A MARINE ENVIRONMENTAL SURVEY

OF PITI BAY AND PITI CHANNEL, GUAM

A MARINE ENVIRONMENTAL SURVEY
OF PITI BAY AND PITI CHANNEL, GUAM

Prepared for
Guam Power Authority

BY

JAMES A. MARSH, JR.
and
GREGORY D. GORDON

June, 1972

University of Guam
The Marine Laboratory
Environmental Survey Report
No. 3

CONTENTS

A MARINE ENVIRONMENTAL SURVEY OF PITI BAY AND PITI CHANNEL, GUAM

James A. Marsh, Jr.[1]
Gregory D. Gordon[2]

INTRODUCTION

This report presents the results of preliminary environmental investigations conducted in Piti Bay and Piti Channel, Guam, and attempts to assess the environmental effects of the construction of a steam power plant at Cabras Island. It presents general biological surveys of the immediate areas to be affected and a study of water movements. Potential environmental problems associated with construction activities are discussed. An assessment of the probable effects of future plant operations on the marine environment and biological communities, with particular emphasis on the thermal budget of the outfall area, will be presented in a later report.

The power plant is to be constructed on a site northwest of the existing Piti Power Plant operated by the U. S. Navy Public Works Center. Most of the construction site is submerged land to be filled to an elevation of +9 feet (2.4 meters) above Mean Low Low Water. Locations of the construction site, Piti Power Plant, and other important features discussed in this report are shown in Figure 1.

Tepungan Channel, cutting through the Piti Reef Flat is to be enlarged to accommodate the increased cooling water demands of the new plant and other facilities proposed for the future. The channel is approximately 2000 ft (610 m) long and extends from the deeper part of Piti Bay proper to the Piti Power Plant intake; it is less than 6 ft (1.8 m) deep (MLLW Datum) over most of its length. Material dredged from the channel will be used as fill on the construction site. Specifications call for the enlarged channel to provide a cooling water capacity of 400,000 gallons per minute (25.2 cubic meters per second), with a velocity not to exceed 2 ft per second (0.61 m per second) anywhere in the channel. To meet the specifications of delivery volume and flow velocity, the channel is to be dredged to a depth of 15 ft (4.6 m) below MLLW. The width of the dredged channel is to be determined by the contractor.

---

[1]Assistant Professor, Marine Laboratory, University of Guam.
The views expressed by the author are his own and do not necessarily reflect those of the Marine Laboratory, the University of Guam, or the Government of Guam.

[2]Graduate student, Marine Laboratory, University of Guam

Tepungan Channel, Piti Channel, and Cabras Island are natural features which have been extensively altered by man's activities. Until the present causeway was built Cabras Island was not connected to the island of Guam, and there was a natural flow of water from Piti Bay through Piti Channel into Apra Harbor. Rubble fragments indicate that there was some growth of corals, especially *Acropora formosa*, but the extent of this growth is unknown. Construction during and after World War II (summarized in a report by the Tudor Engineering Company, 1964) produced the causeway and the Piti Power Plant. Piti Channel became an outfall area for thermal waste water from the plant. These activities, plus development of the Commercial Port in Apra Harbor in the 1960's, resulted in extensive dredging in Piti Channel and adjacent areas. There has also been some dredging in Tepungan Channel, particularly where it passes under the causeway near the power plant intake. A swimming area at Hoover Park and a small channel connecting this with Tepungan Channel were also dredged. Piti Canal was later constructed as an auxiliary source of cooling water for the Piti Power Plant during low spring tides. In contrast, the shallow Piti Reef Flat has apparently not been subjected to any significant alteration by man's activities.

CONCLUSIONS

The most serious environmental problem anticipated in conjunction with construction of the Cabras Island Power Plant is the potential blockage of water exchange and circulation in the USO swimming area during the dredging of Tepungan Channel. Present circulation is mostly dependent on surf-generated movement of water across the western Piti Reef Flat and into the extreme western end of Tepungan Channel. Some of this water then enters the small channel leading to the swimming area. If the proposed access dike is constructed parallel to Tepungan Channel, this could limit water circulation in the swimming area to tidal exchange only. Tidal exchange presently accounts for almost no circulation in the area and is not expected to be a very effective mechanism while the dike is in place. The limiting of water circulation to tidal exchange could increase the possibility of potentially polluted Masso River water moving into the swimming area.

In any case some siltation in the USO swimming area should be expected as a result of dredging Tepungan Channel.

There will probably also be some silt movement onto the reef flats adjacent to Tepungan Channel during dredging. This will probably kill some bottom-dwelling organisms. This disturbance should be temporary and will probably not cause a long-term alteration of the habitat or biological communities. A recolonization by the silt-adjusted communities which are there now should occur.

On the fill site there will be permanent loss of habitat for marine organisms. Similar habitat should remain in adjacent areas. Disturbance to nearby biological communities should be temporary, with some organisms being smothered by heavy siltation. No extermination of species is expected. Since there are already silt-adjusted communities in Piti Channel and adjacent areas, recolonization should occur after dredging. No long-term biological damage is expected.

RECOMMENDATIONS

1. Reconsider the proposal to construct an access dike and roadway alongside Tepungan Channel. If a dike is necessary, provision should be made to allow continued movement of water from the western Piti Reef Flat into Tepungan Channel and the USO swimming area. This could be accomplished by putting a series of large culverts through the dike near the point where it joins the Cabras Island causeway and keeping these open as long as the dike is in place. An alternative might be to construct a bridge instead of a dike here. In any case, the dike should be left in place no longer than necessary and then be removed so that the original level of the reef flat is restored.

2. Avoid altering the point of land at the mouth of the Masso River or the reef flats lying south of Tepungan Channel and adjacent to the USO swimming area, since these features help prevent movement of potentially polluted river water into the swimming area.

3. Avoid altering the Piti Reef Flat over larger areas than necessary. Construction activities should be confined to the immediate vicinity of Tepungan Channel to insure the integrity of biological communities.

4. As soon as construction activities are completed in a given area, there should be a clean-up of all debris and waste materials.

METHODS

Information on living organisms, biological communities, zonation, and substrate was gathered during extensive field observations; some organisms were collected and preserved for later examination and identification. Data on patterns of water movement and volume transports were gathered at various tidal stages by timing the movement of patches of fluorescein dye over known distances, determining the compass direction of movement, and measuring the water depth. These observations were augmented with drift cross data. Additional information was obtained by personal communication with persons knowledgeable about the study area. Observations were made from January through May, 1972, and are continuing.

PITI BAY

Description of the Area

The study area consists of the western portion of Piti Bay and Reef Flat shown in Figs. 1-4. Approximate dimensions are 3000 ft (914 m) east-west by 2000 ft (610 m) north-south. There are four important features: the deeper portion of the bay, or Piti Bay proper; Tepungan Channel; the USO swimming area; and the broad expanses of reef flats which account for more than 75% of the total area.

The deeper portion of the bay, or Piti Bay proper (Fig. 2), is defined by a boundary of diverse corals which forms a vertical wall extending from the low tide level to an approximate depth of 10 ft (3 m), where there is a sandy bottom. This sandy bottom slopes gradually away toward the middle of the deeper portion of the bay. There is a high diversity and probably a high standing crop of fishes associated with the rim of coral and free swimming in the deeper water.

Piti Bay proper was not extensively investigated because it is not likely to be significantly affected by dredging activities. It will probably receive some silt from dredging operations, but it is already turbid and receives silt from Masso River runoff during the rainy season. The deeper portion of the bay is of concern here primarily as the potential source of cooling water to be funneled through Tepungan Channel after that channel has been enlarged; presently it is not very important as a source of cooling water during most of the tidal cycle.

