Pacific Community
Communauté du Pacifique

SYNTHESIS REPORT

Review of Nauru water and sanitation master plan

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

GEM
Geoscience, Energy and Maritime Division

SYNTHESIS REPORT

REVIEW OF NAURU WATER AND SANITATION MASTER PLAN

March 2021

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Geoscience, Energy, Maritime Division – Pacific Community

Pacific Community
Communauté du Pacifique

Suva, Fiji

Original text: English

Contents

1. INTRODUCTION

A review of the Nauru Water and Sanitation Master Plan (NWSMP) was undertaken by the Pacific Community's Geoscience, Energy and Maritime (SPC-GEM) Division. The review focussed on the following areas:

- A technical assessment of the proposed water and sanitation infrastructural systems
- A review of the capacity for Nauru institutions, and government agencies to implement, maintain, and operate the proposed interventions regarding the existing environmental and social context of Nauru,
- a review of the existing policy and governance arrangement and their adequacy to support the NSWMP.
- Considerations for alternate improvements related to the proposed water supply and sanitation infrastructure systems, and in view of Nauru's current legislation, institutional capacity and socio-economic context.

The review process did not include the verification of the budgeted costs but looked at the suitability of the NWSMP's approach and proposed infrastructures given the environmental and socio-economic context of Nauru.

Background:

The NWSMP was developed by NRW Specialists Pty Ltd (Australia) in association with NRW Macallan (Fiji) Ltd in 2017 and covers a planning period from 2015 to 2035. The master plan was endorsed by the Government of the Republic of Nauru (RoN) in 2017 and its design and delivery were in response to SPC support to the Nauru Government through its European Union-supported Global Climate Change Alliance: Pacific Small Island States project, together with the Secretariat of the Pacific Regional Environment Programme (SPREP) through the United Nations Development Programme – Global Environment Facility funded Pacific Adaptation to Climate Change project.

The NWSMP can be viewed as an advancement towards an improved and sustainable delivery and management in water and sanitation in Nauru. This is very much aligned with a number of global, regional, and RoN aspirations and declarations such as the National Sustainable Development Strategy (2005-2015) National Water, Sanitation and Hygiene Policy (2012) United Nations' 2030 Sustainable Development Goal 6. This review however is an assessment of whether the NWSP still meets the RoN objectives and can still be implemented.

The objective of peer review:

The objective of the peer review of the 2017 NWSMP was to:

- assess the suitability of NWSMP's proposed water and sanitation infrastructural system, inclusive of RoN's governance and institutional capacity to implement the NWMSP and its acceptability within the socio-economic context of Nauru.
- to support the Government of Nauru, with a due diligence review of the NWSMP investment proposal to assist the Government, international agencies, donor partners and other multi-lateral banks with discussions for the development of support.

2. METHODOLOGY

The approach taken for the peer review included the engagement of three external water resources specialists that collaborated with the Water and Sanitation unit within the Geoscience, Energy, and Maritime Division of SPC.

SPC contracted experienced external consultants with demonstrated understanding familiar with Nauru's social, physical, and institutional setting, as well as other Pacific settings to provide valuable and specific insight on the proposed infrastructural systems, existing governance mechanisms and socio-economic capacity of the government and communities to implement, operate, manage, and maintain the recommendations within the NWSMP.

Each of the consultants was tasked to review the NWSMP with a specific focus on their area of expertise

- Tony Falkland: undertake a technical assessment of the proposed water and sanitation infrastructural systems
- Dr Louis Bouchet: undertake a review of the capacity for Nauru institutions, and government agencies to implement, maintain, and operate the proposed interventions regarding the existing environmental and social context of Nauru,
- Professor Ian White: undertake a review on the existing policy and governance arrangement and their adequacy to support the NSWMP.
- All consultants were requested to provide comment on considerations for alternate improvements related to the proposed water supply and sanitation infrastructure systems, and in view of Nauru's current legislation, institutional capacity and socio-economic context.

SPC incorporated the consultants' recommendations into this synthesis report to provide the government of Nauru with an overall assessment of the NWSMP proposal with recommendations and where appropriate alternate options for proposed water and sanitation infrastructure systems improvement in Nauru, to assist Nauru Government and donors alike with development of improvements to Nauru's water and sanitation needs.

The review focused on the Nauru Water and Sanitation Status Report (NRW, 2015) and the NWSMP (RoN, 2017) with other relevant background information obtained from the following, (but not limited to) documents, plans and legislation:

- *Groundwater as a social-ecological system: A framework for managing groundwater in the Pacific Small Island Developing States (2019).*
- National Sustainable Development Strategy 2019-2030: Revised 2019 (2019)
- *Nauru Priority Water Sector Development and Funding Needs Report (2017).*
- *Rapid Review of Water Knowledge for Pacific Small Islands Developing States (World Bank June 2018).*
- *ADB Strategic Country Analysis (2014).*
- *National Water, Sanitation and Hygiene Implementation Plan, (NWSHIP, 2012).*
- *Nauru Infrastructure Strategy and Investment Plan (NISIP, 2011).*
- *Nauru Water, Sanitation and Climate Outlook (2011).*
- *National Integrated Water Resource Management Diagnostic Report Nauru (2007).*
- *National Sustainable Development Strategy (2005-2015).*
- *National Land Act (1976).*

Where required, additional information or verification of information was remotely sourced from relevant person and organisations within Nauru.

3. TECHNICAL REVIEW OF WATER SUPPLY & SANITATION

A comprehensive technical review of the NWSMP undertaken by the consultant has delivered a significant number of detailed recommendations, which can be found as Annex A. The following refers to those key findings which are most relevant for government and donor considerations and have been to assist with readability.

General

- Planning projections are based on 2011 census data and should be updated for 2019 census data, especially for water demand projections.
- The planning time frame of the NWSMP should extend from 2035 to 2040 or 2050.
- The NWSMP should include a section on the consideration of fees for water and sewerage services.

Water sources

- The NWSP correctly states, that "Rainwater is considered to be the lowest cost, high quality water source that is available on the island". During droughts, desalinated water becomes the primary source of potable water.
- Groundwater is a valuable source of non-potable water and can reduce the use of rainwater and desalinated water. Comments in the NWSMP that groundwater will "diminish or run out" are misleading. Groundwater is recommended for secondary purposes e.g. toilet flushing to offset the significant cost for desalinated water and conserve rainwater supplies.
- While recognising that all three main sources of water are a valuable part of the total water resources, the NWSMP focuses primarily on desalinated water, which has significant cost implications for Nauru communities and their government.

Water Supply Systems

Conjunctive use of rainwater harvesting, groundwater, and desalinated water should be more strongly incorporated into the NWSMP, referencing both the existing importance and reliance on these water sources and the capacity of rainwater harvesting and groundwater to offset desalination costs into the future. A demand of 110L/p/d used in the NWSMP is considered reasonable for residential consumption.

Desalinated water

- A piped water distribution system for desalinated water, including a ring main around the island, is supported. Distribution points accessible by both individual users, and tankers, would greatly improve the access of desalinated water to consumers.
- Land ownership issues in Nauru are likely to be challenging for piped distribution networks, requiring significant consultations, and negotiations. An adequate fleet of tankers, maintenance facilities and staff should be incorporated into the NWSMP to address this if land issues cannot be resolved.
- The allowance of Non-Revenue Water NRW in the NWSMP, to estimate losses, based on similar water supply operations in the pacific should increase from 20% to 30% of demand, based on similar sized distribution systems in the Pacific.

Rainwater Harvesting at households and other buildings

- Household rainwater harvesting is well known in the Pacific Islands, being essentially free once the system is installed, providing water for potable and domestic needs at the required location without cost. There is a general preference for rainwater over other water sources, including desalinated water, for most water needs.
- Rainwater harvesting importance is recognised in the Nauru Water Sector Development and Funding Needs Report (NRW, 2017) as being essential that "each and every household (and business) has working rainwater tank that is connected to the guttering and provides a meaningful amount of storage so that it can become the primary water source at that location".
- The water storage capacity of 20.4ML at households and other buildings compared to current government storage of 6.3ML indicates the importance of this water supply to Nauru.

- The NWSMP identifies the need for rainwater tanks at all households, with repairs or replacements of roofing, guttering and downpipes required to improve rainwater harvesting potential. In many cases, improvements to guttering alone would significantly improve rainwater harvesting collection
- Concerns over the quality of harvested rainwater in relation to asbestos roof and phosphate dust, needs to be addressed. World Health organisation guidelines state "no consistent evidence that ingested asbestos is hazardous to health, and there is no need to establish a health-based guideline for asbestos in drinking water". Rainwater quality samples tested in 2010 showed that the concentrations of cadmium and lead were below detection indicating no health risk. While dust is recognised as a taste issue and needs to be considered, the application of first flush devices have potential to assist.
- Savings of up to $2000 annually for households is identified from rainwater harvesting, rather than reliance on desalinated water, 2018-2019 NUC costs.
- Inhalation of asbestos as dust remains an issue and a separate project to systematically remove and properly dispose of asbestos roofs and gutters should be implemented at households.

Groundwater development potential

- Groundwater is currently used in Nauru to provide water for domestic non-potable needs, including toilet flushing and washing.
- There is potential for additional groundwater pumping systems to be installed, for example the more densely populated Location area.
- Additional groundwater reserves are identified in Ewa and Anetan with potential for further development of a useful freshwater supply with an estimated lens average thickness and storage potential of 7 m and storage potential of 45,000 m^3, respectively. (Bouchet et al 2019)
- The NWSMP acknowledges that groundwater is a valuable source of non-potable water and can reduce both the use of rainwater and desalinated water, however the NWSMP focuses on desalinated water and does not include the use or application of groundwater.

Water resources monitoring and management

- Very little efforts in water resources monitoring and assessment is presented in the NWSMP.
- The heavy reliance on rainwater as a primary water source and the vulnerability of Nauru to droughts triggers prompt the need to strengthen the monitoring and management of water resources.

Sanitation and sewerage supply

- The NWSMP correctly notes that there are no national standards of service for sanitation or sewerage systems.
- The proposed installation of a piped sewerage collection system is supported as it would greatly improve the current groundwater contamination problem provided that land ownership issues can be resolved if they arise.
- If land ownership issues prevent the construction of all or part of the proposed piped sewerage collection system, it will be necessary to make changes to the NWSMP with the focus on improved septic tanks and improved on-site effluent disposal systems. The present methods of desludging would need to continue with the sludge taken to a proposed sewage treatment plant.
- The adoption in the NWSMP of the "Septic Tanks and Common Effluent Disposal" option in the NWSMP is considered reasonable but has the obvious disadvantage that desludging of septic tanks will need to continue.
- Further review of the "Conventional Gravity Sewerage System" option is recommended before rejecting this option.
- If the Septic Tanks and Common Effluent Disposal option is adopted:
    - Consider bypassing the "greywater" from bathrooms and laundries

    - All “blackwater” from toilets to pass through septic tanks. This would relieve the “hydraulic load” on septic tanks.
    - The use of polymer double chamber type septic tanks is supported rather than current septic tanks using concrete blocks mortared together.
    - Septic tanks with capacities larger than 2,500 L should be considered for large households.

- The NWSMP proposal to install a sewage treatment plant (STP) is supported. The selection of a conventional trickling filter treatment system to produce the Class C effluent is also supported.

- The NWSMP concluded that the treated effluent from the STP should be disposed by irrigation of mine rehabilitation areas. This land disposal option is problematic because it (a) would involve further major infrastructure to pump the effluent into the centre of the island, (b) would impose additional operation and maintenance requirements and costs on NUC and presumably the Nauru Rehabilitation Corporation, and (c) could present potential health risks during effluent disposal in the mine rehabilitation areas, particularly if problems with the treatment process arise.

- Ocean outfall disposal option should be further considered, with advantages including much lower operational costs and maintenance requirements than land disposal in the centre of the island. This method of disposal has been successfully operating in South Tarawa, Majuro, Ebeye and Funafuti, and should be considered as an option for Nauru.

Operation and maintenance

- The NWSMP section on O&M requirements and staffing to be updated with current information and would benefit from experiences with other utilities in other small PICs that operate and maintain water and sewerage systems.

4. REVIEW OF EXISTING POLICY AND GOVERNANCE ARRANGMENTS

This review looks at relevant policies, strategies, plans and institutional arrangement as well as broader sectoral information that will enable and strengthen the implementation of the NWSMP.

Key findings of this review include:

- The NWSMP, when implemented, will fulfil Nauru’s commitments to the UN’s 2030 Sustainable Development Goal no. 6 and to Pacific Regional Action Plan for Sustainable Water Management, 2003.
- Nauru’s National Sustainable Development Strategy, 2005-2025 (NSDS, revised 2009) is the overarching Government Policy determining national priorities and directing government resources, having the following goals to: (1) “*Provide a reliable, safe, affordable, secure and sustainable water supply to meet socio-economic development needs”, and to ensure the* : (2) “*Effective management of waste and pollution that minimizes negative impacts on public health and environment*” are consistent with the overall goals of the NWSMP.
- In addressing the numerous water and sanitation strategies highlighted in the NSDS, the NWSMP fails to provide cost-effective measures for water supplied through reverse osmosis in relation to other alternative water sources; or development of marine pollution management strategies, which will be linked to proposed sanitation systems, particularly the ocean outfalls.
- NWSMP supports and promotes the application of Nauru’s policies, plans and strategies such as the 2011 Nauru Infrastructure Strategy and Investment Plan (NISIP) and the 2012 National Water, Sanitation and Hygiene Policy.
- The NWSMP, however, fails to address the 2025 targets in the NSDS that rain and groundwater harvesting are to comprise 50 percent of total water production and that rainwater-harvesting production be increased by 50 percent.

- There is no current legislation to protect, conserve and manage Nauru's public water resources and the designated lead agency has no statutory powers in the regulation of water. A draft Environment Bill in various forms has been before Parliament since 2011 and is currently being further amended to cover the management and protection of water resources.
- The Land Act 1976 represents a major cost to the NWSMP and will delay its implementation. The Government does not own land in Nauru. Land for public use must be leased from extended family landholder groups. This involves lengthy negotiations. The NSDS recommended a "*Review of land tenure system and land legislation to be more investor friendly and market driven*" because of the negative impact of the current system on development projects.

5. REVIEW OF INSTITUTIONAL CAPACITY

This review looks at the capacity of the Nauru institutions and government agencies to implement, operate and maintain the proposed infrastructural interventions and to provide considerations for alternative improvements given Nauru's current institutional capacity.

Key findings are summarised below:

- The NWSMP is viewed to be primarily technical and lacks consideration for the local socio-cultural and economic context, which is critical for the sustainability of any water and sanitation project in the Pacific Region.
- In many Pacific SIDS such as Nauru, there is a central authority responsible for water and sanitation (e.g.NUC) but it has limited in-house technical and financial capacity. The authority relies on regional agencies and donors for technical and financial assistance.
- The NWMSP is a clear example of a command-and-control approach to water and sanitation management in the region.
- It was noted that the proposed infrastructure is not "new" to Nauru. A similar reticulation network of desalinated water was already proposed by a team of engineers from JICA in the early 2000 and was never considered further by the government.
- Other key aspects missing from the NWSMP include the sustainability of the proposed infrastructures. Specifically;
    - Is the current institutional system robust enough to support the development of the proposed infrastructures?
    - If the Nauru Utilities Corporation (NUC) oversees the maintenance and operation (M&O) of the proposed network, how will this be funded? Will this be done by the government alone or by bilateral support from donor organisation or country?). Can the cost of M&O be covered by the water service fee? If yes, can households afford the proposed fee?
    - How successful are the reticulated water supply networks currently in operation in any other Pacific Small Island Developing State (PSIDS) and what are the key challenges faced and how different are these issues from the Nauru context?
    - What happened to previous water and sanitation infrastructure in Nauru, both in during the time of prosperity and economic hardship? Why did they fail? How and why will it be different this time?
    - Is it likely that the implementation of a reticulated network will be challenged by local landownership?
    - Is it likely that, without a long-term commitment from donor partners, NUC will have enough capacity (technical and financial) to operate and maintain the proposed infrastructure?

<u>Identified risks associated with proposed infrastructure</u>

a) Land ownership challenge

The implementation of the proposed reticulated network, including the planning, construction and installation of the reticulated pipe network around the island, is highly complicated requiring lengthy discussions and costly negotiations between government and landowners prior to the installation of any infrastructure on their land.

This will require the government to carefully consider where to place infrastructures as potential disputes between neighbours and/or the government are highly likely, leading to costly infrastructural damages. Even if a law was to be put in place to protect such infrastructure, the customary law of landownership will likely prevail, and the government may not be willing to take the matter to court. Information from the NUC general manager Mr Ali in 2017 revealed that a project to have a reticulated water supply from NUC to the hospital, covering a distance of 1 km, have been in the pipeline for years but has not progressed due to landholder issue.

If land ownership issues prevent the construction of all or part of the proposed piped water distribution system, it will be necessary to make changes to the NWSMP with a greater focus on ensuring that an adequate budgetary allocation and government commitments is made to ensure that a fleet of tankers, maintenance facilities and staff are available at all times.

b) High cost of desalination system

The following two statements extracted from the World Bank (2018) highlight the reality of operating a reticulated network for desalinated water and is very relevant within the Pacific Islands context:

1. *“some reticulation systems are unable to meet demands (especially because leakage is typically significant); therefore, water is supplied for only a few hours per day as de facto demand management. Because of uncertainty of supply, people leave taps open to intercept the supply. This greatly increases losses.”*
2. *“The success rate of desalination has been poor in Pacific Island countries because the equipment is expensive to operate and maintain […] The development of desalination facilities is an option for supplementing water supplies during times of drought, but in most instances the high costs prevent this being a widespread adaptation option”.*

The above statements suggest the high risk and cost attached with the sustained operation and maintenance of desalination infrastructure as the primary water source. Recommend the need to consider desalination as an option for extreme climatic periods while the development and usage other alternative water sources such as rainwater and groundwater be improved and strengthened during normal conditions.

c) Funding need for the on-going operation and maintenance of water supply and sanitation systems

Funding mechanisms for the long-term operation and maintenance of these water and sanitation systems need to be considered, planned and committed. It is unclear from the NWSMP where the funding will be sourced from and whether households are expected to be charged by NUC to recover the operation and maintenance cost. At present, the production of desalination water is subsidised, the proposed improved infrastructure will put pressure on the RoN and its donor partners and hence will necessitate the establishment of the water and sewage service fees to be covered by users. The setting up water and sanitation service fees will require careful consideration on what the households can afford and their implications on either wasting water resources if fees are too low or illegal water connections and usage if the fees is unaffordable.

6. RECOMMENDATIONS

6.1 GENERAL REMARKS

Each of the independent peer reviews offers a range of recommendations. The following summarises the main recommendations, with specific detail provided in the individual reviews.

- Change the 20-year planning horizon from 2015 - 2035 to 2021 - 2040 or a later period depending on when improvements are likely to commence.
- Review and, if necessary, revise the population projections for water supply and sanitation planning purposes based on the estimated Nauruan population in 2020.

6.2 WATER SUPPLY IMPROVEMENTS

- Update the NWSMP with:
  - Current desalination plant and water storage capacities
  - Current operational arrangements for the desalination plants and deliveries of desalinated water.
  - Current reliance on rainwater harvesting and status of both roofing and storage tanks conditions.
  - Current groundwater potential and establish abstraction limits and appropriate development options
  - Current sewage treatment plant details including the current methods of effluent disposal and disposal/treatment of septic tank sludge.

Water source

- Recognise the importance of conjunctive water use, including rainwater harvesting, groundwater, and desalinated water supply,
- Recognise the need for rainwater harvesting at all households, with repairs or replacements of roofing, guttering and downpipes required to improve rainwater harvesting potential
- Due to the significant cost savings to households from using rainwater, conduct further consultations with the Government of Nauru and the Nauruan community about the need to include new or improved rainwater harvesting components.
- Develop guidelines for the design and maintenance of rainwater harvesting systems for households and communal buildings using readily available information used in other PICs. Items of particular importance include the use of high-capacity gutters and overflow pipes that need to be directed to groundwater wells where possible.
- Collect and test 10 rainwater samples from selected households in each of the 14 districts and include the results in education and awareness programs.
- Include training of households in maintenance procedures in any future rainwater harvesting improvement projects.
- Introduce financial incentives for the maintenance, repair and enhancement of household rainwater harvesting using schemes such as subsidised rainwater harvesting materials and a revolving fund for loans to purchase rainwater-harvesting components.
- Implement a separate project to remove and properly dispose of asbestos roofs and gutters especially at households.
- NWSMP to recognise that groundwater will be available for use in droughts at least for toilet flushing.

- Determine the potential development and best use of coastal sand aquifer at Ewa and Anetan and establish sustainable abstraction limits of this resource.
- Provide comments about monitoring and management of groundwater pumping including upper limits on pumping rates to minimise impact on groundwater salinity.

Water demand and future scenarios

- Accept the estimate of 110 Lpd for average per capita demand for internal household water use in households as reasonable using all sources.
- Revise the loss rate from a potential piped water supply distribution system to a minimum of 30% of demand.

Water supply standards of service and design criteria

- Adopt the proposal to install a piped water distribution system, including a ring main around the island, provided that land ownership issues can be resolved if they arise. Consider the introduction of serviced distribution points for improved access by residential users and tankers if land issues cannot be resolved.

Water supply system design details

- Design the water supply system components for target years later than 2025 and 2035 as specified in the NWSMP.

Sanitation/sewerage supply standards of service and design criteria

- Adopt the proposal to install a piped sewerage collection system if land ownership issues can be resolved if they arise. Otherwise, improve on-site treatment on every household with adequate septic tanks (not cesspit).

Sewerage system design details

- Further consider the review of a "Conventional Gravity Sewerage System" rather than the "Septic Tanks and Common Effluent Disposal System"
- If the Septic Tanks and Common Effluent Disposal System is adopted:
    - Consider bypassing septic tanks for "greywater" from bathrooms and laundries while ensuring all "blackwater" from toilets and probably kitchens pass through septic tanks.
    - Revise the NWSMP to recommend that double chamber polymer septic tanks be used for all new and replacement installations.
    - Revise the NWSMP to recommend that septic tanks larger than 2,500 L (e.g. 3,000 L and 4,000 L) be used for large households.

Sewerage treatment and disposal

- Adopt the proposal to install a sewage treatment plant using the conventional trickling filter treatment method provided that land ownership issues can be resolved if they arise.
- Adopt the disposal option of discharge to the ocean via outfall(s) rather than irrigation of mine rehabilitation areas in the centre of the island as proposed in the NWSMP.

Operation and maintenance

- Contact utilities in other small PICs that operate and maintain water and sewerage systems to gain a more accurate assessment of typical staffing levels required.
- Update the organisational structure and technical capacity needs based on anticipated operation and management requirements for the water and sewerage systems including RO plants and STP(s).
- Include a new section that considers fees for water and sewerage services and the ability of Nauruans to pay for these services.

6.3 POLICY AND GOVERNANCE ARRANGEMENT

- In addressing the water and sanitation sector strategies highlighted in the NDS, it is recommended that the NWSMP also provides cost-effective measures for water supplied through reverse osmosis and provides direction towards the development of a or monitoring guideline for receiving waters and its periphery.
- The NWSMP should recognise the current absence of legislation on the regulation, management, conservation and protection of water will be a major impediment to its implementation.
- It is recommended that the Nauru Government enact as soon as possible the draft Environment Management and Climate Change Bill 2020 which should include regulations around water quality standards, theft of water, tampering with water meters and misuse of water, water conservation, and specifying the maximum pumping capacity of groundwater pumps. The establishment of a water unit within CIE, as recommended by NWSMP would be also beneficial.
- Land tenure is the biggest deterrent to any future infrastructural investment and improvement in Nauru. The Lands Act 1976 represents a major impediment to improving water and sanitation in Nauru. Although this is a politically complex task because of deep-seated traditional customs, it appears for the common good that some changes to the Act to specifically exempt a basic and essential water supply and sanitation plan and allow it to proceed would be of immense benefit to Nauru. This will require extensive consultation and purposeful leadership. It does not involve negating all tenure, merely allowing two vital services to be delivered to all Nauruans.

6.4 INSTITUTIONAL ARRANGEMENT AND STRENGTHENING

- In view of the recent advancements in water and sanitation and proposed systems in the NWSMP, it will be imperative that the RoN establishes a systematic and coordinated approach to:
    - allow clearly defined government-donor dialogue and participation in funding aspects of the proposed infrastructures at both household and community levels
    - prioritise and address training needs within the key stakeholders
    - strengthen the regulatory roles of key government institutions
    - provide periodical widespread consultation and engagement on planned infrastructural improvements and the associated fees or levies.
- To ensure the success and sustainability of the proposed water and sanitation systems, proper planning and budgetary consideration and commitment will be required for the long-term operation, maintenance and management of the proposed systems. A funding agreement between the RoN and potential donors will be necessary to support both the capital and the ongoing operation and maintenance cost.
- Funding will extend in to meeting the training needs of key government institutions and NUC personals. These training needs may include water quality monitoring and surveillance, rainfall collection and data analysis and weather forecasting, water safety planning, water treatment, water

rates collection and management, plumbing works and tank repair maintenance, and coastal and environmental monitoring specific around the ocean outfalls.

6.5 MULTIPLE STAKEHOLDER ENGAGEMENT AND COMMUNITY CONSULTATIONS

- Engage all relevant stakeholders including key government authorities and non-government organisation, civil societies and academic institutions to look at the following:
  - the planned infrastructural options NWSMP and responsibilities of each stakeholder,
  - budgetary agreement by government and others around the training and capacity building of key authorities, as well as the long-term operation and maintenance of water supply and sanitation systems
  - establishment of a national water supply and sanitation standards and their subsequent governance and enforcement mechanisms; and
  - implementation of key activities in the NWSMP.
- Conduct inclusive community consultations and engagement with a special focus on all vulnerable groups about the proposed water supply and sewerage system designs including locations of water and sewer pipelines, additional water storage tanks, sewage treatment plant(s) and ocean outfall(s), as well as the potential introduction of service fees.
- Conduct community consultations regarding household rainwater harvesting improvements and maintenance and the type of incentive schemes that would assist implementation.

General report format

It is recommended that the NWSMP document be improved through:

- Correction of all spelling, grammatical and other errors in the text (e.g. regarding units)
- Inclusion of a references section
- Thoroughly proofread the revised document.

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8. ANNEX A – Consultants Reports

A1 – Technical review of proposed Water and Sanitation infrastructures by Tony Falkland

Pacific Community
Communauté du Pacifique

FINAL DRAFT

Technical Review of Nauru Water and Sanitation Master Plan, 2017

Prepared for

The Pacific Community (SPC) and Government of Nauru

by Tony Falkland, Island Hydrology Services

November 2020

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ABF	Australian Border Force
ADB	Asian Development Bank
ADWF	Average dry weather flow
BPC	British Phosphate Commission
CED	Common effluent disposal
DCIE	Department of Commerce, Industry and the Environment
DICL	Ductile iron cement lined (pipe)
GoN	Government of Nauru
HGL	Hydraulic grade line
MDPE	Medium density polyethylene
NPC	Nauru Phosphate Corporation
NRC	Nauru Rehabilitation Corporation
NRW	Non-Revenue Water Specialists Pty Ltd
NSDS	National Sustainable Development Strategy
NUC	Nauru Utilities Corporation
NWSMP	Nauru Water and Sanitation Master Plan
O&M	Operation and maintenance
PACC	Pacific Adaptation to Climate Change
PE	Polyethylene
PIC	Pacific Island Country
PRIF	Pacific Regional Infrastructure Facility
PVC	Polyvinyl chloride

RO	Reverse osmosis
RoN	Republic of Nauru
RPC	Refugee Processing Centre (also known as Regional Processing Centre)
SOPAC	Secretariat of the Pacific Islands Applied Geoscience Commission
SPC	The Pacific Community
SPREP	South Pacific Regional Environment Programme
STP	Sewage treatment plant
WHO	World Health Organization

List of Units

kL	kilolitre (one thousand litres)
kL/day	kilolitre per day
L	Litre
L/day	litre per day
Lpd	litre per person per day
L/s	litre per second
m	metre
m^2	square metre
ML	megalitre (one million litres)
ML/day	megalitre per day
mm	Millimetre
m/s	metre per second

Summary

Introduction

This technical review report of the Nauru Water and Sanitation Master Plan, 2017 (NWSMP) has been prepared in response to a request from The Pacific Community (SPC). The NWSMP was prepared by consultants in the period 2015-2017 and approved by the Nauru Cabinet in 2017.

