# Appendix 6
# Design Data

# THE BASIC DESIGN STUDY ON THE PROJECT FOR IMPROVEMENT OF INTERISLAND ACCESS ROAD

## APPENDIX 6 DESIGN DATA

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# 1. NATURAL CONDITIONS SURVEY

## 1.1 GEOTECHNICAL SURVEY

1) General

The Republic of Palau, which consists of islands dotted over an expanse of sea approximately 3,120,000 km$^2$ in size on the western edge of the Carolina Islands, has a total land mass of 441 km$^2$ and is located at 6°53′~8°12′ north latitude and 134°08′~134°44′ east longitude.

Palaou islands belong to a part of circum-Pacific volcanic zone, and are based on the volcanic island due to upthrowing of Palau ocean bottom ridge by the sliding of plates. Coral coral reefs were formatted on the base since Tertiary Era, and many coral islands were formatted due to the crustal and sea movements.

Baberudaob, or the main island of Palau, was formed from volcanic breccias and tuff residuum. As for the "Lock islands", they were formed from the erosion of limestone in the shape of mushrooms.

Table 1-1 Landform of Palau Islands

| | Volcanic Islands | Limestone Islands | |
|---|---|---|---|
| Name of Island | Baberudaob Island (397 km$^2$)<br>Koror Island (9.1 km$^2$)<br>Arakabesang Island (5.2 km$^2$)<br>Malakal Island (2.3 km$^2$) | Rock Islands | Peleliu Island<br>Angaur Island<br>Kayanger Island<br>Garungel Atoll, etc. |
| Geological Features | The surface is 216 m (or less) above sea level and consists of andesite, basalt, tuff, and loam. | The surface is 60 m (or less) above sea level and consists of Tertiary Period limestone. | The surface is 50 m (or less) above sea level and consists of new limestone. |

According to a March 1983 geological survey report (i.e., the "Soil Survey of the Island of Palau, Republic of Palau") produced by the U.S. Department of Agriculture, the geological structure of Palau can be classified into 18 different types based on soil characteristics such as fertility, particle size and distribution, drainage, the thickness of stratum, etc. Note that in the case of the coral limestone islands, highly homogeneous calcareous rock exists under thin topsoil. On the other hand, the volcanic islands have a complex stratum composition and steep geographical features. The surface is covered with a mat of un-decomposed and partially decomposed grasses and sedges and is formed with well-drained fine sand and loam. The upper part of the subsoil is loamy and the lower part of the subsoil clayey volcanic ash, while outcrops of bedrock consist of tuffaceous basalts and andesites.

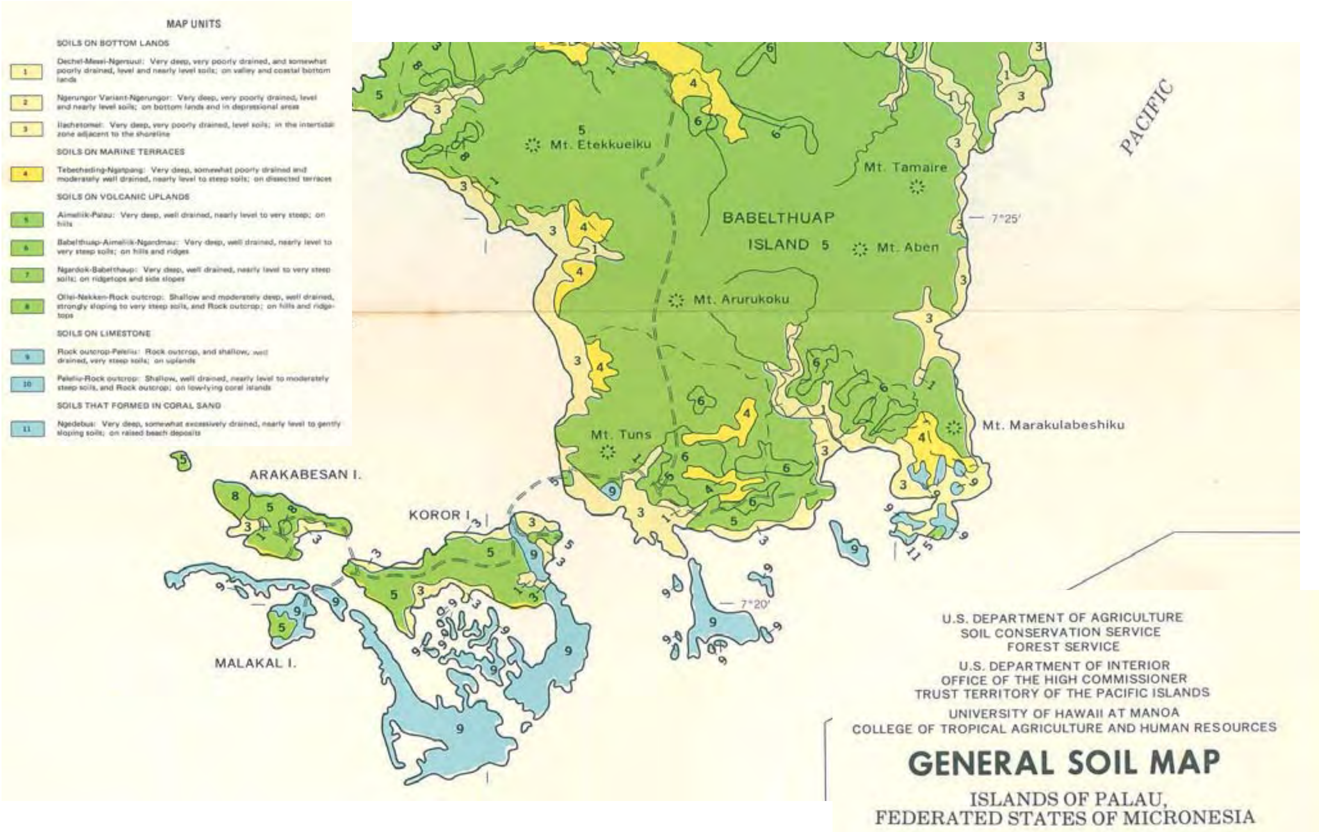



Fig. 1-1 Soil Survey of Islands of Palau Republic of Palau Issued March 1983
By United States Department of Agriculture

2) Topography and Geology of Project Roads

The topographic of project roads with geological feature for subsoil conditions are summarized inTable 1-2.

Table 1-2 Topographic and Subsoil Conditions of Project Roads

| Project Roads | Topographic an Subsoil Conditions |
|---|---|
| Myunze Causeway | Aimeliik-Palau soil is distributed inland excluding the causeway, which has been placed on artificialmarine terrace soil. Iiachetomel soil is distributed in the vicinity of the coast. |
| Malakal Causeway Malakal Island Road | Outcrop-Peleliu soil is dominant throughout except for the in the area of the man-made causeway. |
| Airai Causeway Babeldaob Trunk Road | Iiachetomel soil on top of marine terrace soil is distributed on the Koror side, while Outcrop-Peleliu soil is distributed on the middle island. Aimeliik-Palau soil and marine terrace soil are distributed on the Airai side on Baberdaob Island. |

3) Geological Survey Results

The sampling of subsoil together with documentation comprising sketches and photographs of pavement structure were conducted for each of the existing roads. Soil texture and CBR test results for the subsoil of each project road are summarized below, with details appended at the end of the report for reference.