Tepungan Channel (Fig. 2) is physically distinct from the adjacent reef flats but is not biologically distinct to any marked degree. It does not contain different habitats from those found on the surrounding reef flats. However, it does represent a portion of the reef flat habitat that is not exposed to the air at low tides. The sides and bottom of this channel, with good water circulation and no low-tide exposure, support numerous small coral colonies. The genera Pocillopora, Pavona, Favites, Porites, and Acropora are common; and Pocillopora appears to be the dominant among these. Numerous small fishes are associated with these coral colonies.

The largest concentrations of fishes occur at each end of Tepungan Channel. These areas are physically different from the rest of the channel and reef flat. At its western end, where it passes under the causeway, the channel is deepened to about 10 ft (3 m) for a distance of about 100 ft (30 m) from the causeway. Here water velocity increases considerably as it moves into the passage under the causeway. A heavy iron grating with bars spaced about 6 inches (15 centimeters) apart covers the entrance to this passage under the road. Further diversity of the physical habitat results from the sheer wall forming the south side of the channel and appears to be responsible for a greater fish diversity here. At its eastern end Tepungan Channel gradually merges into the deeper portions of Piti Bay proper, and greater numbers and species of fish are found. The Appendix, prepared by Robert Jones and Helen Larson, contains a checklist of fishes in Tepungan Channel and adjacent reef flat areas.

The USO swimming area is a dredged area at the southwest corner of Piti Reef Flat. Persons familiar with this area say that it tends to silt in and must be dredged occasionally to maintain it as a suitable swimming area. The swimming area is connected with the western end of Tepungan Channel by a small dredged channel adjoining the shoreline (approximate dimensions of the connecting channel: 10 m wide by 2 m deep by 40 m long, MLLW Datum). See Fig. 2.

The largest portion of the area may be designated as reef flat and can be subdivided into the zones indicated in Fig. 2. Most of the reef flat substrate is mixed sand-rubble and partially consolidated pavement. There are scattered larger boulders (not exceeding 1 m in diameter), particularly at the eastern end of the reef flat. The substrate is very irregular. Depths differ from one part of the reef flat to another; but large portions of it are exposed at low spring tides, as shown in Fig. 3. There is less exposure at low neap tides, when only scattered areas are exposed to the air.

The entire outer edge of the reef flat, or Reef Margin (see Fig. 2), is slightly elevated but seldom exposed to the air during normal tides and moderate surf conditions. However, on exceptionally calm days, when there is light surf, this zone is exposed to the air; such conditions are more likely to occur during the summer months than at other times of the year. Biologically the Reef Margin is dominated by the brown alga <u>Sargassum</u> <u>cristaefolium</u> during at least a portion of the year (including the months January through June), but a normal die-off may be expected as the summer progresses and brings calmer seas with less wave wash over the Reef Margin at mid-day low tides.

Landward, the Reef Margin gives way to the gradually sloping Outer Reef Flat which in turn grades into the Inner Reef Flat (Fig. 2). The Inner Reef Flat may be distinguished from the Outer Reef Flat primarily by the slightly lower elevation of the former; there is not a clear-cut biological distinction between the Outer and Inner Reef Flats. The Inner Reef Flat is dissected by Tepungan Channel, which extends perpendicular to the axis of zonation of the reef flats. The area between Tepungan Channel and the shoreline is similar to the area lying immediately seaward of the channel, but small depressions in this area retain some water even at low spring tides (Fig. 3). The substrate of the entire reef flat is reasonably homogeneous; but localized areas may be dominated by sand, small rubble, larger rubble and boulders, consolidated pavement, or small depressions. This variation creates a number of micro-habitats for specific organisms. The larger rubble and scattered boulders (usually less than 1 m in diameter) are more concentrated at the eastern end of the reef flat near the deeper portion of Piti Bay proper; this gives way westward to smaller rubble, fewer boulders, and more sand and a generally lower-elevation substrate.

Algae are abundant throughout the reef flats and in Tepungan Channel, with the visually dominant ones being the brown algae Padina tenuis, Hydroclathrus clathratus, and Dictyota bartayresii, the blue-green alga Hormothamnion enteromorphoides, and the calcareous green Halimeda macroloba. Certain of these algae, i.e., Hydroclathrus clathratus, Padina tenuis, and Hormothamnion enteromorphoides, will die off as the summer progresses and midday low spring tides expose the reef flats to the stresses of air drying, fresh water rainfall, and solar heating. Other algae and sea grasses observed in the area are noted in Table 1.

Many sea urchins are associated with rubble microhabitats and sea cucumbers are common throughout the reef flats. At least two species of the sea cucumber genus Holothuria and the echinoids Echinothrix diadema, Echinometra mathaei, and Diadema spp. are abundant. The sea cucumber Holothuria argus is common in sandy habitats. Individuals of the genus Stichopus can be found on the Inner Reef Flat but are much more common on the Outer Reef Flat. The blue starfish Linckia laviegata is common on the Outer Reef Flat.

At the western end of the Piti Reef Flat is a somewhat deeper zone which extends from the outer Reef Margin to Tepungan Channel. Except for the Reef Margin, most of this area is not exposed at low tides. The seaward 900 ft (274 m) of this region supports a thriving coral community. This gives way to the Transition Zone and finally a distinct Sand Flat covered by at least 3 ft (.9 m) of water at high tides (see Fig. 2).

The Coral Community has a distinct zonation, with zones extending roughly parallel to the surf. Superficially this zonation is remarkably similar to that which has been described for other reefs on Pacific atolls. The dominant corals are massive and branching colonies of Porites, Acropora, and Millepora. Landward from the surf zone, as the water becomes deeper, the growth form of many corals changes from small heads to larger heads which grow up to the low tide level. Many algae and invertebrates are found among the corals and on the substrate, with the sea urchin Echinothrix diadema being one of the visual dominants among the invertebrates. For purposes of this report it is not necessary to describe the zonation in detail since the area is not expected to be affected by construction activities. The Coral Community is apparently subject to heavy pressure from shell collectors at times, but the effects of this are not known. The apparent low density of fishes in this community as compared with similar reefs in other parts of the Pacific is noteworthy, but this is more a visual impression than a documented fact. The area appears to have as many fishes as other inshore reef areas on Guam, so in the context of the local situation the standing crop of fishes many not be particularly low. The pressure due to spear fishermen and netters is an unknown factor here.

The western corner of the area lying just seaward of Tepungan Channel is a sand flat, different from other Piti Bay areas with respect to the physical nature of the substrate. The dominant algae noted previously for the reef flats are also dominant in this area, but Hormothamnion enteromorphoides and Halimeda macroloba are more abundant on the Sand Flat. Because of the relative lack of rubble and boulders there are fewer microhabitats on the Sand Flat, and therefore fewer macroinvertebrates, than on the general reef flats.

To summarize, the biotic communities found in these reef flat zones and in Tepungan Channel are classed as algae-echinoderm communities typical of many reef flats around Guam. These communities are silt-adjusted communities, with some seasonal changes brought about by excessive low-tide exposure at different times of day during different months. Hence, some natural seasonal changes may be expected in these communities during dredging operations in Tepungan Channel. However, they will be subjected to higher than normal silting and will probably be altered thereby. The disturbance is expected to be temporary since the biotic communities are already adjusted to silty conditions. As noted in the Appendix, disturbance to the fish fauna is expected to occur as habitat is physically removed from the present channel and adjacent areas. This is not considered a major disturbance. The luxuriant coral community at the western end of the reef flats should not be affected by siltation. Overall, there is not expected to be a long-term change in the reef flat communities as a result of dredging Tepungan Channel.

Water Movements

The most important factors affecting movement of water across the Piti reef flats are tidal state and surf action on the Reef Margin. Sea state and wind force are important primarily through their effect on surf action. Presumably, pumping of cooling water through the Piti Power Plant intake affects water movement in Tepungan Channel during low spring tides.