Main Findings and Conclusions

Updating the NWSMP

- Many sections of the NWSMP require updating. For example, the use of a planning horizon from 2015 to 2035 is now well outdated. Also, the population projections which are based on the 2011 Census should be reviewed.

Sources of water

- The NWSMP correctly acknowledges that the main sources of water are rainwater, desalinated water and groundwater.
- The NWSP states, again correctly, that "Rainwater is considered to be the lowest cost, a high-quality water source that is available on the island". However, during droughts, rainwater is not available at least for non-potable uses in most households and desalinated water becomes the primary source of freshwater.
- The NWSMP correctly points out that there is a need for rainwater tanks at all households and repairs or replacements of roofing and downpipes are required to improve rainwater harvesting potential.
- The NWSMP acknowledges that groundwater is a valuable source of non-potable water and can reduce the use of rainwater and desalinated water.
- The NWSMP recommends that groundwater be used only for toilet flushing due to health risks. However, it could also be used for garden watering depending on its salinity.
- The NWSMP has some misleading comments about groundwater status and availability including statements that the freshwater lens may be damaged by pumping (noting that most of the groundwater is brackish) and groundwater availability will diminish or "run out" in droughts (noting that this is not the case as the groundwater level is controlled by sea level and the groundwater will be available provided wells are sufficiently deep).
- While recognising that all three main sources of water are a valuable part of the total water resources, the NWSMP focuses primarily on desalinated water.

Water demand and future scenarios

- The adopted per capita water demand of 110 litres per person per day (Lpd) is considered reasonable for internal household uses. It is reasonably consistent with estimates for other Pacific Island Countries (PICs).
- The estimated allowance in the NWSMP for water losses (non-revenue water) in a water supply distribution network of 20% of water demand is reasonable for a well maintained piped water supply system. However, it is optimistic based on loss rates for water distribution systems in many other PICs and a minimum loss rate equal to 30% of demand is more appropriate.
- The six possible future water demand scenarios have some incorrect assumptions related to groundwater and rainwater availability which need correcting.

Water supply standards of service and design criteria

- The NWSMP correctly notes that there are no national standards of service for water supply. Further, it notes that the water supply system does not meet minimum standards that would reasonably be expected in most countries and the lack of a piped supply is indicative of an "emergency" supply system.
- The proposed installation of a piped water distribution system, including a ring main around the island, is supported as it would greatly improve the supply of desalinated water to consumers provided that land ownership issues can be resolved if they arise.
- Piped water supply systems have been operating in many small Pacific Islands including South Tarawa in Kiribati, Majuro and Ebeye in the Marshall Islands and several islands in the Cook Islands and Tonga. The piped water supply system on Ebeye uses desalinated water as would be the case on Nauru.
- If land ownership issues prevent the construction of all or part of the proposed piped water distribution system, it will be necessary to make changes to the NWSMP with a greater focus on ensuring that an adequate fleet of tankers, maintenance facilities and staff are available at all times.
- The maximum design water pressure of 50 m for the proposed distribution system is high compared with water supply systems on some other Pacific Islands. Higher pressures lead to higher losses due to leakage in water supply networks. This should be reduced to 30 m to minimise losses.
- The minimum design water pressure of 10 m for the proposed distribution system is also high. This should be reduced to 5 m, again to minimise losses.
- Other design criteria related to reservoir volumes, pumping hours and pipe diameters, materials and classes are all considered appropriate.
- The proposed fire fighting provisions including the number of fire hydrants and future use of the six large abandoned concrete tanks at the Golf Course to provide additional fire-fighting capacity are also considered appropriate.

Water supply system design details

- A number of design issues are raised in the detailed comments within this review report including:
  - The need to reduce the pressure from the Command Ridge tanks to Buada residents to no greater than the recommended maximum pressure of 30 m.
  - The need to reconsider the pipeline route as shown in the NWSMP from the Command Ridge tanks to the proposed Anetan tanks owing to mining of much of the ridge road since 2017.
  - The need to consider extending the pipe network to include the facilities in Topside.

Sanitation/sewerage supply standards of service and design criteria

- The NWSMP correctly notes that there are no national standards of service for sanitation or sewerage systems.
- The proposed installation of a piped sewerage collection system is supported as it would greatly improve the current groundwater contamination problem provided that land ownership issues can be resolved if they arise.
- If land ownership issues prevent the construction of all or part of the proposed piped sewerage collection system, it will be necessary to make changes to the NWSMP with the focus on improved septic tanks and improved on-site effluent disposal systems. The present methods of

desludging would need to continue with the sludge taken to a proposed sewage treatment plant.

- The selection of 130 Lpd for "unit household demand" for sewerage system design is not consistent with the adopted 110 Lpd for per capita water demand and should be reduced.
- The selection of pipe materials is considered appropriate.

Sewerage system design details

- The adoption in the NWSMP of the "Septic Tanks and Common Effluent Disposal" option in the NWSMP is considered reasonable but has the obvious disadvantage that desludging of septic tanks will need to continue.
- It is considered there is not enough evidence in the NWSMP to reject the "Conventional Gravity Sewerage System" option from further consideration. This option was rejected in the NWSMP because deep trenching and additional pump stations would be required owing to the need for the gravity pipes to be straight and at a constant gradient. A further possible problem is that limestone pinnacles may be encountered during excavation which would make the construction work very difficult and expensive. However, no hard limestone (pinnacles or other) was encountered in the top 3-5 m of sediments in most boreholes drilled in the coastal margin and the low-lying Buada lagoon in 2008-2009.
- Conventional gravity sewerage systems with multiple pump stations and ocean outfalls have been operating on South Tarawa in Kiribati and on Majuro and Ebeye in the Marshall Islands for many years. These systems have all been installed on atoll islands where the predominant sediments in which the sewer pipes have been laid are unconsolidated sands and gravels.
- If the Septic Tanks and Common Effluent Disposal option is adopted:
    - Rather than having all wastewater from houses and other buildings flow through septic tanks as indicated in the NWSMP, consider bypassing the "greywater" from bathrooms and laundries while ensuring all "blackwater" from toilets and probably kitchens passes through septic tanks. This would relieve the "hydraulic load" on septic tanks.
    - The use of polymer double chamber type septic tanks is supported rather than current septic tanks using concrete blocks mortared together.
    - Septic tanks with capacities larger than 2,500 L should be considered for large households.
- The sewage flow calculations used for the "worst case scenario" in an example area need to be checked and revised as higher flows are likely to occur.
- A number of items in the Effluent Quality section of the NWSMP require checking and updating.

Sewerage treatment and disposal

- If either piped sewerage system option is installed, the NWSMP proposal to install a sewage treatment plant (STP) is supported. The selection of a conventional trickling filter treatment system to produce the Class C effluent is also supported.
- The preferred site in the NWSMP for a STP is at the Location due to its proximity to the serviced area, accessibility to ocean outfalls and the non-desirability of locating an STP on elevated ground due to groundwater contamination risks.
- The NWSMP concluded that the treated effluent from the STP should be disposed by irrigation of mine rehabilitation areas in the centre of the island and emergency discharge, if necessary, via outfall to the ocean. This land disposal option is problematic because it (a) would involve further major infrastructure to pump the effluent into the centre of the island, (b) would impose additional operation and maintenance requirements and costs on NUC and presumably the

Nauru Rehabilitation Corporation, and (c) could present potential health risks during effluent disposal in the mine rehabilitation areas, particularly if problems with the treatment process arise.

- The NWSMP does not include a comparison of the advantages and disadvantages of effluent disposal options i.e. via irrigation on land or discharge to the ocean via outfall(s).
- The outfall disposal option has several advantages including much lower operational costs and maintenance requirements than land disposal in the centre of the island. This method of disposal has been successfully operating with conventional gravity sewerage systems on South Tarawa, Majuro and Ebeye and should be considered as the preferred option for Nauru.

Proposed capital works and timing

- The timings of the two implementation phases for water and sanitation improvements need to be changed to later years.
- The budget shown in NWSMP was updated in the later Nauru Priority Water Sector Development and Funding Needs Report, 2017 including a household rainwater harvesting improvement component.

Operation and maintenance

- The NWSMP section on O&M requirements and staffing to be updated with current information and would benefit from experiences with other utilities in other small PICs that operate and maintain water and sewerage systems.
- There is a need for a new section that considers fees for water and sewerage services and the ability of Nauruans to pay for these services.

Possible Additional Water Supply Measures

- Possible additional water supply measures include increased rainwater harvesting at households and at government, community and commercial buildings and increased use of groundwater supply systems. Other possible measures are also outlined.

(a) Increased rainwater harvesting at houses and other buildings

- The advantages of household rainwater harvesting are well known in the Pacific islands including Nauru. The water is essentially free once the necessary rainwater harvesting components are installed and maintained. For Nauru, when rainfall is plentiful, rainwater can supply most, if not all, household needs depending on the sizes and conditions of roofs, gutters, downpipes and tanks and the number of people in the household. At times of plentiful rainfall, rainwater is conveniently available at household tanks and deliveries of desalinated water can be minimal. However, during droughts, rainwater is generally not available in most households and desalinated water becomes the primary source of freshwater.
- The NWSMP correctly points out that there is a need for rainwater tanks at all households and repairs or replacements of roofing and downpipes are required to improve rainwater harvesting potential. The Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017), prepared shortly after the NWSMP was published, mentions it is essential "that each and every household (and business) has a working rainwater tank that is connected to the guttering and provides a meaningful amount of storage so that it can become the primary water source at that location".
- Information about rainwater harvesting components (roofs, gutters, downpipes and tanks) from the 2011 Census, a 2019 NUC survey and a 2020 mini-census indicate that some households require adequately sized storage tanks while a significant number of households require repairs to or replacements of roofs, gutters and downpipes in poor condition.

- The total water storage capacity of 20.4 ML of the tanks at households and other buildings is very significant being about 3.2 times greater than the current total storage capacity of the large tanks (6.3 ML) within the public water supply system at Aiwo and Meneng. It is also slightly more than double the estimated storage capacity of 9.9 ML once additional tanks are installed. This shows the importance of storage tanks at households and other buildings to the total storage capacity on the island.
- Government of Nauru strategy and policy documents over the past 15 years indicate strong support for improvements to rainwater harvesting particularly at households including the need for incentive schemes to encourage households to improve and maintain roofs, gutters, downpipes and tanks.
- Despite this support, the Nauru Integrated Infrastructure Strategic Plan, 2019 does not include any household rainwater harvesting improvements in its list of 53 priority infrastructure projects. Also, a 2020 Project Design Document for installing water storage tanks for deliveries of desalinated water at 50 most vulnerable households dismisses rainwater harvesting. This is largely based on concerns about the quality of rainwater in relation to asbestos roofs and phosphate dust.
- Regarding asbestos roofs and the impact on rainwater collected from them, World Health Organisation drinking water guidelines states there is "no consistent evidence that ingested asbestos is hazardous to health, and thus it is concluded that there is no need to establish a health-based guideline value for asbestos in drinking water. The primary issue surrounding asbestos-cement pipes is for people working on the outside of the pipes (e.g. cutting pipe), because of the risk of inhalation of asbestos dust". The same comments regarding asbestos cement pipes would apply to asbestos cement roofs and gutters. Based on this, there is no reason that rainwater collected from asbestos roofs and gutters cannot be used. Obviously, from the viewpoint of inhalation, asbestos roofs and gutters should be removed and replaced with suitable materials. A separate project to remove and properly dispose of asbestos roofs and gutters should be implemented especially in households.
- To examine the impacts of dust on rainwater quality ten rainwater samples were tested in 2010. The results showed that the concentrations of cadmium and lead were below the detection limit indicating no health risks from the dust. However, as mentioned in a 2014 report, dust seems to a taste issue and has led some households to completely abandon rainwater harvesting.
- This report includes results of rainwater harvesting simulations using the Nauruan rainfall data for typical households including the number of people, per capita water demand, roof area and tank capacity. The results confirm findings in other locations that in many cases the most effective method of significantly increasing household rainwater harvesting potential is to repair, replace or install additional gutters and downpipes on existing roofs rather than increasing storage capacity.
- The results of rainwater harvesting analyses show there are significant average annual cost savings to be made by maximising the use of rainwater when available rather than relying solely on desalinated water. Using the NUC water rates for desalinated water in 2018-19, the average annual cost saving for typical households is in the order of $500 to $2,000.
- Further household rainwater harvesting analyses should be made to assess the optimal improvements for houses on Nauru.

(b) <u>Increased rainwater harvesting at government and other buildings</u>

- There is scope for increasing rainwater harvesting at government, community and commercial buildings.

- Activities that would assist are:
    - Preparation and introduction of a building code requiring all new government, community and commercial buildings to install appropriately sized gutters, downpipes and rainwater storage tanks.
    - Rehabilitation of concrete tanks C7 - C12 and installation of rainwater harvesting facilities to supply rainwater to these tanks

(c) <u>Increased use of groundwater</u>

- Groundwater pumping systems have been installed on the island to supply water primarily for toilet flushing at households, some government and other buildings and for part of the Meneng district.
- There is potential for additional groundwater pumping systems to be installed especially for densely populated areas such as the Location.

(d) <u>Other possible water supply improvement measures</u>

- Collection and treatment of runoff from the airport runway, as mentioned in previous reports including the Nauru Economic Infrastructure Strategy and Investment Plan, 2011.
- Large scale rainwater harvesting in mined-out areas. This type of large scale rainwater harvesting is practiced on some small islands such as some of the Torres Strait islands, Australia. From a technical viewpoint this option could be further investigated but if land ownership issues arise, this option is not worth considering.

Possible Alternative Sanitation Measures

Possible alternatives were considered regarding the following aspects:

- Type of sanitation system (Conventional Gravity Sewerage System rather than the Septic Tanks and Common Effluent Disposal System), as previously mentioned.
- Three separate sewerage systems each covering part of the island rather than one system. The advantage of three systems would be smaller pipe and pump sizes in each system and experience with the first system would be useful regarding any modifications to the design for the second and third systems.
- Outfall locations and designs.

Community consultations

- It will be necessary to conduct community consultations about the proposed water supply and sewerage system designs to determine any land ownership or other issues that may arise including locations of water and sewer pipelines, additional water storage tanks, sewage treatment plant(s) and ocean outfall(s).
- It will also be useful to conduct community consultations regarding household rainwater harvesting improvements and maintenance and the type of incentive schemes that would assist implementation.

Report format

- There are a number of spelling, grammatical and other errors in the text (e.g. regarding units) which require correcting in a revised version of the NWSMP.
- Details of some reports referred to in the NWSMP are not provided and there is no section containing a list of references.
- It is evident that the NWSMP was not thoroughly proofread before publishing.

Summary of Recommendations

Planning horizons and population projections

- Change the 20-year planning horizon from 2015 - 2035 to 2021 - 2040 or a later period depending on when improvements are likely to commence.
- Review and, if necessary, revise the population projections for water supply and sanitation planning purposes based on the estimated Nauruan population in 2020 and the most likely future scenario regarding the Refugee Processing Centres.

Infrastructure details

- Update the NWSMP with:
  - Current desalination plant and water storage capacities at both the Aiwo and Meneng sites and the arrangements for delivery of water-based on current information.
  - Current operational arrangements for the desalination plants and deliveries of desalinated water.
  - Current sewage treatment plant details including the current methods of effluent disposal and disposal/treatment of septic tank sludge.

Groundwater status and use

- Revise the NWSMP to recognise that groundwater is not limited at houses and other buildings that have wells but rather that it is mainly brackish and will be available for use in droughts at least for toilet flushing.
- Revise the part of the NWSMP referring to a freshwater lens that may be damaged by pumping, noting that most groundwater is brackish.
- Provide comments about monitoring and management of groundwater pumping including upper limits on pumping rates to minimise impact on groundwater salinity.

Water demand and future scenarios

- Accept the estimate of 110 Lpd for average per capita demand for internal household water use in households as reasonable using all sources.
- Revise the loss rate from a potential piped water supply distribution system to a minimum of 30% of demand.
- Recalculate or delete the possible future water demand scenarios which are based on incorrect assumptions related to groundwater and rainwater availability.
- Recalculate the adopted future water demand scenario for the 20 year period 2021 to 2040 or a later period depending on when improvements are likely to commence and also take account of (a) groundwater use for at least toilet flushing and (b) non-residential demands if not already included.
- Revise the water supply estimates that NUC are supplying as a percentage of "real demand" under "normal" and drought conditions. Losses in pipelines should be deleted from the calculations to enable valid comparisons and the data should be updated to the year 2020.
- Revise the water supply estimate to the RPCs based on their current and expected future use.

Water supply standards of service and design criteria

- Adopt the proposal to install a piped water distribution system, including a ring main around the island, provided that land ownership issues can be resolved if they arise.

- Reduce the maximum design water pressure from 50 m to 30 m and the minimum design water pressure from 10 m to 5 m in the proposed water distribution system.
- Adopt other design criteria related to reservoir volumes, pumping hours and pipe diameters, materials and classes as specified in the NWSMP.

Water supply system design details

- Design the water supply system components for target years later than 2025 and 2035 as specified in the NWSMP.
- Outline the preferred measure to control the maximum pressure to Buada residents at 30 m rather than 50 m.
- Investigate alternative route option(s) for the proposed pipeline from the Command Ridge tanks to the proposed Anetan tank.
- Consider extending the pipe network to include the facilities in Topside.

Sanitation / sewerage supply standards of service and design criteria

- Adopt the proposal to install a piped sewerage collection system provided that land ownership issues can be resolved if they arise.
- Reduce the 130 Lpd for “unit household demand” for sewerage system design to be consistent with the adopted 110 Lpd for per capita water demand.
- Correct the errors in the average dry weather flow and peak flow values and units.
- Justify the inflow/infiltration estimate of 5% of the average dry weather flow which seems low.

Sewerage system design details

- Further consider the installation of a “Conventional Gravity Sewerage System” rather than the “Septic Tanks and Common Effluent Disposal System” based on available evidence of the type of sediments and possible presence of limestone pinnacles, particularly in the coastal margin and the low lying Buada lagoon area where most sewerage pipes would be laid. Any drilling logs additional to those drilled in 2008-2009 and geotechnical information should be checked to assess the type of sediments and likelihood of encountering limestone pinnacles.
- If the Septic Tanks and Common Effluent Disposal System is adopted:
  - Consider bypassing septic tanks for “greywater” from bathrooms and laundries while ensuring all “blackwater” from toilets and probably kitchens passes through septic tanks.
  - Revise the NWSMP to recommend that double chamber polymer septic tanks be used for all new and replacement installations.
  - Revise the NWSMP to recommend that septic tanks larger than 2,500 L (e.g. 3,000 L and 4,000 L) be used for large households.
- Check and revise the sewage flow calculations used for a “worst case scenario” example area.
- Update the Effluent Quality section based on the recommendations shown in that section of this report.

Sewerage treatment and disposal

- Adopt the proposal to install a sewage treatment plant using the conventional trickling filter treatment method provided that land ownership issues can be resolved if they arise.
- Adopt the disposal option of discharge to the ocean via outfall(s) rather than irrigation of mine rehabilitation areas in the centre of the island as proposed in the NWSMP.

Proposed capital works and timing

- Revise the timings of the two implementation phases for water and sanitation improvements to appropriate later years than shown.
- Update all tables, figures and associated text in the NWSMP with the additional items, including a household rainwater harvesting improvement component, and the revised budget as presented in the Nauru Priority Water Sector Development and Funding Needs Report, 2017.

Operation and maintenance

- Contact utilities in other small PICs that operate and maintain water and sewerage systems to gain a more accurate assessment of typical staffing levels required.
- Update the organisational structure based on anticipated O&M requirements for the water and sewerage systems including RO plants and STP(s).
- Include a new section that considers fees for water and sewerage services and the ability of Nauruans to pay for these services.

Possible Additional Water Supply Measures

(a) Increased rainwater harvesting at houses and other buildings

- Update the NWSMP with:
  - The most recent data regarding the status of rainwater harvesting systems at households and other buildings.
  - Comments regarding the considerable support for household rainwater harvesting improvements in Government of Nauru strategy and policy documents over the past 15 years and the need for incentive schemes to encourage households to improve and maintain roofs, gutters, downpipes and tanks.
  - Comments regarding asbestos roofs and phosphate dust in relation to rainwater quality based on the latest (2017) World Health Organization guidelines and a 2010 report on rainwater sample testing.
  - A household rainwater harvesting improvement component and revised budget for the 20-year capital works program based on the Nauru Priority Water Sector Development and Funding Needs Report, 2017.
- Analyse all household rainwater harvesting systems and assess best strategies to improve rainwater harvesting which in many cases will be replacing existing gutters and downpipes and/or installing them on parts of house roofs where they are not already fitted.
- Due to the significant cost savings to households from using rainwater, when available, rather than purchasing desalinated water, conduct further consultations with the Government of Nauru and the Nauruan community about the need to include new or improved rainwater harvesting components with any project that focuses on the installation of household water storage tanks, including the proposed project in the 2020 Project Design Document for installing water storage tanks for deliveries of desalinated water at 50 most vulnerable households.
- Develop guidelines for design and instructions for maintenance of rainwater harvesting systems for households and other buildings using readily available information that has been used in other PICs. Items of particular importance are the use of high capacity gutters and overflow pipes directed to groundwater wells where possible.
- Prepare and implement a building code with mandatory requirements for rainwater harvesting facilities (gutters, downpipes and tanks) to be installed at all new houses and government, community and commercial buildings.

- Collect and test 10 rainwater samples from selected households in each of the 14 districts and include the results in education and awareness programs.
- Include training of households in maintenance procedures in any future rainwater harvesting improvement projects.
- Reactivate community and school education programs about the need to maintain rainwater harvesting systems for the benefit of households, especially due to significant cost savings that can be made by using rainwater, when available, rather than expensive desalinated water.
- Introduce financial incentives for the maintenance, repair and enhancement of household rainwater harvesting using schemes such as subsidised rainwater harvesting materials and a revolving fund for loans to purchase rainwater harvesting components.
- Advise the authors of the 2020 Project Design Document (SPC and RoN, 2020) to update the document with consistent terminology about the definition of a water storage tank in relation to its capacity.
- Prepare and introduce regulations requiring all new government and community buildings to install appropriately sized gutters, downpipes and rainwater storage tanks.
- Rehabilitate and install liners in concrete tanks C7 - C12, construct a roof over these tanks and install appropriately sized gutters and downpipes.
- Implement a separate project to remove and properly dispose of asbestos roofs and gutters especially at households.

(b) <u>Increased use of groundwater</u>

- Identify the location and current status including groundwater salinity of all groundwater pumping systems installed at Government and other buildings in 2008-2009 and more recent schemes such as the one in the Meneng district.
- Design and install, as a high priority, a groundwater pumping system using nearby groundwater to supply toilet flushing water at the Location housing blocks.
- Implement additional groundwater pumping systems in other parts of Nauru including houses in the Aiwo district which are situated above groundwater contaminated with oil and other hydrocarbons.
- Design all groundwater systems to ensure that groundwater salinity is well managed within reasonable limits and does not impact on nearby household groundwater supplies.
- Implement a regular groundwater monitoring program at existing and new groundwater pumping systems.
- Reactivate a regular groundwater monitoring at the remaining monitoring boreholes drilled in 2008.

(c) <u>Other possible water supply improvement measures</u>

- Assess the feasibility and costs of a rainwater harvesting scheme using the airport runway including associated pumping, treatment and storage requirements in a revised version of the NWSMP, as previously recommended in the Nauru Economic Infrastructure Strategy and Investment Plan, 2011.
- Assess the feasibility of a large scale rainwater harvesting in mined-out areas from a land ownership perspective. If feasible, investigate this potential option from a technical and economic perspective using experiences from other islands including Torres Strait Islands, Australia.

Possible Alternative Sanitation Measures

- Further consider the installation of a Conventional Gravity Sewerage System rather than the Septic Tanks and Common Effluent Disposal System, as recommended above.
- Consider a possible alternative to the proposed single sewage collection, treatment and disposal system consisting of three separate systems.
- Consult with GoN and local communities about possible outfall sites in the north and south of the island.
- Conduct hydrodynamic studies of ocean currents and background water quality studies near the edge of the reef.
- Decide on whether STPs are required at the possible northern and southern outfall sites.
- Consider alternatives to a piped sewerage system if land ownership issues prevent a piped sewerage system from being implemented. One alternative is to install improved septic tanks and improved on-site disposal via effluent disposal pipes or beds.

Community consultations

- Conduct community consultations about the proposed water supply and sewerage system designs including locations of water and sewer pipelines, additional water storage tanks, sewage treatment plant(s) and ocean outfall(s).
- Conduct community consultations regarding household rainwater harvesting improvements and maintenance and the type of incentive schemes that would assist implementation.

Report format

- Correct all spelling, grammatical and other errors in the text (e.g. regarding units)
- Include a references section
- Thoroughly proofread the revised document.

1. Introduction

1.1 Terms of Reference

This technical review report of the Nauru Water and Sanitation Master Plan (NWSMP), 2017 has been prepared in response to a request from The Pacific Community (SPC). The NWSMP was prepared by consultants (NRW Specialists Pty Ltd and NRW Macallan (Fiji) Ltd) in the period 2015-2017 and approved by the Nauru Cabinet in 2017.

The objectives of the review, as outlined in the Terms of Reference provided by SPC, were to:

- Review the NWSMP interventions from a technical perspective regarding water demand assumptions, appropriate technologies, and fit for purpose interventions, with consideration to "value for money" and existing reliance on water sources.
- Consider alternate interventions or approaches more suited to Nauru's needs given the socioeconomic context to construct, operate and maintain, improved water and sanitation systems for Nauru.

1.2 Structure of this report

Sections 2 to 9 of this report have been organised according to the same headings and numbering system as used in sections 2 to 9 of the NWSMP (RoN 2017). The one exception is that the Introduction and Objectives (sections 1 and 2) of the NWSMP are both reviewed in section 2 of this report. Review comments about the NWSMP are provided in each section based on the information in the NWSMP and other references where relevant. Recommendations arising from these comments are provided in each section where appropriate.

Sections 10 and 11 consider possible alternative or additional water supply and sanitation measures, respectively, to suit Nauru's water and sanitation needs. These measures are based on assessment of conditions on Nauru as well as experiences with water and sanitation on other small Pacific islands.

Section 13 provides conclusions and recommendations.

Annex A provides comments regarding problems with the text in the NWSMP.

All costs shown in this report are in Australian dollars.