Table 1-3 Summaries of Soil Laboratory Test Results

| Sample Number | KM Post (m) | Surface Geology | Soil texture: Natural Water Content | 75μ> | LL | PL | PI | Nature of Soil Classification | Soaked C.B.R. | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| Meyungs (A 0.67 km causeway) | | | | | | | | | | |
| A01 | 0 | Iiachetomel soil | 55.2 | 73.5 | 57 | 31 | 26 | SC | 12 | Silt clay (reddish brown) in vicinity of starting point of Arakabesang and is very fine. Compaction assumed to be difficult. |
| A04 | 1,000 | Relaid soil (clay) | 57.6 | 74.0 | 59 | 31 | 28 | SC | 10 | Ditto |
| A06 | 1,850 | Re-laid soil (clay) | 72.2 | 91.4 | 62 | 43 | 19 | SC | 6 | Ditto |
| Malakal (A 0.97 km causeway and a 1.58 km island road for a total distance of 2.55 km) | | | | | | | | | | |
| M01 | 0 | Aimeliik -Palau soil | 29.0 | 46.9 | 41 | 28 | 13 | SC | 21 | Silt clay soil (reddish brown) with high degree of compaction and CBR even with natural water content. |
| M03 | 1,200 | Ditto | 30.3 | 43.4 | 41 | 27 | 14 | SC | 24 | Ditto |
| M06 | 2,800 | Ditto | 26.3 | 40.9 | 30 | 26 | 4 | SC | 18 | Ditto |
| M12 | 3,250 | Outcrop-Peleliu soil (Coral Mix) | 25.4 | 40.1 | 30 | 26 | 4 | S | 19.5 | Fine silt/sandy soil mixed with coral limestone. High degree of compaction even with natural water content. |
| Babeldaob (A 0.72 km causeway and a 0.4 km inland road for a total distance of 1.12 km) | | | | | | | | | | |
| B04 | 300 | Iiachetomel soil & marine terrace soil. Causeway has Re-laid soil | 65.9 | 90.8 | 61 | 42 | 19 | CH | 10 | Lime mixed with clay forms roadbed and has a high natural water content and low CBR. |
| B06 | 500 | Approach fill Re-laid soil | 61.3 | 89.8 | 56 | 32 | 24 | SC | 11 | Ditto |
| B09 | 200 | Aimeliik -Palau layer | 69.5 | 74.5 | 59 | 40 | 19 | SM/MH | 8 | Silt mixed with loamy clay that has a low CBR with a large amount of natural water. Necessary to replace roadbed to improve CBR. |

Comments for Subgrade Soil

The existing subgrade materials composing causewas are clayey soil which were take from the islands. They have enough bearing strength on normal conditions. However, it has a remarkable character to be weaken for the materials with clayey portions of more than 70%, and with 60% or more water contents. It is anticipated to show low strength by the water during the construction, and some kinds of measures are, such as replacing or stablilization expected on the execution of the improvement.

4) Rock Quarry Survey

Two crushed rock quarries are available near the site. The quality of the crushed stone is summarized below.

The PTC rock quarry mines the Aimeliik-Palau soil strata produces tuff and tuffaceous andesite-basalt. Agglomeration degrees of alomost of the rocks are low, and the comparatively high allongation rocks are mined selectively.

HBRC quarry that produces calcareous sandstone and limestone aggregate exists in the Outcrop-Peleliu soil strata.

Table 1-4 Quality Test Results for Crushed Stone

| Type of Rock/Course / Testing Criteria | PTC Quarry | HBRC Quarry | United States Standard * | Japanese Standard ** | |
|---|---|---|---|---|---|
| | Basalt | Limestone | Class B | Surface and Binder Course | Upper Base Course |
| Specific gravity for saturated surface-dry aggregate | 2.56 | 2.5 | - | 2.45 or more | - |
| Water absorption coefficient | (3.52) | 2.804 | - | 30% or less | - |
| Abrasion value | 25.0 | (35.1) | 45% or less | 30% or less | 50% or less |
| Stability examination with sulfuric acid sodium | (17.4) | 1.2 | 12% or less | 12% or less | 20% or less |

*AASHTO M283-81 Coarse Aggregate for Highway & Airport Construction (ASTM D2940)
**Asphalt pavement outline (company) Japan Road Association

Excluding the items "specific gravity for saturated surface-dry aggregate" and "abrasion value", the aggregate produced in the PTC quarry does not fulfill the criterion of an aggregate. On the other hand, limestone from the HBRC quarry only fails to satisfy the "abrasion value" criterion.

## 1.2 TOPOGRAPHIC SURVEY

A topographical survey was conducted in accordance with the following specifications.

Table 1-5 Specifications for Topographic Survey

| Type of Survey | Type of Measurement | Measurement Methodology | Output |
|---|---|---|---|
| Land topographical survey | Setting of center line and plane surveying | Placement of central tacks at 100 m intervals and use of paint at a 20 m pitch<br>30 m wide plane-table survey | Plan (1/500) |
| | Road profile leveling | Elevation of road centerline measured. | Profile<br>(H=1/500, V= 1/100) |
| | Road cross-section leveling | Cross-section leveling on either side of road for a width of 30 m at 20 m intervals at topographical control points | Crossing chart (1/100) |

Before the topographical survey was conducted, the Tentative BM was set up based on the B.M. and the coordinates shown in the table below obtained with the cooperation of the Bureau of Land & Survey (BLS) of the Ministry of Resource Development (MRD).

Table 1-6 Lists of Control Points

| Route Name | Name of Control Point | Coordinates | | B.M. |
|---|---|---|---|---|
| | | X coordinates (E) | Y coordinates (N) | Height (EL) |
| Koror Trunk Road | FLA1 | 51888.19500 | 148696.9990 | 10.492 |
| | T-DOCK | 52823.31000 | 149886.4400 | - |
| | BM6 | - | - | 3.114 |
| Meyungs Causeway | DIDAL 1 | 51343.55219 | 149233.5975 | - |
| | DIDAL 2 | 51261.29859 | 149757.5269 | - |
| Malakal Causeway and Island Road | CINN | 50696.15293 | 148543.8343 | - |
| | KAL | 49794.80000 | 147551.0800 | |
| | BM1 | - | - | 1.538 |
| | BM2 | - | - | 2.366 |
| | BM3 | - | - | 1.914 |

Source: Bureau of Land & Survey, Ministry of Resource Development

Table 1-4 List of KBM

| Route Name | Name | Coordinates | | B.M. |
|---|---|---|---|---|
| | | X coordinates (E) | Y coordinates (N) | Height (EL) |
| Meyungs Causeway | KBM1 | 51364.87500 | 149174.0500 | 3.897 |
| | KBM2 | 51257.41300 | 149854.5440 | 1.950 |
| Malakal Causeway and Shimauchi road | KBM3 | 50429.31600 | 148386.6050 | 1.985 |
| | KBM4 | 50259.35000 | 147680.7070 | 2.266 |
| Airai Causeway | KBM5 | 54986.81000 | 150472.0460 | 2.028 |
| | KBM6 | 55315.37300 | 150811.9440 | 1.819 |
| Babeldaob Shimauchi road | KBM7 | 56217.77000 | 151223.8470 | 2.288 |

Source: Local re-consignment measurement

# 2. PRESENT STATUS OF WATER SUPPLY AND SEWER FACILITIES IN THE KOROR STATE

## 2.1 WATER SUPPLY

### 2.1.1 General Description of Water Supply Facilities

Drinking water to the Koror, Arakabesan and Malakal is distributed from the Airai Water Purification Plant (hereafter Airai WPP) in the Baberdaop Island. The water supply system in the study area consists of the transmission lines, the main water tanks located at Ngermid, Ngerkesor and Arakabesan, and the distribution lines. In the Malakal Island, there is a water tank on the hillside, but water has not been stored since it was constructed due to lack of pressure. Drinking water is distributed from the main distribution pipeline to each customer without the Malakal water tank. Main water supply facilities in the study area are shown in the Figure 2-1.

Transmission pipelines were constructed by Japanese Grant Aid Project in 1992. The distribution pipelines were constructed by American aid in the late 1970s. Present water supply system is summarized in the Table 1-1.