The current pattern during low spring tides is shown in Fig. 3. At such times the Inner and Outer Reef Flats are exposed, and there is a significant flow of water only across the lower-elevation Coral Community (Fig. 2) and back-reef zones at the western end of the Piti Reef Flat. With tides lower than about MLLW, when there is a light surf, the entire Reef Margin may be exposed and have no water flowing across it. At such times the Coral Community remains submerged but has little water circulation.

During low spring tides the water flow in Tepungan Channel is variable, and the direction of flow in the channel is dependent on surf conditions. With heavy surf there is some eastward movement of water in the channel, particularly in its eastern half. At any tidal state lower than about MLLW there is not likely to be much water movement in the channel. When the surf is light to moderate there is little or no water driven across the reef flats into Tepungan Channel. In such cases the intake pumps for the power plant exert enough demand to reverse the flow in the channel; and there is a westward movement of water along its entire length, although at a very low velocity. The direction of flow in Tepungan Channel is not always certain when the surf is moderate and the tidal state intermediate. In the "region of uncertainty" shown in Fig. 3 water may flow in either direction at a given time. The effects of the power plant intake pumps extend eastward in the channel for some distance. How far this influence extends is dependent on tidal level and surf conditions. Hence, the exact point of reversal in the direction of flow is variable and unpredictable. The limits of the "region of uncertainty" (Fig. 3) are approximate.

Fig. 4 indicates general water movements on the reef flats at high spring tides and at most stages of the neap tides. This movement is heavily dependent on surf conditions since the propelling force which moves water across the reef top is surf action on the Reef Margin. Water is piled up on the outer Reef Margin by breaking waves and is forced across the Outer and Inner Reef Flats and into Tepungan Channel. This water spreads out laterally as it moves across the Coral Community at the western end of the reef flats and into the Transition Zone and Sand Flat (Fig. 2). In the latter zones it becomes less constricted by the shape of the adjoining shoreline. Higher surf on the Reef Margin increases the velocity and volume of water moving across the reef flats but does not change the basic pattern and direction of water movements.

Water in the extreme western end of Tepungan Channel enters the Piti Power Plant as the result of the suction created by the plant's intake pumps. Greatest velocity (about 1.6 ft/sec, or .49 m/sec) occurs where water moves through the narrow constriction under the causeway. Most of the water flowing across the reef flats enters Tepungan Channel, where it moves eastward during the higher tidal stages depicted in Fig. 4 and thence into the deeper portion of Piti Bay proper. Since the channel is not of uniform width and depth throughout, water velocity varies at different points along its axis. Actual flow velocity and volume transport are dependent upon the volume of water piled up on the Reef Margin and moving across the reef flats. The velocity apparently never exceeds 2 ft/sec (.61 m/sec) anywhere in the channel.

An important consideration is the pattern of water movements through the USO swimming area. Water enters primarily through the small channel which connects the dredged area with Tepungan Channel. Water does not move through this channel into the swimming area during all tidal states because it does not always have an exit. At high tides, water moves through the USO swimming area and out over the reef flat adjoining the area in an easterly direction. This pattern of water movement is indicated in Fig. 4. Because the reef flat lies higher than the mean water level at low tides, it blocks water movement out of the swimming area at such times. This condition precludes a net movement of water through the area during low tides. Since water in the swimming area is normally renewed during high tides, there is presently little problem with water in the swimming area becoming stagnant. Greater or lesser exchange of water occurs here depending upon particular conditions of surf and tidal level.

Potential Problems

As shown in Fig. 1, the Masso River flows onto the Inner Reef Flat south of Tepungan Channel. There is some sewage pollution upstream in this river, and high counts of fecal coliform bacteria (greater than 200/100 ml) are sometimes detected in the river mouth by the Government of Guam Water Pollution Control Commission in their regular monitoring program. The normal water flow across the reef flats at high tide iseasterly, presumably sweeping any coliform bacteria away from the USO swimming area; and the river mouth is blocked from the swimming area at low tides by the exposed reef flat. This usually precludes movement of coliform bacteria into the swimming area. The circulation pattern is influenced by the small point of land which extends out onto the reef flat just west of the river mouth. This diverts river water away from the swimming area. Apparently this small point was artificially built up in the past. It is obviously important that efforts be made to preserve the basic pattern of water movements on the Inner Reef Flat to reduce the potential danger of pollution in the swimming area. Hence, the reef flat bordering Tepungan Channel should not be altered by dredging. There is no compelling reason to do so anyway except for possibly dredging more material to be used for fill on the construction site. If pollution problems in the Masso River are controlled in the future, the possible backflushing of river water into the swimming area would not represent such a significant problem; but preserving the present pattern of water movements provides a margin of safety. There is apparently still occasional movement of river water into the swimming area under certain specific conditions, although such a pattern has not been observed in this investigation. During the rainy season when there is a heavy runoff some of this water probably moves westward in Tepungan Channel at low spring tides. The reversal of water movement in Tepungan Channel, created by the cooling water demands of the Piti Power Plant, suggests that at such times silt and bacteria from the river would move westward toward the plant intake. River water could move far enough up Tepungan Channel to reach the small channel which serves as the water source for the swimming area. Under such conditions there is a possibility of silt and coliform bacteria moving into the swimming area, although this would most likely occur not at the time of low water (when there is essentially no water movement into the swimming area) but after the tide had turned and water began to move into the swimming area again. It is difficult to predict the extent of this phenomenon, and it is likely that much of the river water mixed with reef water in Tepungan Channel would simply reverse its movement and move back down the channel into the deeper portion of Piti Bay proper, without being cycled through the swimming area. However, some portion of the river/water could be entrapped in the entrance channel to the swimming area. Lifeguards at the USO beach have observed such a movement of muddy water in the past. It will be instructive to observe water movements in the upcoming rainy season; observations so far have been only for the dry season (January - April). If this is now a problem,it will probably be increased by the plan to enlarge Tepungan Channel and reverse the current flow for a greater percentage of the tidal cycle.

A further environmental problem is the possible lack of water movement through the USO swimming area while Tepungan Channel is being dredged. One suggested plan for working the Channel is to construct a dike and roadway alongside it on the seaward side. This dike would serve as a temporary access for dredging equipment and trucks hauling fill material dredged out of the channel to the construction site. Once the enlarging of the channel has been completed then this dike would presumably be removed and the material also used as fill on the construction site. The exact length of time this would remain in place is not known. It should be clear from the preceding discussion of current patterns and water movement that these patterns would be altered,and that water movement into and through the USO swimming area would be reduced. If a dike were to extend the length of Tepungan Channel, this would create a cul-de-sac composed/of reef flat, channel, and dredged swimming area. Presumably this would result in a reversal of water movement in Tepungan Channel, with the new water flow being westward. Tidal currents would cause some exchange of water over the Inner Reef Flat and in the swimming area, but this would be only a small percentage of the water renewal currently in effect. This is a serious potential problem, even if temporary. Such tide-generated circulation as did occur might move Masso River water into the USO beach, particularly since dredging will take place during the rainy season when river flow is greatest.

A possible solution would be to place a series of large culverts through the proposed dike near the Cabras Island causeway. This might allow surf-generated movement of water through the dike and into Tepungan Channel and the swimming area so that the present pattern of water movement would be at least partially maintained. The western end of the access roadway might also be constructed on a bridge instead of a dike.

PITI CHANNEL

Description of the Area

Piti Channel extends from the Piti Power Plant in an approximate east-west direction for about 5800 ft (approx. 1.75 km) to the dredged area of Commercial Port. This channel is less than 5-10 ft (1.5-3 m) deep over most of its length. Adjacent submerged areas are extensive shallow mud and sand flat generally less than 3 ft (0.9 m) deep at MLLW. The construction site is such a sand flat. There are scattered dredged channels (as much as 10 ft, or 3 m, deep) throughout the area, as well as scattered small islands and peninsulas (see Fig. 1). Much of the area has apparently been extensively reworked by dredging and can hardly be considered a "natural area." As noted in the Introduction, there was a free movement of water from Piti Bay into this upper end of the harbor before the Cabras Island causeway was constructed; and the biological characteristics were completely different from presently existing conditions.