2. Introduction and Objectives in the NWSMP

Introduction

Comments:

- The Introduction (Section 1) provides the background to, and processes used in, developing the NWSMP.
- It is noted that no Terms of Reference are shown in the NWSMP for the Master Plan study. Rather, 14 "principal objectives" are listed (refer section 0).
- The first paragraph refers to a "planning horizon of 2015 to 2035" and the fourth paragraph to "…planning considerations including the investigation of the water supply infrastructure needs of Nauru for the next 20 years". The 20 year planning horizon, as selected in the NWSMP, should be revised to 2021-2040 and possibly later depending on when improvements are likely to commence.
- The NWSMP refers to the Water and Sanitation goal in the National Sustainable Development Strategy, 2005-2025 (RoN, 2009) i.e. "Provide a reliable, affordable, secure and sustainable energy supply to meet socio-economic development needs" but does not refer to the Waste

and Sewerage Goal i.e. “”Effective management of waste and pollution that minimizes negative impacts on public health and environment”.

- While reference is made In the Introduction to the three Water and Sanitation “key performance indicators” In RoN (2009), no reference is made to the specific milestones which appear very relevant to a Water and Sanitation Master Plan. Some of the relevant milestones listed for 2015 and 2025 are “Improvements made to groundwater harvesting infrastructure” and “Rain and ground water harvesting comprised 50 percent of total water production”.
- No reference is made in the NWSMP to either the key performance indicators or specific milestones for the Waste and Sewerage Goal in RoN (2009).
- Regarding goals, reference should also be made to the National Water, Sanitation and Hygiene Policy (RoN, 2012a) which was endorsed by Cabinet in February 2012. RoN (2012a) states these goals as “Reliable, safe, affordable, secure, efficient and sustainable water supply systems established” and “Sanitation systems introduced to meet appropriate sanitation needs, minimise impacts on the environment and encourage improved hygiene”.

Recommendations:

(a) Include the Terms of Reference for the Master Plan study.

(b) Change the 20 year planning horizon from 2015 - 2035 to 2021 - 2040 or a later period depending on when improvements are likely to commence (in this section and all subsequent sections which mention the planning horizon).

(c) Modify reference to the National Sustainable Development Strategy (NSDS) to include the years “2005-2025” and include details in a References section (which is not currently part of the NWSMP),

(d) Cite the National Water, Sanitation and Hygiene Policy (RoN, 2012a) in this section and include details in a References section.

(e) Include the Waste and Sewerage goal from the NSDS, 2005-2025 in the Introduction.

(f) Provide discussion (preferably in a separate section) of the strategies and milestones in the NSDS, 2005-2025 for both the Water and Sanitation goal and the Waste and Sewerage goal and how the NWSMP addresses these strategies and milestones.

Objectives of the Study

Comments:

- The overall aim of the NWSMP is stated as: “to assess the water and sanitation situation and then develop a Capital Works program up to and including the 20 year planning horizon from 2015 to 2035 to cater for current and future needs”. Again, the 20 year planning horizon should be revised to 2021-2040 or a later period depending on when improvements are likely to commence.
- The NWSMP lists 14 “principal objectives” which are referred to below as “objectives”.
- The first objective of selecting a population model in line with the 2011 census (RoN, 2011a), the most recent census for Nauru, was relevant in the period 2015-2017 when the Master Plan study was conducted. However, now that nine years have elapsed since the 2011 census, a revised population projection is warranted based on the estimated Nauruan population in 2020 and the most likely future scenario regarding the Refugee Processing Centres (RPCs). Population data and projections are discussed in section 0.
- Objectives 2 to 11 are related to current and future water demand and sewage flows, performance assessment of current water supply and sanitation systems and operations, future

needs for water supply and sewage treatment and disposal, and analysis of options. Details of these items are provided in sections 0 and in sections 6 and 7.

- Objectives 8 and 9 refer to "adopted Standards of Service" which are further discussed in sections 0 and 5.
- Objective 10 is for the examination of current water supply operational procedures and for recommendations regarding the existing and future water supply network performance. Operations regarding current and future sanitation are not mentioned in the objectives. Section 9, however, outlines operation and maintenance aspects for both water supply and sewerage infrastructure.
- Objective 12 is for infrastructure planning to meet the projected 20 year water supply demand and sewage flows. This item is covered in in sections 6 and 7.
- Objective 13 is for production of a capital works program for both water and sewerage and preliminary costs estimates. This item is covered in in section 8.
- Objective 14 is the production of the NWSMP.

Recommendations:

(a) Change the 20 year planning horizon to 2021-2040 or a later period depending on when improvements are likely to commence, as per same recommendation as in section 0.

(b) Review and, if necessary, revise the population projections for water supply and sanitation planning purposes based on the estimated Nauruan population in 2020 and the most likely future scenario regarding the Refugee Processing Centres.

Commercial Objectives

Comments:

- It is correctly noted in the NWSMP that Nauru will need to obtain "external financial assistance" to meet its water and sanitation goals.
- Five "major commercial objectives" are listed. The first two objectives about long-term continuity of water and "wastewater" services could be combined into one. Also, the word "wastewater" in the second objective should be changed to "sanitation" as this covers the solid waste component (septic tank sludge) as well as the liquid effluent component, especially given the preferred sanitation option in the NWSMP is to continue with septic tanks and treat the combined effluent from these. The third objective is reasonable. The fourth objective should be modified to include maintenance costs i.e. "…while covering operation and maintenance costs...". The fifth objective could easily be combined with the first two objectives which could have revised words "To maintain the safe, reliable and continuous delivery of water and sanitation services ". Hence, five objectives could be reduced to three.

Recommendations:

(a) Simplify the five commercial objectives to three.

(b) Change the word "wastewater" to "sanitation" so as to include septic tank sludge.

Standards of Service

Comments:

- The NWSMP correctly notes that there are no national standards of service (for water supply and sanitation). Further, it notes that the water supply system does not meet minimum standards that would reasonably be expected in most countries and the lack of a piped supply is indicative of an "emergency" supply system.

- The NWSMP recognises that the level of service for Nauru may differ (i.e. be lower) from developed countries due to the scarcity of (fresh)water resources and the high costs of desalination. This is considered acceptable in the NWSMP provided the primary objectives of safety and reliability of a potable water supply are achieved.
- For standards of service and the planning of proposed works, the NWSMP says it adopted the "Australian Department of Natural Resources and Mining (DNR&M) *Water Supply and Sewerage Planning Guidelines*". These guidelines were actually produced by the Queensland Department of Natural Resources and Mines and are presumably the same or very similar to the 2010 Planning Guidelines for Water Supply and Sewerage by the Queensland Department of Energy and Water Supply (QDEWS, 2010). This error should be corrected. Also, the relevant reference should be cited in this section and included in a References section (which is not currently included in the NWSMP).
- A question arises as to why the Australian codes for water supply and sewerage planning and design (WSAA, 2011 and WSAA, 2014) are not used. This should be explained in the NWSMP.
- The NWSMP notes that while these were adopted as guidelines, there were instances where it was considered necessary to adopt specific alternative design criteria.

Recommendations:

(a) Correct the author of the Queensland Water Supply and Sewerage Planning Guidelines, cite the correct reference in this section and include details in a References section.

(b) Explain why the Australian codes for water supply and sewerage planning and design are not used.

3. Existing Water Supply and Sanitation

Water Supply System Overview

Comments:

- As documented in the Nauru Water and Sanitation Status Report (NRW, 2015) and summarised in the NWSMP (RoN, 2017), the water sources for the island are rainwater, groundwater, desalinated water and bottled water. Rainwater, when available, is used for drinking water and some other uses. Desalinated water is the main source of freshwater during dry periods and is either collected in containers from the desalination plants or delivered to households and other consumer tanks by water tankers operated by the Nauru Utilities Corporation (NUC). Bottled water is a third source of drinking water. Groundwater from household wells, which is mainly brackish and often contaminated by sanitation systems (septic tanks and cesspits) and domestic animals, is mainly used for non-potable purposes including washing and toilet flushing. Groundwater in the Aiwo district is also contaminated by oil and other hydrocarbons making it unsuitable for any use in some locations. The NWSMP mentions that boiled groundwater is used by some households as a source of drinking water.
- Desalinated water is provided from several seawater reverse osmosis (RO) units. According to the NWSMP, there were three RO plants in operation in 2017 with individual capacities of 800, 400 and 110 kL/day i.e. a total capacity of 1.31 ML/day. At that time, an additional RO plant with capacity of 800 kL/day was awaiting commissioning. With the additional RO plant, the total capacity was 2.11 ML/day in 2017.
- According to NUC's 2018 annual report (NUC, 2018), there were five operational RO plants in 2018 with individual capacities of 900, 800, 480 and 120 kL/day at the Aiwo desalination facility and 100 kL/day at the Meneng desalination facility near the Menen Hotel. An additional 480 kL/day (0.48 ML/day) RO plant is yet to be installed at the Meneng site. The total capacity

of the four RO plants at Aiwo was 2.3 ML/day and the total capacity of the two Meneng RO plants (one yet to be installed) was 580 kL/day. The overall capacity of these six RO plants was 2.88 ML/day.

- Recent information supplied by the Department of Commerce, Industry and the Environment (DCIE), Government of Nauru to SPC indicates the following desalination capacity:
  - Aiwo: 900, 800, 480 and 110 kL/day (total of 2.29 ML/day). The Australian Border Force (ABF) owns the first three RO plants and NUC owns the smallest plant.
  - Meneng: 45 kL/day with a 480 kL/day RO plant yet to be installed (total of 0.525 ML/day).

  The total capacity at both sites, including the RO plant which is yet to be installed at the Meneng site is approximately 2.8 ML/day i.e. about 30% more than mentioned in the NWSMP.
- Also, recent information supplied by DCIE to SPC indicates that the operation and maintenance costs for the Aiwo RO plants is managed by the ABF and electricity costs to run these plants is shared between NUC and ABF. These costs will need to be managed by the Government of Nauru (GoN) when the ABF leaves the island.
- Figure 2 of the NWSMP shows that in 2017 the water storage capacity at Aiwo consisted of four large in-ground concrete tanks with approximate capacities of 300 kL each and one large above-ground steel tank ("B13") with a capacity of 4 ML. The four concrete tanks are part of a six tank cluster (C1-C6) of which two were not operational in 2017.
- It is noted that the large steel tanks (e.g. B13), which are similar to those installed by the British Phosphate Commission (BPC) on both Banaba (Ocean Island), Kiribati and Christmas Island, Indian Ocean, are one million gallon tanks (i.e. 4.5 ML). The NWSMP states their capacities as 4 ML in this and other sections.
- Recent information supplied by the DCIE to SPC indicates the following water storages were in service or yet to be installed at Aiwo and Meneng:

  (a) <u>Aiwo:</u>
  - The 4 ML (actually 4.5 ML) steel tank B13 which has a "safe fill level" equivalent to 3.16 ML.
  - The six concrete tanks C1-C6 which were recently re-lined. These have a capacity of 270 kL each (not 300 kL as shown in the NWSMP) and a total capacity of about 1.6 ML.
  - A new 3 ML tank at the site of the former B10 tank (yet to be installed).
  - A 0.3 ML water treatment tank (yet to be installed).

  (b) <u>Meneng:</u>
  - A 3 ML tank with safe fill level equivalent to 1.5 ML.
  - A 0.3 ML water treatment tank (yet to be installed).

  The current operational total storage capacity at both sites is approximately 6.3 ML. Including the additional storage capacity which is yet to be installed, the total storage capacity at both sites will be approximately 9.9 ML.
- Desalinated water is delivered by NUC to households and other consumers by water tankers, as there is currently no reticulation system. A previous reticulation network in the Aiwo and Denigomodu districts consisting of galvanised iron and asbestos cement pipes is no longer operational and beyond repair.
- Desalinated water was also being delivered (by the ABF) to the three RPCs which are located in Topside. NUC's 2018 Annual Report (NUC, 2018) mentions that the "ABF provides water to the Regional processing centers, the Refugee camps and houses rented by ABF for various purposes".

- As mentioned previously, the NWSMP considers the current water supply system to be an "emergency" water supply system. Current problems mentioned in the NWSMP are:
    - Electrical faults and shortages of diesel affecting RO plant operation
    - Disruptions related to repairs or maintenance of RO plants
    - Tanker breakdowns
    - Insufficient water storage capacity to allow for the above factors.
- Regarding costs, the NWSMP mentions:
    - Rainwater is considered to be the lowest cost, high quality water source on the island with water being provided straight to the customer via rainwater harvesting.
    - Desalinated water provides a safe and reliable water supply option for drinking water although the energy costs are higher than other options. Due to the forecast population growth and future water demand, desalination will form an important part of meeting Nauru's future water supply needs.
- As the NWSMP acknowledges, Nauru sources water from rainwater harvesting, groundwater and desalination. It also points out that Nauru's current water supply and sanitation services are precarious and vulnerable.
- Regarding the quality of rainwater, SPREP (2014) mentions that "Water quality is a major issue in Nauru, with some of the higher rates of diarrhoea in the Pacific (WHO, 2008). Contamination occurs principally in the groundwater but also in rainwater harvesting systems that are poorly maintained. The desalinated water delivered by NUA is now free of contamination, with chlorine disinfection at delivery". Further comments about the quality of rainwater are provided in sections 4.iv and 0.

Recommendations:

- Update desalination plant and water storage capacities at both the Aiwo and Meneng sites and the arrangements for delivery of water based on current information.
- Change the capacities of the large steel "B" tanks from 4 ML to 4.5 ML and the concrete "C" tanks from 300 kL to 270 kL in this and other sections of the NWSMP.

Sewage System Overview

Comments:

- Most sanitation systems on Nauru consist of flush toilets connected to on-site septic tanks and cesspits. The NWSMP mentions that some septic tanks are reported to be leaking and hence not providing the primary treatment that they are designed to provide. These on-site sanitation systems cause contamination of the nearby soil and groundwater and pose a significant health risk.
- The NWSMP mentions that the RPC (actually RPCs) have their own sewage treatment plants (STPs).
- According to the NWSMP, the Nauru Primary School in Meneng district was discharging its sewage into a cesspit adjacent to a STP which also received septic tank waste via sewage tanker from other districts. The effluent from the STP was discharged into a pit and hence into the groundwater. As identified in both the 2015 Status Report (NRW, 2015) and the NWSMP, this STP was not designed for such large volumes of sewage which were obviously causing groundwater pollution in this area.
- While not mentioned in the NWSMP, a reticulated sewerage system was installed by the British Phosphate Commission (BPC) in the Aiwo and Denigomodu districts including the Location. The

flushing water was seawater pumped from an intake in the harbour to concrete tanks on Command Ridge above Aiwo district. The seawater was then gravity fed to toilets in houses and buildings via a pipe distribution network using asbestos cement pipes. The outlets from the toilets were connected to a sewerage pipe network discharging through several outfalls on the reef. Both the sewerage and seawater supply systems have been defunct for many years.

- The NWSMP concludes that there is a significant problem with sewage treatment and disposal on Nauru.
- Recent information obtained from DCIE and NUC by SPC indicates a number of changes since 2017 including:
  - An STP with tertiary treatment is now in operation at the RoN Hospital and the treated effluent is discharged into the stormwater system and subsequently discharged to the ocean.
  - A new STP at the Nauru Primary School, when commissioned, will dispose of treated effluent to land.

Recommendation:

- Update this section of the NWSMP regarding the current status of STPs at the Nauru Primary School, the RoN Hospital and the RPCs, including the current methods of effluent disposal and disposal/treatment of septic tank sludge.

4. Population and Water Demand Projections

Population Projections using 2011 Census

Comments:

- The seven population projections in Table 9 of the NWSMP were taken from the population projections in Table 45 the 2011 Census (RoN, 2011a), the most recent census for Nauru. The population projections are shown for the years 2015 to 2050 at five-year intervals using a base population in 2011 of 10,000 (very close to the 2011 census population of 10,084).
- The two population "scenarios" adopted in the NWSMP are called "Median Growth" and "High Growth". These are the "Low fertility - No migration" and "Constant fertility - no migration" population projections in Table 45 of RoN (2011a). The assumption of "no migration" is reasonable given that this was one of the two migration assumptions in RoN (2011a). It is also a conservative approach as the second migration assumption in RoN (2011a) was an annual decline of 100 people over the projection period.
- The 20 year planning horizon, as selected in the NWSMP, should be revised to 2021-2040 and possibly later depending on when improvements are likely to commence (previously mentioned in section 0).
- Using the end year of 2040 for the 20 year planning horizon, Figure 9 and Tables 1 and 2 show the projected populations as 15,900 and 18,271 (which should be 18,371) for, respectively, the selected "Median Growth" and "High Growth" scenarios.
- Again using the end year of 2040 for the 20 year planning horizon, the projected populations for the two scenarios are 16,966 and 20,948, respectively, from Figure 9. During the period 2035 to 2040, the projected populations for the two scenarios increase by 1,066 and 2,577 or 6.7% and 14.0%, respectively. These increases are quite significant especially for the High Growth scenario.
- To assess whether the population projections in RoN (2011a) and used in the NWSMP are realistic, they were compared with the estimated population of 11,690 in mid-2020 shown in

SPC (2020). This estimated population is closest to the "High fertility - plus migration" population projection of 11,732 in Table 45 of RoN (2011a) and Figure 9 in the NWSMP. It is lower than both population projections in 2020 of 12,570 and 12,751 for the "Median Growth" and "High Growth" scenarios used in the NWSMP. However, it is noted that the "High fertility - plus migration" population projection may not be appropriate because the migration may not be an annual decline of 100 people.

- Using the "High fertility - plus migration" population projections, the projected populations in 2035 and 2040 are, respectively, 14,167 and 15,107. The "High fertility - plus migration" population projection in 2035 is less than the projected populations using the "Median Growth" and "High Growth" scenarios by, respectively, 1,733 and 4,204 or 10.9% and 22.9%. Also, the "High fertility - plus migration" population projection in 2040 is less than the projected populations using the "Median Growth" and "High Growth" scenarios by 1,859 and 5,841 or 11.0% and 27.9%, respectively. These differences are significant and indicate that the population projections used in the NWSMP are quite conservative, especially for the "High Growth" scenario.
- The NWSMP developed Tables 1 and 2 for the "Median Growth" and "High Growth" scenarios showing the populations in each district and at yearly intervals from 2015 to 2035. These are based on the 2011 census data including that shown in Figures 10 and 11 of the NWSMP (which are copies of Figures 4 and 5 in RoN, 2011a). Total populations were interpolated for each year using the 5-yearly projections in the 2011 census and the populations for each district were estimated from the 2011 population percentages for these districts. Very minor adjustments were made to the data which had no significant impact on the results. In summary, the distribution of the population according to the districts is reasonable.

Recommendations:

- Revise the "Median Growth" and "High Growth" population projections for the period 2021-2040 or a later period taking into account the estimated population in 2020 and the current migration rate.
- Check that the percentage populations for the 14 districts and the Location are approximately the same in 2020 as they were in the 2011 census and, if necessary, adjust the population percentages and totals for each district.

Water Demand Estimates

i. Existing Water Consumption Analysis

Comments:

- The first part of section 4.2 in the NWSMP discusses non-residential (institutional, commercial and other) users. Table 3 lists some large water users including hospitals, school, offices, workshops, Aiwo hotel, ship loading and power station based on data from NUC in May 2015. The total water use (not shown) is 330 kL/week or about 47 kL/day. In addition, the Menen Hotel and the Capelle Hotel and Supermarket, which have their own RO plants, are mentioned under Table 3. NUC estimated that the water use at the Menen Hotel was 20 kL/day.
- The NWSMP mentions that about 800 kL/day (0.8 ML/day) was provided by NUC to the island's consumers. Of this, approximately 500 kL/day (0.5 ML/day) was used by the RPC centres and 300 kL/day (0.3 ML/day) by the Nauruan community.
- NUC's 2017 Annual Report (NUC, 2017) mentions the daily demand (or use) was between 800 and 1,200 kL/day (0.8 and 1.2 ML/day) for all consumers (i.e. the Nauruan community and the RPCs). The variation in demand is due to whether or not rainwater is available in household and other tanks (which varies according to wet and dry periods associated with El Niño and La Niña periods, respectively).

- Based on the estimated 0.3 ML/day used by the Nauruan community and an estimated population of 10,000, the NWSMP estimated the per capita demand for desalinated water as 30 litres per person per day (Lpd) in 2017. From the NUC (2017) daily demand figures above and assuming three eighths of the desalinated water is for the community, the per capita water demand was between 30 and 45 Lpd.
- From recent information supplied NUC to SPC, deliveries of desalinated water to the Nauruan community averaged about 10 ML/month with a maximum of about 15 ML/month during the first half of 2020. Using the estimated Nauruan population of 11,690 in mid-2020 (SPC, 2020), the average and maximum deliveries of desalinated water on a monthly basis were about 28 Lpd and 43 Lpd which are similar to those in the NWSMP and NUC (2017).
- The NWSMP also mentions that under "water rationing situations" NUC provides approximately 300 kL/day of which 150 kL/day or 50% is used by the community implying a per capita water demand of 15 Lpd.
- In any case, the deliveries of desalinated water per capita to the community is much less than what can reasonably be expected as a minimum of about 110 Lpd (refer section iii).
- The situation in 2020 has undoubtedly changed owing to the fact that since March 2019 no one has been living in the RPCs. As of the end of July 2020, the remaining 180 refugees were living within the Nauruan community (RCA, 2020a). By comparison, the number of refugees on Nauru in February 2017, the month of publication of the NWSMP, was approximately 400 (RCA; 2020a, 2020b).
- Using recent information obtained from SPC, deliveries of desalinated water to the RPCs and ABF accommodation averaged about 5.2 ML/month with a maximum of about 6.4 ML/month during the first half of 2020. Without knowing exactly where this water was delivered, it is difficult to estimate a per capita demand. However, it appears to be very high based on the relatively small number of refugees and presumably ABF staff.

Recommendations:

- Update the current per capita demands based on the currently available RO capacity and population, given recent changes to the RPC and ABF populations.
- Update the NWSMP to reflect the current operational arrangements for the desalination plants and deliveries of desalinated water.

ii. Proposed Future Non-Residential Projects

Comments:

- This section focuses on a new RO plant and STP for the RoN Hospital.
- From recent information obtained from DCIE by SPC, it is understood an STP with tertiary treatment is now in operation at the RoN Hospital and the treated effluent is discharged into the stormwater system and subsequently discharged to the ocean. This section should be updated to recognise this fact and also regarding the current status of delivery of water to the hospital.

Recommendation:

- Update this section based on the STP installed at the RoN hospital and its current water supply status.

iii. Typical Residential Water Demand Values

Comments:

- The residential water demand values in the NWSMP are based on Queensland Department of Environment and Resource Management's Planning Guidelines which show a water demand of 440 to 680 Lpd for a typical household of 2-4 persons. The NWSMP assumes 4 persons per household and derives a minimum per capita water demand of 110 Lpd (and a maximum value, not shown, of 170 Lpd). If the average number of 6 people per household is used, as per the 2011 census, the minimum and maximum per capita demands would be approximately 75 and 110 Lpd, respectively.
- While the applicability of Queensland average household demand values to Nauru could be questioned, the adopted per capita water demand of 110 Lpd, which equals the maximum value for a 6 person household as well as the minimum value for a 5 person household, is considered reasonable.
- Previous water demand estimates for Nauru include:
    - 170 Lpd consisting of potable and non-potable water demands of 100 Lpd and 70 Lpd, respectively (WHO, 2001).
    - 100 to 150 Lpd including a potable water per capita demand of between 60 Lpd and 100 Lpd (SOPAC, 2010).
    - 88 to 141 Lpd with an average of 114 Lpd consisting of a potable demand (using desalinated water or rainwater) of 20 Lpd and a non-potable (using groundwater) demands and 94 Lpd (Bouchet and Sinclair, 2001).
- The estimate of 110 Lpd for internal household water demand is reasonably consistent with estimates for other Pacific Island Countries (PICs). For South Tarawa, Kiribati, a household water demand of about 90 Lpd, which included water for toilet flushing, was estimated in the 2011 Water Master Plan (White, 2011). For Rarotonga, Cook Islands, where surface water is the predominant water resource, a 2013 water master plan (AECOM, 2014) used a per capita water demand of 200 Lpd. For Funafuti, Tuvalu, which is mostly reliant on rainwater and supplemented in droughts with desalinated water, Kinrade et al. (2014) set a longer term water security target for essential water needs (listed as drinking, cooking, personal hygiene, showering, toilet, clothes washing but not toilet flushing) of 300 L per household during a worst case drought. For the average of 7.4 people per household in 2017 (Government of Tuvalu, 2017), this is equivalent to 40 Lpd. Typical per capita water usage in well managed water supply systems is in the order of 100 to 200 Lpd but can be much higher when losses are taken into account (Falkland and White, 2020).
- The estimated allowance in NWSMP for water losses (non-revenue water) in a water supply pipe network of 20% of water demand, and hence a per capita water demand including losses of 130 Lpd (which actually calculates as 132 Lpd), is reasonable for a well maintained piped water supply system. However, it is optimistic based on loss rates for water distribution systems in many other PICs. PWWA (2016) shows that 13 of 25 urban water utilities and other water supply agencies in PICs had equal to or greater than 50% water losses. Some specific examples are cited in Falkland and White (2020).
- Based on the evidence above, there is a strong case to allow for a higher loss rate in a possible piped water supply system for Nauru. A minimum loss rate of 30% is recommended and hence the per capita demand including losses would be 143 Lpd (which could be rounded to 145 Lpd).
- In the second last paragraph of this section, the 130 Lpd estimate, which includes actual water use as well as losses, is split according to the same percentages as used in Table 4 (Typical Household (2-4 persons) Internal Water). This is incorrect as 20% of the 130 Lpd is for losses. Hence, the other percentages would be different from those shown, especially if a minimum of

30% losses is assumed. For instance, toilet flushing is shown as 26% of water use in Table 4 and should be shown as 22% of 130 Lpd in the second last paragraph if losses of 20% are used. If losses of 30% are selected, as preferred, toilet flushing would be 20% of 145 Lpd. All of the percentages in this paragraph should be updated.

- The NWSMP mentions that "Additional allowances for institutional, commercial and other uses have been separately calculated and included in the calculation." Table 3 in section i has a list of the larger users. However, it is not clear whether these non-residential demands have been accounted for in the total water demand estimates in Tables 6 and 7 in section vi.
- There is no mention of external water use in the NWSMP. It is noted that the NSDS, 2005-2025 (RoN, 2009) has a milestone of "Over 70% of HH [households] have successfully established and operating kitchen gardens with water storage" under the goal for Agriculture. A source of water would need to be provided for kitchen gardens. In wet periods, the source could be rainwater assuming that all households have rainwater harvesting potential including adequately guttered roof areas and storages. In dry periods, the sources could be groundwater where the salinity is sufficiently low for plants or "greywater" from the house (e.g. water that has been used in bathrooms and kitchens).
- Further comments regarding the use of groundwater for toilet flushing and its impact on per capita demand for desalinated water are provided in section 4.2.4 of this report.

Recommendations:

- Include details of the Planning Guidelines, as referred to in this section, in a References section which is not currently part of the NWSMP.
- Accept the estimate of 110 Lpd for average per capita demand for internal household water use in households as reasonable using all sources.
- Revise the loss rate from a potential piped water supply distribution system to a minimum of 30% of demand.
- Recalculate and update the second last paragraph of this section with revised percentages for the various household water uses.
- Clarify whether the non-residential demands from section i have been accounted for in the total water demand estimates in section vi.
- Update this section to include comments about external use in households for gardens and the sources of water that could be used for this purpose.

iv. Meeting the Demand – Conjunctive Water Sources

Comment:

- The opening paragraph mentions the four sources of water on Nauru i.e. rainwater, groundwater, desalinated water and bottled water. This section then proceeds to comment on the first three sources but does not comment further about bottled water.
- It is noted that the 2011 Census mentions that bottled water was used as a source of drinking water by 2% of the population.

