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# Melekeok Conservation Network
# In Situ Water Quality Monitoring Report
# Palau

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Pacific R2R Ridge to Reef

# Melekeok Conservation Network In Situ Water Quality Monitoring Report Palau

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# CONTENTS

# ABBREVIATIONS

| | |
|---|---|
| BWA | Belau Watershed Alliance |
| DO | Dissolved Oxygen |
| EQPB | Environmental Quality Protection Board |
| FNU | Formazin Nephelometric Units |
| GEF | Global Environment Facility |
| ICM | Integrated Coastal Management |
| IW | International Waters |
| IW R2R | International Waters Ridge to Reef Project |
| MCN | Melekeok Conservation Network |
| MNRET | Ministry of Natural Resources Environment and Tourism |
| NNR | Ngardok Nature Reserve |
| NTU | Nephelometric Turbidity Units |
| PAN | Protected Area Network |
| SPC | Pacific Community |
| USGS | United States Geological Survey |
| WERI | Water and Environmental Research Institute |
| YSI | Yellow Springs Instruments |

# LIST OF TABLES



# LIST OF FIGURES

Lake Ngardok
Babeldaob, Melekeok

# EXECUTIVE SUMMARY

A partnership between the Palau International Waters Ridge to Reef (IW R2R) project, the Ministry of Natural Resources, Environment and Tourism and the Melekeok Conservation Network (MCN) enabled a one-year water quality monitoring at the Ngardok Nature Reserve (NNR). The Pacific Community (SPC) Regional Programme Coordination Unit purchased the water quality test kits to assist with the water quality monitoring work. The monitoring included classroom-type sessions, site visits and field work. At the end of monitoring and field work, the test kits were handed over to MCN.

The NNR water quality monitoring programme delivered on the following outputs:

- Achieved the outcomes of Palau IW R2R demonstration project for increased local community and agency capacity in water quality monitoring and improved data collection for the development of a national catchment management plan for the participating Belau Watershed Alliance (BWA) states;
- Achieved goals for the NNR in providing research opportunities and capacity building for local researchers;
- Trained two MCN staff in water quality monitoring; and
- Collected a year's worth of in situ water quality data and established a water quality programme for MCN.

Preliminary results from the in-situ water quality monitoring offered the following observations:

- Physical water properties vary slightly for dry and rainy months;
- Overall low levels of nutrients at the sites;
- Higher levels of Nitrate and Nitrite at sites located outside the protected area;
- Conductivity increased at all sites during the dry season;
- Stream levels correspond with rainfall;
- Ongoing monitoring is needed to validate trends and inform or complement current rehabilitation and restoration efforts at the NNR; and
- An existing need to improve the water quality monitoring if a water quality programme were to be established.

# 1. BACKGROUND

The Melekeok State Government through Melekeok State Public Law 4-32, which was enacted in 1997 and updated in 2010, created the Melekeok State Conservation Network (MCN). MCN includes the Ngardok Nature Reserve (NNR) and Ngermedelim Marine Sanctuary. MCN has a management plan which is currently used for managing the two protected areas. MCN has eight employees, all of whom live in Melekeok State and who are active members of the Melekeok Community.

Ngardok Lake is the largest freshwater lake in Palau and the Micronesia region. The lake is Palau's only wetland to be designated as a Wetland of International Significance under the Ramsar Convention on Wetlands. Ngardok Lake is an important component of the Ngerdorech watershed as the lake and its tributaries are the headwaters for the watershed. Ngardok Lake and its surrounding forest are a habitat for the endemic biib (*Ptilinopus pelewensis*), ius (*Crocodylus porosus*), and newly discovered kesiamel (*Osmoxylon ngardokense*). Ngardok Lake is important to the Melekeok State community as the lake and its tributaries flow to the Melekeok Dam. This dam provides water to the national capital of Palau and the Melekeok State's 277 residents.

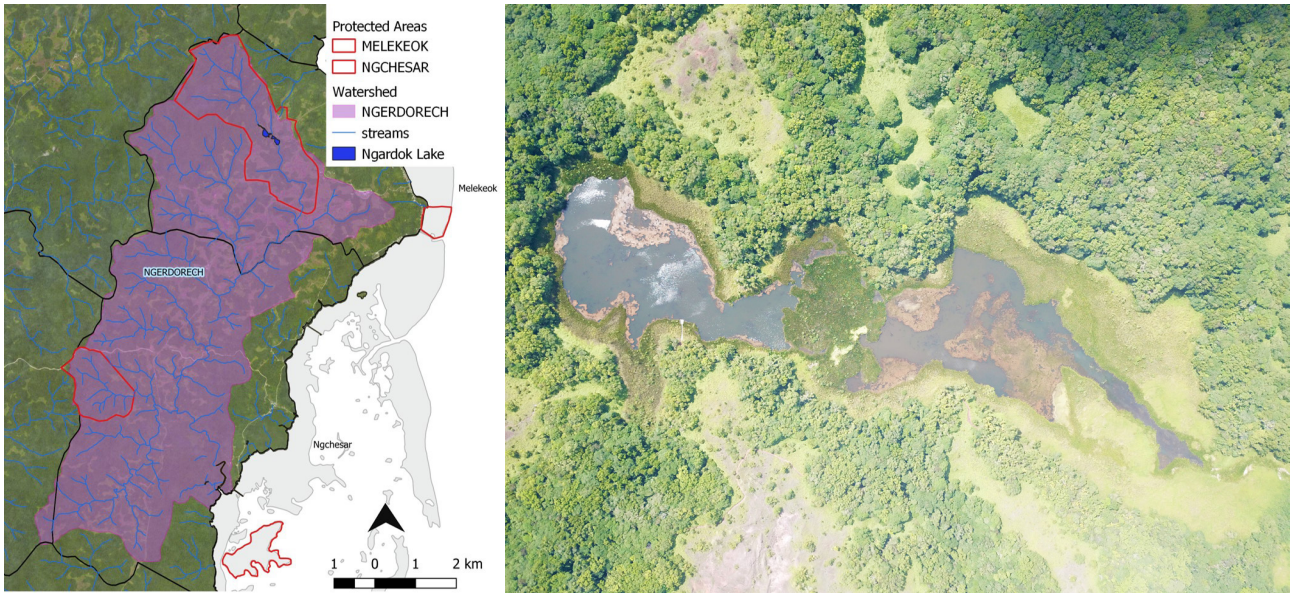


Figure 1. (a) Ngerdorech Watershed. (b) Ngardok Lake.

The Palau Environment Quality Protection Board (EQPB) monitors piped water in Melekeok monthly. A 1996 United States Geological Survey (USGS) study remains the most comprehensive water quality study available for Ngardok Lake. To date, no water quality study has been conducted across the Ngerdorech Watershed in Melekeok State.

The goals of the NNR include clean and abundant water, maintaining the ecological integrity of Ngardok Lake, and providing research opportunities. Current interventions to meet these include soil and forest rehabilitation, establishing best management practices, and surveillance.

MCN, through its valuable partners has developed robust techniques for monitoring terrestrial and marine flora and fauna. The need was identified for training of staff on water quality monitoring to enable the commencement of a water quality programme for MCN. The first of its kind, the one-year water quality work conducted by the International Waters Ridge to Reef Project (IW R2R) implemented by the Ministry of Natural Resources, Environment and Tourism ((MNRET) achieves the goals for NNR set out in the MCN plan.

# 2. INTRODUCTION

The MCN recognises the importance of water quality. The MCN management plan states specific goals for the Ngardok Nature Reserve, which include ensuring clean and abundant water to meet the needs of Melekeok State; maintaining the ecological integrity of Lake Ngardok and its natural habitats; and providing opportunities for research on the organisms and natural systems within the watersheds as well as the connected systems in the surrounding area.

Activities to meet these goals have centred around reforestation and education/outreach. No activities have been previously undertaken for continuous water quality monitoring. Water quality studies have been conducted either by visiting scientists or at one-time data collection.

The outcomes of Palau's IW R2R project, implemented by the MNRET, calls for increased local community and agency capacity for water quality monitoring and improved data collection for the development of a national catchment plan for the participating Belau Watershed Alliance (BWA) states. Component 1 of the Regional IW R2R programme provides national demonstration support for R2R integrated coastal management and integrated water resource management (ICM/IWRM) approaches such as through the procurement of water quality monitoring equipment.

To elevate staff capacity and implementing activities in their management plan, MCN partnered with the IW R2R demonstration project implemented by MNRET to assist in the creation of a water quality programme, a first for MCN.

The purpose of undertaking water quality monitoring in the NNR and the broader catchment is to collect the necessary data and information to establish or review baseline indicators towards understanding the current state of priority environmental threats caused by municipal waste pollution, land use activities and natural disasters, including climate change. The results would assist with future coordinated water quality monitoring of the NNR and broader catchment area, and most importantly, inform future sustainable conservation and resource use of natural resources including upscaling R2R investments and ICM planning.

This report provides a snapshot of the monitoring approach, initiation and implementation, results, and discusses how to further improve MCN water monitoring capability. It is envisioned that this report will be annexed to the next update of the MCN management plan.

Figure 2. Southside of Ngardok Lake looking towards visitors' floating dock.

# 3. MONITORING APPROACH

## 3.1 Safety

As with any activity undertaken by the MCN, the utmost priority is for safety. Safety measures (Appendix 1). were adopted from the Waterwatch Victoria Methods Manual and are also outlined in the MCN Management Plan.

## 3.2 Water Quality Parameters

Limited water quality testing and funding availability means most water samples are sent off-island for analysis. MCN thus, chose to conduct its water quality monitoring in situ. It is acknowledged that in situ results may not be as accurate as certified laboratory analysis, however, in situ results provide estimates that can be verified against laboratory standard methods in the future.

With assistance of the IW R2R Regional Programme Coordination Unit, a YSI multiparameter multiprobe and a photometer were purchased. Table 1 outlines the parameters and EQPB acceptable levels. Parameters were chosen based on the 1996 USGS study and considering what the available monitoring instruments can measure. [with limitation to the water quality parameters available to the monitoring instruments.]