Heavy smoke emanates from the power plant stacks and is carried over the study area by the prevailing northeast winds. Extensive damage to the terrestrial vegetation is obvious at ground level and in aerial photographs. The noxious stack effluent makes work in the study area difficult and unpleasant because of irritation to the eyes, nose, and throat.

The substrate in the study area is composed of loose sediment which is easily stirred up by waders or passing boats. Some locations have turbid water because of runoff from terestrial areas. There are very few corals, rocks, or pieces of large rubble to serve as points of attachment for stationary organisms requiring a firm substrate. The community of bottom organisms can be generally described as a silt-adjusted community. In the lagoon immediately adjacent to the plant outfall there is much water turbulence created by the cooling water coming from the plant. Finer suspended particles do not immediately settle out of the water here and are swept farther downstream. Hence, the bottom sediments in the outfall lagoon are course-grained. Farther downstream the bottom sediments are finer grained and are more extensively reworked by bottom-dwelling organisms.

General water circulation in the area is highly dependent on the water coming from the plant outfall (see Figs 5&6) This results in water in the area being continually renewed. If it were not for water pumped from the power plant there would be much less water exchange and circulation in this closed cul-de-sac extension of the harbor, since most water movement would come about only through tidal exchange. The fact that plant cooling water is ultimately moving into the harbor area at Commercial Port results in less thermal damage to organisms than if it were pumped back out onto a reef flat.

Algae are most abundant in the lagoon adjacent to and within 900 ft (274 m) of the outfall. This is the same area where the bottom sediments are composed of the coarsest particle sizes. The brown algae Padina tenuis and Dictyota bartayresii and the red alga Gracilaria salicornia are the dominants. Other algae commonly observed are the blue-greens Hormothamnion enteromorphoides, Microcoleus lyngbyaceus and Schizothrix calcicola. Farther away from the outfall are scattered clumps of the brown alga Sargassum polycystum. The same species of algae occur on the shallow sand flats in the areas adjacent to Piti Channel but are less abundant. These algae with their associated fauna, characterize the biological community. Farther east in Piti Channel there are scattered dense beds of the green alga Halimeda opuntia. These beds are as much as 6 ft (1.8 m) across and completely cover the bottom where they exist.

A number of invertebrate animals are common within the boundaries of the construction site, both on the sand flats and on rocky intertidal surfaces. Snapping shrimp (at least two species), hermit crabs, and egg cases of the moon snail Polinices sp. are the visual dominants on the sand flats. On the rocky intertidal surfaces common organisms are the polychaete Eurythoe (fire worm); a serpulid worm (probably Spirorbus); rock-burrowing and bivalve molluscs (including the genus Isognomon); the gastropod molluscs Trochus niloticus, Cyprea moneta (money cowrie), Planaxis sp., and a muricid snail; chitons; portunid crabs; xanthid crabs (at least two species); and two species of snapping shrimp.

Elsewhere in the study area the snail, Nerita albisella, is present in scattered intertidal areas. The "top shell" Trochus niloticus is abundant on the concrete wall at the site of the cooling water outfall; and the snails Planaxis sulcatus and Littorina scabra are present on intertidal rocks at this location. Hermit crabs occupying small Trochus shells aggregate around the raw sewer outfall which enters the eastern end of the area near the cooling water outfall.

Large portions of the bottom of Piti Channel and most of the adjacent sand flats are dominated by two commensal animals, a gobiid fish and an alpheid shrimp. Individual gobies and snapping shrimp cohabit a small burrow in the loose sediment. Two species of goby are present in different burrows and probably two species of snapping shrimp. The burrows are maintained by one or both of these animals and are found where the sediment is composed mostly of intermediate sized particles. There are sometimes several burrows per square meter. The openings are usually surrounded by mounds of sediment, and the animal association is important in reworking the sediments over extensive areas. This results in an irregular bottom rather than a continuously smooth one.

Numerous species of fish are found in the immediate vicinity of the cooling water outfall, a common occurrence at many power plants. Additional information on the fishes is given in the Appendix. Local fishermen set their nets in the area to be filled for new plant construction and in nearby locations.

In summary, the biological communities in this extension of the harbor are what would be expected for such areas, although they are subject to disturbance and stress. The organisms are adjusted to silty conditions, and construction activities are not expected to cause more than a temporary disturbance to biota in areas surrounding the actual construction site. Landfill at the construction site itself will, of course, permanently destroy habitat for bottom-dwelling organisms and fish. None of the species found at the construction site are unique to that area and the organisms should continue to survive in the similar habitats nearby.

Existing Problems

There are several environmental problems in Piti Channel and surrounding areas which can and should be corrected. The effects of the stack effluent have already been noted. This is the most serious environmental problem in the area and one of the most serious on Guam. Its solution will require time and money. Much of the shoreline is caked with oil residues, apparently deposited from the water. At the upper end of the channel next to the cooling water outfall, petrochemicals sometimes drain into the water after running off from a storage area just inside a fence surrounding the power plant. There is a raw sewer from the power plant entering the upper end of Piti Channel near the cooling water outfalls. The whole area is characterized by scattered scrap metal, rotting docks, and other debris, which make it unsafe and unpleasant from an aesthetic viewpoint.

REFERENCE

Tudor Engineering Company. 1964. Study of Apra Harbor, Apra Harbor Military Reservation, Guam, M. I.

Table 1. Common Algae and Sea Grasses on Piti Inner Reef Flat and in Tepungan Channel.

Cyanophyta	Rhodophyta
<u>Hormothamnion enteromorphoides</u>	<u>Amphiroa fragilissima</u>
<u>Microcoleus lyngbyaceus</u>	<u>Centroceras clavulatum</u>
<u>Schizothrix calcicola</u>	
Chorophyta	**Phaeophyta**
<u>Avrainvillea obscura</u>	*<u>Dictyota</u>, 3 sp.
<u>Caulerpa racemosa</u>	<u>D. bartayresii</u>
*<u>Halimeda macroloba</u>	<u>D. divaricata</u>
<u>Halimdea opuntia</u>	<u>D. cervicornis</u>
<u>Boodlea composita</u>	*<u>Padina tenuis</u>
<u>Neomeris annulata</u>	<u>Lobophora variegata</u>
	*<u>Hydroclathrus clathrat</u>
	<u>Sargassum polycystum</u>
Sea Grasses	
<u>Halophila minor</u>	
<u>Enhalus acoroides</u>	

*Dominant organisms in April, 1972.