Recommendation:

- Include comments about the use of bottled water.

(a) Rainwater Harvesting

Comments:

- The first paragraph mentions that Nauru (misspelt as "Nuaru") "has a high annual rainfall exceeding 2,000 mm. As such, rainwater harvesting presents a significant opportunity to provide drinking, washing and general purpose water to households during the wet times of the month." These sentences do not recognise the fact that Nauru has highly variable monthly and annual rainfall as shown, for example, in White (2012). The monthly rainfall data for Nauru shows there are many, often consecutive, months with zero or very low rainfall. For example, in the first five months of 2008 the total rainfall was only 1.6 mm. On an annual basis, rainfall is very variable with a minimum of 279 mm (in 1950) and a maximum of 4,588 mm in 1930. The coefficient of variation of annual rainfall (standard deviation divided by mean) is 0.54 (Falkland and White, 2020), one of the highest for Pacific Islands, indicates the very high variability of Nauru's rainfall.
- In the fifth paragraph of this section, the NWSMP states that "The lack of monthly rainfall data for Nauru does not make it possible to estimate an average rainwater monthly water supply to households and balance volumes to determine and estimate on the rainwater component of water usage per person per day." This sentence is incorrect as monthly rainfall data is available for Nauru from 1897 to 2016 with some gaps (refer to section 10.v). Also, monthly rainfall data has been used in the past with rainwater harvesting software to analyse the required volume of household tank(s) to supply a given number of people for different size roof areas and probabilities of failure (e.g. White, 2012). This sentence should be corrected. More detailed analyses of rainwater harvesting systems have been provided in this report using the available monthly rainfall and a monthly water balance model (refer section 10.v).
- The statistics about rainwater storage tanks in the 2011 Census give a good insight into the number of households with and without tanks and the capacities of tanks in 2011, as well as the condition of gutters, downpipes and roofs. Six years have elapsed between the census and the publication of the NWSMP in 2017 and three years from then until 2020. Some changes to household rainwater harvesting systems have occurred between 2011 and 2020, as identified in a 2019 survey of household rainwater harvesting systems by NUC (refer section 10.i for details).
- It is noted that a recent project design document "Scaling up water storage capacity in Nauru in response to climate change" (SPC and RoN, 2020) mentions that storage tanks will be supplied to an estimated 50 households that do not have a water storage of 5,000 L (5 kL) or more. These storage tanks will be used to accept desalinated water and not rainwater as "the quality of rainwater harvested may be compromised by the ongoing presence of phosphate dust on roofs and the removal of roof asbestos is beyond the scope of the project". Further comments regarding SPC and RoN (2020) are provided in section 10.iv. The NWSMP does not consider the issues of phosphate dust and asbestos roofs regarding rainwater harvesting.
- Regarding asbestos roofs and the impact on rainwater collected from them, SOPAC (2010) reported there is no evidence that asbestos from roofing or pipes is harmful to human health when ingested. World Health Organisation documents (WHO, 2003, 2017) indicate that asbestos in drinking water is not a problem is ingested. The latest WHO drinking water guidelines (WHO, 2017) states there is "no consistent evidence that ingested asbestos is hazardous to health, and thus it is concluded that there is no need to establish a health-based guideline value for asbestos in drinking-water. The primary issue surrounding asbestos-cement pipes is for people working on the outside of the pipes (e.g. cutting pipe), because of the risk of inhalation of asbestos dust". The same comments regarding asbestos cement pipes would apply to asbestos cement roofs and gutters.

- Regarding phosphate dust, Bouchet and Sinclair (2010) present the results of water quality tests on 10 rainwater samples and concluded "For all samples, and all analyses, concentrations of cadmium and lead were below the detection limit indicating no health risks associated with this potential threat". However, as mentioned in SPREP (2014), although the dust seems to be only a taste issue, "it has led some households to completely abandon rainwater harvesting, so they now rely entirely on desalinated water".
- The 2011 Census shows that 15% of all Nauruan households did not have a water tank and this is also mentioned in the NWSMP. In terms of population, this implies approximately 1,500 people did not have access to stored water at their house in 2011. A mini-census in late 2019 and a household survey by NUC are mentioned in SPC and RoN (2020). This report mentions the data shows that 116 of 1,713 total households (about 7%) do not have household water storage of 5 kL or more. Further comments about this data are provided in section 10.i.
- The NWSMP also mentions the problems which are highlighted in the 2011 Census regarding problems with roofs (i.e. a high number requiring repair or replacement), downpipes (i.e. one third had no downpipes) and concludes that there is a need to install tanks and downpipes where these are not present with the following comment "It was considered essential that every household in Nauru should have a fully operational rainwater tank connected to the downpipe within the next five years." While household rainwater harvesting improvements are seen as a high priority in the NWSMP, they were not included in the proposed 20 year capital works program. However, the subsequent Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017) does include rainwater harvesting improvements.
- Regarding costs for household tanks for rainwater harvesting, NRW (2017) calculated a cost for 200 18.5 kL tanks with concrete bases of $3 million based on a unit cost of $15,000. The cost estimate in NRW (2017) appears not to include gutters and downpipe, where required, as these are not specified. A project design document for a proposed "Scaling up water storage capacity in Nauru in response to climate change" project (SPC and RoN, 2020) has an estimated cost of Euro 230,000 (approximately $380,000) for the design and installation of 50 household tanks (with unspecified capacity but most probably about 20 kL based on recent information from SPC). The unit cost per installation including concrete base would be about $7,500. There is a considerable difference in these cost estimates.
- The above estimated costs are for tanks only. An Australian Government funded project in 2007 for the supply and installation of 150 rainwater tanks, gutters and downpipes for selected houses was estimated to cost $600,000 (SOPAC, 2010). The tanks supplied were nominal 18.5 kL (actually 16 kL) galvanised steel tanks with plastic liners. The unit cost of each installation was thus about $4,000. The cost in 2020 would obviously be higher but it is doubtful that the cost would be as high as $15,000 as estimated in NRW (2017).
- Large scale rainwater harvesting using "manmade large catchment areas" where mining has occurred was considered but rejected in the NWSMP on the basis of land ownership issues, possible secondary mining and the high cost of removing pinnacles. A fourth and important issue not mentioned in the NWSMP is the high evaporation rate that would make such catchment areas unviable unless covered which would be very expensive.

Recommendations:

- Include comments about bottled water use, especially the proportion that is satisfied from this source.
- Revise the first paragraph to recognise the high variability of both monthly and annual rainfall on Nauru.

- Correct the first sentence in the fifth paragraph which refers to the lack of monthly rainfall data to analyse household rainwater harvesting when, in fact, monthly data is available from 1893 to the present with some gaps.
- Update the NWSMP regarding household rainwater harvesting systems using data from the 2019 NUC household survey rather than from the 2011 Census.
- Update the NWSMP regarding the rainwater harvesting issues raised in SPC and RoN (2020) about asbestos roofs and phosphate dust and comments regarding these issues in other reports including WHO (2003, 2017) and Bouchet and Sinclair (2010).
- Update the NWSMP to include household rainwater harvesting improvements in the proposed 20 year capital works program as presented in the later Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017).
- Update the unit cost for household rainwater harvesting improvements in the NWSMP after clarifying the large difference in unit costs between those in NRW (2017) and those in SPC and RoN (2020).

(b) Groundwater Use

Comments:

- The NWSMP acknowledges that groundwater is a valuable source of water and notes it is used for toilet flushing and laundry (washing), personal bathing, kitchen use, gardens/outdoor purposes and, in some cases, for drinking water after boiling. It recommends that groundwater be used only for toilet flushing due to health risks. This recommendation is also made in Bouchet (2011).
- This review report considers the use of groundwater for only toilet flushing to be too restrictive. It could also be used for gardens if the salinity is acceptable for plants.
- Data and graphs from the 2011 Census are used in the NWSMP to provide information about the extent of groundwater used in each district. Most households (69% of total) use groundwater.
- There is a problem with Figure 14 in the NWSMP and hence with Figure 119 in the 2011 Census. This figure does not include the proportions of groundwater used for toilet flushing. However, Figure 16 in the NWSMP (Figure 125 in the 2011 Census) shows that groundwater is the primary water source for toilet flushing with other sources being desalinated water and rainwater.
- The second paragraph on page 23 mentions that groundwater is extracted mainly by pumping (70% of households) and less by bailing with buckets (30% of households) as per the 2011 Census. The NWSMP considers that pumping of groundwater is an acceptable level of service but bailing using buckets is not.
- Bouchet and Sinclair (2010) mention that, based on a survey of 423 domestic wells (about a quarter of the total household wells), 88% accessed groundwater with pumps and 12% used buckets. This survey showed a higher proportion of wells with pumps than in the 2011 Census.
- The fourth paragraph on page 25 gives the impression that groundwater abstraction is close to its maximum but does not give reason(s) i.e. whether this is because the groundwater will become unavailable (quantity problem) or become more saline (quality problem). The statement that "Under severe drought conditions the groundwater accessibility will still continue to make a water supply contribution but at a diminished rate" is not correct. In reality, groundwater will always be accessible if wells are sufficiently deep, even in droughts, because the groundwater level is mainly controlled by sea level and to a lesser extent by groundwater recharge from rainfall. The problem with the groundwater is that it becomes more saline in droughts and this can be exacerbated by pumping.

- The fourth paragraph on page 25 also mentions that "Population growth over the next twenty years will place additional demand on this resource [groundwater] and it will need to be carefully monitored and managed." However, no advice is given on how to manage the groundwater extraction including limits on pumping rates.
- A number of assumptions were made about groundwater use in the future. The first assumption (shown as "(a)" on page 25) was that the percentage of the population with access to pumped groundwater would remain constant in future. This percentage is presumably about 48% based on 69% of households that use groundwater of which 70% use pumps. The second assumption (not shown with "(b)" on page 26) was that groundwater would only be used for toilet flushing. The first assumption is probably reasonable but should be updated with any relevant data obtained since 2011. The second assumption, while reasonable from a health perspective, does not recognise that at least some households are likely to continue using groundwater for other purposes such as washing clothes and garden watering, especially in droughts.
- In the first and third paragraphs on page 26, the NWSMP again assumes that the groundwater is limited where it is stated that "Under this situation it is assumed that the groundwater availability is limited and that it will not be possible to dramatically increase access to groundwater in future" and "Under the water supply demand projections, the supply from the desalination plants has to be based on the situation of drought conditions prevailing when rainwater tanks are empty and the groundwater accessibility is dramatically reduced." In fact, the groundwater on Nauru is not limited and will always be accessible to households and other buildings that have wells provided the wells are sufficiently deep, as previously mentioned. Regarding the availability of groundwater, Bouchet and Sinclair (2010) mention that "An estimated 298 KL of groundwater is currently abstracted each day in Nauru and this usage is likely to increase in dry periods". The issue with groundwater is that it is mainly brackish and is polluted by sanitation systems in the areas where housing is located.
- The first paragraph on page 26 also assumes that there is a freshwater lens on Nauru from the sentence "In the event that multiple additional households accessed groundwater through pumping then the abstraction rate would be exceed the availability and risk damaging the freshwater lens and would be limited by this factor." In fact, from groundwater investigations there are only very limited parts of Nauru that have permanent fresh groundwater and most of the groundwater is brackish (SOPAC, 2010, Bouchet and Sinclair, 2010). The salinity of the groundwater will vary according to recharge (which varies significantly in wet and dry periods) and the impacts of pumping from wells.
- The final sentence in this section states "The projected water demand under drought conditions does take into account the groundwater contribution however it was noted to be small in comparison with the overall demand." This sentence does not make sense when groundwater has already been recommended for toilet flushing.
- Based on Table 4 in section 4.2.3 of the NWSMP, 26% of the household water use is for toilet flushing in the houses with groundwater supply. This percentage is actually 25% (or about 27 Lpd) if the per capita demand is assumed to be 110 Lpd. Hence, if groundwater is used for toilet flushing, the required supply of desalinated water in droughts when rainwater is unavailable could be based on a per capita demand of 83 Lpd for households with access to groundwater. As not all households have access to groundwater due to pumps not working or the groundwater being too polluted (e.g. in Aiwo district), a per capita demand of 110 Lpd would need to be used for these households. If it assumed that 75% of households have access to groundwater at all times (close to the 69% in the 2011 Census) while 25% do not, then the average per capita demand for desalinated water over all households would be 90 Lpd. This is approximately 20% less than the 110 Lpd assumed for all households in section iii.

Recommendations:

Revise the recommendation in this section that groundwater should only be used for toilet flushing. Depending on groundwater salinity, it could also be used for garden watering.

Provide comments about the problem with Figure 14 in the NWSMP (and hence with Figure 119 in the 2011 Census) that does not include the proportions of groundwater used for toilet flushing.

Re-assess the assumption that the "percentage of the population with access to pumped groundwater would remain constant in future" based on any relevant data since the 2011 Census.

Revise parts of this section to recognise that groundwater is not limited to houses and other buildings that have wells but rather that it is mainly brackish and that it will be available for use in droughts at least for toilet flushing.

Revise the part of this section refers to a freshwater lens that may be damaged by pumping, again noting that most groundwater is brackish.

Provide comments about monitoring and management of groundwater pumping including upper limits on pumping rates to minimise the impact on groundwater salinity.

Revise the last sentence to recognise that groundwater would be used for toilet flushing at all times (including droughts) and is an important component of the island's water resources that can reduce the use of both rainwater and desalinated water.

Revise the average per capita demand for desalinated water (in droughts) to 90 Lpd based on 25% of internal household water use for toilet flushing being supplied by groundwater for 75% of the households on Nauru.

(c) Desalination Water Treatment (Reverse Osmosis) Plant

Comments:

- The NWSMP notes that 68% of demand is met by desalinated water-based in Figure 112 of the 2011 Census. This percentage of demand does not indicate over which period the desalinated water was used. It is going to be much higher in drought periods than in wet periods.
- The NWSMP also mentions the obvious point that any water supply shortfalls that cannot be met by rainwater harvesting or groundwater will need to be met using desalinated water.

Recommendation:

- Update this section of the NWSMP, based on more recent data, about the percentage of demand that is met by desalinated water in both wet and dry periods.

v. Water Demand Scenarios

Comments:

- Six scenarios are considered in this section. With reference to all six scenarios, the two population projections (Median and High Growth) should be re-assessed for their current relevance, as mentioned in the comments and recommendations for section 0 of this review report.
- Both Scenario 1 (High Population – Maximum Demand (Severe Drought)) and Scenario 2 (Median Population – Maximum Demand (Severe Drought)) are based on an incorrect assumption. They assume that not only household rainwater "would run out" (correct assumption) but also all groundwater "would run out" under severe drought conditions (incorrect assumption). For both scenarios, some of the household water requirements (for toilet flushing) could certainly be met from groundwater (see comments and recommendations in section iv(b)). The statement in this section of the NWSMP about groundwater running out is at odds with section iv(b) where it is stated "Under severe drought conditions the

groundwater accessibility will still continue to make a water supply contribution but at a diminished rate".

- Both Scenario 3 (High Population – High Demand (Drought)) and Scenario 4 (Median Population – High Demand (Drought)) assume the use of groundwater according to the proportions shown in Figure 118 of the 2011 Census for households with pumped groundwater supply and not for households that access groundwater by bailing. This is as per the recommendation in the previous section. However, the final sentence for both scenarios "It is also possible that the percentage of households with access to groundwater may actually reduce below the percentages shown in Figure 118 as the increase in population will lead to increased abstraction of groundwater and this is a limited supply" is not correct because the groundwater is not limited. These sentences should be rewritten.

- Both Scenario 5 (High Population – "Normal" Demand") and Scenario 6 (Median Population – "Normal" Demand") make assumptions regarding rainwater and groundwater use. Firstly, the word "normal" needs to be defined given that the rainfall situation on Nauru has large variations between low rainfall during La Niña events and high rainfall during El Niño events with some intervening periods considered neutral.

- Regarding rainwater use assumptions, both Scenarios 5 and 6 assume that all households will have rainwater tanks "in the next five years" (i.e. by 2022) and that households will be able to supply an average of 50 Lpd from rainwater tank(s). Regarding the first assumption, the 2011 Census showed that 15% of all Nauruan households did not have a water tank. A household survey by NUC in 2019 showed that the percentage of houses without a tank had reduced to 10%. From this information, the assumption that all households will have rainwater tanks by 2022 will most probably not be correct. The second assumption of 50 Lpd being available at all households is not necessarily correct. It appears there has been no rainwater harvesting calculations done using Nauru rainfall data to justify the assumption of 50 Lpd. Section 10.v of this review report shows the results of rainwater harvesting calculations using a water balance model with monthly rainfall data from 1946 to 2016 and selected combinations of roof area, storage tank capacity and water demand. Using the average population per household of 6 from the 2011 Census, a per capita demand of 50 Lpd and typical values of roof area (100 m^2) and tank storage capacity (20 kL), rainwater would be available for only 70% of the time. If the roof area was 200 m^2 and the other parameters remained the same, rainwater would be available for about 86% of the time. However, larger roof areas and tanks would be required to enable rainwater to be available at all times at the per capita rate of 50 Lpd.

- Regarding groundwater use assumptions, both Scenarios 5 and 6 assume that households with pumps at groundwater wells will have sufficient water for toilet flushing. This is a reasonable assumption.

- The paragraph below the description of the six scenarios states "The water demand curves for each scenario are shown in the Figure below. The details behind the calculation of the individual demands for each scenario has been calculated and is shown in Appendix A". No Figure is shown but rather a table (Table 5) is provided which shows future water demand estimates in megalitres per day (MLD) for the six scenarios.

- The paragraph below Table 5 explains that the identical results for Scenarios 1 and 3 is due "not only on the lack of rainwater but also the reduced groundwater availability. On this basis when the reduced groundwater availability was taken into account, there was almost no difference between Scenario 1 and Scenario 3 situation." However, as commented above, groundwater is available for both these scenarios for toilet flushing. Hence the results for Scenarios 1 and 3 may not be the same if the groundwater was not assumed to be limited for toilet flushing in drought periods.

- Table 5 shows water demand estimates for all years 2015 to 2035. As previously mentioned, the 20 year period 2021 - 2040 should be used or a later period depending on when improvements are likely to commence.
- It is noted that the detailed calculations of water demands have not been reviewed as these calculations are not available other than a summary in Appendix A for 2035 demands for each house and building.

Recommendations:

- Re-calculate the "Median Growth" and "High Growth" population projections to 2040 or later taking into account the estimated population in 2020 and the current migration rate (also mentioned in section 0).
- Delete Scenario 1 (High Population - Maximum Demand (Severe Drought)) and Scenario 2 (Median Population - Maximum Demand (Severe Drought)) as these incorrectly assume that groundwater would not be available in a severe drought and that only desalinated water would be available.
- Correct the final sentences for Scenario 3 (High Population - High Demand (Drought)) and Scenario 4 (Median Population - High Demand (Drought)) regarding the incorrect statement about the groundwater being limited.
- Define the word "normal" as used for Scenarios 5 (High Population - "Normal" Demand) and 6 (Median Population - "Normal" Demand).
- Check and, if necessary revise Scenarios 5 and 6 regarding the assumption that "all households will have rainwater tanks in the next five years" (i.e. 2022) based on current information.
- Correct the assumption that 50 Lpd will be available from rainwater tanks for each household under "normal" conditions as used for Scenarios 5 and 6.
- Change "Figure" to "Table 5" in the paragraph above Table 5.
- Update Table 5 with revised scenarios and calculated water demands for the 20 year period 2021 to 2040 or later period depending on when improvements are likely to commence.

vi. Master Plan Water Demand Option Selection

Comments:

- After a discussion of the scenarios (with some errors related to groundwater use, as already described), Scenario 3 was selected as the most appropriate for estimating water demands in drought periods and, as stated in the final sentence, "was adopted for planning purposes". Table 6 shows these demands for each year from 2015 to 2035 and each district. These demands should be re-calculated for a later 20 year period, as previously mentioned, and also take account of (a) groundwater use for at least toilet flushing and (b) non-residential demands if not already included.
- As mentioned above, Scenario 3 scenario gives identical results as Scenario 1. In other words, Scenario 3 is in fact adopting the "worst case scenario".
- It was stated that Scenario 5 water demands would apply under "normal" conditions. Table 7 shows these demands for each year from 2015 to 2035 and each district. These demands should be re-calculated. This table and commentary about Scenario 5 could be deleted as Scenario 3 was adopted for planning purposes.
- On page 32, comparisons of the percentages that NUC was supplying in 2015 and the estimated demand requirements for "normal" and drought conditions (i.e. Scenarios 5 and 3, respectively) in that year. The conclusions that NUC was supplying only 26% and 19% of the "real demand" under "normal" and drought conditions, respectively, are incorrect as the "real demand" includes the assumed 20% losses in a pipe network. These percentage should be recalculated

without losses included to provide valid comparisons. Also, the assumed 0.3 MLD supply from NUC and the 0.5 MLD supply to the RPCs should be updated to 2020 data.

Recommendations:

- Re-calculate water demands for Scenario 3 (drought conditions) in Table 6 for the 20 year period 2021 to 2040 or a later period depending on when improvements are likely to commence and also take account of (a) groundwater use for at least toilet flushing and (b) non-residential demands if not already included.
- Delete or re-calculate water demand for Scenario 5 ("normal" conditions) in Table 7 for the 20 year period 2021 to 2040 or a later period depending on when improvements are likely to commence.
- Revise the water supply estimates that NUC are supplying as percentage of "real demand" under "normal" and drought conditions. Losses in pipelines should be deleted from the calculations to enable valid comparisons and the data should be updated to the year 2020.
- Revise the water supply estimate to the RPCs.

5. System Design Criteria

Water Supply Standards of Service & Design Criteria

Comments:

- It is assumed in this section that a piped water supply system will be the adopted solution for Nauru. This assumption is considered reasonable given the need to improve the method of water distribution on the island.
- The first paragraph recognises that the standards of service need to take account of the reliability of electricity, availability of spares, the need to conserve water due to limited resources and high desalination costs, and the availability of land for key items such as storage tanks. Comments above the desirable levels of service are provided below.
- The maximum design water pressure in the proposed reticulation network (or distribution system) is shown as 50 m. This is high compared with water supply systems on some other Pacific Islands. Higher pressures lead to higher losses due to leakage in water supply networks. On South Tarawa, Kiribati, the static head based on elevated tank heights is quite low (between about 6 m and 8 m). More recently, a document about reduction of non-revenue water (i.e. losses) has presented design criteria for South Tarawa including a maximum design pressure of less than 3.0 bar, equivalent to about 30 m pressure (Posch and Partners, 2017). It is recommended that the maximum design water pressure in a possible future reticulation system for Nauru be reduced from 50 m to 30 m.
- The minimum design water pressure in the proposed reticulation network is shown as 10 m. It is recommended that this be reduced to 5 m, again to minimise losses in a (possible) reticulation network. Posch and Partners (2017) has presented a minimum design pressure of less than 0.5 bar, equivalent to about 5 m pressure. As mentioned in the NWSMP for the Odn Aiwo Hotel, buildings that need a higher pressure to supply water to levels higher than 5 m would need to install their own pumping systems.
- Reservoir volume of three times the average daily demand, while conservative compared with some other Pacific Island water supply systems, is reasonable.
- The main pipelines (or "delivery mains" or "bulk supply mains") should be designed for 2040 (or later) rather than 2035 as suggested in the NWSMP, especially given the statement in the NWSMP that "this will avoid pipeline augmentations in approximately ten years' time".

- The two other "conservative standards" regarding bulk supply pumping mains and gravity bulk supply mains sound reasonable (i.e. transmit flows in 12 rather than 18 hours for pumping mains and 18 rather than 24 hours for gravity mains). This is based on the recurring problems with electricity supply.
- For the same reason regarding electricity supply, the use of 12 rather than 20 hours for pump stations to supply the daily water demand to reservoirs is considered reasonable in the design process. However, the design target years of 2025 and 2035 for installation of pumps should be increased by at least 5 years each.
- For the same reason regarding electricity supply and also due to inevitable desalination plant breakdowns, the use of 18 rather than 20 or 24 hours for desalination plants (shown as water treatment plants) to produce the average daily demand is considered reasonable. The words "water treatment plants" should be changed to "desalination plants".
- In the paragraph about the water treatment plants, the statement "The proposed new 600 kl/day desalination plant near the Menen Hotel" should be updated noting that this RO plant, which is yet to be installed, has a capacity of 480 kL/day as per the 2018 NUC annual report (NUC, 2018) and section 0 of this review report.
- The adoption of minimum pipe diameters of 75 mm (actually nominal 80 mm) for PVC and ductile iron (DICL) pipes and 90 mm for MDPE (medium density polythene) pipes rather than 100 mm are considered appropriate due to relatively small demands. The other reason given about "funding constraints" needs further explanation.
- The selection of MDPE pipe as the main pipe material to be used due to its flexibility, durability, ease of installation and cost reduction regarding spare parts is considered very appropriate. Another reason is that it can be supplied in long lengths (as coils) for smaller diameters which means less joints are required.
- The selection of DICL pipe for above-ground and difficult terrain applications is considered appropriate.
- The selection of PN12 as the minimum class of pipe regarding wall thickness and the maximum flow velocity of 2.5 m/s are also considered appropriate.
- The design philosophy of providing interconnectivity where possible and avoiding dead-end mains for the pipe network is very appropriate.

<u>Recommendations:</u>

- Reduce the maximum design pressure from 50 m to 30 m for any possible reticulation system.
- Reduce the minimum design pressure from 10 m to 5 m for any possible reticulation system.
- Design the main pumping and gravity pipelines for 2040 or later depending on when improvements are likely to commence if a piped water supply system is agreed.
- Increase the design target years of 2025 and 2035 for installation of pumps by at least 5 years each.
- Revise the paragraph about the water treatment plant design by (a) changing the title to desalination plants and (b) updating the RO plant capacity at the Menen Hotel to the current capacity.
- Explain what the "funding constraints" are in relation to the selected minimum pipe diameters.

Fire Fighting Standards of Service

Comments:

- The approach adopted whereby fire hydrants would be located at seven strategic points on the network to provide for fire truck filling is reasonable.
- The proposed use of the six large abandoned concrete tanks (C7-C12) at the Golf Course by the Fire Department to provide additional fire-fighting capacity is also reasonable. Further comments regarding these tanks are provided in section 6.i.