Table 1. Water Quality Parameters

| Parameters | Description and EQPB Acceptable Levels | Sampling Method | Collection |
|---|---|---|---|
| Temperature (°F) | Important role in health and quality of a water body. Temperature affects biological, chemical, and physical features of a river.<br>Temperature shall not vary by more than 1.5-degree Fahrenheit (EQPB 2015) | YSI multiprobe | Sample main current |
| Dissolved Oxygen (mg/L) | Measure of how much oxygen is dissolved in water.<br>DO concentrations shall not vary by more than 25% from natural conditions (EQPB 2015) | YSI multiprobe | Sample main current |
| Conductivity (µS/cm) | Ability of water to carry an electric current. Used as an indicator of salinity and concentrations of dissolved salts in a water body | YSI multiprobe | Sample main current |
| pH | Measure of how acidic or basic water is. A pH of 7 is called neutral, above 7 is basic (alkaline), and below 7 acidic.<br>pH variation shall not be greater than 0.2 pH units from natural conditions; but not lower than a pH of 6.5 or higher than a pH of 8.5 from other than natural (EQPB 2015) | YSI multiprobe | Sample main current |
| Total Dissolved Solids (mg/L) | Sum of all the substances, organic and inorganic, dissolved in water. | YSI multiprobe | Sample main current |

| Parameters | Description and EQPB Acceptable Levels | Sampling Method | Collection |
|---|---|---|---|
| Turbidity (FNU) | Measure or absence of soluble, suspended particles that hinder the transmission of natural light at the surface to the lower depths. Turbidity affects the potential rate of photosynthesis, growth of plant or algae in a water body.<br>Turbidity shall not be greater than 5% above natural conditions (EQPB 2015)<br>*FNU and NTU comparable, no conversion of data values necessary if YSI instrumentation is used to collect data | YSI multiprobe | Sample main current |
| Ammonia (mg/L N) | Occurs as breakdown product of nitrogenous material in natural waters. | YSI 9300 Photometer | Sample main current |
| Nitrate (mg/L N) | Present in natural water. Enter water bodies through natural vegetation breakdown or using chemical fertilizer or sewage effluent. | YSI 9300 Photometer | Sample main current |
| Nitrite (mg/L N) | Found in natural waters and are product in the nitrogen cycle. Harmful to fish and aquatic life. | YSI 9300 Photometer | Sample main current |
| Phosphate | Used in detergents. Fertilisers can contain phosphate; phosphate can also come from breakdown of plant and animal waste. | YSI 9300 Photometer | Sample main current |
| Dam Water Level | Possible context to Water Quality and surroundings | Visual Survey Water Meter in Dam | |
| Presence and Type of Rubbish | Possible context to Water Quality and surroundings | Visual Survey | |
| Weather | Possible context to Water Quality and surroundings | General Observation | |

## 3.3 Planning Meeting

An initial planning meeting introduced the IW R2R project and highlighted the objectives of MCN and IW R2R relating to water quality. MCN staff proposed three sampling locations to monitor water quality based on the 1996 USGS study on Ngardok Lake, the flow of the Ngerdorech River, land use and safety.

A monitoring workplan was discussed and agreed upon (Appendix 2). It was decided that the sites chosen would be monitored at least twice a month for the full year. The water quality team includes the IW R2R project manager, MCN Conservation Officer and an MCN Ranger. It was noted that other staff may assist if required.


Figure 3 Initial Planning Meeting held at Ngardok Nature Reserve Office

## 3.4 Site Selections

As a follow up to the planning meeting, the water quality monitoring team met to scout and plot the proposed monitoring sampling sites. Initially, in the planning meeting, three sites located in the NNR reserve were selected, however during the scouting, MCN staff took the initiative and proposed two additional sites outside NNR following the downward direction of the Ngerdorech River. Section 4.1 of this report describes each of the sampling locations.

Figure 4 Site Selection Field Day

## 3.5 Classroom Session

A day-long classroom session activity was organised for MCN. Topics discussed in this activity included:

- Water cycle and watersheds
- Concepts of water quality
- Water quality parameters
- Land use
- Climate Change effects on weather patterns
- Sampling Protocol to be used

MCN staff were able to share their observations of NNR noting that some streams are perennial while others are intermittent and dry during summer months.

Figure 5. Classroom Session at MNRET Ngerulmud Office

Two additional classroom sessions were provided throughout the monitoring as refreshers to the team.

## 3.6 Equipment Training

Prior to monitoring, the team went to one of the sampling sites to demonstrate and test in situ sampling procedures. Tasks for the training included:

- Training on sampling protocol: equipment, field gear, data sheets, storage, preservation, and transport of samples.
- Downloading data from the YSI multiparameter multiprobe.
- Analysing samples using the YSI Photometer.
- Basic quality assurance and quality control requirements for water quality when in the field based on ISO17025; 2017.
- Disposal of used chemicals.
- Importance of instrument calibration.


Figure 6. Equipment training at Euall

# 4. IMPLEMENTATION

## 4.1 Sampling Location

Sampling locations (Figure 7) include:

- (SS1) the bridge on the way to the lake;
- (SS2) the dock at the lake;
- (SS3) Ngeokib (Melekeok Water Dam);
- (SS4) Ngerkoranges;
- (SS5) Euall.

Appendix 3 contains a larger version of the map and site photos. Table 2 describes sampling site locations.

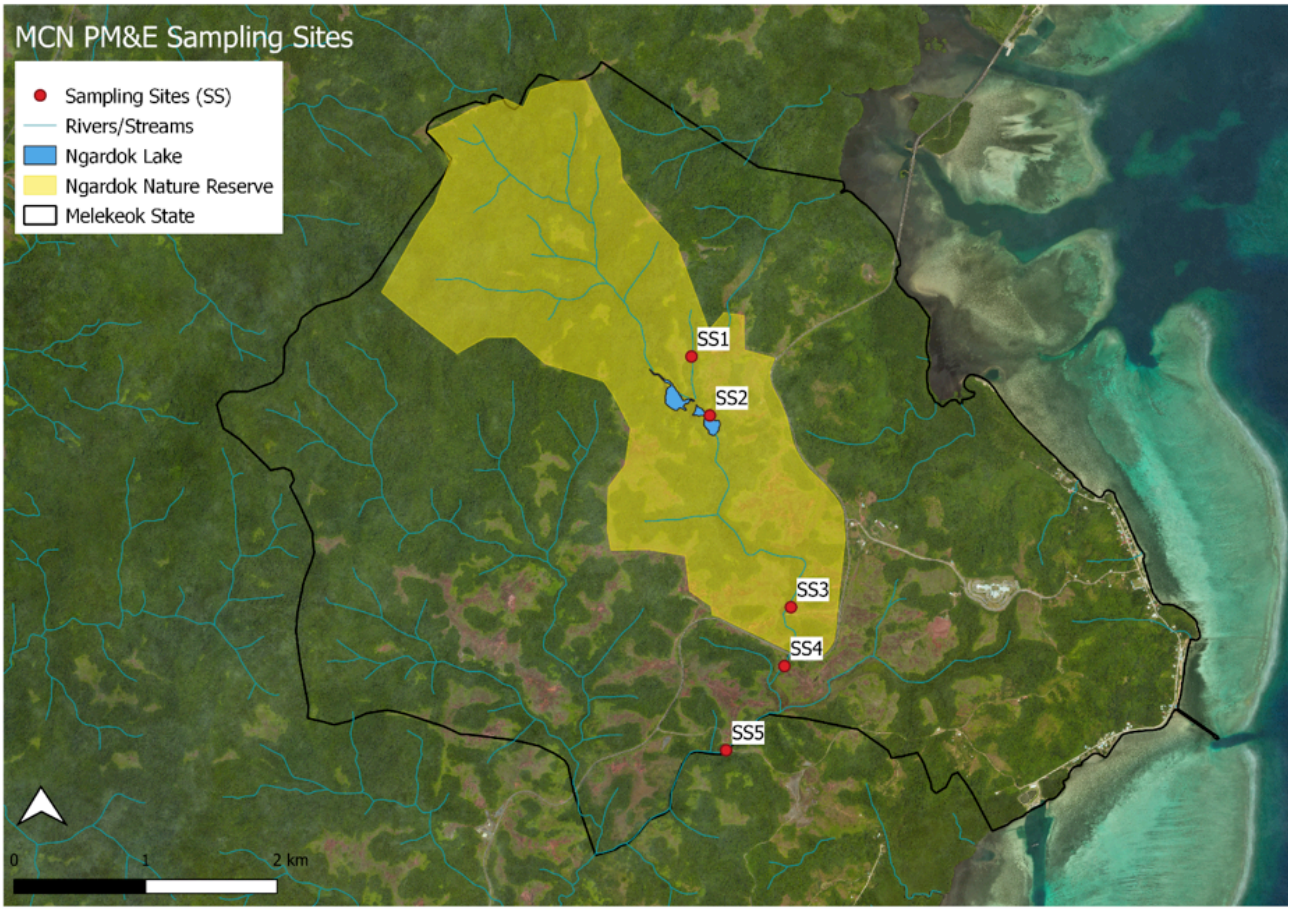


Figure 7. Map of Monitoring Sites

Table 2. Locations and Descriptions of Monitoring Sites

| Site ID | Location | Palauan Name | MCN Activities | Land Use | Other |
|---|---|---|---|---|---|
| SS1 | 7.51643°N<br>134.60338°E | None | Bird monitoring<br><br>Erosion control and reforestation | Ngardok Nature Reserve<br><br>Stream passes through a wooden bridge. | No stream flow during dry season<br><br>Stream depth less than 1m<br>Stream reach ~ 1m<br><br>Soil type: Aimeliik Silt Loam, bedded tuff substratum,<br>12 to 30 percent slopes |
| SS2 | 7.51242°N<br>134.60461°E | Ngardok | Bird monitoring<br><br>Erosion control and reforestation | Ngardok Nature Reserve | Ngardok Lake<br><br>Surface area of lake 0.09 $km^2$<br><br>Floating dock for visitors to lake<br><br>Soil type: Dechel, Silt Clay, 0 to 2 percent slopes |
| SS3 | 7.49888°N<br>134.60988°E | Ngeokib | Fire Monitoring<br><br>Erosion control and reforestation | Ngardok Nature Reserve<br><br>Melekeok Water Dam | Shallow Stream ~10 m<br>Stream reach 5m<br><br>Soil type: Dechel, Silt Clay, 0 to 2 percent slopes |
| SS4 | 7.49522°N<br>134.60983°E | Ngerkoranges | Fire Monitoring | Farming activities<br><br>Recreation Area<br><br>Stream passes through Compact Road | Stream Depth ~ 12m<br>Stream reach ~6m<br><br>Soil type: Dechel, Silt Clay, 0 to 2 percent slopes |
| SS5 | 7.48944°N<br>134.60580°E | Euall | None | Farming activities<br>Recreation Area<br><br>Stream passes through old Melekeok Road | Stream Depth ~ 9m<br>Stream Reach ~7m<br><br>Soil type: Aimeliik Silt Loam, 30 to 50 percent slopes |

## 4.2 Fieldwork

Monitoring occurred twice a month from September 2018 to September 2019. The lake and its corresponding streams are not uniform in depth and width. For the YSI multiprobe, sampling locations were sampled mid-depth except for site 1, which is a shallow stream. For nutrients, samples were obtained by immersing a hand-held open bottle with the mouth of the bottle directed towards the current.

