is indicated by three drill holes (Anthony and Peterson, 1987; Hamlin and Anthony, 1987; Figure 2).

On the ocean side, the longshore sediment transport is not as significant as on the lagoon side because more beaches are gravely. To north of Laura, sand from the lagoon side is moved to the ocean side and redistributed along the ocean beach of the north Laura because of relatively east-northeast strong wave and rather high ebb current.

COASTAL EROSION

Both ocean and lagoon coasts of the east, south and southwest rims have been eroded except a few areas such as in front of some causeways. The total eroded coastline is some one hundred kilometers long. More than half of the shorelines on east rim and the east section of south rim are protected by seawalls.

On the ocean shore, erosion scarps are very common. Based on conversations with local residents the shoreline has retreated about 10 m in the last 50 years in some places. Shoreline recession was even as much as 20 m somewhere by a comparison of 1944 and 1983 aerial photographs (Manoa Mapworks, 1989). Compared with the others areas, the erosion of ocean coast on the west section of south rim and on southwest rim (Laura) is not severe.

The lagoon coasts are eroded even more severely than the ocean coast, except the stable or prograding coasts in limeted areas. A large land tree *Callophyllum inophyllum* indicates that the shoreline on the south section of east rim has retreated at least 4 m. However, based on the information from an elder resident, the shoreline of the south Uliga has retreated about 17 m since the end of the Second World War. On the west part of Rairok a surviving large tree, *Callophyllum inophyllum* indicates that the shoreline has retreated at least 17 m. The old road east to the airport has mostly disappeared and the present shoreline reaches the trees on south side of the road. It is estimated that the shoreline has receded more than 10 m. On the west section of south rim, surviving large trees *Callophyllum inophyllum* indicate that the shoreline has retreated at least 18 m in some places (Figure 3.). This recession occurred in the last 25 years (counting

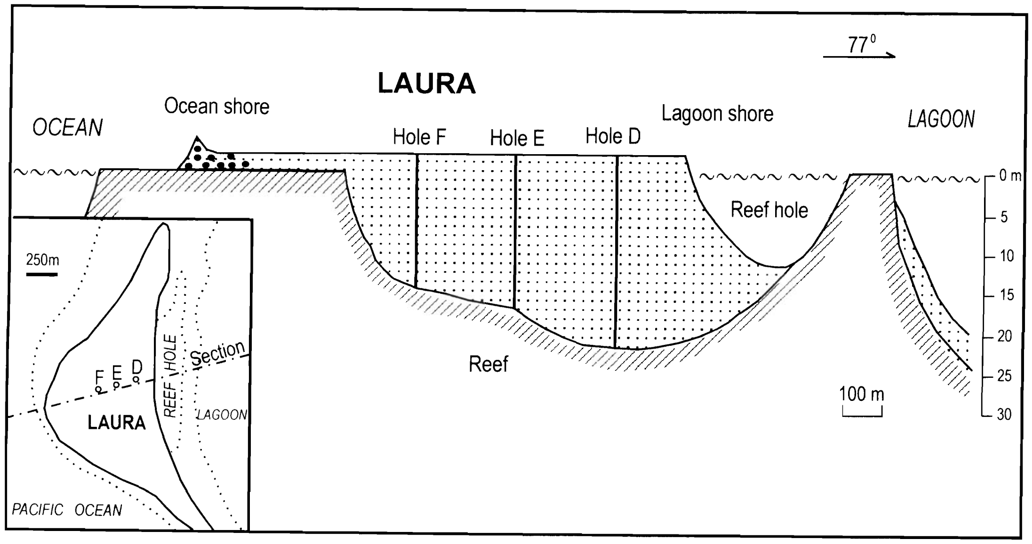

Figure 2. A cross-section from ocean to lagoon in middle Laura, showing that the original reef hole has been mostly filled up by sand transported from the lagoon coast of the south rim. The data of the drill holes are from ANTHONY and PERTESON (1987). The surface and shallow subsurface sediments are based on field survey and some shallow drill holes. Location in Figure 1.

from 1997 in this paper, information from local residents). The lagoon shore of south Laura has suffered light erosion. The shore at the middle Laura has no evident change. Severe erosion occurred on the lagoon shore of north Laura. A surviving coconut tree indicates that the shoreline has retreated at least 5.8 m. A local resident provided information that the shoreline has retreated for 12–17 m in last 20 years and the erosion started 20 years ago. In summary, severe erosion occurred on the lagoon coasts of the east and south rims and the north Laura, where the shorelines have retreated for 4–18 m in the last five or three decades.

EVENTS AND THEIR EFFECTS

It is interesting that erosion also occurred on the lagoon shores of the west section of south rim and Laura, which are far from the developed east atoll, and few inappropriate human activities occurred in. In 1944 and the early 1970s a series of causeways were built. Continuous land from Djarrit to Laura has formed. It was considered that the closure of passages made the lagoon water level rise, which results in lagoon coastal erosion (ROSTI, 1990).