Sewerage Standards of Service and Design Criteria

Comments:

- It is assumed in this section that a piped sewerage system will be the adopted solution for Nauru.
- The opening paragraph states "The sewage standards of service and design criteria may be based on typical Australian Standards and Guidelines". However, the design criteria / parameters from Australian Standards and Guidelines for sewerage system design are not necessarily applicable to Nauru as indicated below.
- The selection of 130 Lpd for "unit household demand" for sewerage system design is not consistent with the adopted 110 Lpd for per capita water demand (refer section 4.iii). The 130 Lpd value includes losses in the water supply pipelines which would obviously not enter a sewerage system.
- The average dry weather flow (ADWF) is shown as 0.0015 L/person/day (Lpd) which is incorrect. It should be shown as 0.0015 L/person/second which is equivalent to 130 Lpd. However, as mentioned above, 130 Lpd is higher than the adopted per capita water demand of 110 Lpd. It also assumes that all water that enters a household enters a sewerage system which is not necessarily correct (e.g. leaks in household plumbing would not enter the sewerage system). So 110 Lpd would be an upper limit for the ADWF.
- It is noted that two "typical Australian Standards and Guidelines" use higher values of ADWF. The Gravity Sewerage Code of Australia, version 3.1 (WSAA, 2014) uses 180 Lpd and the South East Queensland Water Supply and Sewerage Design and Construction Code (SEQ, 2020) uses either 180 or 200 Lpd. These higher values are not applicable to Nauru as the adopted per capita water demand is 110 Lpd.
- The inflow/infiltration estimate of 5% ADWF seems low. This should be justified.
- The peak flow (or peak wet weather flow or PWWF) is shown as 0.006 L/person/day (Lpd) which is incorrect as for the ADWF above. It should be shown as 0.006 L/person/second which is equivalent to 520 Lpd. However, it is based on an ADWF of 130 Lpd which should be no greater than 110 Lpd. Hence, on this basis alone the PWWF should be no greater than 440 Lpd. It is noted that the PWWF is 4 times greater than the ADWF. This is reasonable based on calculations shown in WSAA (2014) and a formula in SEQ (2020).
- The selection of MDPE pipe as the main pipe material to be used due to its flexibility, durability, ease of installation and cost reduction regarding spare parts is considered very appropriate.
- Also, the selection of DICL pipe for above-ground and difficult terrain applications is considered appropriate.

Recommendations:

- Revise the first sentence as typical Australian Standards and Guidelines for sewerage system design are not necessarily applicable to Nauru.

- Change the unit household demand from 130 Lpd to a maximum of 110 Lpd as adopted for per capita water demand.
- Correct the errors in the average dry weather flow (ADWF) and peak flow (PWWF) values and units.
- Justify the inflow/infiltration estimate of 5% ADWF which seems low.

6. Water Supply Analysis and Planning

Water Production Requirements

Comments:

- The first paragraph refers to installed desalination capacity of 1.31 ML/day and an additional 0.8 ML/day RO plant awaiting commissioning giving a total of 2.11 ML/day combined capacity (at the Aiwo desalination facility). As noted in section 0, these capacities are different from NUC (2018) and recent information supplied by DCIE to SPC. This paragraph should be updated.
- The second paragraph excludes 0.5 ML/day desalination capacity as it was being used for the RPCs in 2017. As mentioned in section 4.i of this report, the situation regarding the RPCs in 2020 has undoubtedly changed owing to the fact that since March 2019 no one has been living in the RPCs but rather in the Nauruan community (RCA, 2020). The desalination capacity available to the RPCs and the Nauruan community needs to be updated. Also, the "average available reliable production" which is shown as 1.2 ML/day should be updated.
- The third paragraph mentions that "NUC has advised that an additional 600MLD maximum desalination plant is to be procured at installed at [*sic*] the Menen Hotel". The capacity of 600 MLD (or ML/day as used in this review report) should be 1,000 times less i.e. 0.6 ML/day or 600 kL/day. Also, this RO plant has an actual capacity of 480 kL/day (refer sections 0 and 0). This paragraph should be updated.
- The first dot point in the third paragraph refers to a "1.2 MLD water storage tank at the Menen Hotel". The units "MLD" should be corrected to read "ML".
- The capacity of the tank at the Menen Hotel should be checked and, if necessary, updated here and elsewhere in the NWSMP. Recent information obtained from DCIE by SPC indicates that the capacity of this tank is 3 ML with a safe fill capacity of 1.5 ML. There is also a 300 kL (0.3 ML) tank on Nauru awaiting installation at this site. Once installed, this would bring the total storage capacity to 1.8 ML at this location.
- The 0.6 ML/day RO plant mentioned above was down-rated in the NWSMP to a "reliable" production capacity of 450 ML/day (0.45 ML/day) based on 18 hours operation per day. Including the 1.2 ML/day, this brought the total desalinated water production capacity to 1.65 ML/day. This total desalination capacity should be updated based on current information.
- The total water demand and production summaries in Figure 19 and Table 8 and the associated text should be updated regarding the demand and production figures and the time frame. Similarly, the proposed water production augmentations in Table 9 and the graph showing water demand and total planned water production in Figure 20 should be updated.

Recommendations:

- Update individual and total desalination capacities of the RO plants at both the Aiwo and Meneng sites based on current information.
- Update quantities of desalinated water used at the RPCs and within the Nauruan community based on current information.

- Update the "average available reliable production" estimate of 1.2 ML/day to the Nauruan community in 2017 to revised amount based on current information.
- Change "600 MLD" to 480 kL/day.
- Check and, if necessary, update the capacity of the water storage tank at the Menen Hotel (currently shown as "1.2 MLD"). In any case change the units from "MLD" to "ML". Make changes, as necessary, in other parts of the NWSMP.
- Update the total desalinated water production capacity of 1.65 ML/day based on current information.
- Update Tables 8 and 9, Figures 19 and 20 and associated text based on current information.

Bulk Water Supply Concept Strategy

Comments:

- The bulk water supply strategy using gravity rather than pumping wherever possible, making use of the Menen Hotel storage and having dual ('two") bulk supply systems (i.e. a large "Aiwo Bulk Water Supply System" and a smaller "Meneng Bulk Water Supply System") is considered appropriate, especially given the two desalinated water production sites.
- Given the comments in the paragraph below Figure 21 (Proposed Aiwo Bulk Supply System) about the Ewa reservoir being not desirable, Figures 21, 24 and 25 and associated text should be updated by removing the Ewa reservoir.
- Figure 23 shows the "Topside Reservoir" supplying "a large area of the coastal are as well as Buada Lagoon area". It appears there is not sufficient elevation at the "Topside Reservoir" site to supply the Buada Lagoon area, especially as the Command Ridge tanks are intended to supply this area. Section 6.4.1(c) of the NWSMP has a comment "In addition, Command Ridge reservoirs are well located to supply the district of Buada to the east of the site." Also, section 6.4.2.1 states "it is intended to supply the "Topside" area and Buada Lagoon Area from Command Ridge reservoir to ensure that there is adequate pressure".
- The use of the terms "Topside Tank" and "Topside Reservoir" in Figures 22 and 23 and elsewhere in the NWSMP is somewhat confusing as, due to the elevation, it could not supply Topside (in the central part of the island). These terms should be checked as to their validity based on common use of the word "Topside" in Nauru and, if appropriate, changed. See related comments in section iv of this review report.
- Figure 26 shows the Meneng desalination plant capacity as 600 kL/day and the reservoir capacity as 1.2 ML. These values should be checked and updated with current information, as previously mentioned.
- Figure 26 should possibly be updated with an additional elevated tank to supply the cluster of high elevation houses to the west of the old State House elevated tank.
- The NWSMP mentions that approximately 83% and 17% of Nauru's water demand with be met, respectively, by the Aiwo and Meneng bulk supply systems. Logically, the desalination capacities at both sites should be approximately similar to these percentages. This needs to be checked and commented on in the NWSMP based on actual desalination capacities at Aiwo and Meneng.

Recommendations:

- Update Figures 21, 24 and 25 by removing the Ewa reservoir and references to it.
- Check the validity and, if appropriate, change the terms "Topside Tank" and "Topside Reservoir" in Figures 22 and 23 and elsewhere in the NWSMP.

- Clarify the note in Figure 23 that "Topside Reservoir to supply large area of coastal area as well as the Buada Lagoon area", especially in light of the comment in section 6.4.1 that the Command Ridge tanks would be used to supply the Buada Lagoon area.
- Update Figure 26 with revised values, as necessary, for the desalination plant capacity and reservoir storage capacity at the Meneng site.
- Update Figure 26 with a possible additional elevated tank to supply the cluster of high elevation houses to the west of old State House elevated tank.
- Check and comment on the actual desalination capacities at Aiwo and Meneng to assess if they are similar to the approximate 83% and 17% of Nauru's water demand in the proposed Aiwo and Meneng bulk supply systems.

Water Storage Facilities

i. Existing Usable Water Storage Facilities

Comments:

- Comments made about the large steel tanks B10 and B13 have several errors. Firstly, the NWSMP states their capacities as 4 ML in this and other sections when they are nominally 4.5 ML (refer to section 0). Secondly, it is stated that "A proposed contract is being let to demolish Tank B13 and this tank base will be available for an additional tank in future. Tank B10 is still in service however it is showing signs of corrosion although the full extent of the corrosion couldn't be ascertained without an internal inspection". By contrast, NUC (2018) states "The B13 steel water storage tank was inspected for structural integrity. The operating life of the tank was estimated to be 5 years. The neighbouring tank B10 was demolished to make way for a new tank to be installed in the near future." Recent information supplied by DCIE to SPC states that a new 3 ML tank is to be installed at the former B10 site.
- It is suggested that the headings for sub-sections (a), (b) and (c) and Figure 31 all use the word "tanks" rather than "tank site" for (a) and "reservoirs" for the other items. This would make the terminology consistent with the word "tanks" in this section. The headings would then read "(a) B10 and B13 steel tanks". "(b) Command Ridge concrete tanks" and "(c) Old Golf Course concrete tanks". Similar changes should be made to other sections in the NWSMP.
- The comments regarding possible future use of the Command Ridge concrete tanks sound reasonable, noting especially that a structural condition assessment is required.
- It would help if capacities of the three concrete tanks at Command Ridge and the six Golf Course (C7-C12) concrete tanks are provided in this section. The combined capacity of the Command Ridge tanks is shown as 1.2 ML (i.e. 0.4 ML each) in section 6.3.2. The capacity of each of the C7-C12 tanks is presumably the same as each of the C1-C6 tanks i.e. 270 kL (refer section 0) giving a total capacity for these six tanks of about 1.6 ML.
- The proposed use of the Golf Course tanks by the Fire Department is reasonable. It is mentioned that these could be filled by rainwater collected from a (roofed) superstructure. During the BPC period, these tanks were fed by overflow pipes from rainwater tanks in the elevated 'Settlement' area (SOPAC, 2010). Before these tanks are possibly used, they would need to be checked for structural integrity and most probably fitted with liners to prevent leakage (as for tanks C1-C6).
- There are several spelling errors and incorrect words used in the paragraphs below Figures 29 and 30 which need to be corrected. Similar corrections should be made elsewhere in the NWSMP, as mentioned in Annex A.

- The first sentence below Figure 31 is hard to comprehend. The words "….appear to be fair condition which has been assisted by the concrete roof being along with the walls which would strengthen the structure" needs clarifying.
- It is noted that the six 270 kL concrete tanks C1-C6 at the Aiwo desalination facility are not mentioned in this section. These are used to temporarily store the desalinated water. Recent information supplied by DCIE to SPC indicates that these tanks were recently fitted with liners and all are operational.

Recommendations:

- Change the capacities of the large steel tanks from 4 ML to 4.5 ML in this and other sections of the NWSMP.
- Correct the information about the B10 and B13 tanks i.e. that B13 is still in operation and a new 3 ML tank is yet to be installed at the former B10 site.
- Use the word "tanks" rather than "reservoirs" in the sub-headings and Figure 31 for consistency of terminology use in this section and make similar changes in other sections.
- Provide the capacities of the three Command Ridge and six Golf Course (C7-C12) concrete tanks.
- Correct spelling errors / incorrect words in the paragraphs below Figures 29 and 30 (and make similar corrections elsewhere in the NWSMP).
- Clarify the first sentence below Figure 31 about the condition of the concrete tanks at the Golf Course.
- Add comments regarding Golf Course tanks C7-C12 about the need to check for structural integrity and whether liners may be required to prevent leakage.
- Update this section regarding the six concrete storage tanks C1-C6 at the Aiwo desalination facility that have recently been fitted with liners and all are operational.

ii. Bulk Water Supply Demands by Reservoir

Comments:

- The header has 2025 twice rather than 2025 and 2035. In any case, this should be updated to 2030 and 2040 or later, as previously mentioned.
- The third dot point on page 48 mentions "…Nauru's past study recommending a total of approximately 14 days storage across the island". This "past study" should be identified and added to a References section. It is noted that 20 days is mentioned in other reports including WHO (2001) and NEISIP (2011b).
- The fifth dot point has several errors and needs to be updated. "Tank 10" should be "Tank B10". Also, the statement "Tank B10 will no longer be serviceable in 2025 and 2035" should refer to Tank B13. The assumption that both tanks B10 and B13 will be replaced with 4 ML tanks needs to be reassessed. Recent information supplied by DCIE to SPC indicates that (a) tank B10 has been demolished and is yet to be replaced by a 3 ML tank at the same site and that (b) the current tank B13 has a current safe fill level equivalent to about 3.1 ML.
- It is not clear why early model results using storage tanks at both Ewa (later deleted) and Anetan shown in Tables 10 and 11 (and in other parts of the report) before the final model results are presented in section 6. Despite the comments in the second (bold) paragraph under Table 10, it seems unnecessary to show these earlier results which just take up extra space in the NWSMP.
- Daily demands in Tables 10 and 11 and the text below both tables including the Meneng desalination and storage capacities should be revised using current information.

- Revise the Menen Hotel storage capacity (shown as 1.2 ML in two places) and the desalination capacity (shown as 0.6 ML/day but de-rated to 0.45 ML/day) based on current information.
- Providing additional storage near the B10 and B13 tank sites to meet the 14 days national storage objective rather than at other sites is reasonable.

Recommendations:

- Change the heading from "2025 and 2025" to 2030 and 2040 or later, as previously mentioned.
- Identify the "past study recommending a total of approximately 14 days storage across the island"" and add it to a References section.
- Correct errors regarding tank B10 at Aiwo.
- Reassess the assumption that both tanks B10 and B13 will be replaced with 4 ML tanks based on current information.
- Rewrite this and other sections (including tables and figures) to show the final modelling results with only the Anetan tank rather than tanks at both Ewa and Anetan in earlier modelling (which can be discussed briefly in the NWSMP).
- Revise Tables 10 and 11 and the text below both tables using current information.

Proposed Bulk Water Supply Solution

iii. Proposed Water Storage Reservoir Locations

Comments:

- The list of key objectives regarding reservoir (or "tank") locations are considered appropriate.
- Regarding the 3rd point ("Past water infrastructure previously constructed at the location to reduce potential land ownership issues"), a significant land ownership issue may arise especially regarding new pipelines in addition to tanks. This is not mentioned in this section.

(a) Tank B10 and B13 site

- Figure 32 needs to be updated to reflect the actual situation regarding tanks B10 and B13 (refer to previous comments about these tanks in section ii).
- The paragraph below Figure 32 is incorrect as demolition relates to tank B10 and not tank B13.
- The paragraph below Figure 32 also mentions that "US Aid is funding the construction of a new 4 ML tank adjacent to the two 4 ML tanks". However, recent information obtained from DCIE by SPC does not mention a new USAid funded tank but rather a 3 ML tank which is yet to be installed at the former B10 tank site.
- The comments regarding B10 in the second paragraph below Figure 32 are again in error.

(b) "Topside" Reservoir Locations

- The comments and Figure 3 re the "Topside Ridge" tanks regarding elevation of 35 m to supply consumers at an elevation of about 8 m, shows a maximum static pressure of about 27 m which is an acceptable pressure i.e. not too high or low (refer to section 0 of this report).

(c) Command Ridge Reservoir Locations

- The use of the three Command Ridge tanks at an elevation of about 65 m to supply the higher elevation connections and the proposed Anetan tank seems reasonable. This assumes that the Command Ridge tanks can be refurbished.
- However, the use of the Command Ridge tanks to supply Buada residents would result in water pressures above 50 m and would need to be controlled. This could be done with either a break

pressure tank or pressure reducing valve to ensure the pressure at Buada connections are not greater than the proposed maximum pressure of 30 m (refer section 0).

- Reference to the Ewa tank should be deleted as it is not part of the proposed design.

(d) Ewa Reservoir

- This sub-section about the originally proposed Ewa reservoir/tank site, including uncertainty about its elevation, can be deleted as it no longer relevant to the proposed storage solution in the northern part of the island.

(e) Anetan Reservoir and

(f) Meneng Reservoir (Hill behind Hotel near Digicel Tower)

- These sub-sections about the Anetan and Meneng reservoir / tank sites, respectively, note there are problems to resolve regarding the site elevations. It is agreed that the GIS data is most likely be more accurate than the Google Earth elevations (which are often not correct).
- Figure 37 (Proposed Location of Anetan Reservoir) mentions a Digicel tower at its base and a Telecom tower next to the actual site for the Anetan tank. This needs correcting.
- From viewing Figure 8 (Map showing Fourteen Districts in Nauru) and Figure 37 of the NWSMP and Google Maps, which shows the district boundaries, it appears that the Digicel tower and hence the proposed "Anetan" tanks may be in Anabar district. This should be checked and if the tanks are found to be in Anabar district, change all relevant text, figures and tables from Anetan to Anabar.

(g) Old State House Elevated Tank (Meneng District)

- This sub-section about the elevated tank at the old State House site in the Meneng district refers to a 12 m high tankstand yet Figure 39 (Proposed Old State House Elevated Tank Location) refers to a 10 m high tankstand. This needs correcting.
- The capacity of the tank proposed for the elevated tank at the old State House site is 0.2 ML (i.e. 200 tonnes of water). This would require a very robust and expensive tankstand. Another option using a ground level 0.2 ML storage with smaller elevated tank (say 10 – 20 kL), transfer pump and water level controls should be considered as a cheaper alternative.

Recommendations:

- Modify the third objective to recognise that pipelines to and from tanks, especially regarding new tanks, are potentially a significant land ownership issue as well as the tanks themselves.
- Modify Figure 32 to reflect actual situation regarding tanks B10 and B13.
- Revise paragraph under Figure 32 as demolition relates to tank B10 and not tank B13.
- Clarify and update, as necessary, the paragraph below Figure 32 regarding a (possible) 4 ML USAid funded tank near tank B10 and tank B13.
- Correct errors regarding Tank B10.
- Change storage capacity from 4 ML to 4.5 ML for the large steel tanks in this and subsequent sections, as previously mentioned.
- Update the section to outline the preferred measure to control the maximum pressure to Buada residents at 30 m rather than 50 m.
- Delete references to a potential Ewa tank/reservoir including all of sub-section (d).
- Correct Figure 37 (Proposed Location of Anetan Reservoir) regarding the proposed site for Anetan tanks/reservoirs by changing Telecom tower to Digicel tower.

- Check the proposed location of the Anetan tanks/reservoirs near the Digicel tower and confirm whether these tanks would be in Anetan or Anabar district. If they are found to be in Anabar district, change all relevant text, figures and tables from Anetan to Anabar.
- Correct Figure 39 (Proposed Old State House Elevated Tank Location) and associated text regarding the height of the proposed tankstand at the old State House site in the Meneng district.
- Consider another option to the proposed 0.2 ML elevated tank at the old State House site consisting of a ground level storage tank, smaller elevated tank, transfer pump and water level control system.

iv. High Elevation Areas Supply Arrangements

Comments:

6.4.2.1 "Topside" – Aiwo District

- The NWSMP has adopted the term "Topside" to refer to the higher elevation houses in the Aiwo and Denigomodu districts. This is confusing as "Topside" commonly refers to the central part of Nauru with the term "Bottomside" used for the lower coastal area. It is recommended that a different term be used to refer to the higher elevation areas of Aiwo and Denigomodu district in this section and elsewhere in the NWSMP.
- The title of section 6.4.2.1 should include the Denigomodu district.
- Reference to "Ewa res" in Figure 40 should be deleted as it is not part of the proposed design.

6.4.2.2 High Ground - Top of Hill (Nibok, Uaboe, Baitsi and Ewa Districts)

- The proposed single connection to the bulk transmission pipeline to supply higher elevation houses between Nibok and Ewa districts is an appropriate solution.
- Several spelling errors or incorrect words in this sub-section should be corrected.

6.4.2.3 High Ground – Meneng District

- The selection of Option 1 (800 m long gravity pipeline from the elevated tank at the old State House site) to supply the cluster of houses near the western side of the Meneng district is appropriate provided that land ownership issues can be resolved if they arise.

6.4.2.4 High Ground – Ijuw District

- The proposed solution for the two housing clusters in the Ijuw district using water from the main transmission (ring) main to feed small storage tanks and mini-pump stations and then pump to elevated tanks at these clusters is appropriate.

6.4.2.5 Possible Additional High Ground Settlements

- The design philosophy to limit pumping as far as possible for any future "high ground" locations is appropriate.

Recommendations:

- Use a different term than "Topside" to refer to the higher elevation houses in the Aiwo and Denigomodu districts in this section and elsewhere in the NWSMP.
- Change the title for sub-section 6.4.2.1 to include the Denigomodu district
- Remove "Ewa Res" from Figure 40.
- Correct several spelling errors / incorrect words in sub-section 6.4.2.2.

Water Reticulation Considerations

Comments:

(a) Ring main

- The use of a ring main around the island is appropriate provided that land ownership issues can be resolved if they arise.

(b) Minimum Mains Size

- The adoption of a minimum main pipe diameter of 90 mm for MDPE pipes rather than 100 mm is appropriate.

(c) Uniform Pipe Material Selection

- The proposed use of only two pipe materials i.e. MDPE in most places and DICL for rough and above-ground locations is appropriate,

(d) House Service Connections

- Again, the proposed use of MDPE pipe is appropriate.
- The proposed installation of flow meters and stop cocks (valves) at connections is considered appropriate and necessary for a piped supply system, especially one using desalinated water.
- The proposed installation of additional stop cocks (valves) at rainwater tanks to enable them to be periodically filled with desalinated water has disadvantages and advantages. It may lead to supply problems if many consumers are filling household rainwater tanks at the same time. However, having desalinated water supplying these household tanks when rainwater is not available adds to the security of water supply in the event of pipe failure or desalinated production problems. On balance, it is best to enable the rainwater tanks to be filled from the pipe system and hence the installation of additional valves at the rainwater tanks is supported.

Network Modelling and Hydraulic Analysis

v. Introduction and

vi. Model Construction

Comments:

- The 2035 demand projections should be updated to 2040 or later depending on when improvements are likely to commence.
- The use of a 10 day simulation period for the network modelling (using WaterGEMS software by Bentley) is appropriate.
- Figure 43 (The Original 2035 schematic on which system analysis was based) includes the Ewa reservoir which was later removed. This figure and associated text could be deleted as Figure 107 (Final 2025 Phase 1 Water Supply Schematic) and 108 (Final 2035 Phase 1 Plus Phase 2 Water Supply Schematic) cover the proposed systems.
- Table 12 (2035 Water Demand by District), Table 13 (2035 Water Demand by District and Demand Type) and associated text should be updated with 2040 (or later) rather than 2035 water demands.
- The detailed description of the model and data seems reasonable and appropriate. Most of the details including many of the screen images could be moved to an Appendix.
- At the base of page 68, the comment is made “Figure 45 shows an early version of the pipework with a route serving the mining buildings in the centre of the island.” However, Figure 45 shows “Demand seed points and elevation contours”. A figure showing this “early version of the

pipework" could not be found. This sentence should be updated and the correct Figure 45 inserted.

- The domestic demand pattern shown in Figure 47 with highest peak at about 8 am and a secondary peak at about 6:30 pm -7 pm looks reasonable.
- The selected images in Figures 48 to 59 and associated text in sections 6.6.2.6 to 6.6.2.15 look reasonable. It is noted that the modelling results cannot be described or assessed in detail within a written document.
- Figure 60 in section 6.6.2.13 shows the proposed pipe network and zones. The light green line showing the proposed gravity transmission pipeline from the Command Ridge tanks to the proposed Anetan (or Anabar?) tank next to the Digicel tower, would have followed the Topside road from the Command Ridge tanks to south of Capelle Hotel in the Ewa district. As there is no road from there through the pinnacles ('karrenfeld') across to the Anetan tank site (a distance of about one kilometre), the NWSMP assumes either the pipeline would be laid on the ground through the pinnacles or a road would be constructed to enable the pipeline to be laid to the side of it. In addition, since the NWSMP was prepared in early 2017, part of the former Topside road has been dug out during mining operations in the Ewa district (based on the most recent Google Earth image from 27 July 2019). The mining of this road could have extended further southwest in the past year or so. This presents a problem for pipe laying along the proposed route shown by the light green line. This matter should be further investigated and a revised network model be developed based on a revised pipeline route to the proposed Anetan (or Anabar) tank in Figure 60.
- At present, the network does not include facilities in Topside including the workshop and RPCs.

Recommendations:

- Redo the hydraulic modelling using 2040 or later demand projections rather than those for 2035 and update the NWSMP accordingly.
- Remove Figure 43 and associated text.
- Update Tables 12 and13 and associated text to 2040 (or later).
- Consider moving most of the hydraulic model details including many of the screen images to an Appendix.
- Update the sentence at the base of page 68 and include correct Figure 45.
- Investigate alternative route option(s) for the proposed gravity transmission pipeline from the Command Ridge tanks to the proposed Anetan (or Anabar) tank given that the road through the Topside area does not run the full length between these sites and part of this road has been dug out during mining operations since the NWSMP was produced in 2017.
- Consider extending the pipe network to include the facilities in Topside.
- Revise the network model, Figure 60 and other relevant parts of the NWSMP based on the above-mentioned investigation.

vii. System Design Criteria

Comments:

- A maximum system pressure of 50 m was adopted. As mentioned in section 0, the maximum pressure of 50 m is considered too high and 30 m should be adopted.
- A minimum system pressure of 10 m was adopted. As mentioned in section 0, the minimum pressure could be reduced to 5 m.

- As previously mentioned, the design should be for flows for 2040 (or later) rather than flows for 2035.
- The selection of 12 and 18 hours to deliver a day's supply of water for pumped and gravity transmission pipelines is reasonable, as previously mentioned in section 0.
- Pipe materials are again outlined and the use of MDPE in all but steep slopes, where DICL pipes would be used, is appropriate.
- Use of a Hazen Williams roughness value of 130 for all pipework is appropriate.
- The selection of pipe diameters of 90, 125, 160, 180 and 315 mm sounds reasonable. These diameters are in fact for the MDPE pipes as later indicated in Table 17, section 6.6.6. The DICL pipe diameters in Table 17 are 75, 100, 150 and 250 mm.

Recommendations:

- Reduce the maximum design pressure from 50 m to 30 m for any possible reticulation system.
- Reduce the minimum design pressure from 10 m to 5 m for any possible reticulation system.
- Redo the hydraulic modelling using 2040 or later demand projections rather than those for 2035 and update the NWSMP, as previously mentioned.

viii. Network Analysis and System Performance

Comments:

- As a new 3 ML tank is to be installed at the former B10 tank site, the water levels in the network model may need to be changed depending on its height.
- The selected images in Figures 64 to 86 and associated text in section 6.6.4.2 provide a good insight into the operation of the various components of the network over the selected time period.
- Figure 87 (Pressures at 8 am peak flow on day 1), Figure 88 (Pressures at 3 am low flow on day 10) and Figure 89 (HGL at 8 am peak flow on day 1) show pipe pressures are between 10 m and 50 m. As previously mentioned, the minimum and maximum pressures should be revised to 5 m and 30 m.
- Figure 90 (Pipe velocities at 8 am peak flow on day 1) show maximum flow velocity as 1.11 m/s which is a good result being below the maximum design flow velocity of 2.5 m/s, as per section 5.1.

Recommendations:

- Check and, if necessary, change water level at the former B10 tank site in the network model based on the height of the 3 ML water tank (yet to be installed).
- Revise the network design and redo modelling with minimum and maximum pressures set at 5 m and 30 m, respectively.

ix. Pipework and Pumping Requirements

Comments:

- Table 17 provides a good summary of the pipe lengths required by zone, diameter and material. The total length of pipes with diameters between 90 mm and 315 mm is about 56.5 km. This may need to be modified especially in relation to the proposed 5.6 km 160 mm diameter pipeline from the Command Ridge tanks to the proposed Anetan (o Anabar) tank.
- Customer connection pipework requirements were estimated based on two samples of the network in (a) the northwest part of the island and (b) southwest of the airport. A total of about

51 km of connection pipes would be required based on the current 1,700 connections and an average length of 30 m per connection. This is a reasonable assumption.