Table 2-1 Summary of Water Supply System in the Koror State

| | |
|---|---|
| Distributed Population | : 15,407 (Census in 2000) |
| Unit Water Demand | : 257 lpcd (in 2000) |
| Water Consumption | : 15,140 $m^3$/day (100 million gallon/day) |
| Nos of Water Meter | : 2,922 nos (Nov. 2003) |
| Water Tariff | : 5.00 USD/month (Airai state)<br>0.85 USD/1,000G (Koror state) |

### 2.1.2 Present Water Supply System in the Study Area

Present water supply system in the study area is summarized in the Table 1-2.

Table 2-2 Existing Water Supply System in the Study Area

| Road | Airai CW | | Miyuns CW | | Malakal CW | Malakal Island Road |
|---|---|---|---|---|---|---|
| Length (km) | 1.12 | | 0.67 | | 0.97 | 1.58 |
| Purpose | Trans-mission | Distri-bution | Trans-mission | Distri-bution | Distribution | Distribution |
| Diameter (mm) | 250 | 200 | 250 | 200 | 200 | 200 |
| Materials | DCIP | AC | SP | AC | AC | AC |
| Pipe Installation | Under-ground | Under-ground | Exposing | Under-ground | Underground | Underground |
| Construction Year | 1991 | 1978-80 | 1991 | 1977-80 | 1977-80 | 1977-80 |

Note) DCIP : Ductile Cast iron Pipe, SP : Steel Pipe, AC : Asbestos Cement Pipe

Test pit survey was executed to chck the subsoil condition and pipe condition in some selected points of the study area. As a result of the test pit survey, present conditions of the pipes were generally estimated as fair. Leakage of water, cracks and corrosion of the pipes were not found by the test pit survey. The minimum soil cover for the underground water supply pipelines was found as ranging 1.0-1.2 m which was in line with a result of interview survey for the related agencies. Sand was used as a backfill material with the sickness of 10-20 cm around pipes. The installation condition of the pipes was generally recognized as good.

The present critical points and past replacement of the pipes were surveyed with the staffs of the beaurou of water supply and sewer of the Ministry of Resources and Development (hereafter MORD). It was found that one replacement of the main distribution pipeline was executed in the last 10 years (refer to Figure 2-1). Leakage of water pointed out in the preliminary study report was ordinary occurred in the branch distribution pipelines other than main distribution pipelines.

The water shortage in the Malakal Island was not identified through the interview survey to some residents and commercial building staffs in the Malakal Island, and current status of water shortage in the Malakal Island was estimated as not serious. If the development is implemented and water demand is also increased drastically, the shortage of the water supply will be expected, and improvement of the existing water supply system will have to be requested.

### 2.1.3 Executing Agency

The beaurou of water supply and sewer of the MORD is recognized as the executing agency for water supply in the Koror and Airai area. The currenttotal number of the staffs is as 26, 10 of them for maintenance of pipeline and remaining 16 staffs for operation of the Airai WPP. It was found that pipe connection, installation and replacement of troubled pipes were as current major work of maintenance staffs. The annual budget in the fiscal year of 2003 and 2004 are shown in the Table 1-3. It was found that the personnel salary accounted for almost 80% of the annual budget.

Table 2-3 Annual Budget for 2003 and 2004 (USD)

| | 2003 | 2004 |
|---|---|---|
| Personnel | 102,380 | 129,000 |
| Supplies/ POL | 5,000 | 20,500 |
| Maintenance | 3,000 | 3,000 |
| Utilities-electricity | 500 | 1,000 |
| Other | 20,200 | 4,000 |
| Total | 131,080 | 157,500 |

### 2.1.4 On-going and Other Donor Project

The status of the on-going project shown in the preliminary study report was surveyed as shown below.

Palau Rural Water Systems Project

- Project completed
- Rural area water supply development except Koror
- Total amount of project cost: 10 million USD.

Koror-Airai Water System Improvement

- Project completed
- Expansion of the Airai WPP
- Total amount of project cost: 0.5 million USD.

Any other future project was currently not found except Airai-Koror Water Supply System Upgrading and Expansion project which was requested to the government of Japan in June, 2003.

### 2.1.5 Needs of Urgent Improvement of Existing Water Supply Facilities

As a result of the field survey, the condition of existing water supply facilities in the study area were justified as fair to be used as they were. It was not necessary for urgent improvement of existing water supply facilities in the study area.

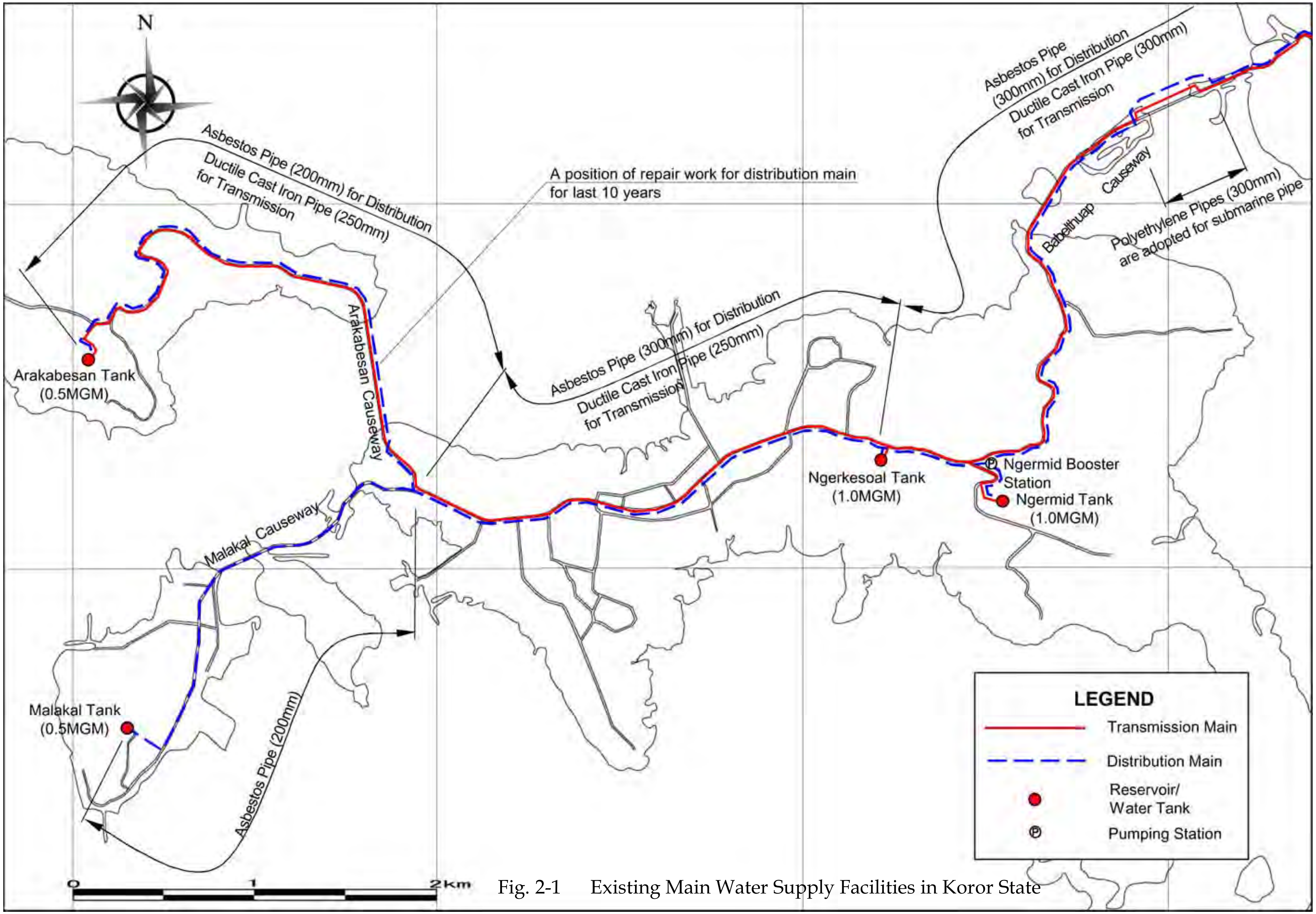



Fig. 2-1 Existing Main Water Supply Facilities in Koror State

## 2.2 SEWER

### 2.2.1 General Description of Sewer Facilities

The separate sewage collection system was adopted in the Koror state, and rainfall water was basically drained to the sea through the side drain along the roads without treatment. The sewage discharged from houses, industry and commercial buildings were conveyed to the Malakal Waste Water Treatment Plant (hereafter Malakal WWTP) by sewer pipeline network. The present capacity of the Malakal WWTP was designed as 3,800m3/day. Treated wastewater was discharged into the sea at a distance of 600 m from the Malakal WWTP.