Before the causeways were built on the east rim in 1944, seawater was moved to lagoon in most time in a tidal cycle due to strong east and northeast waves. The causeways can not make lagoon water rise although they have changed circulation in the easternmost lagoon.

SPENNEMANN (1990; 1992; 1993) reported valuable historical data, which were drawn from unpublished documents as well as published works. These studies are very helpful for understanding historical change of Majuro Atoll in the 20th century. Until 1905 there had been a continuous land connection between Delap and Laura (SPENNEMANN, 1993). The strong typhoon on 30 June 1905 washed over the narrow parts of the long island from Delap to Laura. Majuro lost two tracts of land on its southern coast, apparently close to Delap, a land area of a total of 3 miles length (Spennemnann, 1990; 1992; 1993; Figure 4).

Even though there was no geographic map at the beginning of the 20th century, the existence of a continuous long island on the south rim of Majuro Atoll is believable, because geological phenomena provided effective evidences although they could not indicate when it was breached. When the beachrock formed it surrounded the islet. If a long islet was breached into several islets by exceptional cyclone waves, the roughly parallel ocean and lagoon beachrock on both sides of the original islet still left. Continuous beachrock exists on both sides of present causeways, which are at former breaches on the east section of south rim. They still can be clearly identified although some beachrock has been covered by causeways and reclaimed lands, and a few has been excavated (Figure 5). Therefore, it is definite that a long island from Delap to Laura existed before 1905.

On the east section of south rim, the 1905 cyclone only washed away the loose sediment at some places. The reef flat and beachrock on both ocean and lagoon sides at the breaches have remained. The crest of beachrock is only little lower than the shore. Therefore, the beachrock on both ocean and lagoon sides blocked water exchange between ocean and lagoon. Only a little water could go in and out at high tide passing the breaches and could not affected water level in the large lagoon. The longshore current almost only existed out of the beachrock on the breaches.

On the east section of south rim, the east causeways were built in 1944 and the west causeways including the runway were built in the early 1970s. The action of these causeways just recovers the lagoon circulation system along the lagoon coast on the south rim to the situation before 1905. The lagoon water level and the longshore currents along the lagoon