- The pump duty flows and heads, efficiency assumptions and power requirements for the five main pump stations in Table 18 look reasonable.

Recommendations:

- Check and, if necessary, change the pipe details in Table 17, especially in relation to the proposed pipeline from the Command Ridge tanks to the proposed Anetan (or Anabar) tank.

Summary of Water Supply Proposed Works & Timing

Comments:

- Two phases of works are proposed with Phase 1 for immediate implementation using 2025 water demand projections and Phase 2 for implementation in 2025 using 2035 water demand projections. If the project goes ahead, the timings of the two phases should be revised using water demand projections for 2030 and 2040 (or later).
- Tables 19 to 22 show the proposed work / augmentations for (a) desalination plants, (b) water storages, (c) bulk water supply pipelines and pump stations and (d) water supply reticulation. Many of the years of augmentation are shown as 2016. Below Table 22 an explanation is given: "the year 2016 has been entered to identify that it is an immediate need and year 2016 should be targeted". However, this is difficult to understand given that the NWSMP was produced in 2017. These tables should be updated.
- Reference to the Ewa reservoir in Table 20 should be deleted as it is no longer relevant.

Recommendations:

- Revise the timings of the two implementation phases using water demand projections for 2030 and 2040 (or later)
- Update Tables 19 to 22 with revised years for "Year of Augmentation", noting many are shown as 2016 (before the Master Plan was produced).
- Delete reference to Ewa reservoir in Table 20.

7. Sewerage Analysis and Planning

Background

Comments:

- As previously mentioned, the current sanitation / sewerage system consists of septic tanks and cesspits at houses/buildings with intermittent pump-outs and disposal. The NWSMP states that the sewage disposal on the island is in a state of disrepair and is in need of urgent action.
- The 2015 Status Report (NRW, 2015) recommended immediate actions including:
    - Immediate repairs to the municipal sewage treatment plant (STP) adjacent to the Nauru Primary School.
    - No further use of the cesspit at the school and connecting to the above STP.
    - Use of existing ocean outfalls (with screening) on the outgoing tide for septic tank disposal rather than continued disposal at the above STP leading to overloading and disposal of effluent to the ground with subsequent groundwater contamination.
- The NWSMP needs to be updated to reflect the current status of sewage treatment and disposal on the island including at the RPCs. At the time of the Status Report and the NWSMP (2015-

2017), the option of using the STPs at the RPCs in Topside was considered "unlikely as their plants would similarly be overloaded however they may agree to accept some sewage".

- Since no one is living at the RPCs as of July 2020 (refer section 4.i), the situation regarding the STPs at the RPCs has presumably changed considerably since 2017.
- Recent information obtained from DCIE and NUC by SPC indicates a number of changes since 2017 including:
  - An STP with tertiary treatment is now in operation at the RoN Hospital and the treated effluent is discharged into the stormwater system and subsequently discharged to the ocean.
  - A new STP at the Nauru Primary School, when commissioned, will dispose of treated effluent to land.

Recommendation:

- Update this section regarding the current status of STPs at the Nauru Primary School, the RoN Hospital and the RPCs, and the current methods for disposal of septic tank sludge on the island.

Sewage Demand and Design Criteria

Comments:

- The first paragraph states that "all water used by households including rainwater, groundwater and desalinated water will all leave the house and pass to the sewerage system". This is not correct when some households use freshwater or grey water for outside use e.g. plant watering. Also, leaks in household plumbing in some households means less water than enters the house is potentially discharged to a sewerage system.
- The second and third paragraphs make the assumption that the per capita demand for water, estimated at 110 Lpd, will include the allowance for non-revenue water (shown as 20 Lpd and expressed as 20% of water demand in section 4.2.3 of the NWSMP but recommended to be 30% in section 4.iii of this review report). However, it is not correct to assume that the per capita demand increases beyond 110 Lpd and somehow makes the non-revenue water allowance available for use within the houses. The use of 130 Lpd for estimating per capita sewage flows is considered too high and a maximum of 110 Lpd should be used.

Recommendation:

- Revise the statement that all water used by households will enter the sewerage system.
- Revise the per capita sewage flow from 130 Lpd to a maximum of 110 Lpd.

Sewage Collection Systems and Comparisons

Comment:

- Five "main possible collection systems" are considered in the NWSMP, as outlined below.

i. Septic Tanks and Common Effluent Disposal (CED)

Comments:

(a) Septic Tanks

- The NWSMP correctly points out that (a) septic tanks need to be inspected to ensure they are operating correctly and, if not, replaced, and (b) cess pits require removal and replacement with septic tanks and that their contents should be removed and suitably treated and disposed.

- The NWSMP mentions the advantages of septic tanks are familiar technology and low cost and the disadvantages are that many of these leak and the sludge needs to be periodically cleaned out.
- There is an inconsistency between the words in this section i.e. "advantages of septic tank use at Nauru is that they already exist on site at nearly all houses and although a large number are reportedly damaged or leaking, it is likely that a large number would still be in satisfactory condition." and the words in section 8.1 i.e. "it is expected that due to the reported poor condition of existing septic tanks, use of cesspits or complete absence of an existing septic tank, most households will require a new septic tank to be installed."

(b) Common Effluent Disposal (CED)

- The NWSMP outlines the advantages of a Common Effluent Disposal (CED) system using a small bore gravity pipe system over a conventional sewerage system including:
    - Smaller diameter pipes (minimum of 80 mm rather than 100 mm) and lower pipe gradients owing to effluent only being discharged.
    - No requirements for straight, uniform gradient pipe systems.
    - Use of water pumps rather than more expensive sewage pumps which are required where solids are discharged in conventional sewerage systems.
    - The effluent can be disposed of to land by irrigation or to the ocean via outfalls.

Recommendation:

- Correct the inconsistency between this section and section 8.1 about the extent of septic tanks that leak and need replacement.

ii. Household (Mini) On-Site Treatment Systems

Comments:

- The NWSMP outlines (a) the advantage of these mini wastewater treatment plants for either a single household or a cluster of households as better effluent quality than from septic tanks, and (b) the disadvantages are higher operation and maintenance (O&M) requirements and costs, the requirement (as for standard septic tanks) for disposal of the treated effluent in a suitable location and the system reverting to a poorly functioning septic tank in the event of electrical or mechanical failures.
- Although not mentioned in the NWSMP for this option, the treated effluent could also be disposed to the ocean via outfall(s) as with the CED option.

iii. Grinder Pump Collection Systems

Comments:

- The NWSMP explains that grinder pumps could be fitted to existing septic tanks or small tanks where septic tanks are not present.
- The advantages are that solids can be ground (macerated) and fed into a small diameter sewer connection to a conventional pump station and then to a STP. Disadvantages are the need for each house to have a grinder pump and power supply to it, high capital and O&M costs and potential overflows in houses if grinder pump failures are not repaired in a timely manner. Another potential disadvantage is the issue of responsibility for remedial action (households or NUC).

iv. Vacuum Sewerage Collection System

Comments:

- With a vacuum sewerage collection system, sewage from several properties flows under gravity to vacuum collection pits from where it is transported via pipeline under vacuum to a pressure vessel and then to a conventional pump station and STP.
- The advantages of a vacuum sewerage system is that the system can be installed in relatively shallow trenches. However, the disadvantages are complexity, the need for regular maintenance and the need for specialist O&M skills.

v. Conventional Gravity Sewerage Collection System

Comments:

- This type of system allows sewage (liquid and solids) to drain under gravity via 100 mm and larger pipes laid at gradients which enable sufficient velocities to prevent deposition of solids. Sewage pumping stations are required where gravity flow is not possible. The sewage can be discharged, as with other options, to a central STP (or several STPs) and thence to land or ocean via outfall(s).
- Advantages of this system are generally low maintenance and any sewage overflows occur at localised points (sewage pump stations or access holes) rather than at households. A disadvantage is that the flat Nauru coastal margin can limit its appropriateness.

vi. Comparison of Options

Comments:

- Table 23 and the text below it presents a good comparison of the five options with more detailed lists of advantages and disadvantages than in the preceding sub-sections.
- One important and potential problem which is not mentioned in the disadvantages is land ownership issues preventing the laying of pipes through private property.
- The five criteria used to assess the five options under Table 23 are considered appropriate.
- The conclusion that the 2nd, 3rd and 4th options (i.e. Household On-Site Treatment Systems, Grinder Pump Collection Systems and Vacuum Sewerage Systems) are unsuitable for a number of reasons is supported in this review.
- The 5th option (Conventional Gravity Sewerage Collection System) was considered reasonable in the NWSMP but was rejected because deep trenching to a maximum depth of 3 m and additional pump stations would be required owing to the need for the gravity pipes to be straight and at a constant gradient. A further possible problem mentioned in the NWSMP was encountering limestone pinnacles during excavation which would make the construction work very difficult and expensive.
- There is the possible presence of limestone pinnacles in the coastal margin and the low lying Buada lagoon area where most sewerage pipes would be laid. However, it is pertinent to note that no hard limestone (pinnacles or other) was encountered in the top 3-5 m of sediments in most boreholes drilled in the coastal margin and the low-lying Buada lagoon area in 2008-2009. These boreholes were drilled to various depths for groundwater salinity and pollution investigations and for obtaining groundwater for toilet flushing. From drilling logs for the 34 boreholes drilled in the coastal margin and the Buada lagoon area, 31 (91%) did not intersect hard limestone in the top 3 m of sediments. The three boreholes that did show hard limestone were located in Anetan, Anibare and Buada districts. Analysis of any other geotechnical information about the top 3 m of sediments in the coastal margin and the Buada lagoon area is recommended.

- It is noted that conventional gravity sewerage systems with multiple pump stations and ocean outfalls have been operating on South Tarawa in Kiribati and on Majuro and Ebeye in the Marshall Islands for many years. These systems have all been installed on atoll islands where the predominant sediments in which the sewer pipes have been laid are unconsolidated sands and gravels.
- The adoption of the 1st option (Septic Tanks and Common Effluent Disposal) in the NWSMP is considered reasonable but has the obvious disadvantage that desludging of septic tanks will need to continue into the future. However, it is considered in this review report that there is not enough evidence to reject the 5th option (Conventional Gravity Sewerage System) from further consideration. This system is considered further in section 0 of this review report.
- The installation of any piped sewerage system(s) will depend on whether or not land ownership issues prevent the laying of sewer pipes. If such issues arise, then a further option involving improved septic tanks and improved on-site disposal via effluent disposal pipes or beds will need to be considered. This method has been proposed for Kiritimati (Island) in Kiribati (Falkland and White, 2008) although other methods are currently being considered.

Recommendations:

- Install a piped sewerage system (or systems) provided land ownership issues can be resolved if they arise.
- Further consider the installation of a Conventional Gravity Sewerage System rather than the Septic Tanks and Common Effluent Disposal System based on available evidence of the type of sediments, particularly in the coastal margin where most sewerage pipes would be laid.
- Consider alternatives to a piped sewerage system if land ownership issues prevent these from being implemented. One alternative is to install improved septic tanks and improved on-site disposal via effluent disposal pipes or beds.

Proposed Sewage Collection System

Comment:

- The proposed sewage system for collection and conveyance is septic tanks and a Common Effluent Disposal system.

vii. Septic tanks

Comments:

- The recommendation in the NWSMP to use double chamber septic tanks for Nauru is supported.
- As mentioned in section 0 of this review report, the use of 130 Lpd for estimating per capita sewage flows is considered too high and a maximum of 110 Lpd should be adopted.
- Further, to relieve the hydraulic load on the septic tanks, some of the wastewater from houses could bypass and enter the pipe system "downstream" of the septic tank. It is important that all highly polluted "blackwater" from toilets and probably from kitchens passes through the septic tanks but much less polluted "greywater" from bathrooms and laundries could bypass the septic tanks. This concept should be considered further especially if an STP is (or STPs are) to be installed. Using this concept, the estimated per capita flow through a septic tank would be approximately 40% of the 110 Lpd or 44 Lpd (which could be rounded to 45 Lpd). The 40% is based on the percentages of 26% for toilet flushing and 13% for kitchen use in Table 4 of the NWSMP which add to 39% (close to 40%). The remaining 60% of the 110 Lpd (approximately 65 Lpd) per capita flow would bypass the septic tank and join the sewer pipe downstream of it. A small pit with mesh screen could be installed on the greywater pipe to collect any objects that may enter this pipe system.

- The use of polymer septic tanks as shown in Figure 96 rather than the conventional septic tank using concrete blocks mortared together as shown in Figure 95 is fully supported. In addition to the advantage of transport cost savings as they are lightweight and can be stacked to reduce shipping volumes, as indicated in the NWSMP, is the even more important advantage that they do not leak. Experience with concrete block type septic tanks in Pacific Islands including Nauru is that they often leak due to cracks caused by poor construction which enable entry of roots from nearby trees.
- Regarding capacities of septic tanks, calculations for 6-8 people are shown in the NWSMP which indicate a 2,500 L polymer septic tank would be adequate. The company indicated in Figure 96 (Everhard) also make 3,000 L and 4,000 L septic tanks which would be more suitable for large households, offices and other buildings. Regarding populations per household, it is noted that Table 35 of the 2011 Census shows that 41% of households had greater than 8 people and nearly 10% had more than 15 people.
- It is also noted in this review that other sources of polymer septic tanks are available including Rotomould (based in Fiji and some other PICs).

Recommendations:

- Revise the per capita sewage flow from 130 Lpd to a maximum of 110 Lpd, as mentioned in section 0.
- Consider bypassing septic tanks for "greywater" from bathrooms and laundries while ensuring all "blackwater" from toilets and probably kitchens passes through septic tanks to relieve the hydraulic load on septic tanks.
- Provide a recommendation in the NWSMP that double chamber polymer septic tanks be used for all new and replacement installations on Nauru.
- Revise this section to mention that polymer septic tanks larger than 2,500 L (e.g. 3,000 L and 4,000 L) should be used for large households.

viii. Common Effluent Disposal (CED) System Details

Comments:

- The details provided in the NWSMP including recommended minimum gradients for typical pipe diameters (100, 150 and 225 mm), small access points and no necessity for straight alignment and uniform gradients are all clear and reasonable.
- Other comments related to lower inflow and infiltration and the reduced sewage treatment requirements than in conventional gravity sewerage systems are also clear. However, inflow and infiltration can be controlled well in the latter type of system if polymer access chambers with tightly fitting lids are used rather than concrete ones, as mentioned in the NWSMP.

ix. Typical Design of CED System

Comments:

(a) Flow (to the sewer system)

- The design flow parameters used in the example need to be revised. The first paragraph states "If we use the worst case scenario of 8 persons per household generating 130 L of wastewater each per day then the total flow into the household's septic tank will be 1,040 L/day which will displace a similar amount into the CED sewer." The assumption of the worst case scenario being 8 persons per household is not consistent with the 2011 Census (RoN, 2011a). As mentioned previously, Table 35 of this census shows that 41% of households had greater than 8 people and nearly 10% had more than 15 people. Also, and as previously mentioned, the maximum design inflow to the sewer system (whether or not all or part of this inflow is from the septic tank) should be set at 110 Lpd rather than 130 Lpd. If 15 people and 110 Lpd are used as the design parameters for a "worst case scenario" for a household, the total inflow from the household to the sewer system would be 1,650 L/day. This daily inflow is nearly 60% greater than the 1,040 Lpd shown in the NWSMP.

- The assumption that the "average inflow" to the sewer system occurs over 6 hours and not 24 hours needs revising. The word "average" should be changed to "total". Also, what is the basis for assuming this inflow would occur over 6 hours? Assuming that all the inflow does in fact occur evenly over 6 hours, then the flow rate to the sewer system, based on 110 Lpd rather than 130 Lpd and 15 rather than 8 people would be approximately 0.075 L/s rather than 0.05 L/s as shown in the NWSMP.
- Based on the revised "worst case scenario" flow to the sewer system, the number of similar size households that can be connected to 100 mm and 150 mm sewer pipes laid at the recommended minimum grades would be, respectively, approximately 50 rather than 80 and 125 rather than 200. However, as not all households in a cluster of 80 to 125 would have 15 people, the actual number of household septic tanks that could be connected to 100 mm and 150 mm sewers is likely to be somewhere between the estimates above. The calculations should be revised on the basis of an average household flow for a cluster of houses rather than for an individual house.

(b) Design constraints

- The assumed outflow pipe depths of 0.5 m at septic tanks and maximum sewer depths of 3 m sound reasonable, although trenching to 3 m may be very difficult in the sandy coastal conditions especially close to existing roads. A revised maximum depth (e.g. 2.5 m) may have to be adopted based on local conditions.
- For the selected area in Baitsi and Uaboe districts, the distance calculation to the (first) submersible pump station of 625 m for a 100 mm diameter sewer at 0.4% grade would need to be revised to 500 m if the maximum excavation depth was 2.5 m.
- Table 25 showing the Concept Design Results uses 0.05 L/s outflows from septic tanks to calculate the flows for each node in the right hand column. As mentioned above, 0.05 L/s may be too low and should be based on a revised average household flow for a cluster of houses.
- The proposed fibreglass pumping (lift) station and associated details in Figures 99 and 100 are considered appropriate.
- The calculations for the selected area in Baitsi and Uaboe districts show the average cost per household connection as about $5,000. This includes the costs of the 100 mm and 150 mm sewer pipelines, access chamber and a pump station.
- Added to the $5,000 above is the cost of installing new septic tanks at an average cost of $4,000. It is assumed that this average cost is for polymer septic tanks. This needs to be checked and the average costs need to be based on a range of septic tank capacities to suit households with larger than 8 people and also for other connections (e.g. offices, workshops).
- The discussion and calculations shown in section ix(a) and (b) are for Baitsi and Uaboe districts which represent a relatively small area of Nauru. There is no discussion about the design of the sewerage system including pipe diameters required to cope with the sewage effluent flows from all districts of Nauru, especially when it is assumed in the NWSMP that all effluent will be piped to one STP (at Location).
- There is also no discussion about the proposed sewerage system in parts of the island not in the coastal margin. These include the houses in the Buada district and the workshops and RPCs in Topside. The main question is whether some or all of these will become part of the island's

piped sewerage system. A revised version of the NWSMP should outline what is proposed for these locations.

Recommendations:

- Change the "worst case scenario" per capita flow for a single household to the sewer system from 1,040 L/day to 1,650 L/day based on 15 people and 110 Lpd.
- Change the "worst case scenario" flow rate to the sewer pipe for a single household from 0.05 L/s to 0.075 L/s.
- Check and revise, as appropriate, the number of households that could reasonably be connected to 100 mm and 150 mm sewer pipes for a "worst case scenario" for a cluster of houses rather than for an individual house.
- Revise the flows for each node in the right hand column of Table 25 based on a revised average household flow for a cluster of houses.
- Check and, if necessary, update the cost calculations for septic tanks based on capacities required for a range of household sizes and other connections.
- Include discussion about design of the sewerage system including pipe diameters required to cope with the sewage effluent flows from all districts of Nauru.
- Include discussion about the proposed design of the sewerage system not in the coastal margin including the houses in the Buada district and the workshops and RPCs in Topside.

Effluent Quality

Comments:

- The effluent quality was examined in the NWSMP as to whether it is suitable for disposal to the marine or land environment. A range of water quality parameters (dissolved oxygen, total suspended solids, pH, toxicity and micro-organisms) were discussed as to their impacts.
- Regarding toxicity, the NWSMP states "Toxic substances such as the heavy metals; Lead, Cadmium, Chromium etc. can be found in a number of modern vehicles, ships, household devices etc. Fortuitously Nauru does not have any industries that used quantities of these types of substances however lead acid batteries, chrome plated metals will be found in items placed at the Solid Waste Dump and these substances may leach into the groundwater." The sentence quoted above should be modified as cadmium is contained within the phosphate soils on Nauru and is toxic to plants and animals (Gale, 2016). This section of the NWSMP should also mention that some groundwater, particularly in Aiwo district, is contaminated with hydrocarbons (from oil and other hydrocarbon spills) as reported in a number of reports including Bouchet and Sinclair (2010). In some areas, this makes the groundwater in wells unsuitable for any purpose. Also,
- The text above Table 26 (Current Australian Guidelines on Effluent Quality) refers to "Current guidelines in Australia". These guidelines should be cited here and full reference details shown in a References section.
- The Australian and New Zealand Environment and Conservation Council guidelines which are mentioned below Table 26 on page 122 should also be cited and full details added to the References section.
- The drinking water guidelines which are also mentioned on page 122 should be cited and full details added to the References section. The latest World Health Organization guidelines for drinking water quality (WHO, 2017) are appropriate for Nauru.

- The NWSMP mentions that "Ammonia in drinking water should be restricted to below 0.5 mg/L". This is not consistent with WHO (2017, p223) which states "The threshold odour concentration of ammonia at alkaline pH is approximately 1.5 mg/l, and a taste threshold of 35 mg/l has been proposed for the ammonium cation. Ammonia is not of direct relevance to health at these levels, and no health-based guideline value has been proposed". The NWSMP should be updated based on the WHO guideline values.
- Reference to Bribie Island should have further details (e.g. Bribie Island, Queensland, Australia) as not all readers would know where it is located. Also, the method used on Bribie Island of raising the water table due to effluent disposal so as to act as a barrier to freshwater outflow to the sea and hence conserve groundwater, is not relevant to Nauru. This is because there is very little permanent fresh groundwater on Nauru. The NWSMP should be updated to reflect this.
- This section ends with the conclusion "…Class C Quality treated effluent is required for Nauru to facilitate irrigation of the effluent onto the mine rehabilitation areas. To produce the required quality effluent, a suitable sewage treatment plant is required". Treatment of the sewage to Class C quality so that it could possibly be used for irrigation in mine rehabilitation areas is considered to be a reasonable approach in theory. However, in practice, this proposed method of disposal is problematic because it (a) would involve further major infrastructure to pump the effluent into the centre of the island where the mine rehabilitation areas are located, (b) would impose additional O&M requirements and costs on NUC and presumably the Nauru Rehabilitation Corporation (NRC), and (c) could present potential health risks during effluent disposal in the mine rehabilitation areas, particularly if problems with the treatment process arise.
- The other disposal option via existing or new and extended outfalls would be a preferable option from a capital cost and O&M viewpoint. The sewage effluent could be treated to Class C quality in an STP before disposal. It is noted that the 2015 Status Report states that "There has however been a decision made in Nauru that discharge to sea is no longer permitted and therefore all sewage that is pumped out of septic tanks is now discharged into the only plant located at Nauru Primary School" (NRW, 2015, p v). The Status Report also states that "The inadequate facilities largely relate to the decision to avoid discharge of untreated water to the ocean via ocean outfalls which was the system previously adopted." (NRW, 2015, p 59). From the latter statement, it appears the decision to not permit disposal into the ocean is based on "untreated water". If the sewage effluent from septic tanks is treated in an STP, then presumably this means that ocean disposal would be permitted. It is noted that the NWSMP does not mention the decision to disallow ocean disposal via outfalls. This option needs further clarification with and consideration by the Government of Nauru. As mentioned in section vi of this review report, ocean disposal via outfalls has been practised on South Tarawa in Kiribati and Majuro and Ebeye in the Marshall Islands for many years. Further consideration of ocean outfalls is provided in section 0.
- The recommendation in this section that liquid wastes from the RoN Hospital should be treated "using modern biological treatment processes complete with appropriate disinfection" is appropriate and agreed. As mentioned in section 0 of this review report, it is understood an STP with tertiary treatment is now in operation at the RoN Hospital and the treated effluent is discharged into the stormwater system and subsequently discharged to the ocean.

Recommendations:

- Modify the section regarding toxicity to recognise that cadmium is present within the phosphate soils on Nauru and is toxic to plants and animals.
- Include comments about the hydrocarbon pollution of groundwater particularly in Aiwo district.

- Cite the following references in this section and include full details of both in a References section: (a) the reference used for Table 26 (Current Australian Guidelines on Effluent Quality), (b) the Australian and New Zealand Environment and Conservation Council guidelines mentioned on page 122, and (c) the drinking water guidelines mentioned on page 122.
- Update the ammonia value of 0.5 mg/L for drinking water quality using the latest WHO guideline values,
- Update the paragraph regarding Bribie Island by (a) explaining where it is located and (b) revising the text to recognise that Nauru has very little permanent fresh groundwater and hence the method used on Bribie Island to conserve fresh groundwater is not relevant.
- Consider the disposal of treated effluent via outfalls (either present or new and extended) to the ocean rather than the more expensive and complex option of pumping the treated effluent to mine rehabilitation areas on the island. This requires discussion with relevant GoN ministries.
- Further consider whether Class C treatment at a STP or STPs is required if sewage effluent is disposed via outfalls to the sea. This also requires discussion with relevant GoN ministries.
- Update the comments about sewage treatment for the RoN Hospital based on current status.

Sewage Treatment Options

x. Sewage Treatment Plant Options

Comment:

- Table 27 presents a good summary of the advantages and disadvantages of various sewage treatment options. The discussion below this table and the conclusion that a conventional trickling filter treatment system is the proposed method is considered reasonable and appropriate, assuming an STP (or possibly STPs) are to be included in the sanitation improvements.

xi. Preferred Treatment Process

Comments:

- This section reiterates that the wastewater flowing to the STP (or possibly STPs) will already have had primary treatment at the household septic tanks and would just need secondary treatment through the conventional trickling filter treatment system to produce the Class C effluent "required for irrigation purposes". As noted above, the Class C treated effluent could also be disposed via outfalls to the ocean.
- In addition to treatment of effluent is the need to treat the highly contaminated septic tank sludge for septic tanks. Two options are mentioned to deal with the sludge deposits: either the proposed (now actual) RoN Hospital STP or the proposed Municipal STP. It is considered in this review that the proposed Municipal STP is the preferred option as cleaning septic tanks and treating the island's septic tank sludge would be a municipal function (for NUC).
- The proposed elements of, and processes within, the STP including an anaerobic digester for the septic tank sludge are explained and shown diagrammatically in Figure 101. This is clear and appropriate.

Recommendation:

- Update this section to refer to the RoN Hospital STP as installed rather than proposed.

Treated Effluent Disposal and Irrigation

Comments:

- The only sentence in this section "The year 2035 analysis was carried out before the interim planning horizon of 2020 to ensure that the optimal size of augmentations could be determined" is out of place as it does not relate to the heading. In any case, "the interim planning horizon of 2020" and the "year 2035 analysis" should be updated.
- This section does not have a discussion including a consideration of the advantages and disadvantages of effluent disposal using irrigation which is what might be expected given the heading for this section.
- It is also noted that the other option for disposal via ocean outfall is not considered in detail in the NWSMP and there is no comparison of the two options. This is presumably because of the statements in the 2015 Status Report that ocean disposal "is no longer permitted" (refer section 0 of this review report). It is recommended that the two options be considered in detail including a table showing advantages and disadvantages in an updated version of the NWSMP taking account of practices and operational history on other small Pacific islands.
- The outfall disposal option has several advantages including much lower operational costs and maintenance requirements than land disposal in the centre of the island. This method of disposal has been successfully operating with the conventional gravity sewerage systems and without treatment on South Tarawa, Majuro and Ebeye and should be considered as the preferred option for Nauru.