Nutrient samples were obtained and analysed the same day (taken in the morning and analysed by noon) at the NNR Field office. Field blanks and nutrient samples collected were prepared based on YSI 9300 Photometer manual instructions.

Water level measurements were recorded at SS3 as a water level stick was present on the site. Fieldwork data is provided in the appendices. Water levels were recorded in feet and converted to metres for reporting.

Figure 8. Ms. Oberang Antonio conducting fieldwork and sample analyses

## 4.3 Visit to a Certified Water Quality Lab in Guam

Halfway through the monitoring in June 2019, the water quality monitoring team, with funding from the IW R2R project, had the opportunity to attend the 30th Pacific Islands Environment Conference on Guam. Prior to conference sessions, the team visited the Water and Environmental Research Institute of the Western Pacific (WERI), located at the University of Guam. MCN staff had only been exposed to in situ monitoring and analysis, so the visit provided them with a glimpse of the laboratory analysis aspect of monitoring. The team also had the opportunity to meet with WERI director, Dr. John Jenson, and University of Guam Master of Science in Environmental Science Program Chair, Dr. Joseph Rouse.


Figure 9. Water Quality Team visit to WERI

## 4.4 Handover and Post One-Year Fieldwork

On November 14, 2019, a ceremony was held at the Ngardok Nature Reserve, where the IW R2R project handed over water quality equipment and related items to the MCN. The ceremony was attended by the MCN staff, MCN Board representatives, as well as the Protected Areas Network Coordinator. At the ceremony, the MCN coordinator announced that water quality monitoring would continue.

Figure 10. Handover Ceremony with MCN Board and Staff

# 5. RESULTS

As noted in Table 1, EQPB regulations for surface water require that variations should not exceed natural conditions. Except for SS2 (Ngardok Lake), this is the first time in situ water quality monitoring work has been conducted at the sites. It is noted that SS1 is an intermittent stream and was dry for a couple of months, and as a result, SS1 had 16 sampling dates while SS2 to SS5 had 22 sampling dates.

## 5.1 Comparing Selected Parameters

Temperature results ranged from 78°F to 87°F. The stream sites (SS1, SS3, SS4 and SS5) had similar temperature patterns. SS2 (Ngardok Lake) temperature values had greater fluctuations and were higher than that of the other sites, with the highest temperature recorded at 87.2°F.

Dissolved Oxygen (DO) varied across the sites. SS4 and SS5 had higher DO values (ranging from 5 mg/L to 7 mg/L). SS2 and SS3 depict greater fluctuations suggesting extent of flow rate as dictated by dry/ wet seasons.

Values measured for specific conductivity ranged from about 30 µS/cm to 80 µS/cm, noting higher values in the dry season, which suggests a strong seasonal pattern. Specific conductivity values for SS2 (Ngardok Lake) values ranged between 40 µS/ cm to 60 µS/cm.

Turbidity values followed similar patterns except for SS1 with notable spikes in dry season. SS1 is a shallow intermittent stream and was dry multiple times. SS1 spike of 10 FNU was recorded two days after a heavy rain event. Spikes for all the sites were observed during periods of heavy rain. SS2 turbidity values ranged from 1 FNU to 6 FNU, which is consistent with reported values in the 1996 USGS study.

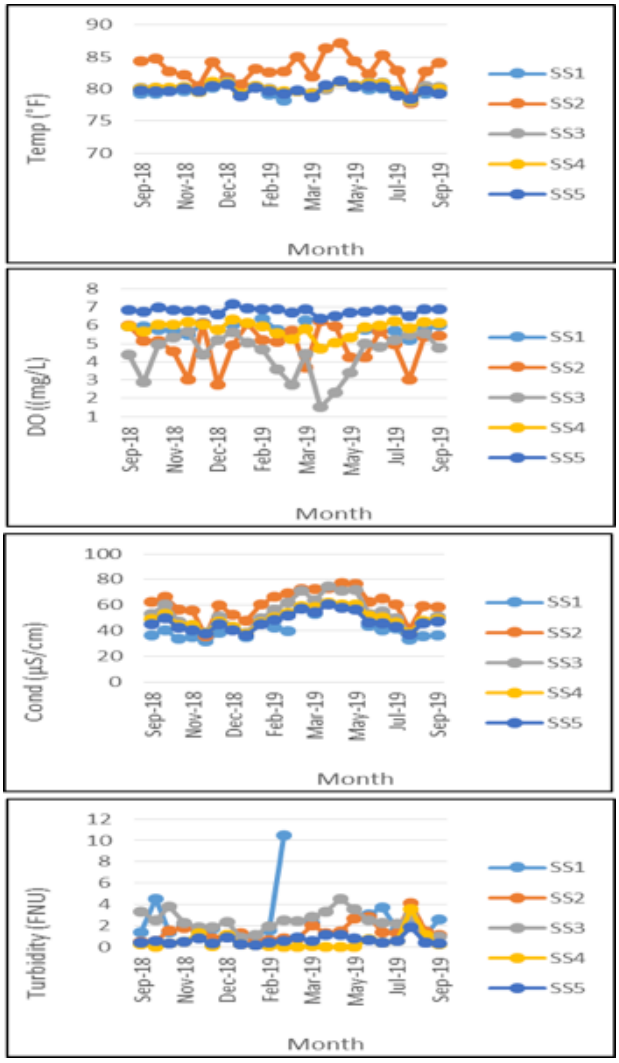


Figure 11. Comparing Selected Parameters

## 5.2 Comparing Nutrients between Sites

Low concentrations of nutrients were found at all the sites. The 1996 USGS study (at SS2) analysed nutrients (nitrate and phosphate) according to the 1996 U.S. Environmental Protection Agency Safe Drinking Water Act and reported results as less than the detection limit.

The bar graphs in Figure 12 provide a comparison of nutrient levels at each of the sites. SS1, SS2 and SS3 are located within the NNR, while SS4 and SS5 are located outside the protected area.

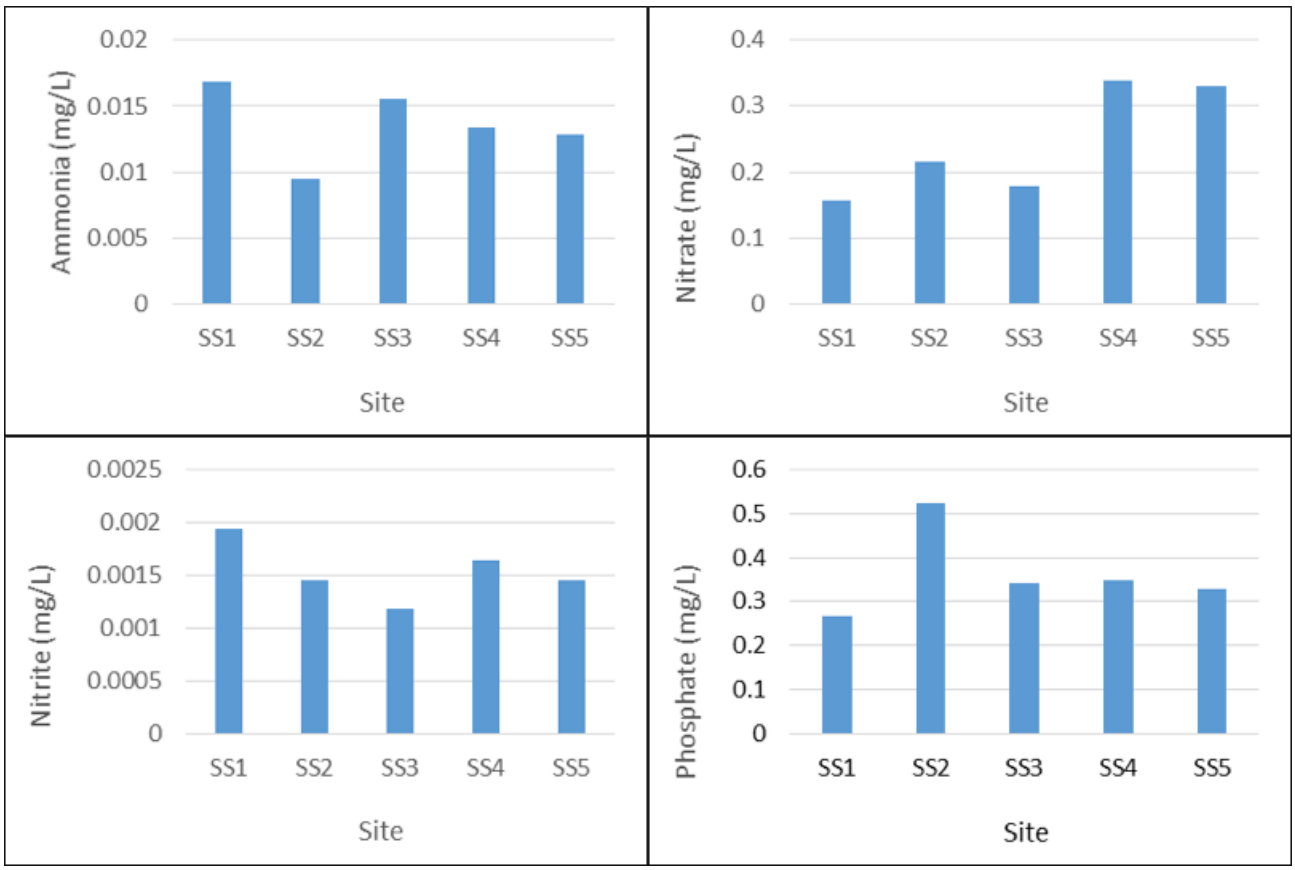


Figure 12. Comparing Nutrients between Sites

## 5.3 Water Level at SS3

For the monitoring period, water level in the Melekeok Dam (SS3) ranged from 2 m to 3 m. In April 2020, Palau's National Emergency Committee issued a water shortage advisory for the Republic of Palau. The advisory noted that, based on data from Palau's Weather Service Office, February, March, and April, are normally dry months for Palau with minimal rainfall. Figure 13 shows that SS3 water levels were low for the same months in the monitoring period.