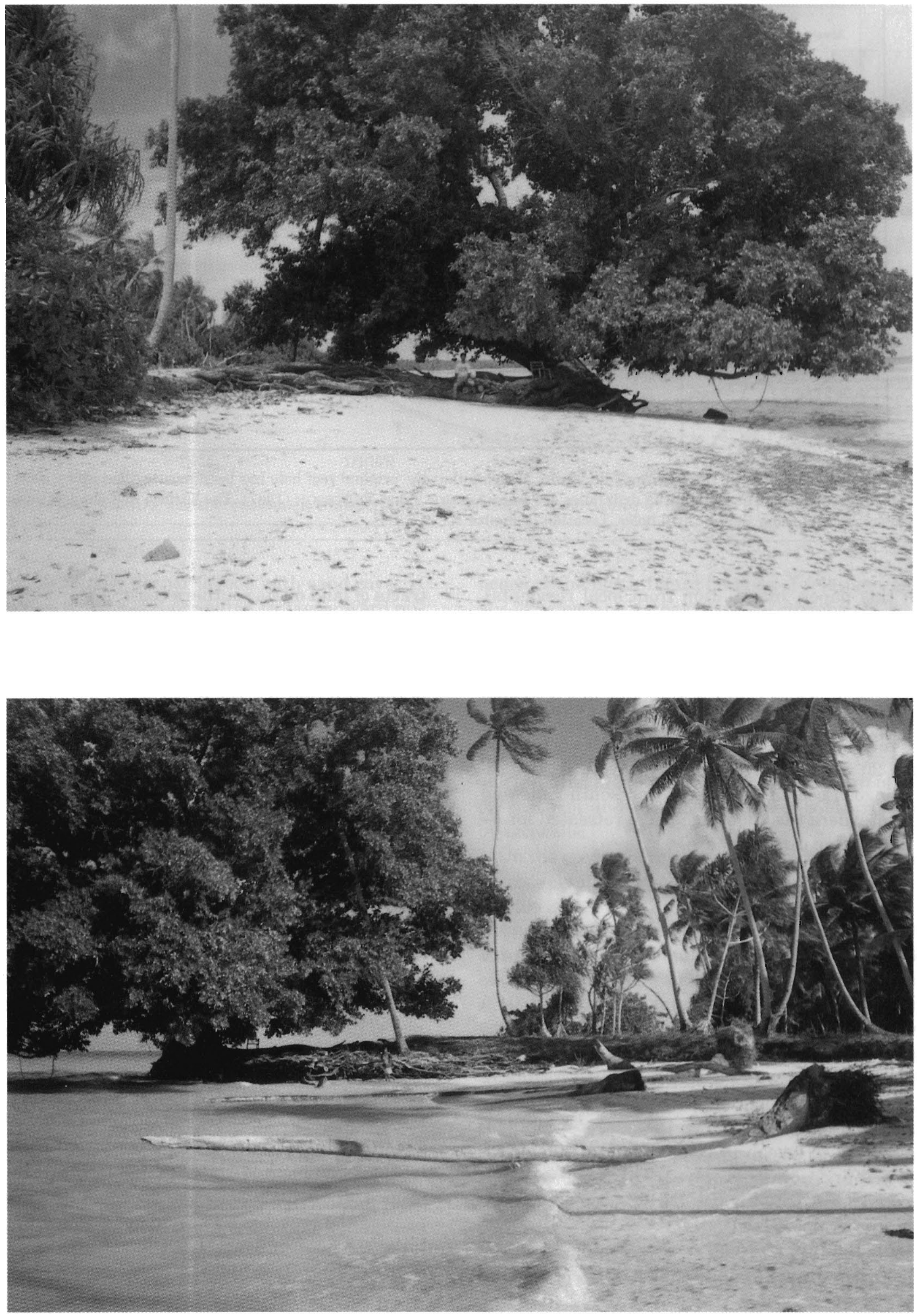

Figure 3. A surviving large tree *Calophyllum inophyllum,* indicating that the shoreline has retreated at least 14 m on the southeast updrift side (upper photo, view from 140°) and 22 m on the northwest downdrift side (lower photo, view from 290°), at average of 18 m, and northwest longshore sediment transport. Lagoon side, the west section of south rim. Location in Figure 1.