Recommendations:

- Delete the only sentence in this section as it is not relevant to the heading.
- Include a table showing advantages and disadvantages regarding the two disposal methods (use of the treated effluent for irrigation and disposal via outfall(s) to the ocean) in an updated version of the NWSMP.
- Consider disposal of treated effluent via ocean outfall(s) as the preferred option for Nauru.

Sludge Management

Comments:

- Two options are presented for sludge drying i.e. drying beds and a mechanical V-belt press. No recommendation is provided in this section for the preferred method but the next section assumes the mechanical press is the preferred method.
- Potential use of the dried sludge cake as a fertiliser for example in the mine rehabilitation areas is a good proposal.

Recommendation:

- Include a statement about the preferred sludge drying method in this section.

Odour Control

Comments:

- It is stated that odour should not be an issue due to the primary treatment of sewage before it arrives at the proposed (Municipal) STP together with the mechanical method of sludge dewatering. This sounds reasonable.

- It is also stated that the (proposed) RoN Hospital STP is more likely to present an odour risk due it treating raw sewage including medicinal wastes. The current situation with odour, now that this STP has been installed, should be mentioned.
- Further comments and a recommendation regarding odour are made in section 0 based on the comments in the NWSMP.

Recommendation:

- Include a statement about the current situation regarding odour from the RoN Hospital STP.

Proposed Location of Sewage Treatment Plant

Comments:

- Two sites are considered for the STP i.e. at the rubbish dump (Topside) and at the "Location" (Bottomside). Table 28 presents advantages and disadvantages of both sites.
- The preferred site is at the "Location" due to proximity to the serviced area, accessibility to ocean outfalls and the non-desirability of locating an STP on elevated ground due to groundwater contamination risks. The proposed site is at a "derelict part of Location where the buildings are severely damaged and abandoned" which is reasonable.
- The comment is made that "With the site being alongside the ocean, the ocean breeze should also dissipate any odour from the plant". This would be dependent on wind direction. It is recommended that this aspect be investigated and reported in the NWSMP based on observed wind direction and speed data.
- This section also discusses the proposed (now actual) RoN Hospital STP including that the proposed site at the hospital would be better re-located near the proposed Municipal STP. Another option is suggested whereby the Municipal STP is modified to accept the raw sewage including hospital waste from the RoN Hospital. As mentioned in section 4.ii of this review report, it is understood an STP with tertiary treatment is now in operation at the RoN Hospital and the treated effluent is discharged into the stormwater system and subsequently discharged to the ocean. This section including Figure 106 should be updated based on the operating status of the RoN Hospital STP.
- There is an assumption in the NWSMP that one municipal STP is the desired option. Other options which involve more than one STP and disposal via outfalls to the ocean have not been considered in the NWSMP. This aspect is considered further in section 0.

Recommendations:

- Investigate and comment about the wind direction and speed data for the proposed Location STP site using available Nauru meteorological data.
- Update the comments regarding sewage treatment based on the current status of the RoN Hospital STP.
- Update this section to recognise the possibility of more than one municipal STP on the island.

8. 20 Year Capital Works Program and Costs

Unit Rates for Water and Sewerage Infrastructure

Comments:

- All unit rates /construction costs should be updated to current unit rates.

- The unit rates for 100 mm water and sewer pipes are both shown as $230/m and the unit rates for 150 mm water and sewer pipes are both shown as $320/m. As sewer pipes are, on average, laid deeper than water pipes, it would be expected that the unit rates for sewer pipes would be greater than for water pipes. These costs should be checked and updated as necessary.

Recommendations:

- Update all unit rates to current rates.
- Check the unit rates for 100 mm and 150 mm water and sewer pipes and update these as necessary.

Proposed Capital Works Program and Costs

Comments:

- Phases 1 and 2 of the planned works are based on demands in 2025 and 2035. These time horizons need to be changed to later years.
- It is noted that some adjustments were made to the proposed water supply improvements in NRW (2017).
- The costs for the sewerage system appear to be based only on 100 mm and 150 mm diameter sewer pipes. Given that the proposed sewerage system for the whole island is designed to discharge to one STP at the Location, larger diameter pipes (e.g. 225 Mm and possibly larger) would presumably be needed for the final sections of the system before entering the STP. This is considered most likely given the identification of minimum grades for 100 mm, 150 mm and 225 mm sewer pipes in section 7.viii. As mentioned in section 7.ix (b) of this review report, "There is no discussion about the design of the sewerage system including pipe diameters required to cope with the sewage effluent flows from all districts of Nauru". The sewerage system costs based on sewers of only 100 mm and 150 mm diameters needs to be explained. If necessary, these costs should be updated.
- The number of septic tanks requiring replacement and new septic tanks as per Table 41 should be reviewed as well as the estimated costs. The numbers shown in Table 41 are based on 1,678 (70% of existing) households requiring new septic tanks and a further 666 new households requiring septic tanks.
- The total costs of Phases 1 and 2 for the water supply improvements (Table 39 of the NWSMP) were estimated at $22.275 million and $4.815 million, respectively, giving a total of $27.09 million (noting that the total shown in the table is incorrect). The Phase 1 costs were updated in the Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017, Table 11) to $31.060 million due to addition of some items, including household rainwater harvesting improvements costing $3.075 million, and an inflation adjustment.
- The total costs of Phases 1 and 2 for the sanitation improvements (Table 42 of the NWSMP) were estimated at $28.095 million and $9.065 million, respectively, giving a total of $37.16 million. The Phase 1 costs were updated in NRW (2017, Table 15) to $29.81 million due to an inflation adjustment.
- All tables, figures and associated text in sections 8.2.1 (Water Supply Capital Works Program) and 8.2.2. (Sewerage Capital Works Program) should be checked and updated as necessary based on previous comments in this review and changes made in NRW (2017).

Recommendations:

- Explain why the sewerage system costs are based only on 100 mm and 150 mm diameter sewer pipes and update costs as necessary.

- Review and, if necessary, revise the number of households requiring replacement of new septic tanks and the associated costs.
- Check and update all tables, figures and associated text based on current information and changes made in NRW (2017).

Timing of the Proposed Works

Comment:

- The statement in the second paragraph ("…all of the works outlined in Phase 1 should be commenced as soon as possible, ie year 2015 to say 2018") definitely needs updating given that the NWSMP was produced in 2017. Also, the statement "Phase 2 works are required to be completed by 2025…" needs updating.
- Recommendation:
- Update the timing of both Phases 1 and 2.

9. Operation and Maintenance

Infrastructure Driven O&M Changes

Comment:

- O&M requirements for the proposed water and sewerage infrastructure that NUC would be required to manage are briefly outlined

SCADA and Radio Telemetry

Comments:

- The NWSMP recommends that a SCADA (Supervisory Control and Data Acquisition) system combined with telemetry be installed as part of water supply and sanitation improvements. It correctly points out that there are "…many options available for SCADA however the level of sophistication that is adopted needs to ensure that available support and maintenance costs are not excessive for the benefits derived". The advantages are that key components of both water supply and sewerage systems such as pump status and flow rates, tank water levels and pipe pressures can be monitored and controlled from a central location such as the NUC buildings.
- The NWSMP mentions that SCADA is essentially an electrical engineering component and that NUC should have skills to operate such a system given their expertise in operating sophisticated equipment (e.g. electrical generators).
- The NWSMP does not recommend a particular level of SCADA system. This decision could be made during more detailed design work assuming the project proceeds. This is a reasonable approach.

Organisational Structure and Skills

Comments:

- The NWSMP shows an indicative organisational structure for a future NUC Water and Sewerage Section in Figure 110. It mentions, quite rightly, that additional staff and skills (training) will be required at NUC to operate and maintain new water supply and sewerage infrastructure, if they are installed. As suggested in the NWSMP, it is a starting point for discussion with NUC.
- However, given the extent of the proposed water and sewerage systems, additional staff beyond that shown in Figure 110 are likely to be required. In order to assess this in more detail, it is recommended that discussions are held with water and sewerage utilities in other small PICs including (a) the Public Utilities Board in Tarawa, Kiribati, (b) the Majuro Water and Sewer

Company in Majuro and KAJUR in Ebeye Island, Marshall Islands regarding their staffing levels based on populations served with water and sewerage systems and the level of technology used in these systems.

- The NWSMP notes that the RO plants are operated by others and that, if NUC takes over operation of these RO plants, then two additional positions (RO Plant Operator and Assistant RO Operator) would be required. It is quite likely that additional positions will be required.

Recommendations:

- Contact utilities in other small Pacific Island Countries that operate and maintain water and sewerage systems to gain a more accurate assessment of typical staffing levels required.
- Update the organisational structure based on anticipated O&M requirements for the water and sewerage systems including RO plants and STP(s).

Operation and Maintenance Costs

Comments:

- The NWSMP mentions that "operating costs at Nauru are not known as some key costs such as such as [*sic*] desalination electricity is paid for directly by Australian funding. In addition, power and water costs are currently not financially separated within NUC although this will be undertaken shortly".
- Recent information obtained from DCIE by SPC indicates that all O&M costs for the larger (900, 800 and 480 kL/day) RO plants are managed by ABF but the electricity costs for water production is shared between NUC and ABF.
- The estimates of annual O&M costs provided in Table 43 should be updated and the two cost columns for Phase 1 and Phase 2 updated for 2030 and 2040 demands. The NWSMP notes that "NUC is currently budgeting its annual costs and starting to separate out power and water costs" and recommends "NUC acquire power usage data from the operators of the desalination units so that more accurate operating costs may be estimated." The updated cost estimates should take account of these factors.
- There is no discussion in the NWSMP about water tariffs (or water rates) based on the use for desalinated water as supplied through the proposed pipe system and measured at consumer meters. Also, there is no discussion about the ability of Nauruans to pay for this water. It is recommended that these aspects are covered in a new section of a revised NWSMP.
- There is also no discussion in the NWSMP about possible charges for piped sewerage services including the cost of sewage treatment and also no discussion about the ability of Nauruans to pay for sewerage services. Again, it is recommended that these aspects are covered in a new section of a revised NWSMP.
- It is noted that consideration of tariffs charges for water and sewerage charges and the ability to pay were not part of any Terms of Reference for the NWSMP (which are not shown). These aspects are not listed in the "principal objectives of the study" as shown in section 2.1 of the NWSMP.
- The 2018 Annual Report (NUC, 2018) shows desalinated water tariffs in 2018 were $8.40/kL for residential, $9.70/kL for Government and $11.80/kL for commercial/industrial users. In addition, charges for desalinated water deliveries by truck were $5 and $10, respectively, for volumes less than and greater than 5 kL. It is understood that the same tariffs applied in 2018-2019.

Recommendations:

- Update the NWSMP based on current information regarding current and expected O&M arrangements and annual O&M costs.
- Include a new section in the NWSMP which considers fees for water and sewerage services and the ability of Nauruans to pay for these services.

10. Possible Additional Water Supply Measures

Outline

The second objective for this review report (refer section 0) is to "Consider alternate interventions or approaches more suited to Nauru's needs given the socioeconomic context to construct, operate and maintain, improved water and sanitation systems for Nauru."

The NWSMP is focused on water supply improvements that can deliver desalinated water to households and other consumers by means of a piped water supply system. While this is fundamentally a good approach and would improve convenience to consumers and lessen operational requirements associated with water tanker deliveries, it has a number of major potential challenges including land ownership issues and construction difficulties associated with the installation of pipelines.

Piped water supply systems are common on many small Pacific Islands including:

- South Tarawa and Kiritimati in Kiribati using groundwater.
- Majuro in the Marshall Islands which has a piped water supply system for part of the island using groundwater, runoff from the airport and desalinated water.
- Ebeye Island, Kwajalein atoll in the Marshall Islands using desalinated water.
- Rarotonga in the Cook Islands using surface water and
- Aitutaki, Mangaia, Mauke and other southern islands in the Cook Islands using groundwater.
- Many villages throughout the islands of Tonga.

Some small islands such as Fongafale Island on Funafuti atoll, Tuvalu, where rainfall is much less variable than on Nauru, do not have a piped water supply system. Fongafale relies on household rainwater collection and tanker deliveries from community rainwater storage tanks or a backup desalination plant to supply household tanks when stored rainwater becomes depleted.

As mentioned in the NWSMP, in order to improve the distribution of potable (desalinated) water to consumers on Nauru, a piped water supply system is preferable to supply by tankers which is seen more as an emergency measure.

Additional measures to improve water security on Nauru are considered in this section. These are "additional" measures to the main thrust of the NWSMP and not "alternative" measures. Possible additional measures are:

- Increased rainwater harvesting
- Increased rainwater harvesting at government and community buildings
- Increased use of groundwater
- Other possible measures.

Increased household rainwater harvesting

The advantages of household rainwater harvesting are well known in Pacific islands including Nauru as well as other parts of the world. The water is essentially free once the necessary rainwater harvesting components are installed and maintained. For Nauru, when rainfall is plentiful, rainwater can supply most, if not all, needs depending on the sizes and conditions of roofs, gutters, downpipes and tanks. At such times, the water is conveniently available at houses and deliveries of desalinated water can be minimal. The quality of rainwater is generally good if roofs and gutters are kept clean. Hence, maintenance is required. First-flush devices and filters can be used to improve water quality,

i. Status and condition of household rainwater harvesting systems

(a) <u>2011 Census</u>

The 2011 Census (RoN, 2011a) provided information regarding household rainwater harvesting components (tanks, roofs, gutters and downpipes). These are summarised below in percentage terms for the 1,647 households on Nauru in 2011. It is noted that in some cases the totals of the percentages are not exactly 100% owing to some rounding of numbers in RoN (2011a).

- Regarding household storage tank capacity:
  - **15% had no tanks and hence no storage capacity.** This result is similar to the 19% with no tanks found in SOPAC (2007) after an audit of 308 households in early 2007.
  - 16% had less than 13.5 kL (3,000 gallons)
  - 30% had between 13.5 kL and 22.5 kL (3,000 - 5,000 gallons)
  - 25% had between 22.5 kL and 45 kL (5,000 - 10,000 gallons)
  - 14% had greater than 45 kL (10,000 gallons).

  For households with tanks, the tank materials were 35% plastic, 33% concrete, 31% either aluminium or galvanised iron and 1% either fibreglass or “barrel”. The 2011 Census does not comment on the condition of household tanks.
- Regarding roofs:
  - **34% needed repair and 26% needed replacing**. Only 41% were “fully working”,
  - The roof materials were mainly aluminium or “tin” (presumably galvanised steel) (67%) and asbestos (28%). The other 5% consisted of concrete, plastic and thatched. The districts with the highest percentages of asbestos roofs were Denigomodu (51%) and Nibok (49%) while Buada had the lowest percentage (7%).
- Regarding gutters:
  - **30% of houses had none, 12% needed replacing and 19% needed repair**. Only 38% were “fully working”.
  - For the households with gutters, the materials were mainly aluminium or “tin” (73%) with the others being asbestos (17%), PVC (9%) or “improvised” (1%).
- Regarding downpipes:
  - **33% of houses had none, 6% needed replacing and 13% needed repair**. Only 47% were “fully working”.
  - 60% had downpipes connected to a storage tank while 7% had a downpipe which was not connected to a storage tank.
  - The downpipe materials were mainly plastic (67%) and aluminium or “tin” (28%) with the others being asbestos (2%) or “improvised” (2%).

The above summary shows there were many deficiencies in the rainwater harvesting components at the time of the 2011 Census. A number of reports have highlighted sub-optimal condition and poor maintenance of household rainwater harvesting systems including the National Water, Sanitation and Hygiene Policy and Implementation Plan (RoN; 2012a, 2012b) , SPREP (2014). SPC and RoN (2014), RoN (2015) and Clear Horizon (2018).

(b) 2019 NUC survey

According to SPC and RoN (2020, Annex 1), a household survey of rainwater harvesting components by NUC in 2019 showed that "116 out of 1,713 households do not have water storage in excess of 5,000 litres" (i.e. have storage capacity less than or equal to 5,000 litres or 5 kL). The 116 households represents about 7% of the 1,713 households surveyed.

A recent analysis of the 2019 NUC survey data (NUC; 2019a, 2019b) shows that it included (a) 1,562 buildings with water storages (tanks) consisting of 1,536 households, 25 commercial buildings and one government school in the Ewa district, and (b) 175 households with no water storages (tanks). Thus, a total of 1,711 households were surveyed, similar to the total mentioned in SPC and RoN (2020), of which 175 (10%) had no tanks. Also, the NUC survey data shows that the total number of tanks with capacities less than or equal to 5 kL was 491 of which 485 were at households and 6 were at commercial buildings. The NUC survey data indicates that SPC and RoN (2020) has under-estimated the number of household tanks by a large factor of 4.2 (i.e. 485 / 116).

Further to the above, SPC and RoN (2020) provides conflicting statements about the capacity of tanks which will be used as a criterion for selecting 50 households for a proposed project to install larger tanks. Annex 4 of SPC and RoN (2020) states that that "A tank is defined as having a capacity of more than 5,000 litres". This is consistent with the criterion used in Annex 1 of the report, as mentioned above. However, the statement in these two annexes are inconsistent with the criterion used in two other parts of the report where it is stated that "The project will specifically target an estimated 50 households that do not have a water storage of 5,000 litres or more." These statements indicate that only households with less than 5,000 litres water storage capacity would be considered. The NUC survey data shows the total number of water storages at all buildings with capacities less than 5 kL was 373 of which 370 were at households and 3 were at commercial buildings. Using this data, SPC and RoN (2020) has under-estimated the number of household tanks with capacities less than 5 kL by a factor of 3.2. It is suggested that the authors of SPC and RoN (2020) explained this inconsistency and why only 116 households were found to "not have water storage in excess of 5,000 litres".

(c) Comparison of results from 2019 NUC survey and 2011 Census

Analysis of the results for the 1,711 households from the 2019 NUC survey regarding the percentage of tank capacities are shown in Table 1. The tank capacities are shown using the selected values and ranges from the 2011 Census. Table 1 also shows the percentage results for the 1,647 households from the 2011 Census, as listed above, and the percentage changes between 2011 and 2019.

Table 1 Percentage of households with various tank capacities from 2019 NUC survey and the 2011 Census

Household storage tank capacity	2019 NUC survey	2011 Census	Percentage change from 2011 to 2019
Nil (no tank)	10%	15%	- 5%
Between nil and 13.5 kL	52%	16%	+ 36%
Between 13.5 kL and 22.5 kL	11%	30%	- 19%
Between 22.5 kL and 45 kL	19%	25%	- 6%
Greater than 45 kL	8%	14%	- 6%
Total	100%	100%	0%

From Table 1, the following observations are made about the percentages of households with and without tanks:

- Those with no tanks decreased from 15% in 2011 to 10% in 2019.

- Those with tank capacity less than 13.5 kL substantially increased from 16% in 2011 to 52% in 2019.
- Those with tank capacity greater than 13.5 kL substantially decreased from 69% in 2011 to 38% in 2019.
- Those with tank capacity greater than 22.5 kL decreased from 39% in 2011 to 27% in 2019.

Based on the two sets of data, the most significant changes regarding tanks between 2011 and 2019 were (a) a 36% increase in tanks with capacities less than 13.5 kL and (b) a 31% decrease in tanks with capacities greater than 13.5 kL.

The 2019 NUC survey included data about the condition of tanks with 88% of household tanks classified as either "Good Condition" or "Excellent". The remaining 12% of household tanks were classified as being in either bad or poor condition with terms such as "Badly Rusted", "Leaking Badly", "Damaged Tank", "Broken", "Need to replace" and "Minor leak". All of the 25 commercial buildings and the one government school were classified as in good condition. The 2011 Census did not provide information about the condition of tanks.

The 2019 NUC survey did not provide details of roof conditions or materials so a comparison with the 2011 Census results could not be made. However, the 2019 NUC survey provided details of the status of gutters and downpipes. Gutters were classified as "Excellent", "Good", "Minor Leak", "Badly Leak" and "No Gutter" in the survey. Comparisons between the 2019 and 2011 results are shown in Table 2. To make the comparisons, "Badly Leak" in 2019 was equated to the category "needed replacing" in 2011, "Minor Leak" in 2019 was equated to "needed repair" in 2011 and "Excellent" or "Good" in 2019 were equated to "Fully working" in 2011.

Table 2 Percentage of household gutters with various conditions from 2019 NUC survey and 2011 Census

Gutter status	2019 NUC survey	2011 Census	Percentage change from 2011 to 2019
No gutters	42%	30%	+ 12%
"Badly Leak" (in 2019) and "needed replacing" (in 2011)	7%	12%	- 5%
"Minor Leak" (in 2019) and "needed repair" (in 2011)	14%	19%	- 5%
"Excellent" or "Good" (in 2019) and "Fully working" (in 2011)	37%	38%	- 1%
Total	100%	99%	- 1% (round-off error)

From Table 2, the following observations are made about the status of household gutters:

- Households with no gutters significantly increased from 30% in 2011 to 42% in 2019.
- Households with bad leaks (in need of replacement) decreased from 12% in 2011 to 7% in 2019.
- Households with minor leaks (in need of repair) decreased from 19% in 2011 to 14% in 2019.
- Households with excellent or good (fully working) gutters slightly decreased from 38% in 2011 to 37% in 2019.

Based on the two sets of data, the changes in the status of gutters between 2011 and 2019 are not particularly significant except for the 12% increase in households with no gutters.

In the 2019 NUC survey, downpipes are described by "Roof Feed" as either "Yes" or "No" with no description of the condition of the downpipes as occurred with the 2011 Census. Comparisons between the 2019 and 2011 results are shown in Table 3. To make the comparisons, "No" in 2019 was equated to all categories "none, "needed replacing" and "needed repair" in 2011 and "Yes" in 2019 was equated to "Fully working" in 2011.

From Table 3, the following observations are made about the status of household downpipes:

- Those without inadequate or no downpipes decreased from 52% in 2011 to 46% in 2019.
- Those without adequate downpipes increased from 47% in 2011 to 54% in 2019.

Based on the two sets of data, the changes in the status of downpipes between 2011 and 2019 are not particularly significant.

Table 3 Percentage of household downpipes with various conditions from 2019 NUC survey and 2011 Census

Downpipe status	2019 NUC survey	2011 Census	Percentage change from 2011 to 2019
"No" downpipes (in 2019) and "none, "needed replacing" and "needed repair" (in 2011)	46%	52%	- 6%
"Yes" (in 2019) and "Fully working" (in 2011)	54%	47%	+ 7%
Total	100%	99%	+ 1% (round-off error)

From the 2019 NUC survey, of the 88% of households with tanks in good or excellent condition, only 34% of these (or 30% of total households) had the combination of (a) both tanks and gutters in good or excellent condition and (b) downpipes. Of the 25 commercial buildings, all of which had tanks in good condition, only 64% had the combination of (a) and (b) above. These findings clearly indicates there is considerable scope to improve and increase rainwater harvesting for households and other buildings by installing or repairing gutters and downpipes.

Recommendations:

- Update the NWSMP with the most recent data regarding status of rainwater harvesting systems at households and other buildings.
- Advise the authors of the 2020 Project Design Document for expanding national water storage capacity and improving water security in Nauru (SPC and RoN, 2020) to update the document with consistent terminology about the definition of a water storage tank in relation to its capacity.

(d) 2019 mini-census

Data from a mini-census in 2020, as obtained from SPC, provided selected details of 1,895 household rainwater harvesting systems as follows:

- Tank capacity and material
- Gutter condition and material/

The data provided did not include any details of roofs or downpipes and was less comprehensive than the 2019 NUC survey in relation to storage tanks.

Table 4 shows comparisons between the 2020 mini-census 2019 NUC survey results for tank capacity and material and gutter condition.

From the comments above and Table 4, the following observations are made:

- The 1,895 households included in the mini-census were greater than those in the 2019 NUC survey (1,711) and 2011 census (1,647) by 11% and 15%, respectively. The reason for the significant difference in number of households in 2019 and 2020 is not known,
- Comparisons between the three sets of data is not easy as the 2020 mini-census includes an “unknown” category for the three items,
- For tank capacity, there is a large difference between the 2020 and 2019 data particularly for tanks with capacities up to 13.5 kL.
- For tank material, the materials shown for 2019 and 2020 are generally similar but the more detailed 2019 NUC survey data shows a greater percentage of plastic tanks (57% compared with 46%).
- For gutter condition, the percentage of houses with good gutters and those needing repair or replacement are generally similar.

Overall, it is considered that the present status of rainwater harvesting components is better estimated by the 2019 NUC survey data rather than the 2020 mini-census data.

Table 4 Comparison of selected household tank and gutter status from 2020 Mini-census, 2019 NUC survey and 2011 Census

Item	2020 Mini-census	2019 NUC survey	2011 Census
Tank capacity			
Nil (no tank)	6%	10%	15%
Between nil and 13.5 kL	10%	52%	16%
Between 13.5 kL and 22.5 kL	34%	11%	30%
Between 22.5 kL and 45 kL	31%	19%	25%
Greater than 45 kL	9%	8%	14%
“Unknown”	10%	Nil	Nil
Tank material			
Plastic	46%	57%	35%
Concrete	19%	22%	33%
Aluminium or galvanised iron	19%	19%	31%
Other (fibreglass or barrel)	1%	1%	1%
“Unknown”	16%	Nil	Nil
Gutter condition			
No gutters	Not shown	42%	30%
Needs replacing	9%	7%	12%
Needs repair	19%	14%	19%
“Good	31%	37%	38%
“Unknown”	41%	Nil	Nil

ii. Total and average water storage in rainwater harvesting systems

(a) Households

Using the detailed data from the 2019 NUC survey, the total water storage capacity of household tanks, regardless of their condition, was 23.1 ML with an average storage capacity of 15.1 kL. For the 1,368 tanks classified as in good or excellent condition, the total storage was approximately 20 ML with an average capacity of 14.6 kL.

(b) Commercial and government buildings

For the 25 tanks at commercial buildings, all of which were in good condition, the total and average storage capacities were about 0.4 ML and 15.3 kL, respectively. The one government school tank which was in good condition had a capacity of 35 kL.

(c) Total

The total water storage capacity for all tanks surveyed was 20.4 ML for tanks classified as in good or excellent condition. This shows that of all the tanks surveyed, about 98% was at households and the remaining 2% was mainly at commercial buildings.

The total water storage capacity of 20.4 ML of the tanks at households and other buildings is about 3.2 times greater than the current total storage capacity of the large tanks (6.3 ML, as shown in section 0) within the public water supply system at Aiwo and Meneng. It is also slightly more than double the estimated storage capacity of 9.9 ML once additional tanks are installed. These findings show the importance of the tanks at households and other buildings to the total storage capacity on the island.

iii. Support for rainwater harvesting in national documents

Government of Nauru strategy and policy documents in the past 15 years indicate strong support for improvements to rainwater harvesting particularly at households.

The National Sustainable Development Strategy 2005 - 2025 (RoN, 2009) states a number of important milestones related to rainwater harvesting under the Water and Sanitation Goal to "Provide a reliable, safe, affordable, secure and sustainable water supply to meet socio-economic development needs" and within the strategy to "Improve water storage capacity and infrastructure". These include:

- Short-term Milestone, 2012: "Improvements to water catchments and infrastructure revamped and maintained (e.g. installation of guttering and downpipes and renovation of existing water tanks)"
- Medium-term Milestone, 2015: "Water catchment and storage capacity expanded"
- Long-term Milestone, 2025: "Rainwater harvesting production increased by 50%".