However, present Malakal WWTP was not functioned due to less maintenance and wastewater flown into the WWTP was discharged into the sea without treatment. The rehabilitation and expansion project for the Malakal WWTP has been executed since 2001. The capacity of the WWTP will be expanded upto 7,600 m3/day when the project iscompleted.

Almost existing wastewater collection system was constructed by American aid in the late 1970s. The wastewater was conveyed with gravity flow and pressure flow by pumping. There were 47 pump stations in the Koror State. The length of main gravity pipelines and pressure pipelines were about 37 km and 14.5 km, respectively. The materials of PVC pipe and Ductile Cast Iron Pipe were ordinary adopted for the main pipeline. The asbestos cement pipe was still used or remained in the gravity main with diameter of more than 200 mm. The main sewer facilities are summarized in the Table 1-4 and illustrated in Figure 2-2.

Table 2-4 Summary of Sewer System in the Koror State

| | |
|---|---|
| Connected Household | 1,900 (in 2003) |
| Design Daily Sewage Flow | 7,200 m3/day (expected in 2010 at the time of 1994) |
| Treatment Capacity | 3,800m3/day (Rehabilitation project under progress) |
| Outfall | Sea (outlet was located at 600 m apart from shoreline) |

The study for the current status of sewer system in the Koror state was under progress by the American consultant in November 2003. The current issues and critical points of the existing sewer system will be identified when the above said study is completed.

### 2.2.2 Existing Sewer Facilities in the Study Area

Present main sewer systems in the projected roads are summarized as shown in the Table 2-5. There are no sewer lines for Airai CW.

Table 2-5 Existing Sewer System in the Projected Roads

| Road Name | Airai CW | Miyuns CW | Malakal CW | Malakal Island Road | |
|---|---|---|---|---|---|
| Length (km) | 1.12 | 0.67 | 0.97 | 0.97 | 0.60 |
| Conveyance | — | Pressure | Pressure | Gravity | Pressure |
| Diameter (mm) | — | 300 | 300 | 300 | 300 |
| Materials | — | DCIP | DCIP | AC | DCIP |
| PipeInstallation | — | Exposing | Underground | Underground | Underground |
| Construction Year | — | 2001 | — | — | — |

DCIP：Ductile Cast iron Pipe, AC：Asbestos Cement Pipe

Test pit survey was executed to chck the subsoil condition and pipe condition in some selected points of the study area. As a result of the test pit survey, present conditions of the pipes were generally estimated as fair. The manhole survey was also executed in parallel with the test pit survey. Diameter of the pipe, depth of the invert level and failure of the joint between pipe and manhole were surveyed. As a result of the manhole survey, the failure of the joint was not found, and the minimum soil cover was found as 1.2 m. The replacement of the previous pipe beams under the culvert top was found by the field reconnaissanse.

The inundation of wastewater in the Malakal Island during heavy rainfall was pointed out by the local authorities. The interview survey to the residents in the Malakal Island was executed to clarify frequency of the inundation. As a result of the interview survey, it was found that frequency of wastewater inundation was not so many. The last wastewater inundation occurred in last July. The electric power-cut and interruption of the pump operation due to failure of buck-up generator at two main pump stations in Malakal was recognized as a reson of last innundation. The renovation of the generators at two main pump stations were executed after last innundation, and inundation has not occurred since last July.

The lack of the flow capacity of the main gravity pipelines in the Malakal island,which was reported by the previouse study report, was studied based on the collected data in this study.

### 2.2.3 Executing Agency

The beaurou of water supply and sewer of the MORD is recognized as the executing agency for sewer system for the Koror state. The currenttotal number of the staffs is as 14, 3 of them for maintenance of pipeline and remaining 11 staffs for operation of the Malakal WWTP. It was found that pipe connection, installation and replacement of troubled pipes were as current major work of maintenance staffs. The annual budget in the fiscal year of 2003 and 2004 are shown in the Table 2-6. It was found that the personnel salary accounted for almost 80% of the annual budget.

Table 2-6 Annual Budget for 2003 and 2004 ( USD )

| | 2003 | 2004 |
|---|---|---|
| Personnel | 40,140 | 49,000 |
| Supplies/ POL | 7,400 | 11,100 |
| Maintenance | 2,500 | 1,500 |
| Utilities-electricity | 0 | 0 |
| Other | 2,500 | 0 |
| Total | 52,540 | 61,600 |

### 2.2.4 On-going and Other Donor Project

The progress of the on-going project as shown in the preliminary study report was surveyed as shown below.

Koror Sewage Treatment Plant Expansion

- On-going project
- The projected treatment capacity of 7,600 m3/day (as equal to 2 MGD)
- Project cost of 3.5 Million USD

Koror Wastewater System Improvements

- Project completed
- Upgrading and construction of pump station (no relationship to this study)
- Project cost of 5.3 million USD

### 2.2.5 Needs of Urgent Improvement of Existing Sewer Facilities

As a result of the field survey, the condition of existing sewer facilities in the study area were justified as fair to be used as they were. It was not necessary for urgent improvement of existing water supply facilities in the study area.

However, the shortage of the flow capacity of the gravity main will be expected if the Malakal island is constantly developed in accordance with projected population growth.

Table 2-7 Preliminary Estimation of Flow Capacity

| | Existing Pipe | Proposed Pipe |
|---|---|---|
| Length(m) | 390 | |
| Diameter(mm) | 300 | 450 |
| Material | Asbestos Cement | PVC |
| Gradient(0/00) | 2.3 | |
| Roughness Coefficient | 0.013 | 0.010 |
| Flow Capacity ($m^3$/sec) | 0.046 | 0.178 |
| Proposed Sewage ($m^3$/sec) | 0.158 | |