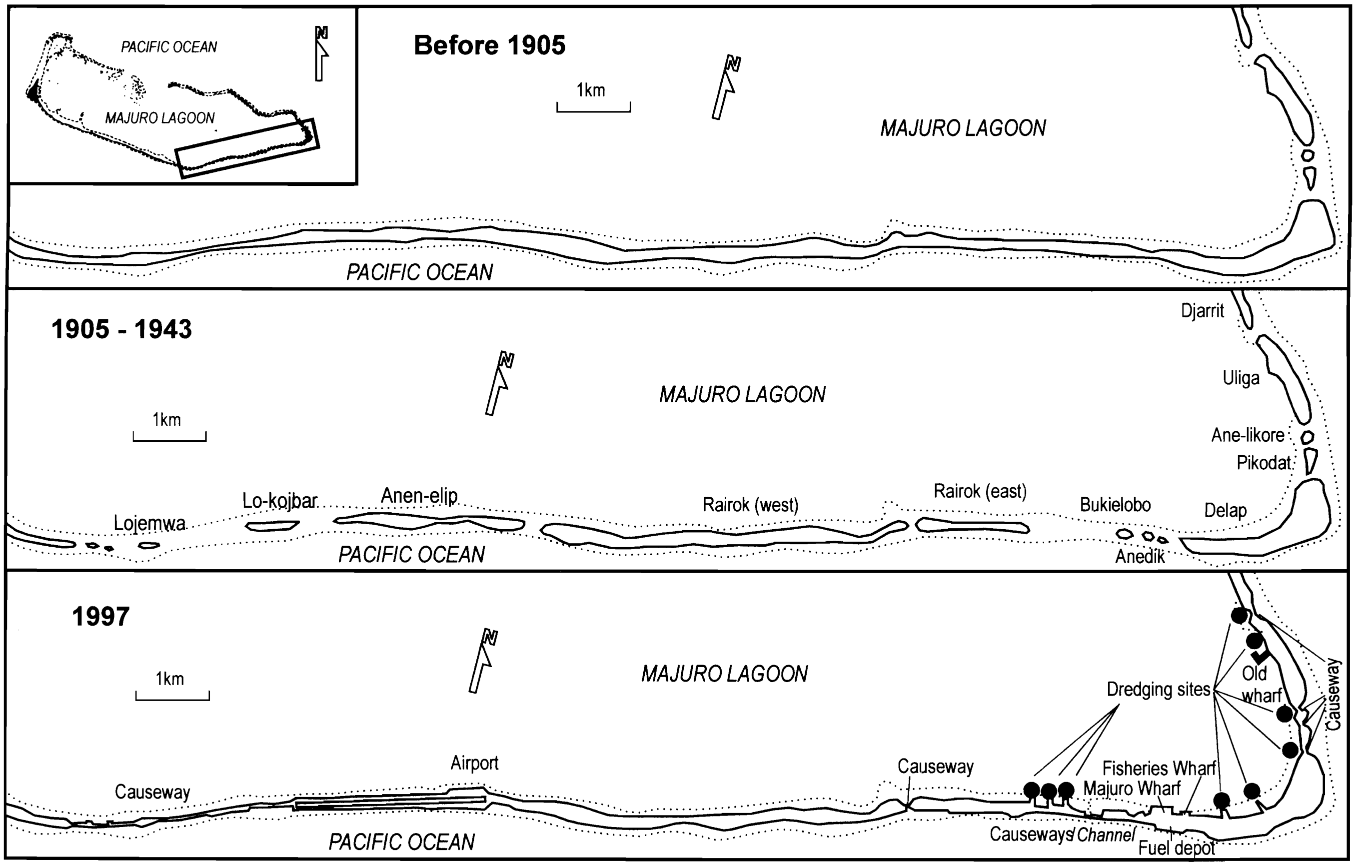

Figure 4. Historical change of shoreline on east rim and the east section of south rim in Majuro Atoll. The upper: before 1905, based on the distribution of beachrock and Spennemann, (1990; 1992; 1993). The middle: 1905–1943, based on 1944 map of Majuro Atoll. The lower: 1977, based on 1997 field survey.

coast on the south rim almost has not changed in a long history (before 1905, 1905–1943 and since 1944, some causeways have been built on the south rim). The lagoon coastal erosion on the south rim can not simply be attributed to lagoon water level rise. As a matter of fact, It is normal situation that the mean water level of a lagoon enclosed and almost enclosed by reef flats is little higher than the ocean mean water level.

CAUSES OF EROSION

Natural Causes

Natural shoreline change including shore erosion occurs for a number of reasons, such as changes of sediment supply, direction and strength of waves and currents.

A series of islets with inter-islet channels on the atoll rim exhibit a tendency towards lagoonward migration of the entire form by erosion on the ocean side coincident with lagoonward deposition (Richmond, 1992). This process occurs in the early stage of atoll islet evolution and now is still occurring on the north rim in Majuro Atoll, where only a little human activity occurs. Before the Second World, the islets on east rim were similar to those islets on north rim, with eroded ocean shores, prograded lagoon shores and trace of islet migration-poorly cemented remnants (conglomerate) higher than neighboring reef flat at front of ocean shores.

In common natural condition, erosion may periodically occur, alternating with accretion because of the change of sediment supply, on the ocean coast of the long island on south rim and southwest rim, which is stable in general. In history the lagoon coast of the long island on south rim was stable or a little prograding and the lagoon coast of Laura was prograding although land expansion need much more sediment to fill the deep reef hole in front of Laura lagoon shore (Figure 2).

However, exceptional cyclone waves can produce great shoreline change and the change may not be recovered for many years. The typhoon of 1905 breached the continuous land on the south rim, which was not recovered naturally.

Man-Induced Causes

Erosion has become a severe problem in last three decades. On the ocean and lagoon coasts of east, south and southwest rims, erosion occurs almost everywhere. The human activities induced erosion on the original stable or prograding coasts and more erosion on the original eroded coasts. The