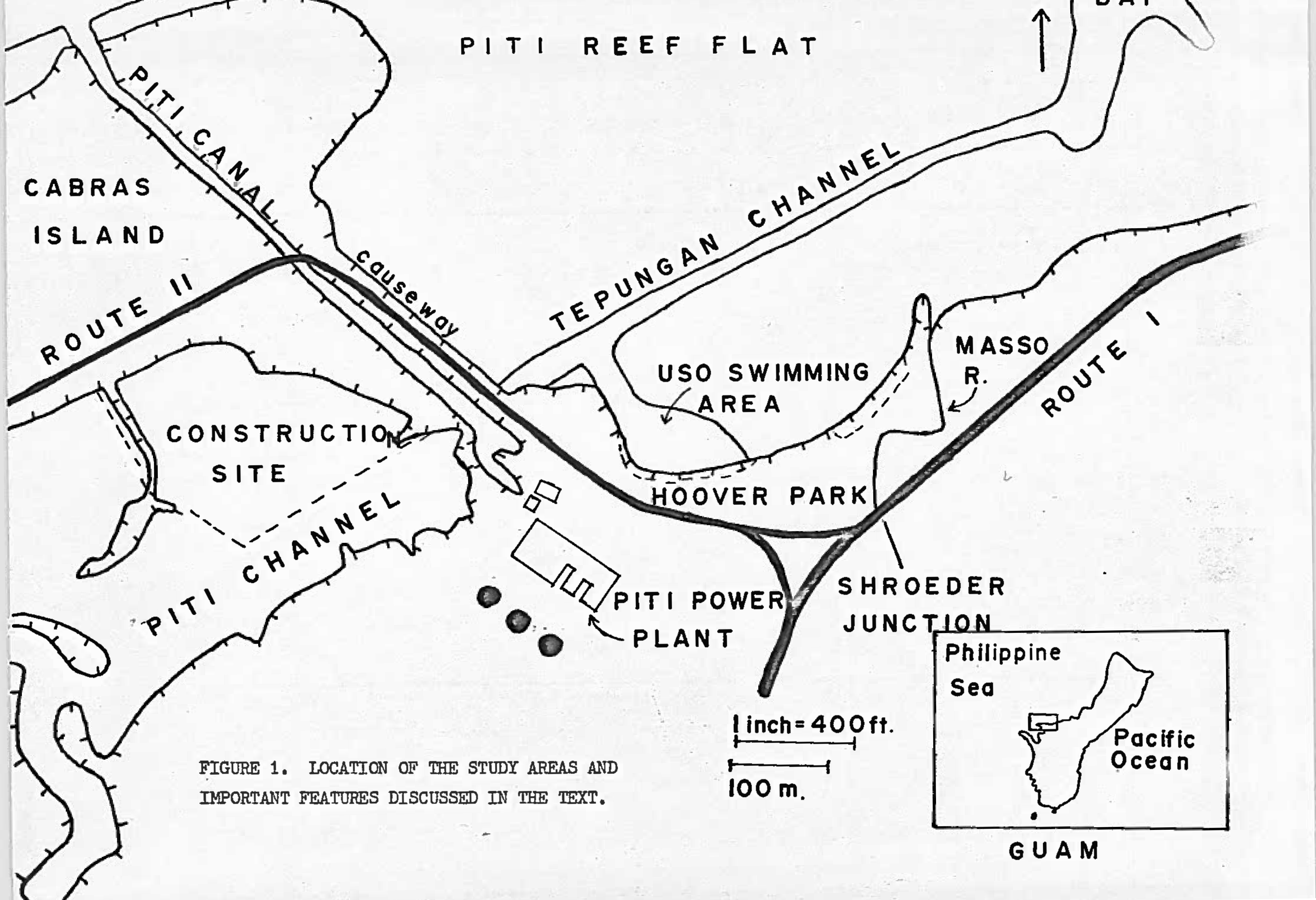


FIGURE 1. LOCATION OF THE STUDY AREAS AND IMPORTANT FEATURES DISCUSSED IN THE TEXT.

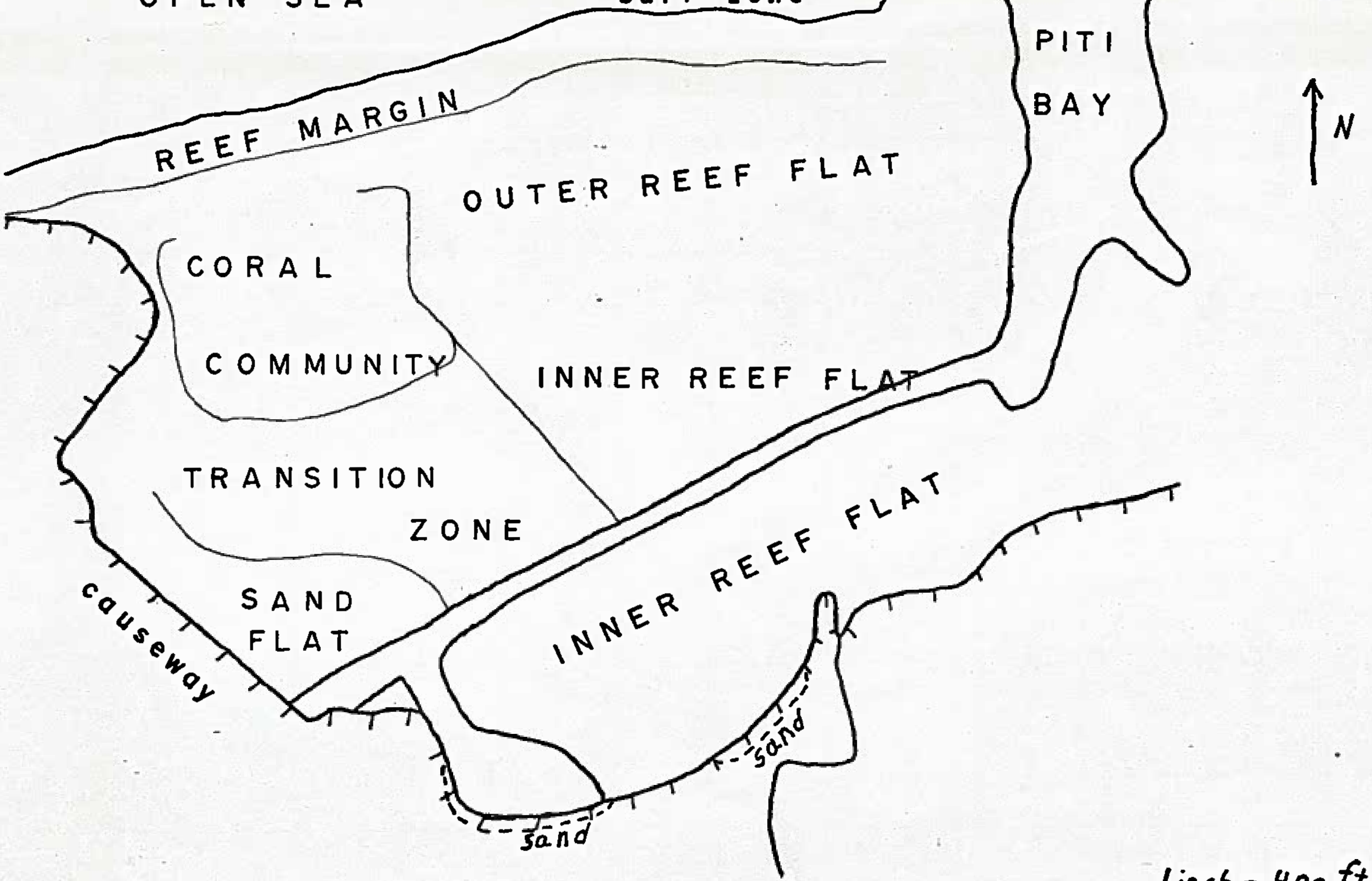


FIGURE 2. MAJOR FEATURES AND ZONATION OF THE WESTERN END OF PITI BAY.