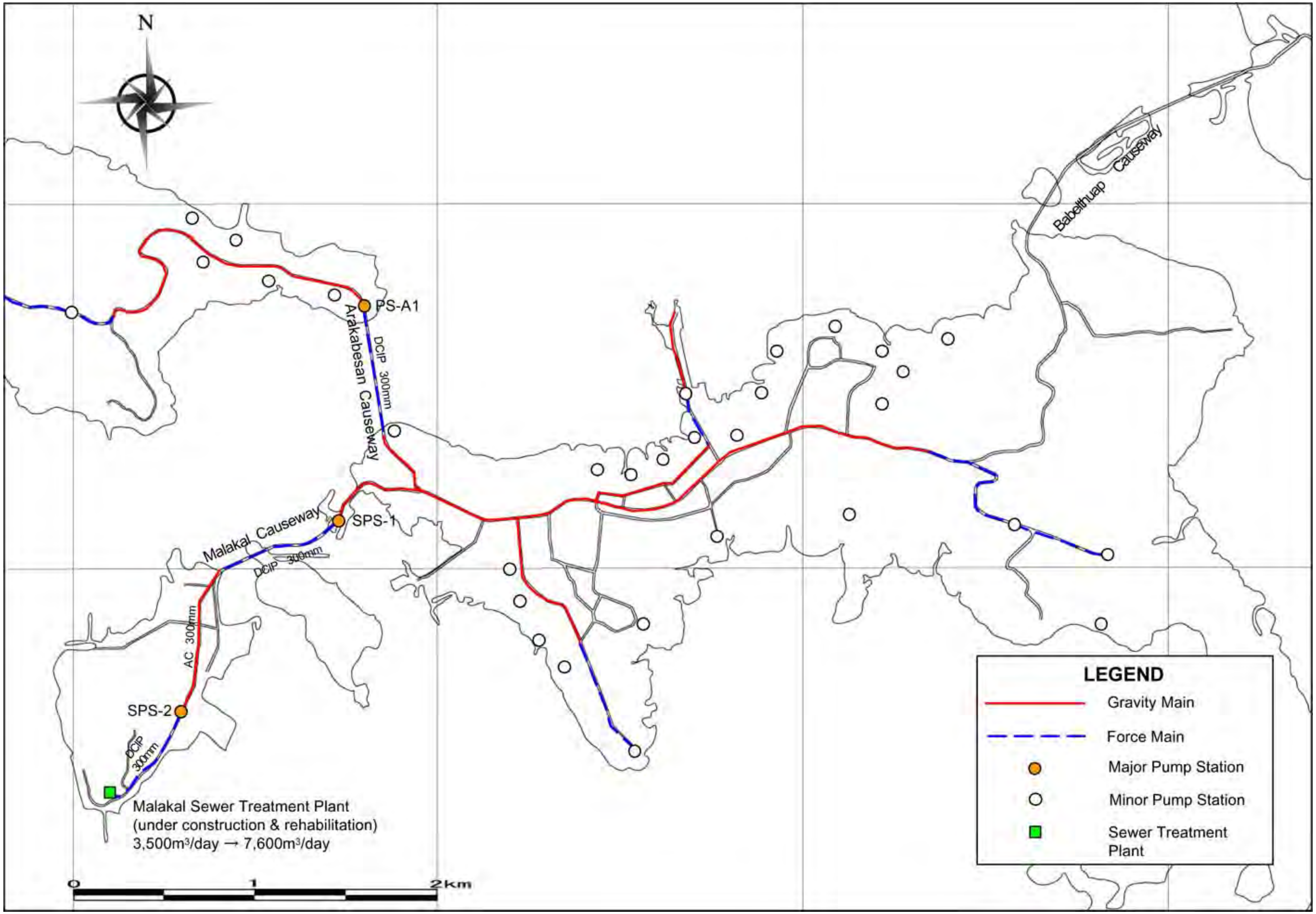



Fig. 2-2 Existing Major Wastewater Collection Facilities in Koror State

# 3. STUDY ON THE REQUIRED NUMBER OF LANES IN CAUSEWAY

## 3.1 TRAFFIC CAPACITY AND REQUIRED NUMBER OF LANES

The traffic demand in 2013 was estimated as around twice of the present traffic volume, as shown in the following table, applying the annual growth rate of 8% onward. The applied growth rate was derived from 15% growth rate of the 1990s vehicle registration (refer to page 6-28 of Palau 2020). The details of present traffic volume are presented in Sub-Chapter 7.2.

Unit: vehicle/day

| | Meyungs CW | Malakal CW | Airai CW | Koror Central Area (for reference) |
|---|---|---|---|---|
| Daily Traffic | 9,000 | 7,000 | 5,000 | 20,000 |
| Peak Ratio | 10% | 16% | 10% | 10% |
| Traffic in 2013 | 18,000 | 14,000 | 10,000 | 40,000 |

In case the carriageway width is 3.6 m and shoulder width is 1.2 m, the required number of lanes for project causeways estimated as two lanes (refer to Highway Capacity Manual, Japan Road Association), as shown in the following calculation table. However when the carriageway width of 3.0 m and shoulder width of 0.6 m were applied to the Project, the adjustment factor by these widths became 0.86 and estimated two-lane capacity become insufficient in Malakal Causeway, and marginal in Meyungs Causeway.

| | Meyungs CW | Malakal CW | Airai CW | Koror Central Area (for reference) |
|---|---|---|---|---|
| Capacity | 2,500 v/h | 2,500 v/h | 2,500 v/h | 2,500 v/h |
| Adjustment Factor for | | | | |
| Lane Width | 1.0 | 1.0 | 1.0 | 1.0 |
| Lateral Clearance | 1.0 | 1.0 | 1.0 | 1.0 |
| Heavy Vehicles | 0.98 | 0.98 | 0.98 | 0.98 |
| Area Type | 1.0 | 1.0 | 1.0 | 0.8 |
| Allowable Capacity | 2,450 v/h | 2,450 v/h | 2,450 v/h | 1,960 v/h |
| Adjustment Factor for LOS | 0.9 | 0.9 | 0.9 | 0.9 |
| Design Capacity | 2,205 v/h | 2,205 v/h | 2,205 v/h | 1,764 v/h |
| Peak Ratio | 10% | 16% | 10% | 10% |
| Allowable Design Capacity | 22,000 v/day | 14,000 v/day | 22,000 v/day | 18,000 v/day |
| Traffic in 2013 | 18,000 v/day | 14,000 v/day | 10,000 v/day | 40,000 v/day |
| Required number of lanes | 2 lanes | 2 lanes | 2 lanes | 3 to 4 lanes |

Remarks, v/h : vehicles per hour
v/day: vehicles per day

## 3.2 SUMMARY TABLE OF TRAFFIC SURVEY

| Road Name | Surveyed Item | 2003 Jan/1 | 2003 Apr/2 | 2003 Nov/3 |
|---|---|---|---|---|
| Meyungs CW Peak Ratio 9~10% | Peak Time East Bound | 325 | 416 | 409 |
| | Peak Time West Bound | 397 | 440 | 415 |
| | Peak Time Total | 722(97%) | 856 | 824(94%) |
| | 12/14 hrs East Bound | 4,268 | 4,340 | |
| | 12/14 hrs West Bound | 3,879 | 4,300 | |
| | 12/14 hrs Total | 8,147(96%) | 8,640(95%) | |
| Malakal CW Peak Ratio 15~17% | Peak Time East Bound | 435 | 319 | 295 |
| | Peak Time West Bound | 369 | 402 | 411 |
| | Peak Time Total | 804(92%) | 721 | 706(92%) |
| | 12/14 hrs East Bound | 2,320 | 4,118 | |
| | 12/14 hrs West Bound | 2,912 | 4,117 | |
| | 12/14 hrs Total | 5,232(93%) | 8,235(91%) | |
| Koror Central Area Peak Ratio 9~10% | Peak Time East Bound | 1,180 | 890 | 780 |
| | Peak Time West Bound | 648 | 1,028 | 953 |
| | Peak Time Total | 1,828(96%) | 1,918 | 1,733(83%) |
| | 12/14 hrs East Bound | 9,744 | 10,455 | |
| | 12/14 hrs West Bound | 8,687 | 10,513 | |
| | 12/14 hrs Total | 18,431(96%) | 20,968(96%) | |
| Airai CW Peak Ratio 10~11% | Peak Time East Bound | 232 | 257 | 160 |
| | Peak Time West Bound | 179 | 353 | 252 |
| | Peak Time Total | 411(89%) | 610 | 412(90%) |
| | 12/14 hrs East Bound | 1,948 | 2,974 | |
| | 12/14 hrs West Bound | 1,910 | 26,652 | |
| | 12/14 hrs Total | 3,858(92%) | 5,626(89%) | |

Remarks: Figures in parenthesis shows passenger car ratio

Source: /1 Traffic Survey by Nippon Koei Co., Ltd.