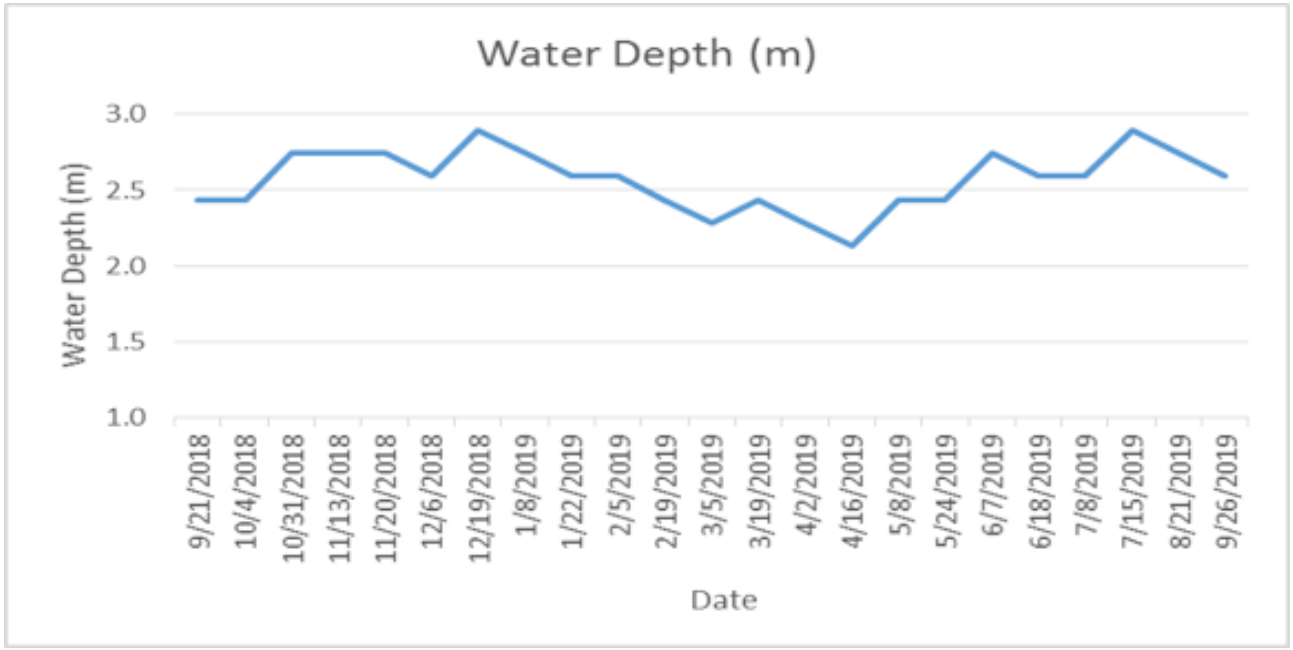


Figure 13. Showing water depths over the duration of sampling Sep-2018 till Sep-2019

# 6. DISCUSSION

## 6.1 Water Quality Monitoring

A participatory and consultative approach was used for planning out the water quality monitoring. By engaging the MCN staff early in the process, involvement and ownership was realised. MCN staff selected sampling locations, participated in the classroom and training sessions, and conducted the year-long monitoring. The water monitoring was a first for MCN; as staff were trained and became more comfortable, MCN agreed that monitoring will continue.

The monitoring delivered on Palau IW R2R was an outcome of increased local community and agency capacity for water quality monitoring. Furthermore, it delivered on the goals of NNR to increase staff capacity and to provide research opportunities for its natural systems.

## 6.2 Preliminary Results

The results of temperature monitoring for SS2 are like those of the 1996 USGS study which reports Ngardok Lake near surface temperature between 82°F and 84°F. Ngardok Lake surface area is about 1 km2 and is much larger than the streams. In addition, the stream sites have canopy cover and are not directly under the sun, which may account for their lower and more consistent temperature values.

SS4 and SS5 are deeper streams with fast-flowing water. SS3 varied in DO concentration from between 1.5 mg/L to 6 mg/L, which is notably low particularly in dry season, suggesting the site is the most stagnant out of all the sites. The DO results for SS2 (Ngardok Lake) are like the 1996 USGS studies that report DO levels around 6 mg/L. The values measured for specific conductivity potentially indicate groundwater seepage to the lake.

SS2 turbidity values ranged from 1 FNU to 6 FNU, which is consistent with reported values in the 1996 USGS study. This implies land-use activities such as land clearing and removal of trees and vegetation, which in turn contribute to sedimentation and increased turbidity of the waterways, including waste seepage, and inundation of lake or catchment banks.

The first assessments point out that the dry months of February, March and April are associated generally with relatively high or increases in temperature, dissolved oxygen, and conductivity. As flow rate decreases with shallow water depths, this translates to high water temperature and DO. Land use activities outside the reserve influence export of sediment and waste pollution down to areas adjacent to point source of discharges and are carried further downstream. This causes potential differences in the readings of water quality parameters, including nutrients, particularly considering circumstances where water movement upstream downstream is restricted during dry months.

Increased turbidity was apparent during heavy rainfall suggesting the need for MCN to continue with the restoration efforts in the barren lands of the Ngerdorech Watershed. The second assessment showed that nutrients assessed in this study were low, suggesting low nutrient input to the lake. The third assessment indicates a correlation in rainfall and SS3 stream levels.

These results are useful and can be treated as preliminary as sampling protocol is improved or considered as baseline against future readings.

## 6.3 Future Prospects

At the handover ceremony, the PAN Coordinator, Mr. Obichang Skebong congratulated MCN and the Palau IW R2R on their partnership and year-long monitoring. He commended MCN for utilising funding outside of PAN sources to increase staff capacity and achieve activities in their management plan. The PAN coordinator also stressed the need for MCN to reach out and cross-train other Palau PAN member States in their acquired skills. Mr. Skebong mentioned that two PAN States have already expressed interest in the water quality monitoring work at MCN and he hoped to facilitate discussions soon.

The water monitoring has also opened exciting new partnerships. Other agencies and research institutions have learned of MCN activities and have shown expressions of interest for partnership. In the first half of 2020, MCN partnered with the Palau Coral Reef Research Foundation to study sedimentation and water quality at Ngardok Lake. Through this partnership, MCN will continue the water quality monitoring work while the Coral Reef Research Foundation will install weather devices, rain gauges and sediments traps around the lake. Another partnership in discussion is with the United States Embassy in Palau to continue the water quality monitoring work and investigate a hydrological watershed model for the NNR.

# 7. CONCLUSIONS

The ridge to reef concept is largely premised on science and evidence-based approaches to integrated resource management and development planning. The one-year water quality sampling and monitoring provides important new datasets, which will be useful in the revision or establishment of baseline indicators associated with water, and more broadly ascertaining security and safe protection of natural resources and increased community resilience against environment threats such as waste pollution, natural disasters, and climate change.

Notably, the results at one site, SS2, are generally similar to those of the 1996 USGS study at the same location, with respect to water temperature, conductivity, DO and turbidity. The results at other sites are also equally important as baselines and for comparison against future water quality readings of sampling and monitoring work. While most of the sampling sites were not covered in the previous study and therefore comparisons cannot be drawn, the results can be still used to inform policy decisions and ensure conservation and sustainable use of natural resources. It is also important to note signs of potential groundwater seepage to the lake, which may be explained by an increased level of land-use activities in areas outside the reserve.

The following are proposed recommendations for the consideration of the responsible agencies. It is recommended:

(i) That improvements to the sampling protocol be continually reviewed, taking into consideration changing circumstances and availability of resources. It is also important to exercise caution not to make too many changes over time as this will affect comparability and usefulness of results.

(ii) That reviews of sampling protocols and design also take into consideration challenges experienced. For instance, there is overgrowth of vegetation and presence of large saltwater crocodiles in the Beriber Stream, making water quality sampling there challenging. It is also likely that such problems may extend to other areas of streams, lakes, and the broader watershed catchment. The Beriber Stream is an outlet of Ngardok Lake located within the Ngerdorech Watershed Catchment.

(iii) That future sampling considers the frequency and location of sites to ensure comparability of measured parameters. For example, SS1 is an intermittent stream and sampling there was carried out sixteen (16) times over the year. SS2–SS5 streams were sampled 22 times over the same year. SS1 and SS2 are potentially better representation of the headwaters for the Ngerdoresch Watershed.

(iv) That future sampling takes into consideration water depths used to collect surface water, which was generally less than a metre. The 1996 USGS study also sampled at different depths and locations around the lake. Sampling was generally satisfactory except for the site SS2, where water depth is shallower and mixing of the water column in the lake restricted. This needs to be considered and endorsed by the MCN Board when sampling at SS2, and to grant permission to install floating devices in the lake for purpose of measuring mixing.

(v) That seasonality is an important feature and future data may be needed to support trends in seasonality. The results of the current study support seasonality with dry months February–April previously documented. It is recommended that a rain gauge is installed at the Ngardok Lake Nature Reserve to monitor and document average rainfall. The Beriber Stream and Ngardok Lake are dependent on rainfall and it is important to measure its contribution.

(vi) That a partnership is established with the Bureau of Agriculture Forestry department to measure canopy cover at each sampling site.

(vii) That the MCN Board considers and approves sampling extended into the future covering both dry and wet seasons. The Board is also requested to consider investing in stream data loggers to monitor sampling sites continuously into the future. A cost-benefit analysis and feasibility study may be needed to inform policy discussion and decisions of the MCN Board.

(viii) It is recommended that the MCN Board invest in back water quality test kits and accessories, recognising that the IW R2R project kits may be donated to the Board following project closure. Article IX para. 2 of the MOU between Palau and SPC requires that ". . . equipment, non-expendable materials or other . . . financed by the project shall be returned to UNDP . . . unless/otherwise agreed upon between Parties and in consultation with SPC."

(ix) That water quality monitoring is continued and remains important to validate trends and inform or complement current rehabilitation and restoration efforts at the NNR. When available, consideration may be given to extending field testing and laboratory analysis of samples for metals, radioactivity and other parameters currently not covered by the test kits.

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# APPENDICES

## Appendix 1: Safety

As with any activity undertaken by the Melekeok Conservation Network utmost priority is held for safety. Safety measures below are taken from the Waterwatch Victoria Methods Manual. It is the responsibility of the MCN PAN Coordinator as well as MCN staff that all safety measures are followed.

### 1. Field Safety

Below are general safety recommendations that should be taken into consideration while sampling is undertaken in the field.

- Utilize a buddy system while out in the field. It is not recommended for one person to undertake sampling.
- Let someone at the Ngardok Nature Field office know when heading out into field. Likewise write in the NNR Board the time when persons left to the field. Let someone know how long plan to be in the field.
- Wear proper clothing and footwear.
- Bring water.
- Utilize common sense when walking to site.
- Do not allow children to sample without adult supervision.
- Do not put yourself or others at risk.

### 2. Chemical Safety

Below are general safety recommendations that should be taken into consideration when working with chemicals.

- Read and familiarize the warnings and first aid procedures of the chemicals.
- Make sure there is running water or water available in the event of an accidental spill.
- Always wear gloves when handling the chemicals.
- Empty waste chemicals onto designated bucket and dispose correctly.
- Provide adult supervision when children are using the chemicals and ensure they are aware of the safety and dangers when using the chemicals.
- When finished using the chemicals ensure hands are washed.