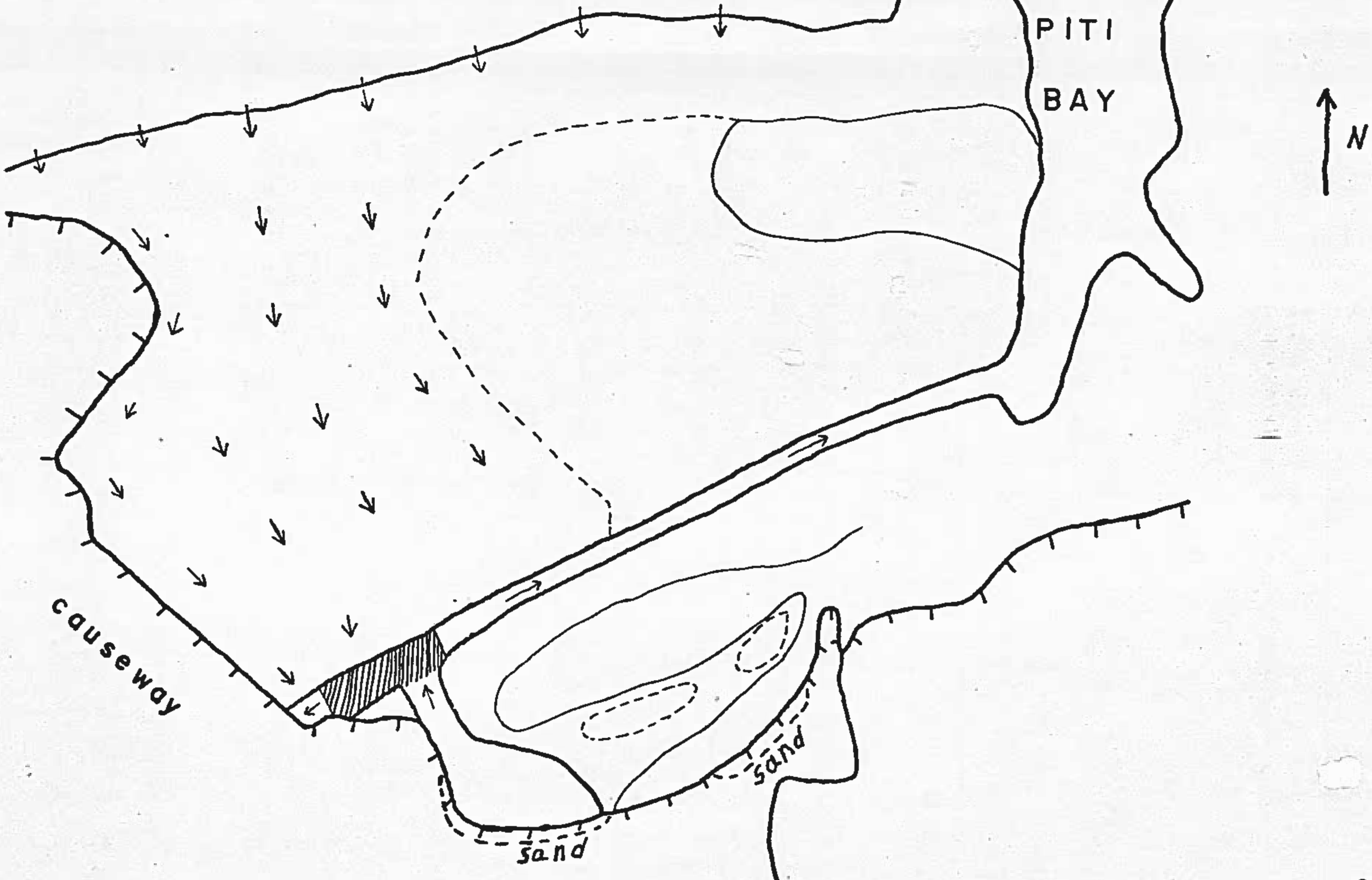


FIGURE 3. WATER MOVEMENTS IN THE WESTERN END OF PITI BAY DURING LOW TIDES, WITH MODERATE TO HEAVY SURF. LIGHT SOLID LINES ENCLOSE AREAS OF THE REEF FLATS EXPOSED AT LOW NEAP TIDES. DASHED LINES NORTH OF THE CHANNEL INDICATE FURTHER REEF FLAT AREAS EXPOSED AT LOW SPRING TIDES. DASHED LINES SOUTH OF THE CHANNEL INDICATE TWO SMALL POOLS OF WATER THAT REMAIN ON THE REEF FLAT AT LOW SPRING TIDES. THE DIAGONAL LINES IN THE CHANNEL INDICATE THE "AREA OF UNCERTAINTY" WHERE WATER FLOW MAY BE IN EITHER DIRECTION, DEPENDING UPON SPECIFIC SURF CONDITIONS.

1 inch = 400 ft.

100 m

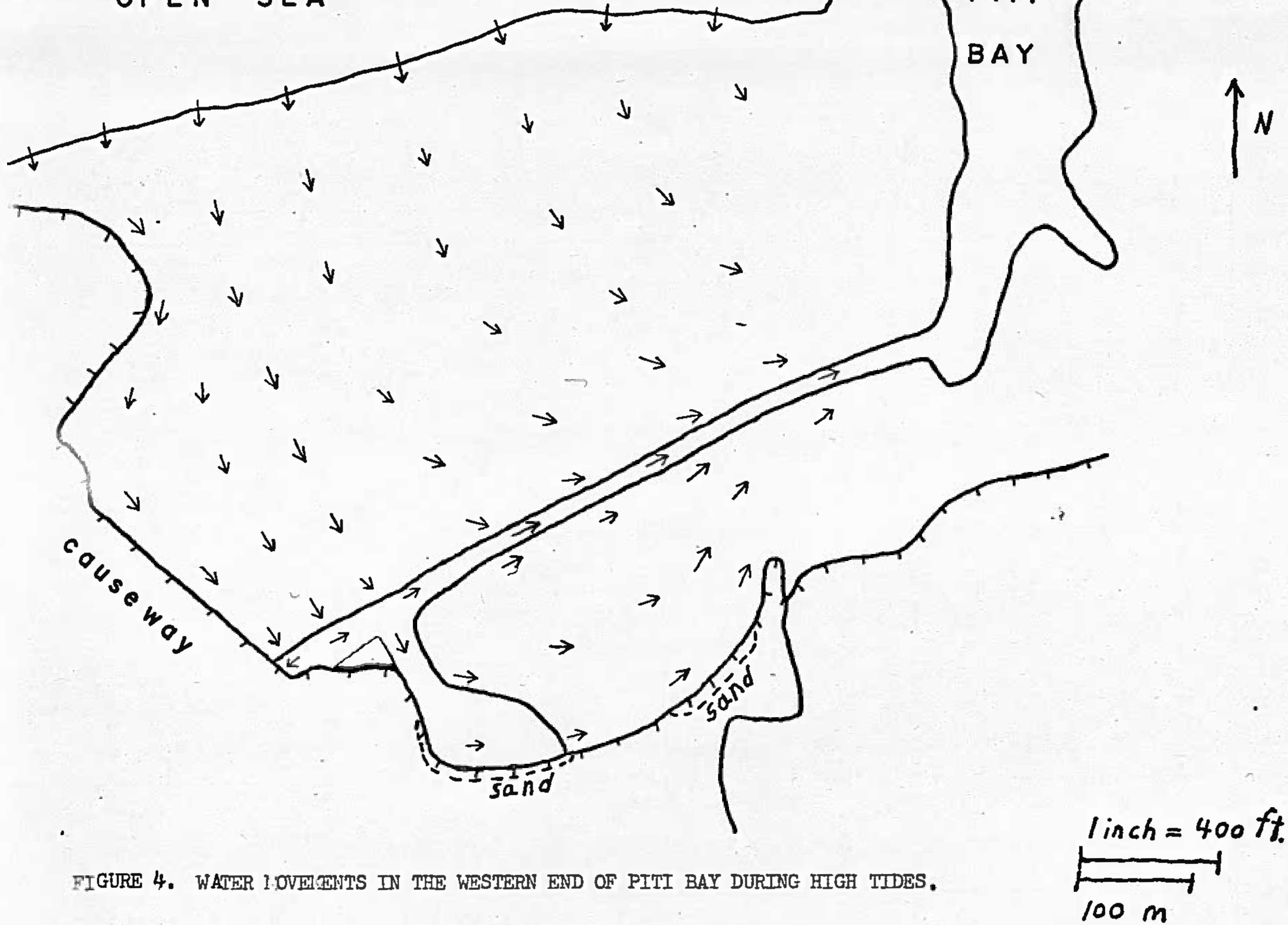


FIGURE 4. WATER MOVEMENTS IN THE WESTERN END OF PITI BAY DURING HIGH TIDES.

FIGURE 5 WATER MOVEMENTS IN PITI CHANNEL DURING HIGH TIDES.