/2 Preparatory Study Report

/3 Traffic Survey by the Basic Design Study Team

# 4. TRAFFIC ACCIDENTS RECORD[1]

## 4.1 NUMBER OF TRAFFIC ACCIDENTS IN AND AROUND KOROR ISLAND

| Year | Total | Outside Roadway | | Inside Roadway | | Injured | Killed | Drunk Driving | |
|---|---|---|---|---|---|---|---|---|---|
| 1997 | 169 | 47 | (40) | 122 | (20) | 28 | 2 | 41 | (28) |
| 1998 | 129 | 25 | (22) | 104 | (23) | 32 | 0 | 34 | (27) |
| 1999 | 129 | 38 | (33) | 91 | (32) | 54 | 0 | 16 | (7) |
| 2000 | 267 | 58 | (21) | 209 | (35) | 47 | 0 | 82 | (36) |
| 2001 | 111 | 16 | (15) | 95 | (12) | 20 | 0 | 9 | (5) |
| 2002 | 293 | 88 | (38) | 205 | (41) | 51 | 1 | 29 | (13) |
| 2003 | 185 | 40 | (25) | 145 | (57) | 81 | 1 | 44 | (31) |
| Total | 1,283 | 312 | (194) | 971 | (220) | 313 | 4 | 255 | (147) |
| Ratio/1 | | 62% | | 23% | | | | 53% | |
| Occurrence/2 | 6 | 1.5 | (1) | 5 | (1) | | | | |

Note: Figures in parenthesis shows the number of serious accidents
/1 Ratio shows the ratio of serious accidents
/2 Occurrence shows the annual occurrence per kilometer

## 4.2 NUMBER OF TRAFFIC ACCIDENTS ON THREE PROJECT CAUSEWAY

| Year | Total | Outside Roadway | | Inside Roadway | | Injured | Killed | Drunk Driving | |
|---|---|---|---|---|---|---|---|---|---|
| 1997 | 22 | 18 | (18) | 4 | (1) | 9 | 1 | 8 | (7) |
| 1998 | 13 | 6 | (6) | 7 | (3) | 8 | 0 | 4 | (4) |
| 1999 | 12 | 10 | (10) | 2 | (0) | 5 | 0 | 2 | (2) |
| 2000 | 21 | 13 | (6) | 8 | (4) | 9 | 0 | 17 | (8) |
| 2001 | 6 | 5 | (5) | 1 | (1) | 1 | 0 | 1 | (1) |
| 2002 | 33 | 17 | (14) | 16 | (6) | 11 | 0 | 7 | (6) |
| 2003 | 5 | 4 | (4) | 1 | (0) | 2 | 1 | 2 | (2) |
| Total | 112 | 73 | (63) | 39 | (15) | 45 | 2 | 41 | (30) |
| Ratio/1 | | 86% | | 38% | | | | 73% | |
| Occurrence/2 | 5 | 3.5 | (3) | 2 | (1) | | | | |

Note: Figures in parenthesis shows the number of serious accidents
/1 Ratio shows the ratio of serious accidents
/2 Occurrence shows the annual occurrence per kilometer

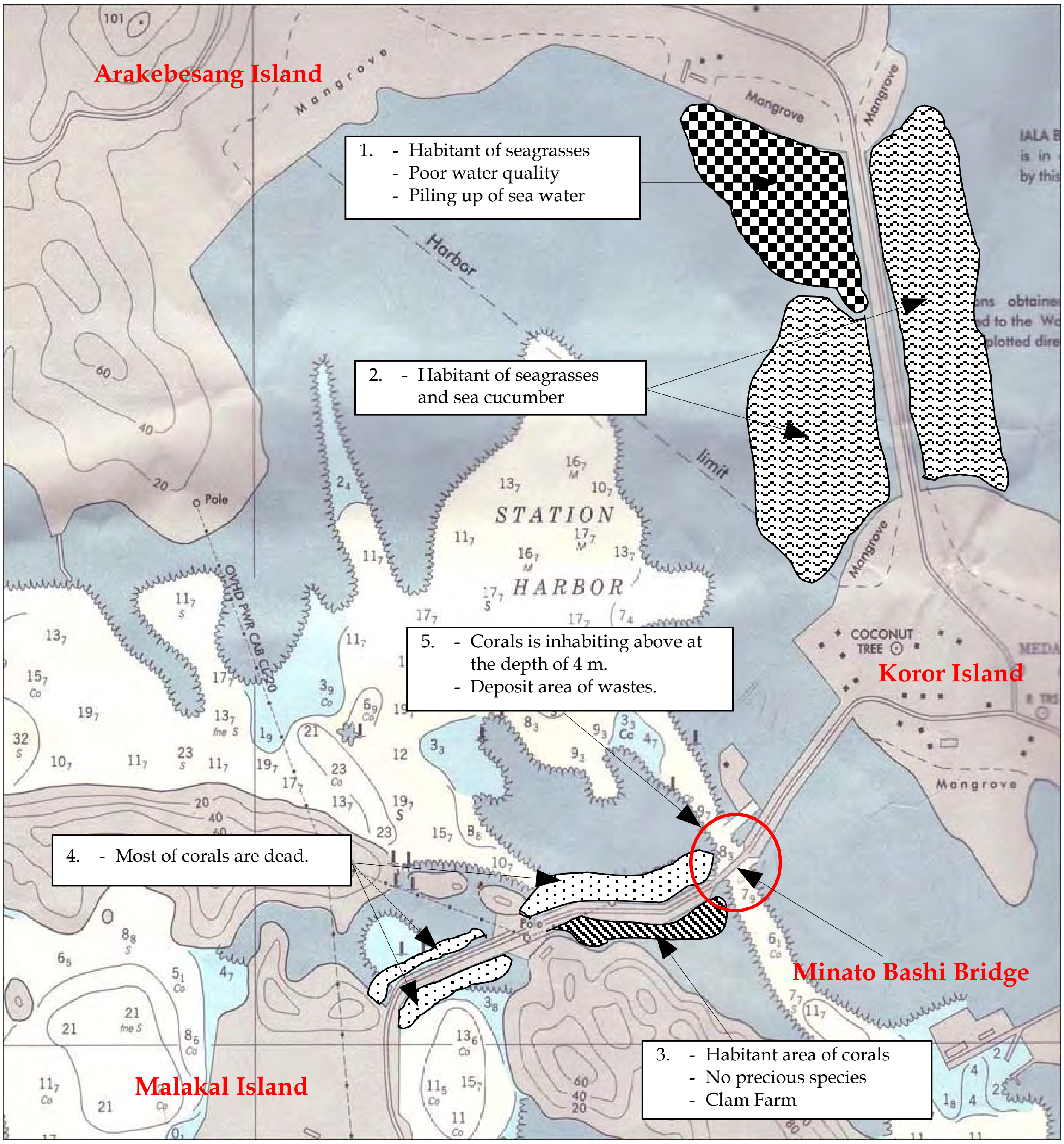
## 4.3 NUMBER OF TRAFFIC ACCIDENTS ON CAUSEWAYS

| Causeway Name | Total | Outside Roadway | | Inside Roadway | | Injured | Killed | Drunk Driving | |
|---|---|---|---|---|---|---|---|---|---|
| Ngetmeduch | 25 | 19 | (19) | 6 | (3) | 7 | 1 | 4 | (4) |
| KB Bridge CW | 20 | 10 | (9) | 10 | (3) | 8 | 1 | 11 | (8) |
| Airai CW | 45 | 29 | (28) | 16 | (6) | 15 | 2 | 15 | (12) |
| Minato-Bashi | 15 | 12 | (12) | 3 | (1) | 11 | 0 | 6 | (6) |
| Malakal CW | 7 | 5 | (1) | 2 | (0) | 1 | 0 | 4 | (1) |
| Toirechuir | 15 | 9 | (9) | 6 | (3) | 8 | 0 | 3 | (3) |
| Malakal CW | 37 | 26 | (22) | 11 | (4) | 20 | 0 | 13 | (10) |
| MeyungsCW PH | 3 | 1 | (1) | 2 | (0) | 0 | 0 | 0 | (0) |
| Meyungs CW | 27 | 17 | (12) | 10 | (5) | 10 | 0 | 13 | (8) |
| Meyungs CW | 30 | 18 | (13) | 12 | (5) | 10 | 0 | 13 | (8) |
| Total | 112 | 73 | (63) | 39 | (15) | 45 | 2 | 41 | (30) |