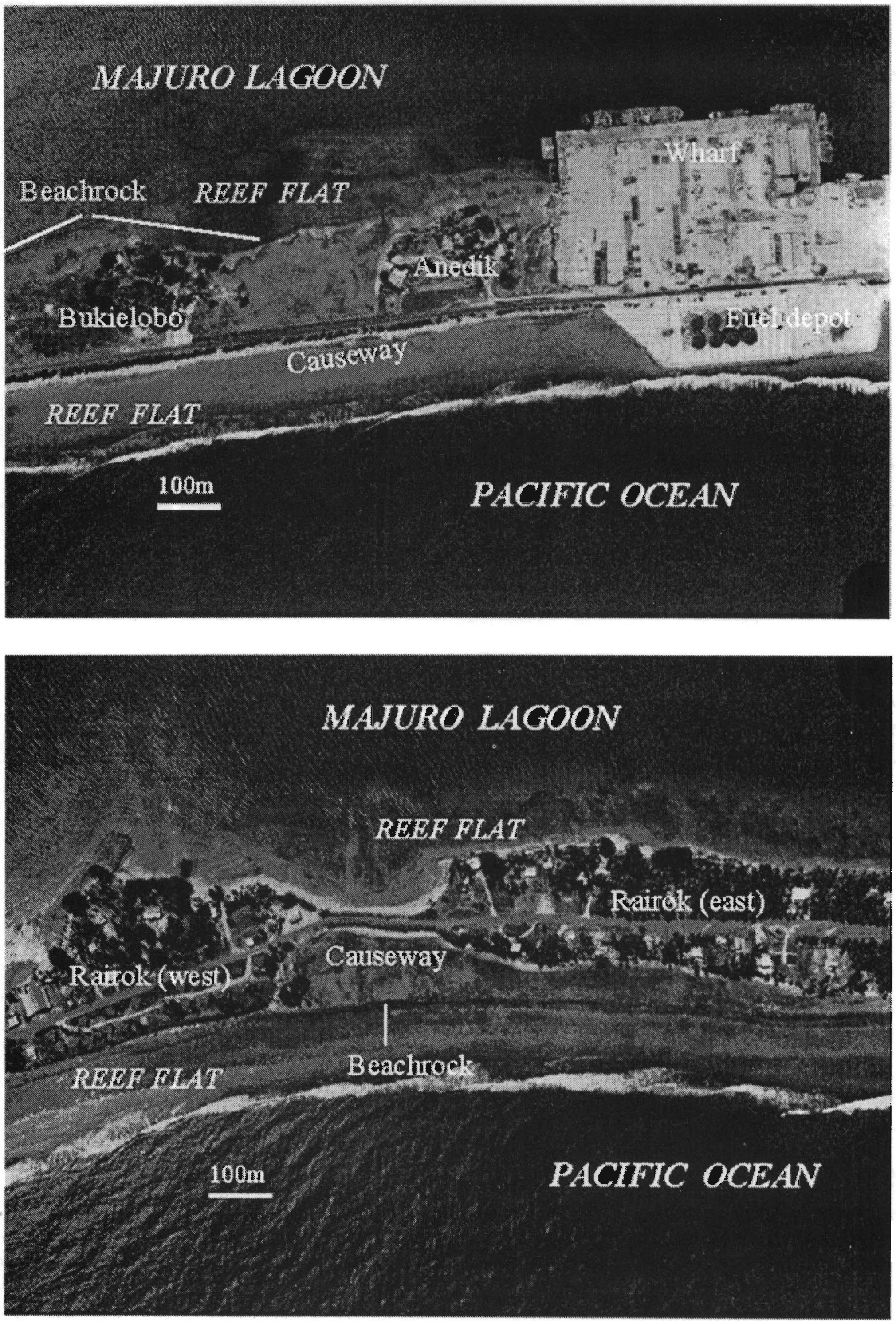

Figure 5. Air photos taken on 19 April 1983, showing beachrock distribution indicating approximate position the old shorelines before 1905. Upper: lagoon side beachrock (conglomerate and sandstone) between Anedik and Bukielobo Islets and west to Bukielobo Islet, west of the Majuro Wharf. The ocean side beachrack is covered by a causeway. Lower: beachrock on both sides of the causeway between the east part of Rairok and west part of Rairok. The ocean side conglomerate beachrock is clear. The lagoon side sandstone beachrock is curved inward, 40-60 m far from the causeway and discontinuous because of excavation. Location in Figure 1.

following human activities or coastal constructions have induced erosion.

Causeways

Before the causeways were constructed, the dominant sediment transportation at the passages on the east ocean coast was lagoonward. The opposite (oceanward) sediment transportation was significantly less because of the east-northeast dominant waves. The lagoon shores were prograding and the ocean shores were eroded if no sufficient sediment supply from the ocean reef flat. After building causeways, two small bays have formed in front of each causeway on both ocean and lagoon sides. Sediment accumulates there (Figure 4). The lagoon shores beside the passage are eroded and the ocean shores suffer more erosion than before due to loss of sediment supplement from lagoon side until the shores become smooth.

The impacts of the causeways in the east section of south rim are small because beachrock is at front of the causeway and bay environment can not form at front of some long causeways.

Aggregate Excavating

In the Second World War, Majuro was a military base. It was necessary to excavate aggregate for building runways, causeways, docks and houses. After the War, Majuro became the administrative center of the Marshall Islands and in 1979 became capital of the Republic of the Marshall Islands. After the war, the popular center moved from Laura to east end of the atoll and population of Majuro Atoll has been rapidly increasing. All of these developments require a lot of aggregate. For procuring low cost aggregate excavating mostly occurred on the lagoon coast of the east atoll.

Excavation of loose sediment from the beach and reef flat has been conducted until now, although it is illegal. This activity directly induces erosion. Commercial dredging of the bulk of sand and rubble from the lagoon might seem to have no significant adverse impact but actually has caused great problems and is one of the most significant causes of lagoon coastal erosion. Dredging sites are located on the edge of the lagoon reef flat and are connected to shore with groins, from Djarrit to the east part of Rairok. Eight disused and one working (west to the artificial channel) dredging sites are showed in Figure 4 and another disused one is at middle of Djarrit, out of Figure 4. This dredging greatly reduces the sediment supply to the lagoon reef flat and beach. Dredging on the east lagoon has induced erosion on these shores and to the west of these dredging sites.