### 3. Field Considerations

Below are general recommendations that should be taken into consideration while sampling is undertaken in the field.

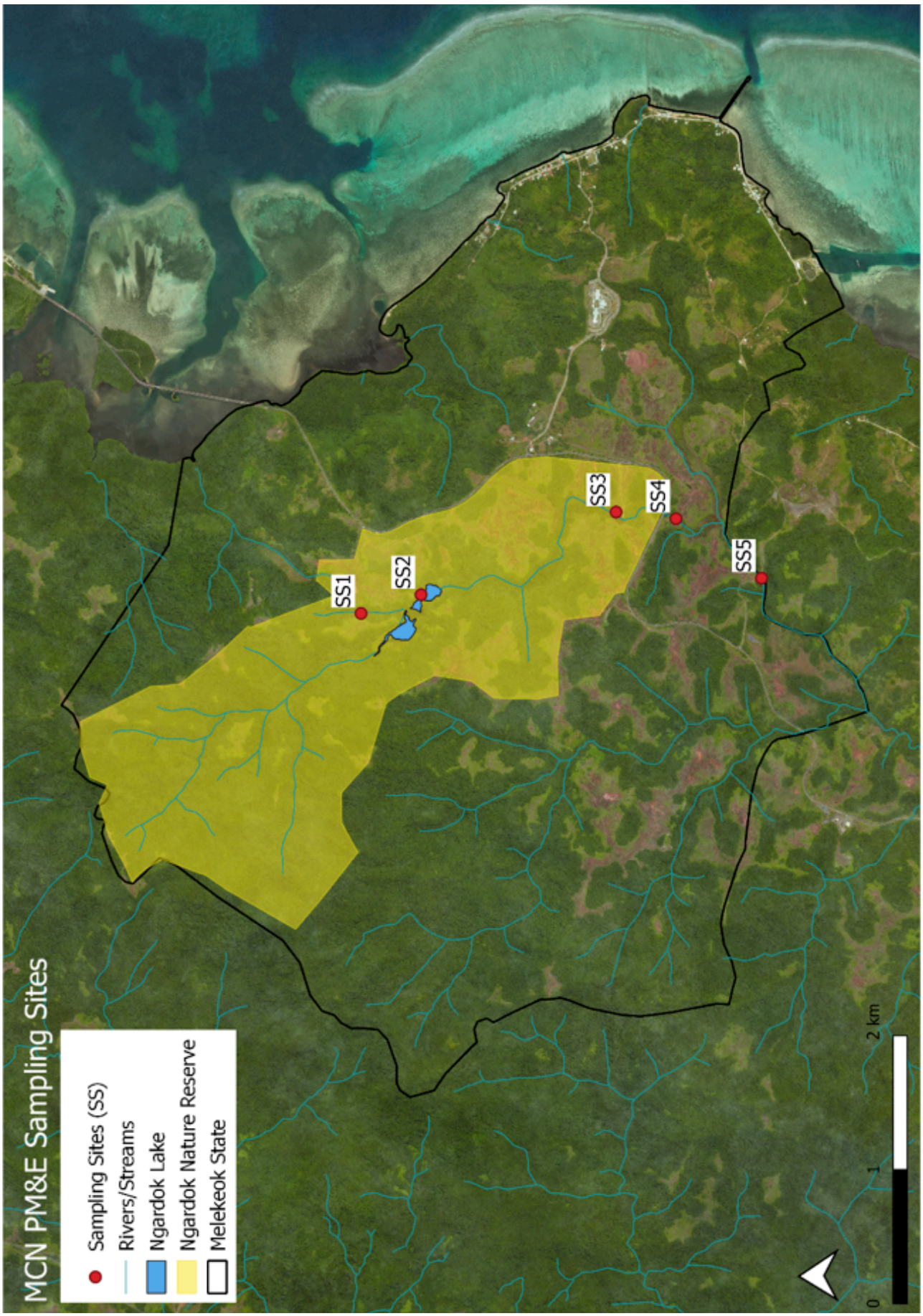
- If a recommendation is made to sample a new location within a private property, seek permission first.
- Keep site as clean as possible by removing excess rubbish.
- If something is tampered or doesn't look normal in the site notify MCN coordinator.

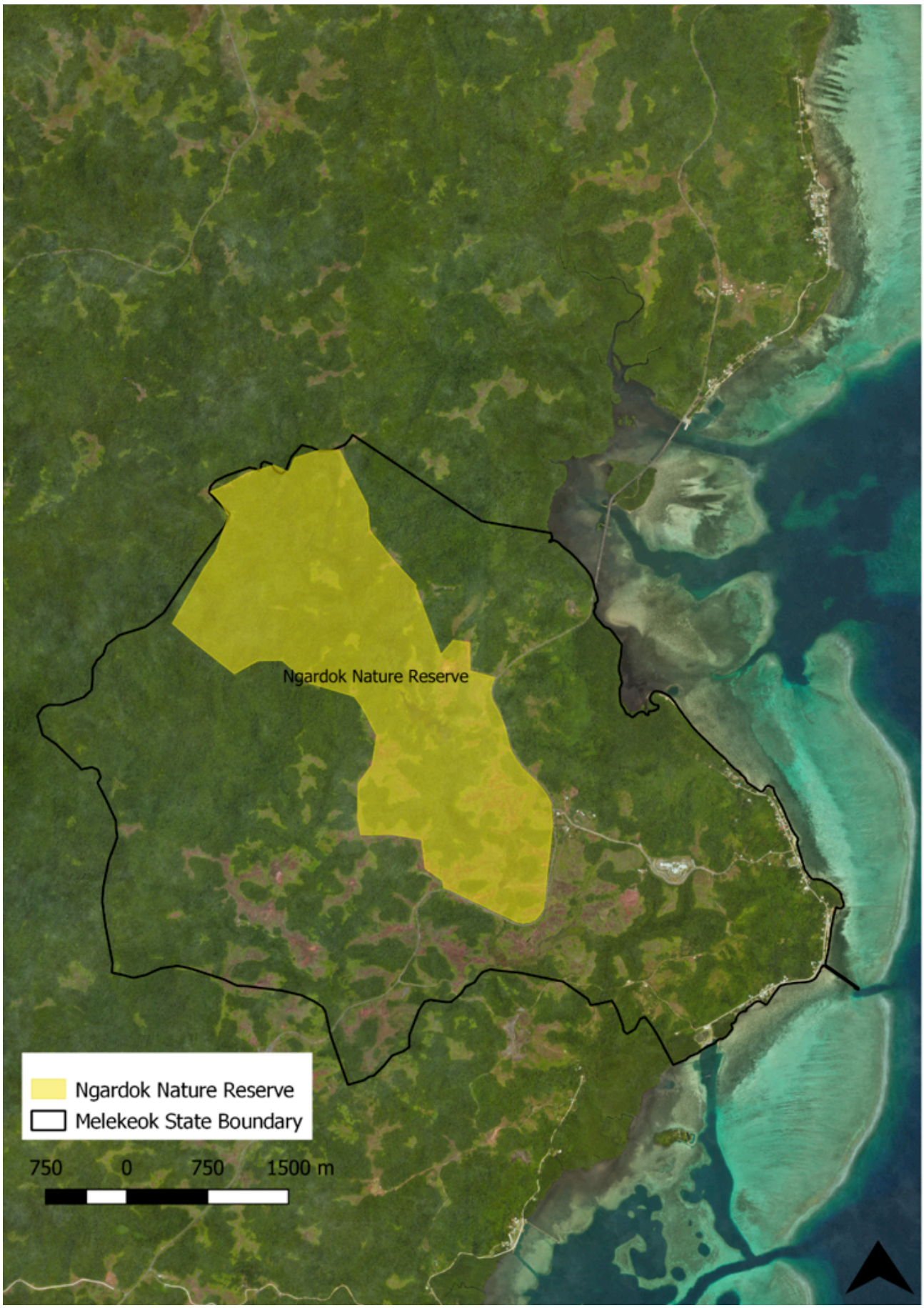
# Appendix 2: Workplan

| | |
|---|---|
| Name | Melekeok Conservation Network (MCN) Water Quality Monitoring |
| Project | Palau R2R IW Project with MCN |
| Date | May-18 |

| Activity | 2018 | | | | | | | | 2019 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May | Jun | July | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov |
| Meet with MCN Coordinator | x | | | | | | | | | | | | | | | | | | |
| Initial Planning Meeting with MCN | | x | | | | | | | | | | | | | | | | | |
| Field Site Selection | | | x | | | | | | | | | | | | | | | | |
| Classroom Session | | | x | | | | | | | x | | | | | | | | x | |
| Monitoring Tools Training | | | | | x | | | | | | | | | | | | | | |
| Data Collection / Field Work | | | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | |
| Preliminary Data Analyses | | | | | | | | | | | | | | | | | | x | |
| Hand Over Monitoring Tools | | | | | | | | | | | | | | | | | | x | |

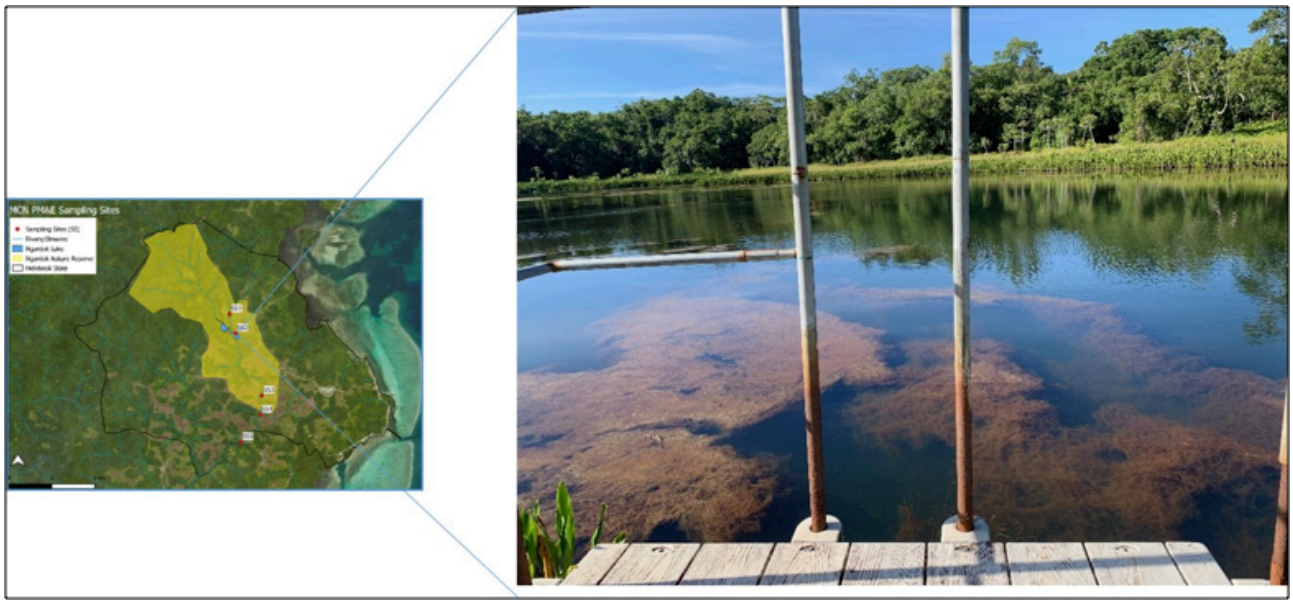
# Appendix 3: Maps and Site Photos




Ngardok Nature Reserve
Ngardok Nature Reserve
Melekeok State Boundary
750 0 750 1500 m