[1] Data was taken from Traffic Accidents Record of Ministry of Justice and Traffic Police

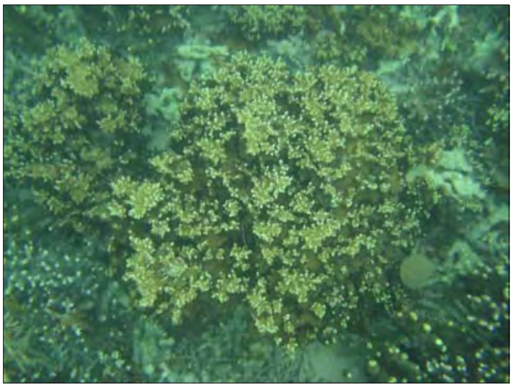
# 5. LIVING BEINGENVIRONMENTS SURROUNDING SITE

## 5-1 HABITAT OF CORAL (SURVEY LOCATION MAP)



## 5-2 HABITAT OF CORAL (MAJOR CORAL RECOGNIZED)

*Polrites sp.*



*Porites rus*

*Porites cylindrica*

*Acropora spp.*

*Anacropora spp.*

*Pavona cactus*

*Pocillopora damicornis*

*Fungia sp.*

## 5-3 HABITAT OF MANGROVE

Mangrove at Airai Causeway

Mangrove at Airai Causeway

Mangrove at Meyungs Causeway

Mangrove at Meyungs Causeway

*Rhizophora sp.*

*Sonneraria alba*

# 6 STRUCTURAL DESIGN OF CAUSEWAY

The design criteria were chosen for no significant damage to the causeway during a 50-year high tide level and possible typhoon wave event., applying "Technical Standards and Commentaries for Port and Harbor Facilities in Japanb 1999"

## 6-1 SELECTION OF STRUCTURAL TYPE

A rock revetment is composed of armor rocks sized according to the design wave height, under layer rocks and fill material. Under layer is designed to distribute the weight of the armor rock and to prevent the loss of fill material through voids in the rocks. A rock revetment is a time-proven shore protection measure. Design parameters are well based on model studies and empirical data. Properly designed rock revetments are durable, flexible, and highly resistant to wave damage. The structure can settle and adjust without major failure, and a revetment can still function effectively even if damaged. The rough surface reduces wave runup and overtopping.

## 6-2 CREST ELEVATION

The crest elevation of a causeway is determined by one of the following two principles, and method b) was selected from economic point.、

| | Methods | Issues |
|---|---|---|
| A) | To take the wave runup height as the reference and to set the crest of the causeway higher than the runup height so that no wave overtopping will occur. | There are some difficulties to estimate the proper runup technically as well as the possibility of unfeasible crest elevation economically. |
| B) | The other is to take the wave overtopping amount as the reference and to set the crest of the causeway at such a height as to keep overtopping below some maximum tolerable quantity. | There are also some difficulties to estimate the rate accurately without hydraulic model tests because the wave-overtopping rate is affected by many kinds of factors. Furthermore, it is problematic to determine the allowable wave-overtopping amount. |

In case of b), the crest elevation of the causeway is calculated by applying the following expression. 50-year provable high tide is adopted as a design high tide (DHT). 60% of the design wave height is added to the design high tide. Observation period of offshore wave record is 37 years and the maximum wave height is 6.5m according to the record. On the other hand, 50-year provable wave height is estimated 6.6m showing small difference. Therefore, the maximum waves height in front of causeway for 50-year could be assumed to be the same as the height for 37 years. In this project, 1.5m is defined as the design criteria.

$$Hc = DHT + 0.6 \times DWH$$

Where;
Hc: Crest elevation of causeway (m),
DHT: Design high tide (m),
DWH: Design wave height (m)

Above calculated crest elevation of causeway is the minimum height to prevent the overtopping of coming waves by an estimated 50-year. So, in the design, the crest elevation of

3.8~3.9 m is proposed. This is equivalent to 2.25~2.35 m by bench mark level. The average height of the exiting causeway is about 1.8m and 45~55cm is lower than the designed level. The causeway shall be raised up or parapet wall shall be installed.

### 6-2-1 Relation between Chart Datum Level and Bench Mark Level

The relation between chart datum level and bench mark level in Palau is shown in right figure.6-1

| Chart Datum Level | Bench Mark Level |
|---|---|
| +2.83 Design Tide | +1.28 |
| +2.02 MHHW | +0.47 |
| +1.55 MSL | 0.00 (Bench Mark) |
| 0.00 MLLW (Chart Datum) | -1.55 |

(Unit: m)

### 6-2-2 Design High Tide

Provable tides by return period in Palau could be estimated based on the actual tidal record including astronomical tide and meteorological tide between 1985 and 2003 (See Table 6-1 and Figure 6-2). In this project, 50-year provable tide (2.83 m) was defined as the design criteria (Bench Mark Level is 2.83-1.55 = 1.28 m).

Table6-1 Provable Tides in Palau

| Return Period | Year | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|---|
| Non-Exceeding Provability | % | 90 | 95 | 97 | 98 | 98 |
| Variable (rv) | - | 1.52 | 1.73 | 1.84 | 1.92 | 1.98 |
| Provable Tide | mm | 2,722 | 2,772 | 2,799 | 2,818 | **2,831** |

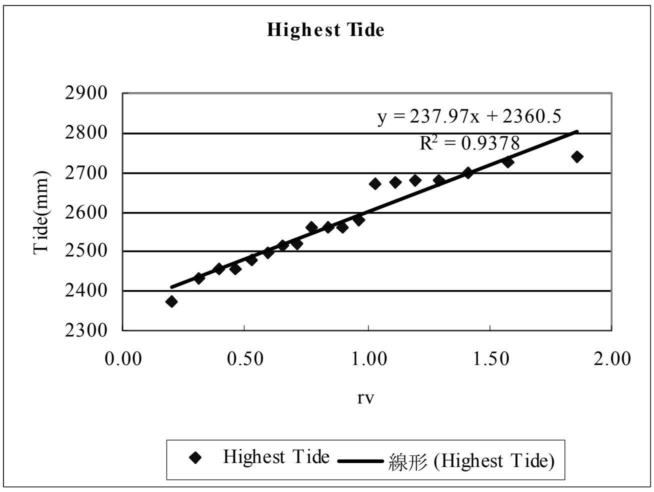



Fig.6-2 Provable Tides in Palau (Weible Distribution (k=20)).

### 6-2-3 Design Wave Height

Palau consists of more than 200 islands, and the reef of Palau encloses all of the islands except two small atolls. Offshore waves, which develop at the sea area adjacent to Palau reach the reef edge through diffraction and refraction, and then proceed on the reef flat deeply up to the shore decreasing their heights. This condition is considered for the causeway design.