The quarry pits on the lagoon reef flat and ocean reef flats of the easternmost section (Delap) and the west section of south rim have trapped sand and gravel, causing erosion. However, most parts of the ocean shore from the western end of Delap to the airport are artificial. In the areas, where is virtually no loose sediment for trapping by the quarry pits, the quarry pits can be excavated as pointed by LAMBERT and MARAGOS (1990).

Artificial Channel Crossing through Reef Flat

A channel crossing through reef flat between ocean and lagoon was excavated in 1980s between Majuro Wharf and

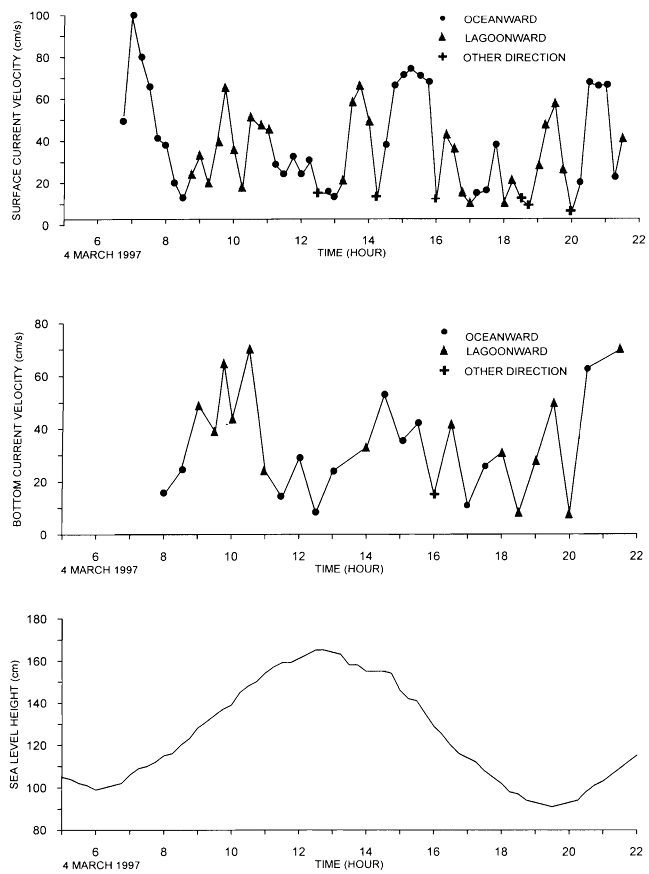

Figure 6. Surface current velocity (upper), bottom current velocity (middle) at the artificial channel crossing through the reef flat between ocean and lagoon, and tidal level (lower) in Majuro Atoll. The tide data are from the Sea Level Center, of the University of Hawaii.

the east part of Rairok, across a causeway and under a bridge. It extends along 345°–165° (magnetic bearing), about 22 m wide, 3.6 m lower than the reef flat (Figures 1, 4 and *cf.* Figure 7). The surface currents were measured with interval of 15 minutes for 14 hours and 45 minutes and bottom currents were measured with interval of half an hour and occasionally one hour for 13 and a half hours on 4 March 1997, local time (both over one tidal cycle, Figure 6). The wind directions were 30°-60° and the wind speeds were 7–13 knots measured by Weather Station of Majuro.

The duration of oceanward currents was close to that of the lagoonward currents. The measured highest oceanward surface current was 99 cm/s and the measured highest oceanward bottom current was 63 cm/s. However, the actual highest bottom current in that morning may be close to 99 cm/s since the bottom current from 6:45 to 7:45 was not measured because of concern for the instrument safety. Both the highest lagoonward surface and bottom currents were 65 cm/s. The threshold for bedload sand transport by tidal currents is typically about 40 to 45 cm/s (KLEIN, 1970; KLEIN and WHALEY, 1972; DALRYMPLE *et al.,* 1978). Therefore the channel not only traps longshore transported sediment but also trans-