## SS1 – “First Bench”


## SS2 – Ngardok Lake Floating Dock




## SS3 – Ngeokib, Melekeok Water Dam

## SS4 - Ngerkoranges


## SS5 - Euall


## Proposed Site – Beriber, Ngardok Late Outlet

# Appendix 4: Nutrients

| Date | Ammonia (mg/L) | Nitrate (mg/L) | Nitrite (mg/L) | Phosphate (mg/L) |
|---|---|---|---|---|
| **9/21/2018** | | | | |
| SS1 | NF/VLR [1] | 0.034 | 0 | NF/VLR[2] |
| SS2 | NF/VLR [3] | 0.049 | 0.003 | 0.16 NF/VLR[5] |
| SS3 | NF/VLR [4] | 0.052 | 0.001 | 0.12 |
| SS4 | 0.01 | 0.036 | 0 | 0.11 |
| SS5 | 0 | 0.054 | 0.001 | |
| **10/4/2018** | | | | |
| SS1 | 0.03 | 0.077 | 0.002 | 0.22 |
| SS2 | 0.02 | 0.06 | 0.001 | 0.47 |
| SS3 | 0.03 | 0.068 | 0.005 | 0.06 |
| SS4 | 0.03 | 0.098 | 0.002 | 0.19 |
| SS5 | 0.02 | 0.119 | 0.003 | 0.27 |
| **10/31/2018** | | | | |
| SS1 | 0.01 | 0.056 | 0.02 | 0.049 |
| SS2 | 0.01 | 0.144 | 0.001 | 0.16 |
| SS3 | 0.01 | 0.094 | 0 | 0.23 |
| SS4 | 0.01 | 0.125 | 0.001 | 0.23 |
| SS5 | 0 | 0.27 | 0.002 | 0.47 |
| **11/13/2018** | | | | |
| SS1 | 0.01 | 0.076 | 0 | 0.38 |
| SS2 | 0.01 | 0.118 | 0.003 | 0.45 |
| SS3 | 0.07 | 0.061 | 0.001 | 0.25 |
| SS4 | 0.02 | 0.049 | 0.001 | 0.4 |
| SS5 | 0.01 | 0.123 | 0.002 | 0.3 |
| **11/20/2018** | | | | |
| SS1 | 0.001 | 0.078 | 0 | 0.11 |
| SS2 | 0.01 | 0.333 | 0.001 | 0.52 |
| SS3 | 0.02 | 0.119 | 0.001 | 0.46 |
| SS4 | 0.01 | 0.064 | 0.001 | 0.4 |
| SS5 | 0.01 | 0.098 | 0.001 | 0.19 |
| **12/6/2018** | | | | |
| SS1 | 0.01 | 0.099 | 0 | 0.22 |
| SS2 | 0.02 | 0.064 | 0 | 0.49 |
| SS3 | 0.02 | 0.065 | 0.003 | 0.25 |
| SS4 | 0.06 | 0.117 | 0.001 | 0.17 |
| SS5 | 0.03 | 0.051 | 0 | 0.17 |
| **12/19/2018** | | | | |
| SS1 | 0.01 | 0.049 | 0.001 | 0.05 |
| SS2 | 0.01 | 0.093 | 0.005 | 0.09 |
| SS3 | 0.02 | 0.058 | 0.002 | 0.1 |
| SS4 | 0.01 | 0.085 | 0.002 | 0.11 |
| SS5 | 0.02 | 0.195 | 0.001 | 0.15 |
| **1/8/2019** | | | | |
| SS1 | 0.08 | 0.233 | 0.007 | 0.39 |
| SS2 | 0 | 0.094 | 0 | 0.31 |

| Date | Ammonia (mg/l) | Nitrate (mg/l) | Nitrite (mg/l) | Phosphate (mg/l) |
|---|---|---|---|---|
| SS3 | 0.02 | 0.135 | | 0 | 0.2 |
| SS4 | 0.01 | 0.049 | | 0.002 | 0.16 |
| SS5 | 0.01 | 0.082 | | 0.002 | 0.05 |
| **1/22/2019** | | | | | |
| SS1 | 0.01 | 0.168 | | 0 | 0.62 |
| SS2 | NF/VLR[6] | 0.209 | | 0.002 | 0.79 |
| SS3 | 0 | 0.129 | | 0.002 | 0.62 |
| SS4 | 0.01 | 0.745 | | 0 | 0.38 |
| SS5 | 0.01 | 0.503 | | 0.001 | 0.63 |
| **2/5/2019** | | | | | |
| SS1 | 0.01 | 0.286 | | 0.001 | 0.38 |
| SS2 | NF/VLR[7] | 0.402 | | 0.002 | 0.39 |
| SS3 | NF/VLR[8] | 0.503 | | 0 | 0.52 |
| SS4 | NF/VLR [9] | 0.835 | | 0 | 0.48 |
| SS5 | 0 | 0.97 | | 0 | 0.35 |
| **2/19/2019** | | | | | |
| SS1 | 0.03 | 0.085 | | 0 | 0.29 |
| SS2 | 0 | 0.144 | | 0.004 | 0.67 |
| SS3 | 0.01 | 0.057 | | 0.001 | 0.38 |
| SS4 | 0.01 | 0.287 | | 0.001 | 0.37 |
| SS5 | 0.04 | 0.221 | | 0 | 0.21 |
| **3/5/2019** | | | | | |
| SS1 | NF/VLR[10] | NF/VLR[10] | NF/ VLR [10] | 0.001 | NF/VLR[10] |
| SS2 | 0.01 | 0.147 | | 0.002 | 0.94 |
| SS3 | 0.01 | 0.153 | | 0.001 | 0.2 |
| SS4 | 0.01 | 0.266 | | 0.001 | 0.11 |
| SS5 | 0.04 | 0.418 | | | 0.11 |
| **3/19/2019** | | | | | |
| SS1 | 0.01 | 0.15 | | 0.001 | 0.08 |
| SS2 | 0.02 | 0.315 | | 0 | 0.29 |
| SS3 | 0.01 | 0.137 | | 0 | 0.09 |
| SS4 | 0 | 0.241 | | 0.002 | 0.17 |
| SS5 | 0.01 | 0.173 | | 0 | 0.5 |
| **4/2/2019** | | | | | |

| Date | Ammonia (mg/l) | Nitrate (mg/l) | Nitrite (mg/l) | Phosphate (mg/l) |
|---|---|---|---|---|
| SS1 | NF/VLR[11] | NF/VLR [11] | NF/ VLR[11] | NF/VLR[11] |
| SS2 | 0.01 | 0.404 | 0 | 0.52 |
| SS3 | 0.02 | 0.07 | 0.004 | 0.43 |
| SS4 | 0 | 0.366 | 0.001 | 0.71 |
| SS5 | | 0.46 | 0 | 0.22 |
| **4/16/2019** | | | | |
| SS1 | NF/VLR[12] | NF/VLR[12] | NF/VLR [12] | NF/VLR[12] |
| SS2 | 0 | 0.438 | 0 | 1.15 |
| SS3 | 0.01 | 0.138 | 0.001 | 0.51 |
| SS4 | 0 NF/VLR[13] | 0.471 | 0.013 | 0.33 |
| SS5 | | 0.418 | 0 | 0.32 |
| **5/8/2019** | | | | |

| Date | Ammonia (mg/l) | Nitrate (mg/l) | Nitrite (mg/l) | Phosphate (mg/l) |
|---|---|---|---|---|
| SS1 | NF/VLR[14] | NF/VLR[14] | NF/VLR[14] | NF/VLR[14] |
| SS2 | 0.02 | 0.292 | 0 | 1.05 |
| SS3 | 0.01 | 0.153 | 0 | 0.28 |
| SS4 | 0 | 0.61 | 0.001 | 0.032 |
| SS5 | 0.01 | 0.59 | 0.001 | 0.27 |
| **5/24/2019** | | | | |
| SS1 | NF/VLR[15] | NF/VLR[15] | NF/VLR[15] | NF/VLR[15] |
| SS2 | 0.01 | 0.52 | 0.003 | 0.38 |
| SS3 | 0 | 0.59 | 0 | 0.54 |
| SS4 | 0.01 | 0.83 | 0.004 | 0.78 |
| SS5 | 0.01 | 0.495 | 0.013 | 0.64 |
| **6/7/2019** | | | | |
| SS1 | 0.02 | 0.295 | 0.001 | 0.46 |
| SS2 | 0.01 | 0.17 | 0 | 0.92 |
| SS3 | 0.03 | 0.418 | 0.001 | 0.43 |
| SS4 | 0.04 | 0.317 | 0.001 | 0.35 |
| SS5 | 0.03 | 0.421 | 0 | 0.68 |
| **6/18/2019** | | | | |
| SS1 | 0 | 0.335 | 0 | 0.39 |
| SS2 | 0.01 | 0.328 | 0.002 | 0.49 |
| SS3 | 0.01 | 0.215 | 0.001 | 0.51 0.33 |
| SS4 | 0.02 | 0.88 | 0.001 | 0.38 |
| SS5 | 0.01 | 0.9 | 0.001 | |
| **7/8/2019** | | | | |
| SS1 | 0.01 | 0.449 | 0 | 0.26 |
| SS2 | 0.01 | 0.334 | 0.002 | 0.58 |
| SS3 | 0.01 | 0.545 | 0.001 | 0.39 |
| SS4 | 0.01 | 0.77 | 0.001 | 0.77 |
| SS5 | 0 | 0.494 | 0 | 0.29 |
| **8/21/2019** | | | | |
| SS1 | 0.01 | 0.067 | 0 | 0.02 0.33 |
| SS2 | 0 | 0.04 | 0.002 | 0.36 |
| SS3 | 0 | 0.055 | 0 | 0.59 |
| SS4 | 0.01 | 0.098 | 0 | 0.48 |
| SS5 | 0.01 | 0.079 | 0.001 | |
| **9/26/2019** | | | | |
| SS1 | 0.01 | 0.115 | 0 | 0.38 |
| SS2 | 0 | 0.052 | 0 | 0.37 0.34 |
| SS3 | 0 | 0.122 | 0 | 0.48 |
| SS4 | 0 | 0.104 | 0 | 0.42 |
| SS5 | 0 | 0.141 | 0.002 | |