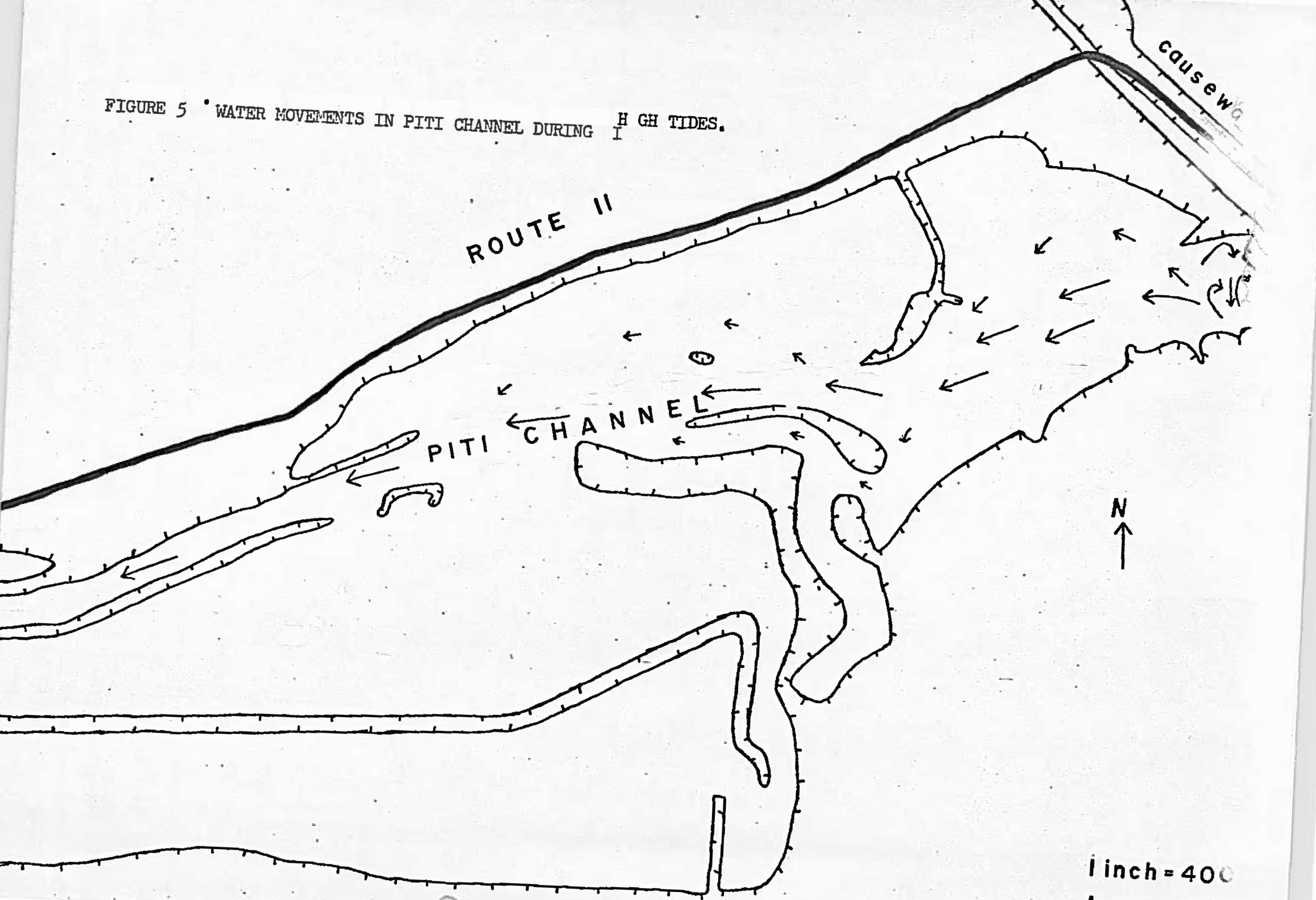
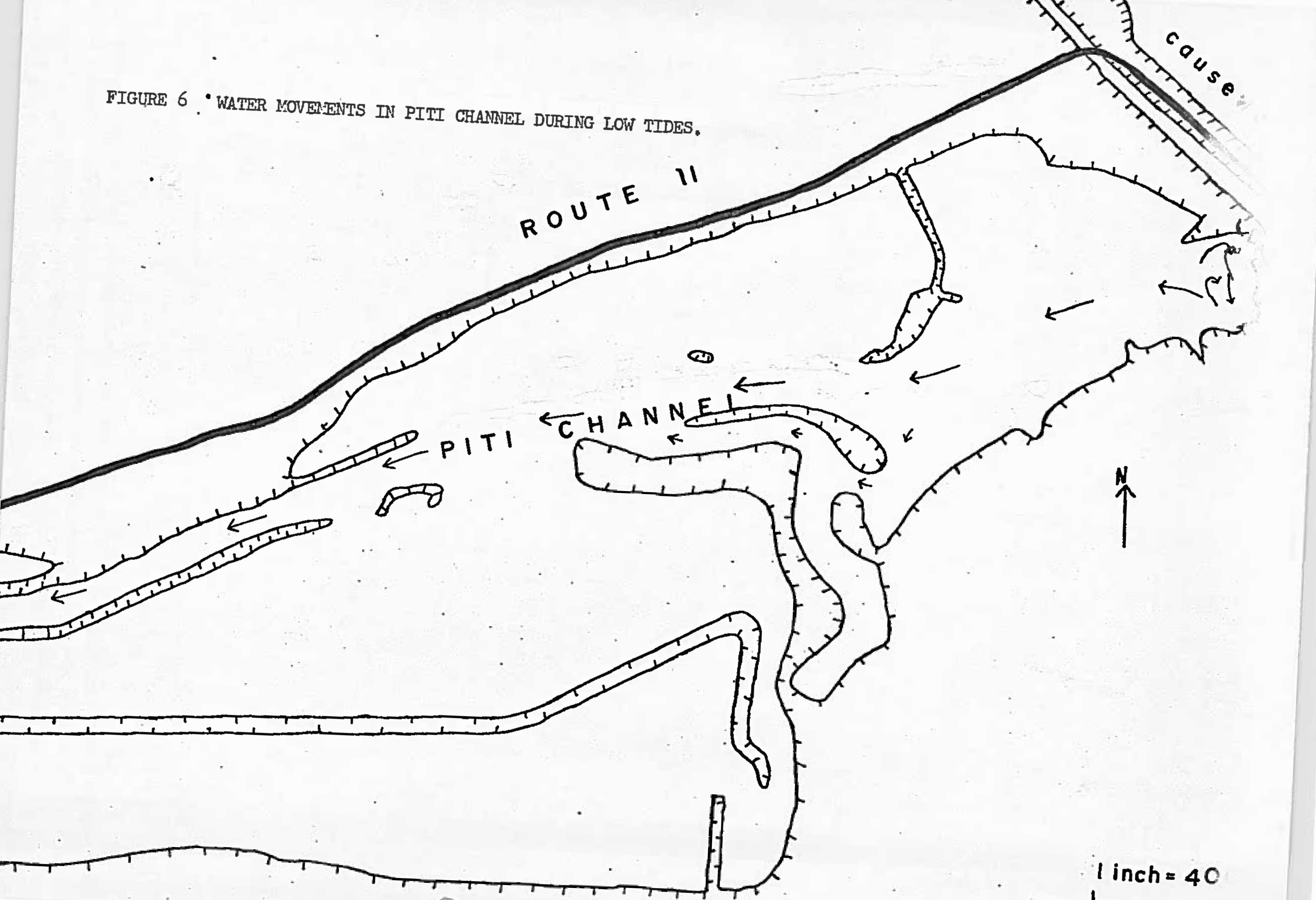


FIGURE 6 . WATER MOVEMENTS IN PITI CHANNEL DURING LOW TIDES.