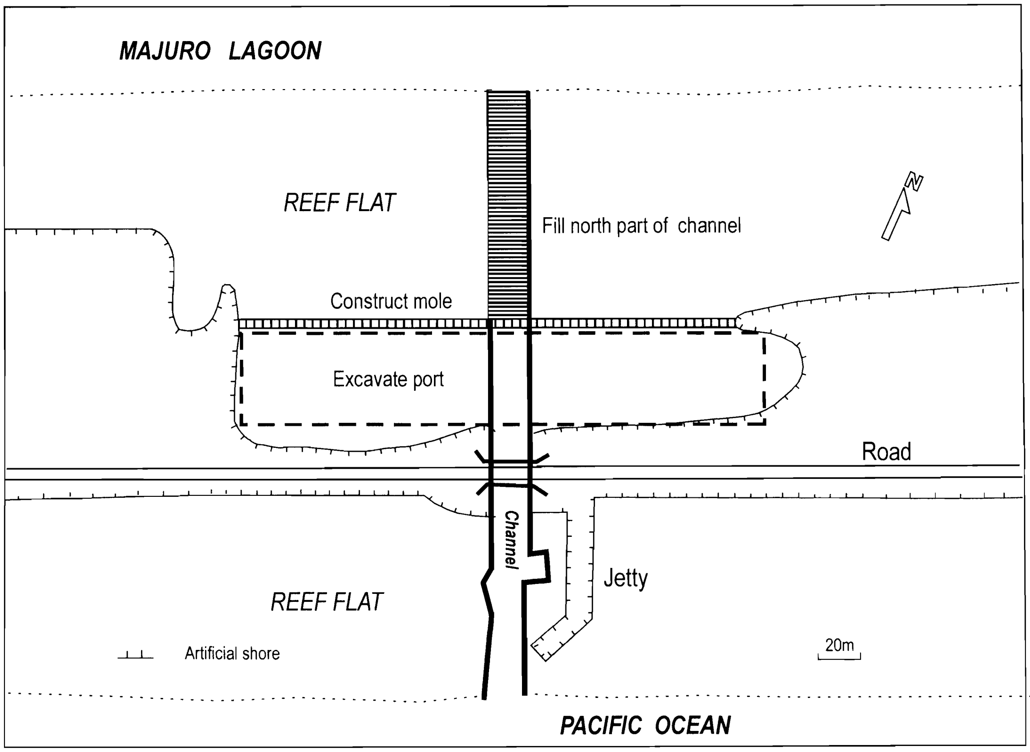

Figure 7. Recommendation of reforming present artificial channel crossing through reef flat into an access channel-port: to excavate a small port on reef flat north to the bridge and fill the channel north to the recommended port. Location in Figure 1.

ports it out of the channel by oceanward and lagoonward currents. In addition, the oceanward current can draw sand at the lagoon side inlet and the lagoonward current almost can not transport any sand from ocean because there is commonly no sand at the ocean side inlet. The artificial channel is a significant cause of lagoon coastal erosion.

The high flood and ebb in tidal channels occur in middle of rising tide and middle of falling tide respectively. The measured current directions in this artificial channel were along the channel except a few low currents. In middle of rising tide the currents were lagoonward and in middle of falling tide the currents were oceanward. In other stages the currents were either oceanward or lagoonward. This demonstrates that the measured currents in this artificial channel were controlled by tide change and waves from ocean and lagoon.

Groins, Landfills, Seawalls, Wharves and Artificial Access Channel-port

Many groins were constructed particularly on the lagoon reef flat from Delap to the east part of Rairok. Landfill with vertical seawalls protruding toward the lagoon or ocean acting as groins also have great adverse effects on environment. The landfill of the airport terminal protrudes toward lagoon and only a narrow reef flat is in front of it (Figure 4). As a large groin, it makes the longshore current with carried sediment to flow to reef flat and further to lagoon, promoting loss of beach sand.

Most seawalls are vertical or nearly vertical, which promotes erosion at the toe of the wall, resulting in absence of sand. The landfill of the fuel depot (south to the Majuro Wharf) and some parts of the airport landfill are close to the edge of ocean reef flat, therefore sand and small rubble can not rest on the reef flats and beaches (Figure 4 and Figure 5, upper).

A large Majuro Wharf (for large cargo ships) constructed about in the late 1970s and early 1980s, faces deeper lagoon water as a result of reclaimed land with excavated berths on both sides of the dock on the reef flat, on the eastern end of south rim (Figure 5, upper). To the east of it, there is fisheries wharf with similar layout, which is smaller than the cargo wharf (Figure 4). The excavated berths trap longshore sediment transport and further move it lagoonward. The reclaimed docks as large groins completely interrupt the longshore sediment transport.

Some small access channel-ports were dug at front of private houses and a hotel on lagoon reef flat of the east section of south rim for small boat navigation in recent years. They trap sediment and may transport it to lagoon by outgoing rip or tidal currents.

Impact of Development of East on West

The causeways, aggregate excavation and other inappropriate human activities on the lagoon coast of the east rim have induced erosion on the coast. However, aggregate excavation, artificial channel crossing through reef flat, landfills, long groins and other inappropriate constructions on the lagoon coast of the east section of south rim have induce erosion not only on this coast but also the coast of the west section of south rim and Laura.

The sediment budget in Majuro Atoll has greatly changed in the last three decades. Great volume of sand extraction along the lagoon coast of the east section of south rim has resulted in reducing sediment supply to the reef flat and beach from lagoon. A series of coastal engineering works in this section interrupted the longshore current and caused beach sand loss. The westward sediment transport has greatly reduced. Under the action of waves and currents caused by the dominant east-northeast winds, sand of the beach and reef flat on the west section of south rim was moved to Laura, but no sufficient sand coming from east replenishes it. Sand loss has constantly acted in last three decades, resulting in severe erosion on the west section of south rim.