Notes:

- NF = No Stream Flow
- VLR = Value Lower than Range for YSI9300 Meter Reading

NF/VLR[1]: (SS1, 9/21/2018) Ammonia Value Lower than Range

NF/VLR[2]: (SS1, 9/21/2018) Phosphate Value Lower than Range

NF/VLR[3]: (SS2, 9/21/2018) Ammonia Value Lower than Range

NF/VLR[4]: (SS3, 9/21/2018) Ammonia Value Lower than Range

NF/VLR[5]: (SS3, 9/21/2018) Phosphate Value Lower than Range

NF/VLR[6]: (SS2, 1/22/2019) Ammonia Value Lower than Range

NF/VLR[7]: (SS2, 2/05/2019) Ammonia Value Lower than Range

NF/VLR[8]: (SS3, 2/05/2019) Ammonia Value Lower than Range

NF/VLR[9]: (SS4, 2/05/2019) Ammonia Value Lower than Range

NF/VLR[10]: (SS1, 3/05/2019) No Stream Flow, No values for all Parameters SS1

NF/VLR[11]: (SS1, 4/02/2019) No Stream Flow, No values for all Parameters SS1

NF/VLR[12]: (SS1, 4/16/2019) No Stream Flow, No values for all Parameters SS1

NF/VLR[13]: (SS5, 4/16/2019) Ammonia Value Lower than Range

NF/VLR[14]: (SS1, 5/08/2019) No Stream Flow, No values for all Parameters SS1 NF/VLR[15]: (SS1, 5/24/2019) No Stream Flow, No values for all Parameters SS1

# Appendix 5:
# Monitoring from September 2018 to September 2019

| Date | Sum of Temp (°F) | Dissolved Oxygen(mg/L) | Conductivity (µS/cm) | pH | Salinity (psu) | Total Dissolved Solids (mg/L) | Turbidity (FNU) |
|---|---|---|---|---|---|---|---|
| 21-Sep-18 | | | | | | | |
| SS1 | 79.3 | 5.96 | 36.1 | 7.73 | 0.01 | 23 | 1.42 |
| SS2 | 84.4 | 6 | 62.8 | 7.41 | 0.03 | 38 | 0.49 |
| SS3 | 80.2 | 4.41 | 53 | 6.85 | 0.02 | 33 | 3.31 |
| SS4 | 80.1 | 5.94 | 48.9 | 7.28 | 0.02 | 31 | 0.3 |
| SS5 | 79.8 | 6.83 | 45.3 | 7.45 | 0.02 | 29 | 0.46 |
| 4-Oct-18 | | | | | | | |
| SS1 | 79.2 | 5.96 | 40.1 | 7.45 | 0.02 | 25 | 4.5 |
| SS2 | 84.7 | 5.16 | 66.3 | 7.2 | 0.03 | 40 | 0.62 |
| SS3 | 80.2 | 2.87 | 60.6 | 6.99 | 0.03 | 38 | 2.48 |
| SS4 | 80.2 | 5.66 | 52.9 | 7.16 | 0.02 | 33 | 0 |
| SS5 | 79.6 | 6.74 | 49.5 | 7.21 | 0.02 | 31 | 0.56 |
| 31-Oct-18 | | | | | | | |
| SS1 | 79.6 | 5.77 | 33.6 | 7.67 | 0.01 | 21 | 1.35 |
| SS2 | 82.7 | 5.12 | 56.4 | 7.21 | 0.02 | 35 | 1.57 |
| SS3 | 80 | 4.96 | 47.2 | 7.11 | 0.02 | 30 | 3.83 |
| SS4 | 80.2 | 6.05 | 44.7 | 7.18 | 0.02 | 28 | 0.33 |
| SS5 | 79.7 | 6.96 | 42.3 | 7.27 | 0.02 | 27 | 0.34 |
| 13-Nov-18 | | | | | | | |
| SS1 | 79.7 | 5.71 | 34.8 | 7.37 | 0.01 | 22 | 1.94 |
| SS2 | 82.2 | 4.59 | 55.8 | 7.23 | 0.02 | 34 | 1.8 |
| SS3 | 80.3 | 5.34 | 44.5 | 7.31 | 0.02 | 28 | 2.3 |
| SS4 | 80.3 | 6.02 | 44.5 | 7.32 | 0.02 | 28 | 0.47 |
| SS5 | 80 | 6.84 | 40.4 | 7.34 | 0.02 | 25 | 0.54 |
| 20-Nov-18 | | | | | | | |
| SS1 | 79.5 | 5.45 | 31.8 | 7.23 | 0.01 | 20 | 1.42 |
| SS2 | 80.5 | 3.05 | 35.7 | 6.68 | 0.01 | 22 | 1.79 |
| SS3 | 79.5 | 5.66 | 38.4 | 7.46 | 0.02 | 24 | 1.91 |
| SS4 | 79.5 | 6.16 | 38.2 | 7.42 | 0.02 | 24 | 1.31 |
| SS5 | 79.7 | 6.79 | 37.6 | 7.34 | 0.02 | 24 | 0.86 |
| 6-Dec-18 | | | | | | | |
| SS1 | 80.2 | 6.12 | 38.7 | 8.1 | 0.02 | 24 | 1.72 |
| SS2 | 84.2 | 6.08 | 60.1 | 7.54 | 0.02 | 36 | 0.79 |
| SS3 | 81 | 4.38 | 51.3 | 7.29 | 0.02 | 32 | 1.86 |
| SS4 | 81.1 | 6.01 | 47.3 | 7.52 | 0.02 | 29 | 0.12 |
| SS5 | 80.4 | 6.84 | 45 | 7.49 | 0.02 | 28 | 0.32 |
| 19-Dec-18 | | | | | | | |
| SS1 | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow |
| SS2 | 81.8 | 2.77 | 52.3 | 7.2 | 0.02 | 32 | 1.17 |
| SS3 | 81.1 | 5.2 | 42.8 | 7.39 | 0.02 | 27 | 2.34 |
| SS4 | 81 | 5.75 | 42.9 | 7.38 | 0.02 | 27 | 1.11 |
| SS5 | 80.7 | 6.6 | 40.3 | 7.37 | 0.02 | 25 | 0.87 |
| 8-Jan-19 | | | | | | | |
| SS1 | 79.3 | 6.02 | 35.1 | 7.81 | 0.01 | 22 | 0.96 |
| SS2 | 80.7 | 4.9 | 47.6 | 7.41 | 0.02 | 30 | 1.28 |
| SS3 | 79.1 | 5.62 | 38.7 | 7.66 | 0.02 | 25 | 0.87 |
| SS4 | 79.2 | 6.31 | 37.9 | 7.7 | 0.02 | 24 | 0.27 |
| SS5 | 78.9 | 7.18 | 36.5 | 7.57 | 0.02 | 23 | 0.26 |
| 22-Jan-19 | | | | | | | |
| SS1 | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow |
| SS2 | 83.2 | 6.07 | 60.8 | 7.9 | 0.03 | 37 | 0.51 |
| SS3 | 80.4 | 5.04 | 50.1 | 7.84 | 0.02 | 31 | 1.11 |
| SS4 | 80.4 | 6.13 | 46.3 | 7.77 | 0.02 | 29 | 0.15 |
| SS5 | 80.2 | 6.92 | 44.9 | 7.79 | 0.02 | 28 | 0.22 |