APPENDIX

Fishes in Tepungan Channel and Piti Channel

by

Robert S. Jones and Helen K. Larson

Visual fish counts were made in Tepungan Channel from the trash grates at its western end to the two steel channel markers at its eastern end. A second count was made in Piti Channel near the Piti Power Plant and on the construction site of the new Cabras Island Power Plant. These counts were made on May 5 and May 11, 1972, respectively. Each count required approximately three hours. The Tepungan count was made by a team of two biologists and the Piti Channel count, by one. Our previous experience indicates that the difference between a one and two-person count is 10-20% at the maximum.

The largest concentration of fishes occurred at each end of Tepungan Channel and in the immediate vicinity of the Piti Power Plant outfall. Table 2 lists the species observed and the relative abundance of each. Of the 92 species observed, 73 were found on the Tepungan side and 37 on the outfall side. There are at least three reasons for the differences encountered. First, two biologists counted on the Tepungan side and only one on the outfall side. Second, the Tepungan and outfall habitats differ greatly, with the Tepungan side being the least influenced by man and the more favorable habitat. Third, the thermal effluent on the Piti side may be a factor excluding some species, although many species were found in the immediate vicinity of the outfall, as is common at many power plants. Of the three reasons, we consider the second to be the most tenable at this time.

Fish counts were made by a team of two biologists from the Guam Division of Fish and Wildlife in August, 1971. The team worked only on the outfall side. Their checklist is not complete in that many of the fishes are listed by family only. Overall their list seems to contain about one-half the number of species we counted on the outfall side. Approximately 15 of the species are the same, and only six differ from those we counted.

Anticipated environmental damage on the Tepungan side centers around the physical removal of the substratum in the present channel and the adjacent reef flat habitats which will be affected by widening the channel. The effect of siltation outside the dredging area is expected to be minimal and temporary. Resident channel species will be most disturbed. Species of the families Apogonidae, Blenniidae, Callionymidae, Canthigasteridae, Eleotridae, Gobiidae, Mugiloididae, and Pomacentridae will suffer the brunt of the disturbance. Most of these species reside permanently among the boulders and coral heads that are found scattered throughout the present channel. There are also several species that burrow in the sand and one species of apogonid (<u>Paramia</u>

quinquilineata) that lives among the spines of sea urchins common along the ch channel. These are all characteristically small species, and it is doubtful that their removal will constitute a biomass loss as great as 100 pounds. These species are common on the remainder of the reef flat and would not be considered rare.

On the outfall side, environmental disturbance involves land fill for the new Cabras Island Power Plant. The number of species involved will probably not exceed 10 resident species and 25 pounds of biomass.

Large numbers of the juvenile rabbitfish, Siganus spinus (mañahac), were found near the outfall on the Piti Channel side on May 11. These fishes characteristically enter the bays and estuaries of Guam in April or May. They come only once each year. The species was not recorded in great numbers on May 5 because the schools had not begun their migrations at that time.

The most unusual and interesting part of the ichthyofauna in either area is the presence of two species of gobies that form a symbiotic relationship with a species of snapping shrimp. The shrimp maintain burrows in the sand bottoms of the two channels and share the burrows with the gobies.

Obtortiophagus koumansi is the dominant goby on the Piti Channel side. The other species has not yet been identified, but resides more commonly on the Tepungan side. Their ecological separation further serves to delineate the habitat differences of the two areas in question.

It is the opinion of the investigating ichthyologists that the ichthyofauna of both Tepungan and Piti Channels will not be affected significantly by the proposed construction.

Table 2. CHECKLIST OF FISHES. Compares the ichthyofauna of Tepungan Channel with the Piti outfall area including the Cabras Island Construction site. TNTC = Too numerous to count, D = Dominant (10+), C = Common (6-10), P = Present (2-5), R = Rare (1).

Fish Species	Tepungan Channel	Outfall Area
Acanthuridae		
Acanthurus lineatus	-	R
A. triostegus	D	D
A. xanthopterus	-	D
Ctenochaetus striatus	C	P
Naso lituratus	P	-
N. unicornis	P	P
Zebrasoma veliferum	-	P
Apogonidae		
Apogon novemfasciatus	P	-
A. sp.	P	P
Paramia quinquilineata	TNTC	-
Aulostomidae		
Aulostomus chinensis	P	-
Balistidae		
Rhinecanthus aculeatus	TNTC	P
R. rectangulus	-	R
Blenniidae		
Aspidontis taeniatus	P	-
Meiacanthus atrodorsalis	P	-
Petroscirtes mitratus	-	P
Runula tapeinosoma	P	-
Salarias fasciatus	P	-
Callionymidae		
Callionymus xanthosemeion	P	-
Canthigasteridae		
Canthigaster solandri	TNTC	P
Carangidae		
Caranx melampygus	-	D
C. sp.	P	-
Trachinotus sp.	P	-

Fish Species	Tepungan Channel	Outfall Area
Chaetodontidae		
Chaetodon auriga	C	P
C. citrinellus	P	-
C. ephippium	R	C
C. falcula	-	P
C. lunula	P	-
C. ornatissimus	R	-
C. trifasciatus	-	P
Heniochus permutatus	P	-
Eleotridae		
Asterropteryx semipunctatus	P	P
Eleotriodes strigatus	P	-
Fistularidae		
Fistularia petimba	P	-
Gobiidae		
Amblygobius albimaculatus	-	P
A. sp.	-	P
Fusigobius neophytus	P	-
Gnatholepis deltoides	C	P
Oplopomus oplopomus	-	D
Obtortiophagus koumansi	-	TNTC
(This goby shares a burrow with the burrowing shrimp)		
Another goby/shrimp association occurs on the Tepungan side, unsure of genus	TNTC	-
Holocentridae		
Holocentrus sammara	P	-
Labridae		
Cheilinus rhodochrous	R	-
C. trilobatus	C	-
C. sp.	-	R
Cheilio inermis	R	-
Coris gaimardi	R	-
Epibulus insidiator	P	-
Halichoeres hortulanus	R	-
H. margaritaceous	P	-
H. trimaculatus	TNTC	-
Hemigymnus melapterus	R	-
Labroides dimidiatus	C	-
Macropharyngodon meleagris	P	-
M. pardalis	C	-
Stethojulis axillaris	P	-
S. linearis	P	-
Thalassoma hardwickei	R	-
Xyrichthys taeniourus	D	-

Fish Species	Tepungan Channel	Outfall Area
Leiognathidae		
Gerres argyreus	R	P
Leiognathus equulus	-	P
Lutjanidae		
Lethrinus rhodopterus	P	C
Lutjanus monostigmus	-	P
L. vaigiensis	-	C
Plectorhynchus schotaf	-	R
Scolopsis cancellatus	P	P
Mugiloididae		
Parapercis cephalopunctata	C	-
P. clathrata	P	-
Mullidae		
Mulloidichthys auriflamma	P	-
M. samoensis	P	P
Parupeneus barberinus	P	-
P. bifasciatus	P	-
P. chryserydros	P	-
Ostraciontidae		
Ostracion cubicus	P	-
Pomacentridae		
Abudefduf leucopomus	P	-
A. leucozona	P	-
A. septemfasciatus	P	-
A. sexfasciatus	P	P
Chromis caeruleus	TNTC	-
Dascyllus aruanus	TNTC	P
D. trimaculatus	P	-
Pomacentrus albofasciatus	TNTC	-
P. lividus	R	-
P. pavo	P	P
P. vaiuli	D	-
Scaridae		
Calotomus spinidens	P	-
Scarus chlorurus	-	R
S. lepidus	P	-
S. sordidus (juveniles)	TNTC	TNTC
Siganidae		
Siganus spinus	R	TNTC

Fish Species	Tepungan Channel	Outfall Area
Sphyraenidae		
Sphyraena sp.	-	R
Zanclidae		
Zanclus cornutus	R	-
Sub totals	73	37
Total	92	