When northeast wind blows, the longshore sediment transport is southward along the lagoon coast of north Laura, which suffered erosion in the last three decades since it lost sufficient sediment supply from south.

On ocean side, the coastal erosion on the west section of south rim is partly caused by human activities on the coast of the east section of south rim but not evident because longshore sediment supply is not important on the ocean gravel beach. It is mainly caused by human activities on this coast, particularly aggregate excavation.

COASTAL MANAGEMENT

Improve and Reform Coastal Constructions on the Lagoon Coast

The large Majuro Wharf stops the west longshore sediment transport. However, it could not be reformed because it is a large construction. Reform of coastal constructions on the lagoon coast from the artificial channel to the airport has to be and still can be implemented for improving environment and maintaining shore stability of the south rim and Laura.

1. To reform the artificial channel crossing through the reef flat between ocean and lagoon into an access channel-port. The reform includes excavating a port for passenger, tourist and fisher boats to north of the bridge, building a mole with oblique slope along the north side of the port, and filling the channel to north of the mole. Such reform can keep lagoon side longshore sediment transport and stop oceanward sediment loss from lagoon (Figure 7). To east of the artificial channel on the ocean side, there are nearly no beach and loose sediment on the reef flat extending for 1.2 km, and a jetty has been constructed. Therefore, the remained access channel on the ocean reef flat almost can not trap sediment.

2. To remove the lagoon side groins west of the artificial channel, and fill small private access channel-ports.

3. To remove over-protrusive landfills.

4. To build a detached breakwater on the edge of lagoon reef flat at front of the seawall of the airport terminal. After building breakwater the longshore sediment transport can pass behind the breakwater.

On Reopening Passages on the South and East Rims

Rosti (1990) studied the circulation and shoreline erosion of Majuro Atoll. He thought that closure of the pre-existing passage resulted in the water quality decrease and the lagoon water level rising, which resulted in erosion of the lagoon shore. He recommended widening the existent artificial channel and excavating some new channels on the south rim, reopening passages on the east rim, to improve the water quality, and reduce the water level and erosion.

The reopening problem in this paper is divided into two parts: reopening on south rim and on east rim.

The water level and circulation in the lagoon almost has not changed during 20th century. The action of causeways built on the south rim just recovers the land to similar situation before 1905 (Figure 4). Moreover, excavating some new channels on the south rim will increase erosion, because these channels will trap longshore transported sediment, move it out of these channels and draw sand at the lagoon side inlet to ocean. If the lagoon water level is really reduced by large artificial channels, it will cause disastrous consequences-killing the emerged living corals. Such things may have occurred at Caton Atoll, Kiribati (Carpenter and Maragos, 1989; Maragos, 1993).

Reopening the pre-existing passages on the east rim is not very necessary. Better environment protection can improve the water quality.

Stop Aggregate Dredging along Lagoon Coast on the East Atoll

Dredging along the lagoon coast should stop. The Alternative sources of aggregates are located on the back-reef slope of the northern Majuro Atoll, where sustainable extraction may be possible (Smith, 1995). Excavation of sand at Laura is acceptable. The pit can be used as fresh water reservoir.

DISCUSSION

Evident impacts of human activities on coastal environments in Majuro began in the Second World War and greatly expanded after the War. Such activities for military purpose could not avoid in the War. However, many inappropriate human activities should have avoided after the War.

Even now there are still several large areas available for reclamation, which are located in the original breaches formed in 1905 by cyclone. A very protrusive land (the site of fuel depot) has been reclaimed on the ocean reef flat just south to Majuro Wharf, while there is an area for reclamation without adverse effects just west to the wharf (Figure 5, upper).

Before building the present large wharf there was an L-shaped wharf on the lagoon coast of Uliga (Figure 4), where wave and current are weak. Even it is not a pier type dock, the effect on the coast is not great. If it is necessary to build a deepwater harbor, a long pier could be built, extending from the existent wharf to deep water with no further effects. It does not cost much. L-shaped pier wharves without negative effects could also be constructed at the south rim, replacing the present wharves.

The artificial channel in the west to Delap is a costly construction but of a little use and creates great negative effects. Only a few boats pass the channel every day. The natural channels on the middle of the north rim can be used for any size ship although they are far from the population center.

Impact of construction on coast can be far from the construction sites for sandy shores, where longshore sediment transportation plays an important role. The construction sites on updrift side as in Majuro Atoll and on downdrift side as in Kosrae Island, the Federated States of Micronesia (XUE, 1999) produce same results-inducing erosion along the long sandy shores.

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