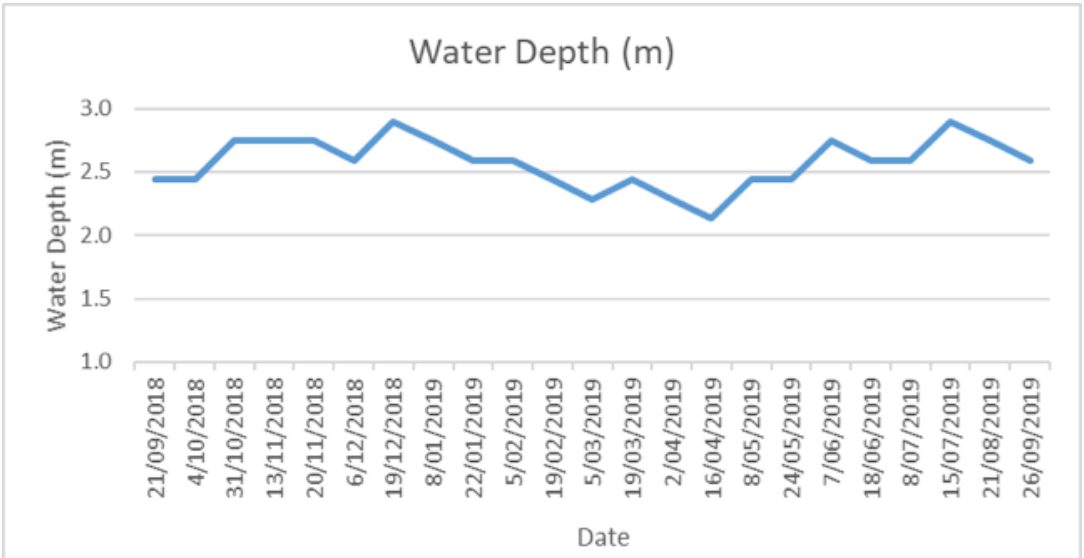
| Date | Sum of Temp (°F) | Dissolved Oxygen(mg/L) | Conductivity (µS/cm) | pH | Salinity (psu) | Total Dissolved Solids (mg/L) | Turbidity (FNU) |
|---|---|---|---|---|---|---|---|
| 5-Feb-19 | | | | | | | |
| SS1 | 79.1 | 6.34 | 42.6 | 8.76 | 0.02 | 27 | 1.58 |
| SS2 | 82.6 | 5.19 | 66.3 | 8.08 | 0.03 | 41 | 0.67 |
| SS3 | 80 | 4.66 | 56.3 | 7.93 | 0.02 | 35 | 1.98 |
| SS4 | 79.9 | 5.92 | 50.5 | 7.82 | 0.02 | 32 | 0.1 |
| SS5 | 79.6 | 6.89 | 48.5 | 7.79 | 0.02 | 31 | 0.41 |
| 19-Feb-19 | | | | | | | |
| SS1 | 78.2 | 5.77 | 40 | 8.02 | 0.02 | 26 | 10.51 |
| SS2 | 82.7 | 5.08 | 69.2 | 7.68 | 0.03 | 42 | 0.81 |
| SS3 | 79.4 | 3.57 | 61.7 | 7.38 | 0.03 | 39 | 2.48 |
| SS4 | 79.6 | 5.54 | 53.8 | 7.57 | 0.02 | 34 | 0.02 |
| SS5 | 79.3 | 6.86 | 51.5 | 7.74 | 0.02 | 33 | 0.58 |
| 5-Mar-19 | | | | | | | |
| SS1 | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow |
| SS2 | 85 | 5.71 | 72.3 | 8.11 | 0.03 | 43 | 0.81 |
| SS3 | 79.6 | 2.76 | 71.1 | 7.63 | 0.03 | 45 | 2.43 |
| SS4 | 79.6 | 5.22 | 59.2 | 7.54 | 0.03 | 37 | 0 |
| SS5 | 79.8 | 6.69 | 57.2 | 7.56 | 0.02 | 36 | 0.88 |
| 19-Mar-19 | | | | | | | |
| SS1 | 78.9 | 6.26 | 53.4 | 8.34 | 0.02 | 34 | 2.28 |
| SS2 | 82 | 3.67 | 72.8 | 7.46 | 0.03 | 45 | 2.06 |
| SS3 | 79.4 | 4.43 | 63.8 | 7.52 | 0.03 | 40 | 2.83 |
| SS4 | 79.3 | 5.79 | 58.5 | 7.58 | 0.03 | 37 | 0.07 |
| SS5 | 78.7 | 6.86 | 54.8 | 7.64 | 0.02 | 35 | 0.58 |
| 2-Apr-19 | | | | | | | |
| SS1 | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow |
| SS2 | 86.3 | 6.2 | 73.4 | 8.02 | 0.03 | 43 | 1.28 |
| SS3 | 79.9 | 1.55 | 74.7 | 7.2 | 0.03 | 47 | 3.31 |
| SS4 | 80.3 | 4.74 | 62 | 7.27 | 0.03 | 39 | 0 |
| SS5 | 80.6 | 6.36 | 60.4 | 7.44 | 0.03 | 38 | 1.16 |
| 16-Apr-19 | | | | | | | |
| SS1 | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow |
| SS2 | 87.2 | 5.95 | 77 | 7.9 | 0.03 | 45 | 1.45 |
| SS3 | 81.1 | 2.31 | 71.3 | 7.44 | 0.03 | 44 | 4.49 |
| SS4 | 81.2 | 5.05 | 60.8 | 7.45 | 0.03 | 38 | 0.02 |
| SS5 | 81.3 | 6.48 | 58.1 | 7.49 | 0.02 | 36 | 1.17 |

# Monitoring from September 2018 to September 2019

| Date | Sum of Temp (°F) | Dissolved Oxygen- (mg/L) | Conductivity (µS/cm) | Salinity (psu) | pH | Total Dissolved Solids (mg/L) | Turbidity (FNU) |
|---|---|---|---|---|---|---|---|
| 8-May-19 | | | | | | | |
| SS1 | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow | not enough stream flow |
| SS2 | 84.4 | 4.27 | 76.6 | 8.11 | 0.03 | 46 | 2.66 |
| SS3 | 80.6 | 3.41 | 72 | 7.85 | 0.03 | 45 | 3.55 |
| SS4 | 80.6 | 5.34 | 60.5 | 7.72 | 0.03 | 38 | 0 |
| SS5 | 80.3 | 6.67 | 56.3 | 8.03 | 0.02 | 35 | 0.83 |
| 7-Jun-19 | | | | | | | |
| SS1 | 79.9 | 5.75 | 43.6 | 8.22 | 0.02 | 27 | 3.09 |
| SS2 | 82.4 | 4.26 | 62.2 | 7.75 | 0.03 | 38 | 2.84 |
| SS3 | 81 | 5.01 | 53 | 7.93 | 0.02 | 33 | 2.5 |
| SS4 | 80.9 | 5.89 | 51.8 | 7.87 | 0.02 | 32 | 0.73 |
| SS5 | 80.4 | 6.74 | 46.7 | 7.81 | 0.02 | 29 | 0.66 |
| 18-Jun-19 | | | | | | | |
| SS1 | 80 | 5.67 | 40.3 | 7.78 | 0.02 | 25 | 3.76 |
| SS2 | 85.3 | 5.68 | 65.5 | 7.75 | 0.03 | 39 | 1.35 |
| SS3 | 81 | 4.79 | 54.9 | 7.72 | 0.02 | 34 | 2.28 |
| SS4 | 80.8 | 6 | 50.4 | 7.81 | 0.02 | 31 | 0.41 |
| SS5 | 80.3 | 6.83 | 45.8 | 7.81 | 0.02 | 29 | 0.44 |
| 8-Jul-19 | | | | | | | |
| SS1 | 79.3 | 5.69 | 41.9 | 8.47 | 0.02 | 27 | 1.63 |
| SS2 | 82.9 | 4.93 | 60.8 | 7.87 | 0.03 | 37 | 1.28 |
| SS3 | 79.8 | 5.21 | 49.9 | 7.93 | 0.02 | 31 | 2.17 |
| SS4 | 79.7 | 6.23 | 46.6 | 7.92 | 0.02 | 29 | 0.57 |
| SS5 | 79 | 6.85 | 42.9 | 7.83 | 0.02 | 27 | 0.59 |
| 15-Jul-19 | | | | | | | |
| SS1 | 78.8 | 5.19 | 33 | 7.66 | 0.01 | 21 | 2.85 |
| SS2 | 77.8 | 3.04 | 40.9 | 7.42 | 0.02 | 26 | 4.14 |
| SS3 | 78.1 | 5.48 | 38.2 | 7.67 | 0.02 | 25 | 2.94 |
| SS4 | 78.2 | 5.86 | 38.3 | 7.63 | 0.02 | 25 | 3.56 |
| SS5 | 78.5 | 6.5 | 37 | 7.65 | 0.02 | 24 | 1.87 |
| 21-Aug-19 | | | | | | | |
| SS1 | 79.3 | 5.77 | 35.8 | 8.55 | 0.01 | 23 | 1.13 |
| SS2 | 82.8 | 5.38 | 59.2 | 8.39 | 0.02 | 36 | 1.49 |
| SS3 | 80.4 | 5.54 | 46.8 | 8.59 | 0.02 | 29 | 0.97 |
| SS4 | 79.9 | 6.19 | 47.8 | 8.27 | 0.02 | 30 | 1.14 |
| SS5 | 79.8 | 6.88 | 45.8 | 8.26 | 0.02 | 29 | 0.4 |
| 26-Sep-19 | | | | | | | |
| SS1 | 79.5 | 5.98 | 36.1 | 9.36 | 0.01 | 23 | 2.63 |
| SS2 | 84.1 | 5.41 | 58.5 | 8.34 | 0.02 | 35 | 1.11 |
| SS3 | 80.3 | 4.76 | 51.4 | 8.84 | 0.02 | 32 | 1.02 |
| SS4 | 80 | 6.12 | 49.2 | 8.75 | 0.02 | 31 | 0.23 |
| SS5 | 79.3 | 6.87 | 47.4 | 8.95 | 0.02 | 30 | 0.33 |

# Appendix 6: Water Depth at Ngeokib (Dam)

| Date | Water Depth (ft) | Water Depth (m) |
|---|---|---|
| 21/09/2018 | 8 | 2.4 |
| 4/10/2018 | 8 | 2.4 |
| 31/10/2018 | 9 | 2.7 |
| 13/11/2018 | 9 | 2.7 |
| 20/11/2018 | 9 | 2.7 |
| 6/12/2018 | 8.5 | 2.6 |
| 19/12/2018 | 9.5 | 2.9 |
| 8/01/2019 | 9 | 2.7 |
| 22/01/2019 | 8.5 | 2.6 |
| 5/02/2019 | 8.5 | 2.6 |
| 19/02/2019 | 8 | 2.4 |
| 5/03/2019 | 7.5 | 2.3 |
| 19/03/2019 | 8 | 2.4 |
| 2/04/2019 | 7.5 | 2.3 |
| 16/04/2019 | 7 | 2.1 |
| 8/05/2019 | 8 | 2.4 |
| 24/05/2019 | 8 | 2.4 |
| 7/06/2019 | 9 | 2.7 |
| 18/06/2019 | 8.5 | 2.6 |
| 8/07/2019 | 8.5 | 2.6 |
| 15/07/2019 | 9.5 | 2.9 |
| 21/08/2019 | 9 | 2.7 |
| 26/09/2019 | 8.5 | 2.6 |



# Appendix 7: Water Shortage Advisory

**NATIONAL EMERGENCY COMMITTEE**
*P.O. Box 100*
*Koror, Republic of Palau 96940*
*Tel.# (680) 587-6366/6367, Fax# (680) 587-6368*
*E-mail: palaunemo@gmail.com / nemo@palaugov.org*

*Planning, Mitigation, Preparedness, Response and Recovery, The essential ingredients for a successful Disaster Management.*

**FOR IMMEDIATE RELEASE**

**April 7, 2020**

**PUBLIC ADVISORY**

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**WATER SHORTAGE ADVISORY**

The National Emergency Committee (NEC) is placing the Republic of Palau under "Water Shortage WATCH" beginning April 8, 2020 and informs the general public that water reservoir levels at Ngerimel and Ngerikiil, Airai have fallen drastically in recent days due to lack of rainfall and high consumption of water. The NEC advises the general public that should water levels continue to fall drastically as it did in recent days, the Republic will be put on Water Shortage WARNING and a water rationing schedule will be implemented by the Palau Public Utilities Corporation.

Water Conservation is instrumental in addressing water shortage. The NEC is encouraging the general public including the public and private sector to practice water conservation measures by minimizing water use and limit water use to ESSENTIALS only, as advised by the Palau Public Utilities Corporation.

The general public is also advised that car washing, water blasting, and non-essential use of water is PROHIBITED at this time until further notice as advised by the Palau Public Utilities Corporation. The public is advised to conserve water whenever possible.

Historical data from the Palau National Weather Service Office indicate that the months of February, March and April are normal dry months for the Republic of Palau with minimal rainfall. The amount of rainfall forecast for Palau for the months of April to May 2020 may not be sufficient to maintain adequate water levels in Palau's two main water reservoirs (Ngerimel and Ngerikiil), including main water sources in all other States.

The Palau Public Utilities Corporation (PPUC) will continue to monitor water levels and inform the NEC and the general public accordingly.