Assuming that the water depth of the planned causeway is around minus 2m, the maximum wave height in front of causeway is estimated as 1.5 m referring to the model tests. (See, Table 6-2)

Table 6-2 Distribution of Wave Height: High Tide (in case of —2m)

Number **AREA 63**

| $H_0$ | SE | S | SW | W | NW | N | NE | E | Total |
|---|---|---|---|---|---|---|---|---|---|
| $H_{1/3}$ | 0 | -25 | -22 | -15 | 0 | 15 | 22 | 25 | (Number) |
| 2.5 m | | | | | | | | | 0 |
| (%) | | | | | | | | | |
| 1.5 m | | 8 | 982 | 2,218 | 1,320 | 1,716 | 3,508 | 20 | 9,772 |
| (%) | | 0.02 | 2.14 | 4.83 | 2.87 | 3.74 | 7.64 | 0.04 | 21.28 |
| 0.5 m | 4,158 | 3,752 | 2,928 | 2,092 | 1,630 | 1,744 | 7,522 | 12,330 | 36,156 |
| (%) | 9.05 | 8.17 | 6.38 | 4.55 | 3.55 | 3.80 | 16.38 | 26.85 | 78.72 |
| Total | 4,158 | 3,760 | 3,910 | 4,310 | 2,950 | 3,460 | 11,030 | 12,350 | 45,928 |
| (%) | 9.05 | 8.19 | 8.51 | 9.38 | 6.42 | 7.53 | 24.02 | 26.89 | 100.00 |

## 6-3 GRADIENT OF SLOPE

The gradient of the slope was designed as 1:1.5 considering the workability of the construction.

## 6-4 WEIGHT OF ARMOR ROCK AND UNDER LAYER STONE

The weight of armored rock covering the slope surface of a structure receiving the wave action is calculated using the formula by Hudson R.Y:

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

Where; W : Minimum weight of rock (ton), 0.4

γr : Unit weight of rock in air (ton/m3), 2.6

Sr : Specific gravity of rock to seawater, 2.6 x $\frac{1.00}{1.03}$ =2.52

α : Angle of the slope to horizontal plane (degree) cot α=1.5

H1/3 : Design wave height (m), 1.5

KD : Constant determined by the armoring material and damage rate, *4.0* for crushed stone and less than 10% damage rate based on the hydraulic model tests

As a result, minimum weight of rock having 0.4 ton is required as armor rock. The weight of under layer stone is designed as a tenth of armor rock

## 6-5 FOOT PROTECTION WORKS

Setting the toe stone in order to protect the causeway slope against the scouring should be done. The cross section of the foot protection works is shown in Figure 2-17.

## 6-6 COMPOSITION OF ARMOR ROCK AND UNDER LAYER STONE

The slope of rock revetment is composed of armor rock and under layer stone. Dimensions of each composition are designed as follows.

Table 6-3 Outline of Rock Revetment

| | Armor rock: | Under layer stone |
|---|---|---|
| Layer (number) | 1 | 2 |
| Minimum weight of rock (kg) | 400 | 40 |
| Thickness (m) | 0.6 | 0.3 |
| Gradient of slope | 1:1.5 | 1:1.5 |
| Allowable unevenness of layer surface (m) | ±0.15 | ±0.1 |

## 6-7 STRUCTURAL DESIGN

The standard cross section of the rock revetment is shown in the following figure.

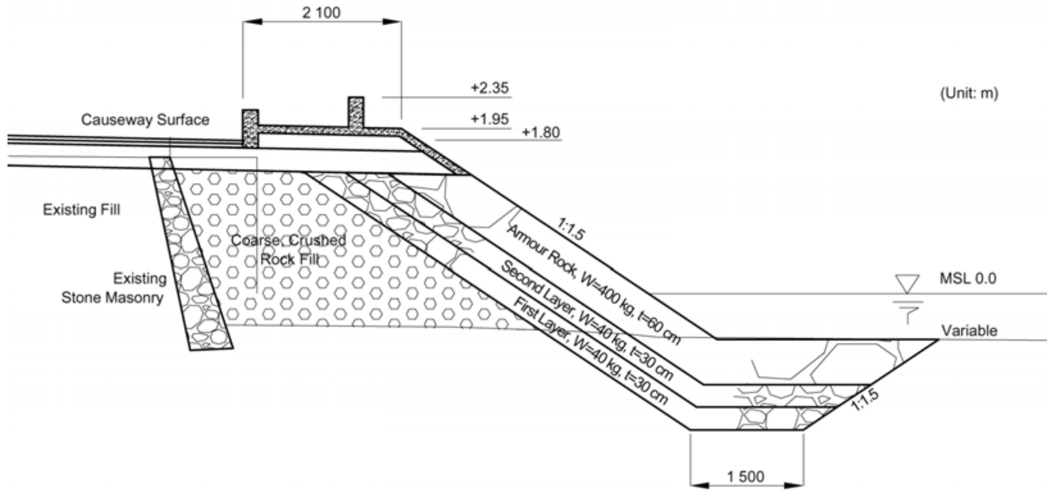



Fig. 6-3 Cross Section of Rock Revetment

# 7. SEA LEVEL CHANGE DUE TO GLOVAL ENVIRONMENTAL CHANGING

A long-term rise in sea level relative to the land exists in many areas of the world. This rise results in a slow, long-term recession of the shoreline, partly due to direct flooding and partly as a result of profile adjustment to the higher water level.

One of the South Pacific Ocean countries claims that the sea level is rising around 3 mm annually.

However, the sea level rise is not observed significantly in the tide observation record of Malacal Port in the latest 10 years, as given in Figure 6-1. Therefore, sea level rise is not considered in the causeway design. However, it is desirable to monitor the sea level change through the long-term observation.

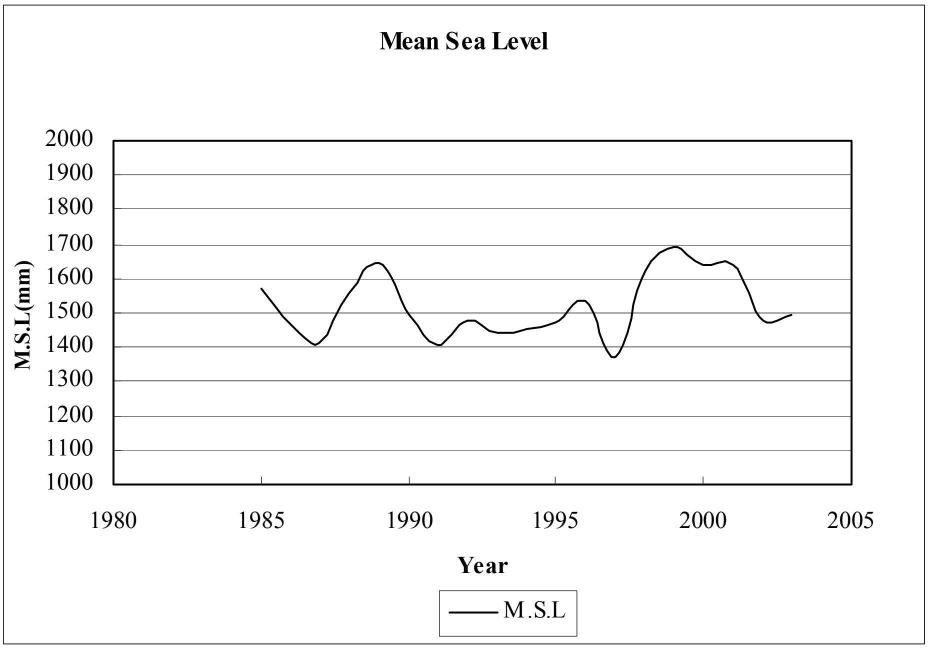



Fig. 7-1 Historical Change of Mean Sea Level in Palau