Also, under the Environment Goal to "Sustainable use and management of the environment and natural resources for present and future generations" and within the strategy to "Enhance resilience to climate change impacts" additional milestones are stated in the NSDS 2005 – 2025:

- Short-term Milestone, 2012: "Strengthen resilience of water sector to drought through improvements to rainwater harvesting infrastructure"
- Medium-term Milestone, 2015: "Continued strengthening resilience of water sector to drought through improvements to rainwater harvesting infrastructure"
- Long-term Milestone, 2025: "Water sector resilient to impacts of drought resulting from global warming and climate change by at least 30 percent".

The Nauru Economic Infrastructure Strategy and Investment Plan (RoN, 2011b, item 70) mentions "The data does indicate that the strengthening of rainwater harvesting capability and capacity by households and communities has extraordinary potential, and be extremely cost-effective".

Other reports (e.g. SOPAC, 2010, DCIE, 2012) have also raised the need to increase household rainwater harvesting.

The Nauru Water, Sanitation and Hygiene Policy (RoN, 2012a), which was endorsed by the Nauru Cabinet in 2017, outlines specific objectives for rainwater harvesting. Policy Objective 2.5 is "Guidelines for rainwater harvesting, storage and maintenance in private systems introduced and building codes for systems in public buildings established" and Policy Objective 7.4 is "Incentive programs created for improving and maintaining rainwater harvesting and storage at the household and business level". The Nauru Water, Sanitation and Hygiene Implementation Plan (RoN, 2012b) provides details of proposed activities under the above two policy objectives. Under Policy Objective 2.5, RoN (2012b) shows four activities:

- 2.5.1. Guidelines for installation of rainwater harvesting and storage produced.
- 2.5.2 Instruction manual for maintenance of household rainwater harvesting and storage systems
- 2.5.3. District committee training sessions developed on installation and maintenance of household rainwater harvesting and storage systems
- 2.5.4. Rainwater harvesting and storage building code established for all new government and public buildings including the refugee processing centre (Master Plan),

and under Policy Objective 7.4, RoN (2012b) shows two activities:

- 7.4.1. Review rainwater incentive schemes in other PICs including revolving loan fund schemes
- 7.4.2. Establish appropriate rainwater collection incentive schemes.

The scheduled completion times for the above six activities varied from December 2012 to July 2014 with two activities (2.5.3 and 7.4.2) having an ongoing status. Further comments related to the items listed above in RoN (2012a, 2012b) are provided in section vii.

The NWSMP (RoN, 2017), which was approved by the Nauru Cabinet in 2017, states "Rainwater is considered to be the lowest cost, high quality water source that is available on the island". During high rainfall periods, mainly associated with El Niño episodes, rainwater can supply most of the water needs for households that have adequate roof areas and are fitted with sufficient gutters, downpipes and storage tanks. However, during droughts, mainly associated with La Niña episodes, rainwater is not available at least for non-potable uses in most households and desalinated water becomes the primary source of freshwater.

Section 4.2.4 of the NWSMP correctly points out that there is a need for rainwater tanks at all households and repairs or replacements of roofing and downpipes are required to improve rainwater harvesting potential. However, gutters were not mentioned and these should also be repaired or replaced where necessary. The Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017, section 4.6) states that "rainwater harvesting at a household level is to be considered to be the **primary source** of water. When the rainwater tank has water in it, then the typical household would draw its water from the tank in the usual manner. When the rainwater tank is running low, then the household would open the valve of its future water service connection from the NUC reticulation network and top the rainwater tank up again and then close the valve." NRW (2017, section 4.6) also states "There are currently partially complete rainwater tank installation projects on the island. What is essential however is that each and every household (and business) has a working rainwater tank that is connected to the guttering and provides a meaningful amount of storage so that it can become the primary water source at that location". A tank with capacity of 18.5 kL is seen as one with a "meaningful amount of storage" based on discussions NRW and GoN in 2017. NRW (2017) mentions that it was unclear as to the number of households requiring suitable tanks, gutters or downpipes and suggested a survey. This survey was conducted by NUC in 2019 (refer section i). NRW (2017 estimated a cost of $3 million for 200 rainwater tanks based on $15,000 per installation and a further cost of $75,000 for a survey of all households and entry of the data into a GIS. The total cost of $3,075,000 was included in a revised budget (Table 4, NRW, 2017). The report also mentioned that investment in rainwater harvesting could defer the capital expenditure on Phase 2 of the Master Plan if the if rainwater harvesting proves very effective in reducing overall water use.

From the above documents, it is abundantly clear that the Government of Nauru has shown considerable support for increased rainwater harvesting.

Recommendations:

- Update the NWSMP with comments regarding the considerable support for household rainwater harvesting improvements in Government of Nauru strategy and policy documents over the past 15 years and the need for incentive schemes to encourage households to improve and maintain roofs, gutters, downpipes and tanks.
- Update the NWSMP with a household rainwater harvesting improvement component and revised budget for the 20 year capital works program based on the Nauru Priority Water Sector Development and Funding Needs Report, 2017.

iv. Focus of recent and proposed projects

Recent and proposed projects involved with household water supply have focused on supplying tanks to store desalinated water rather than for rainwater harvesting from roofs (which require roof repairs / replacement, installation of gutters and downpipes). Examples of household water storage improvement projects in recent years are:

- An Australian Government funded project designed to install household rainwater tanks. According to SPC and RoN (2014) the number of tanks to be installed was originally 250. Clear Horizon (2018) states "The effectiveness of this project has been low, given implementation issues resulting in reduction in scope from 200 household water tanks to 106, and the delivery of even this quantity remains at risk. There is also a lack of maintenance strategy, and maintenance will be challenging given the ownership of tanks at the household level".
- A household water storage project funded by the Government of Italy was completed in 2019 (SPC and RoN, 2020). This project supplied 39 households with 20 kL coated steel (Colorbond) water tanks on concrete slabs. These tanks are used by households for storing desalinated water delivered by tankers and not for rainwater harvesting.
- A proposed project "Scaling up water storage capacity in Nauru in response to climate change" (SPC and RoN, 2020) has the objective of contributing to increased water storage for 50 vulnerable households that have no or less than 5 kL of water storage by installing storage tanks. These water storage tanks, with capacities yet to be determined, will be for storing delivered desalinated water and not for rainwater harvesting. SPC and RoN (2020) states the "project will only focus on increasing water storage specifically for desalinated water for vulnerable households".

Regarding the proposed project above, SPC and RoN (2020) also states that "The project is consistent with the Nauru National Sustainable Development Strategy (2005-2025) and the Nauru Water and Sanitation Master Plan (2015-2035) which identify increased water storage as priority actions for climate change adaptation". However, SPC and RoN (2020) does not mention the strong support for rainwater harvesting evident in NSDS 2005-2025, the NWSMP (RoN, 2017), NRW (2017) and other documents referenced in section iii.

SPC and RoN (2020) mentions that an in-country consultation in January 2020 was conducted with 26 stakeholders to discuss the water security issues currently faced in Nauru. According to SPC and RoN (2020), "they unanimously agreed that increased water storage is the priority requirement at the household level. They ranked rainwater harvesting and the development of groundwater resources as second and third respectively." The main reason for the lesser priority of rainwater harvesting appears to be due to water quality. The report states the "project will therefore specifically store desalinated water only as the quality of desalinated water can be assured as opposed to the quality of rainwater harvested from roof catchments" and also the "quality of rainwater harvested may be compromised by the ongoing presence of phosphate dust on roofs and the removal of roof asbestos is beyond the scope of the project".

The fact that rainwater harvesting was ranked second indicates that it should not be ignored. This is especially so when rainwater harvesting components other than tanks i.e. gutters and downpipes and if necessary some roof replacements are cheaper than tanks and the benefits in terms of cost savings to households are significant (refer section vi).

In this review report, it is considered that the decision to exclude rainwater harvesting components (mainly gutters and downpipes) is too restrictive as there are many parts of the island where phosphate dust is not a problem and where roofs are not made from asbestos sheeting. In any case, asbestos roofs and gutters are not a problem for human health when using rainwater collected from these surfaces (refer section 4.iv). Regarding phosphate dust, section 4.iv also provides comments about the results of water quality tests on 10 rainwater samples and concludes "For all samples, and all analyses, concentrations of cadmium and lead were below the detection limit indicating no health risks associated with this potential threat".

The recent and proposed projects mentioned above, which focus on household storage tanks and do not include other rainwater harvesting components (mainly gutters and downpipes and could also include at least partial roof repairs or replacements where necessary), are not consistent with various Strategy, Policy and Plan documents approved by the Nauru Cabinet including the Nauru National Sustainable Development Strategy, 2005 - 2025 (RoN, 2009), the Nauru Economic Infrastructure Strategy and Investment Plan (RoN, 2011b), the National Water, Sanitation and Hygiene Policy (RoN, 2012a) and the Nauru Water and Sanitation Master Plan (RoN, 2017).

Despite the support for improved rainwater harvesting in many Government of Nauru documents, the Nauru Integrated Infrastructure Strategic Plan (RoN and PRIF, 2019) does not include any household rainwater harvesting improvements in its list of 53 priority infrastructure projects. In fact, only three water projects were included in the priority list which were (a) relining of four of the C water storage tanks (at Aiwo), (b) a water pipeline from Aiwo to the RoN hospital and (c) a water remineralisation plant. The first of these has already been implemented.

v. Analyses of household rainwater harvesting systems

Household rainwater harvesting systems were analysed for this report using a monthly water balance model (White, 2010) and Nauru monthly rainfall for the period January 1946 to December 2015 (i.e. 70 years or 840 months). The rainfall data was mainly from rainfall stations located in Bottomside including the ARC-2 site which ceased operation in early March 2013. Additional data was available from an automatic rain gauge located in Topside from March 2013 until mid-March 2016. It is understood that no rainfall data is available after this time.

For the analyses, the following parameters were used:

- Number of people in house: Two cases are considered based on the 2011 Census (a) 6, the average household size and (b) 15, a large household size.
- Daily per capita demand: Two cases are considered (a) 20 Lpd to cover potable water needs and (b) 90 Lpd to cover most of the estimated 110 Lpd (as per section 4.iii) with the remaining 20 Lpd supplied from groundwater for toilet flushing.
- Effective roof area (i.e. roof area that is contributing to storage tanks with effective gutters and downpipes): Two cases are considered (a) 100 m^2, smaller than average area, and (b) 200 m^2, approximately average area. SOPAC (2007) mentions the average roof area was approximately 190 m^2 based on a survey of 308 houses. The range was from less than 50 m^2 to greater than 500 m^2.
- Runoff coefficient: 0.8 which assumes 80% of the rainfall on the roof adds to the water storage in the tank. 20% losses are assumed due to (a) evaporation of small rainfall amounts from roofs

and gutters, and (b) losses (mainly overflows) from gutters and tanks during medium to heavy rainfall.

- Tank capacity: Four cases are considered 10 kL, 20 kL, 30 kL and 45 kL which show the results for (a) a smaller than the average capacity of tank of about 15 kL from 2019 NUC survey (refer section), (b) close to 18.5 kL capacity which was the "meaningful amount of storage" in NRW (2017), (c) approximately double the average capacity tank, and (d) a large tank.

The results of analyses are summarised in Table 5 and Table 8 using various combinations of the number of people in the household, daily per capita rainwater demand, effective roof area and tank capacity. The criterion used for the relative merit of each option was the percentage of months that the tank is empty in the full period of 840 months. This can also be expressed as the percentage failures of the tank (to supply the required demand) or "failure rate".

Table 5 Percentage of months that tank is empty for household rainwater harvesting system for 6 people in household and daily per capita rainwater demand of 20 Lpd

Number of people in household	Daily per capita rainwater demand (Lpd)	Effective roof area (m^2)	Tank capacity (kL)	Percentage of months that tank is empty
6	20	100	10	9%
6	20	100	20	5%
6	20	100	30	2%
6	20	100	45	0%
6	20	200	10	4%
6	20	200	20	0.7%
6	20	200	30	0%
6	20	200	45	0%

Table 6 Percentage of months that tank is empty for household rainwater harvesting system for 6 people in household and daily per capita rainwater demand of 90 Lpd

Number of people in household	Daily per capita rainwater demand (Lpd)	Effective roof area (m^2)	Tank capacity (kL)	Percentage of months that tank is empty
6	90	100	10	55%
6	90	100	20	50%
6	90	100	30	46%
6	90	100	45	42%
6	90	200	10	39%
6	90	200	20	33%
6	90	200	30	29%
6	90	200	45	26%

Table 7 Percentage of months that tank is empty for household rainwater harvesting system for 15 people in household and daily per capita rainwater demand of 20 Lpd

Number of people in household	Daily per capita rainwater demand (Lpd)	Effective roof area (m^2)	Tank capacity (kL)	Percentage of months that tank is empty
15	20	100	10	36%
15	20	100	20	30%
15	20	100	30	25%
15	20	100	45	20%
15	20	200	10	21%
15	20	200	20	14%
15	20	200	30	11%
15	20	200	45	7%

Table 8 Percentage of months that tank is empty for household rainwater harvesting system for 15 people in household and daily per capita rainwater demand 90 Lpd

Number of people in household	Daily per capita rainwater demand (Lpd)	Effective roof area (m^2)	Tank capacity (kL)	Percentage of months that tank is empty
15	90	100	10	96%
15	90	100	20	96%
15	90	100	30	96%
15	90	100	45	96%
15	90	200	10	68%
15	90	200	20	63%
15	90	200	30	60%
15	90	200	45	57%

From the four tables above, the following observations are made about the results:

- **Table 5 and Table 6 (6 people in household)**
    - For a 6 person household and 20 Lpd rainwater demand (total rainwater demand of 120 Lpd), the percentage of months when the tank is empty (failure rate) varied from a reasonably low 9% for a 100 m^2 roof and 10 kL tank to 0% for a 100 m^2 roof and 45 kL tank.
    - For the same total demand of 120 Lpd, the combination of a larger 200 m^2 roof and a smaller 20 kL tank achieved a very low 0.7% failure rate. This is practically equivalent to the 0% failure rate for a house with a 100 m^2 roof and 45 kL tank.
    - For a 6 person household and 90 Lpd rainwater demand (total rainwater demand of 540 Lpd), the failure rate varied from a high 55% to a moderate 26% depending on the combination of effective roof area and tank capacity.
    - The failure rate could be lowered to 16% for an effective roof area of 300 m^2 roof and a 45 kL tank.
    - It would not be possible to achieve a 0% failure rate for 6 people and a 90 Lpd rainwater demand, without an impractical large combination of roof area and storage tank. Even a combination of a very large effective roof area of 500 m^2 and 90 kL tank capacity (i.e. two 45 kL tanks) the failure rate would be 4%.

- **Table 7 and Table 8 (15 people in household)**
  - For a 15 person household and 20 Lpd rainwater demand (total rainwater demand of 300 Lpd), the failure rate varied from a moderately high 36% to a reasonably low 7% depending on the combination of effective roof area and tank capacity.
  - For the same total demand of 300 Lpd, the failure rate could be lowered to a very low 1.3% for a large effective roof area of 500 m^2 roof and a single 45 kL tank.
  - For a 15 person household and 90 Lpd rainwater demand (total rainwater demand of 1,350 Lpd), the failure rate varied from a very high 96% to a high 57% depending on the combination of effective roof area and tank capacity.
  - For the same total demand of 1,350 Lpd, even a combination of a very large effective roof area of 500 m^2 and 90 kL tank capacity (i.e. two 45 kL tanks) would only lower the failure rate to a moderately high 27%.
  - The results in Table 8 for the effective roof area of 500 m^2 show that increasing the tank capacity from 10 kL to 45 kL makes no difference to the failure rate. This highlights the fact with rainwater harvesting that increasing tank capacity is of little benefit in many houses with small effective roof areas. It is often more appropriate and a lot less costly to ensure gutters and downpipes are adequate and make use of the full available roof area.

Further examples to those used above could easily be analysed. Each house in Nauru could be analysed if data was available on household sizes, effective roof area and tank capacity. Such analyses can be used to assess the effect of measures such as installing more or replacement gutters and downpipes on existing roofs where these are either missing or in poor condition.

Recommendation:

- Analyse all household rainwater harvesting systems and assess best strategies to improve rainwater harvesting which in many cases will be replacing existing gutters and downpipes and/or installing them of parts of house roofs where they are not already fitted.

vi. Cost savings by maximising rainwater use

The average annual cost savings by using rainwater when available rather than desalinated water can be calculated from the above results using the 2017-2018 NUC residential water tariff ($8.40/kL) and $5 fee for tanker deliveries based on less than 5 kL per delivery (NUC, 2018). It is understood that the same tariffs applied in 2018-2019. It was assumed that deliveries of desalinated water would be made in 5 kL rather than greater than 5 kL quantities where the delivery fee increases to $10. The following approximate average annual cost savings can be made using the above tariff and delivery fee for the selected options of effective roof area and storage tank capacity:

- 6 person household and 20 Lpd rainwater demand: **$370 - $410 per year**
- 6 person household and 90 Lpd rainwater demand: **$830 - $1,380 per year**
- 15 person household and 20 Lpd rainwater demand: **$660 - $950 per year**
- 15 person household and 90 Lpd rainwater demand: **$170 - $2,000 per year**.

From the results above, the average annual cost savings are substantial especially for per capita rainwater demands of 90 Lpd when rainwater is available and for larger effective roof areas and storage tank capacity. One other example to demonstrate this is a household of 10 people using 90 Lpd of rainwater when available with a large effective roof area of 400 m^2 and a large tank capacity of 45 kL. The average annual cost saving by using rainwater when available rather than desalinated water is approximately $2,300 per year.

vii. Inclusion of rainwater harvesting in NWSMP and future projects

While there are well-documented maintenance problems with household rainwater harvesting systems, the cost savings to Nauruan households by using rainwater should be taken into account when considering whether to include rainwater harvesting components (gutters and downpipes) in addition to storage tanks.

The NWSMP (RoN, 2017) should be revised to include household rainwater harvesting improvements in addition to the proposed water distribution system in the 20 year capital works program. As mentioned in section iii, household rainwater harvesting improvements for 200 households were included in a revised budget in the Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017). The exact details would need further discussion with relevant stakeholders in the Government of Nauru and the Nauruan community.

Future water supply improvement projects including the proposed project outlined in SPC and RoN (2020), which target household water security by installing storage tanks for desalinated water, should include rainwater harvesting components including gutters and downpipes.

Recommendations:

- Due to the significant cost savings to households from using rainwater, when available, rather than purchasing desalinated water, conduct further consultations with the Government of Nauru and the Nauruan community about the need to include new or improved rainwater harvesting components with any project that focuses on installation of household water storage tanks, including the proposed project in the 2020 Project Design Document for expanding national water storage capacity and improving water security in Nauru (SPC and RoN, 2020).

viii. Other activities related to rainwater harvesting

Guidelines for design and instructions for maintenance of rainwater harvesting systems should be developed for Nauru. Such guidelines and instructions have previously been recommended in a number of reports including Bouchet (2011), RoN (2012a, 2012b) and DCIE (2012). Two ""Harvesting the Heavens" publications could be used as a basis for developing locally applicable guidelines (SOPAC, 2004a, 2004b). One important aspect that needs to be considered is the use of large capacity gutters for households and other buildings to capture all available rainfall, including in heavy downpours. Often gutters are under-sized and cause overflow of valuable rainwater when this occurs. Also, overflow pipes from tanks can be directed into groundwater pumping wells where possible to provide additional freshwater recharge to the groundwater.

For the design of rainwater harvesting systems for households with a known roof area and number of residents, easy-to-use spreadsheet calculators using monthly rainfall data can be used to assess appropriate tank capacity. One such rainwater harvesting design calculator (White, 2010) was used for the results shown above in this section.

Water sampling and testing of selected rainwater tanks in each of the 14 districts would provide very useful information about rainwater quality in the various parts of the island. Parameters to be tested should include major cations and anions, conductivity, metals including cadmium and lead, and bacteria (faecal coliforms). The results for cadmium and lead should be compared with the results obtained in 2010 for 10 rainwater samples which showed concentrations below the limit of detection (Bouchet and Sinclair, 2010). It is suggested that 10 samples be collected from household tanks in each district giving a total of 140 samples. Tests for bacteria should be done in Nauru while the other tests would best be done at an accredited laboratory in Australia. The results should be made available to the Nauruan community and included in education and awareness programs about rainwater harvesting on Nauru.

As outlined in the RoN (2012a, 2012b) and White (2020), there is a need for a building code which covers rainwater harvesting requirements for new houses and other new buildings.

Training of households in maintenance procedures should be part of any rainwater harvesting improvement projects, as outlined in RoN (2012a, 2012b), SPC and RoN (2020) and other reports.

Ongoing community and school education and awareness programs about the need to maintain rainwater harvesting systems (and groundwater pumping systems) for the benefit of households are required. The need for such programs has been raised in previous documents including the National Water, Sanitation and Hygiene Policy and Implementation Plan (RoN; 2012a, 2012b) which also raises the need for community awareness of wider water resource, sanitation and hygiene issues. The benefits of rainwater harvesting should be presented including significant cost savings that can be made by using rainwater, when available, rather than expensive desalinated water.

Financial incentives should be introduced for households to maintain, repair or enhance their rainwater harvesting components using schemes such as subsidised rainwater harvesting materials or a revolving fund for loans to purchase rainwater harvesting components. This matter has been raised in previous documents including RoN (2012a, 2012b) and DCIE (2012). RoN (2012a) highlighted the fact that there were no incentives for encouraging improvement of household rainwater harvesting and sanitation systems and limited information on maintaining and repairing them. RoN (2012b) proposed specific activities to review incentive programs in other Pacific Island countries including revolving fund schemes and then to establish incentive programs for improving and maintaining rainwater harvesting and storage at the household and business level. DCIE (2012) recommended a water micro-credit scheme for low income households to maintain and develop their rainwater harvesting systems. It mentioned the credit should be provided as vouchers "to purchase water related infrastructure items, preferably from on-island business or from overseas for items that are not available on the island". One approach which was used to assist households In Tarawa, Kiribati, with rainwater harvesting and sanitation improvements was a government-run revolving loan fund scheme whereby loans were provided to purchase materials and paid back over two years. This scheme was established during an Asian Development Bank (ADB) funded project in the early 2000s. It was administered by the Kiribati Housing Corporation (White, 2010) and operated for at least seven years.

Recommendations:

- Develop guidelines for design and instructions for maintenance of rainwater harvesting systems for households and other buildings using readily available information that has been used in other Pacific Island Countries. Items of particular importance are the use of high capacity gutters and overflow pipes directed to groundwater wells where possible.
- Prepare and implement a building code with mandatory requirements for rainwater harvesting facilities (gutters, downpipes and tanks) to be installed at all new houses and government, community and commercial buildings.
- Collect and test 10 rainwater samples from selected households in each of the 14 districts and include the results in education and awareness programs.
- Include training of households in maintenance procedures in any future rainwater harvesting improvement projects.
- Reactivate community and school education programs about the need to maintain rainwater harvesting systems for the benefit of households, especially due to significant cost savings that can be made by using rainwater, when available, rather than expensive desalinated water.
- Introduce financial incentives for the maintenance, repair and enhancement of household rainwater harvesting using schemes such as subsidised rainwater harvesting materials and a revolving fund for loans to purchase rainwater harvesting components.

Increased rainwater harvesting at government and other buildings

There is scope for increasing rainwater harvesting at government, community and commercial buildings although it is considered greater benefits accrue from household rainwater harvesting as outlined in the previous section.

Activities that would enhance rainwater harvesting at government and community buildings and at presently unused tanks are:

- As mentioned in section viii, prepare and introduce a building code requiring all new government, community and commercial buildings to install appropriately sized gutters, downpipes and rainwater storage tanks for use within the buildings. The regulations should provide a method of estimating the storage capacity of rainwater tanks based on roof areas of buildings. The rainwater harvesting calculator mentioned in the previous section could be used to develop appropriate tables of roof areas and capacity of tanks.
- The concrete tanks C7 - C12 at the former Golf Course should be rehabilitated and lined to store rainwater as mentioned in the NWSMP and earlier in this review report. This water could be used by the Fire Department. A roof similar to that over concrete tanks C1 - C6 should be constructed and fitted with appropriately sized gutters and downpipes.

Recommendations:

- As in section viii, prepare and implement a building code with mandatory requirements for rainwater harvesting facilities (gutters, downpipes and tanks) to be installed at all new houses and government, community and commercial buildings.
- Rehabilitate and install liners in concrete tanks C7 - C12, construct a roof over these tanks and install aappropriately sized gutters and downpipes.

Increased use of groundwater

Groundwater, which is mainly brackish, is pumped or bailed from wells at many households and some other buildings in the coastal margin and the low-lying Buada lagoon area. The groundwater is primarily used for non-potable requirements, including toilet flushing and washing, especially in dry periods when rainwater depletes. Use of groundwater acts to lower the use of high quality yet expensive desalinated water.

As mentioned in section 7.vi, groundwater boreholes were drilled in 2008-2009 using a drill rig that was brought to the island for groundwater investigations and later purchased by the NRC. In all, 26 boreholes in the coastal margin and the Buada lagoon area were fitted with 100 mm PVC casing and screen to enable groundwater pumping. One borehole, near the RoN Hospital was fitted with a pump to feed a desalination plant at the hospital. The other 25 boreholes were drilled at various locations around the island and were intended to supply groundwater primarily for toilet flushing. Pumps were installed at the borehole near the Government offices in Yaren district (SOPAC, 2010) and at some other boreholes although the actual number that were equipped with pumps was not known at the time of preparing this report.. The locations and current status of these groundwater pumping systems including groundwater salinity should be obtained.

A groundwater supply system to supply toilet flushing water for 400 people has been installed in the Meneng district (NRW, 2017). This system consists of a pump station about 50 m from the ocean, a pipeline to a headtank near the Nauru Primary School and a piped reticulation system to nearby houses. This is a good initiative as it reduces dependence on either desalinated water or rainwater for toilet flushing. As the pump station is located close to the ocean, the groundwater is likely to be very brackish. The current status of this water supply system and any other similar systems should be obtained.

Additional groundwater supply systems should be implemented to supply water for at least toilet flushing in other parts of the island which could possibly be based on districts. One such system was recommended in SOPAC (2010) for the Location housing blocks which have the highest population density on Nauru. The recommended system, which would be the highest priority of any new groundwater pumping system, would include drilling one of more boreholes or possibly construct an infiltration gallery in nearby open land (e.g. near tanks C7-C12), install pump(s), pipelines and a head tank on a tankstand, and supply groundwater to toilets or possibly standpipes at the ends of each Location block. Exact details need further discussion with GoN and the Location residents.

Another area which would benefit from a supply of clean groundwater are the houses in the Aiwo district which are situated above groundwater contaminated with oil and other hydrocarbons. These houses are identified in Bouchet and Sinclair (2010, Map 9).

Pipes for groundwater could be laid in the same trenches as pipes intended for potable water supply. This was done, for instance, in South Tarawa when freshwater pipes and saltwater pipes were laid in the same trenches during projects in the 1970s and 1980s.

Groundwater pumping systems need to be properly designed and monitored to ensure that groundwater salinity is well managed within reasonable limits and does not impact on nearby household groundwater supplies. A regular groundwater monitoring program at existing and new groundwater pumping systems should be implemented.

In addition, the groundwater monitoring program for the monitoring boreholes drilled in 2008 and monitored between 2008 and 2011 should be re-activated. A number of the Topside boreholes are no longer present due to mining activities but there are others which would still be present in Topside and Bottomside. Monitoring data from these boreholes indicated that fresh groundwater only occurs at all times, especially during the major drought period in 2008-early 2009, in the northern part of the island. The groundwater in some other parts of the island varies from fresh in wet periods to brackish in droughts.

It is noted that seawater could be used instead of groundwater, as was previously the case in the Aiwo and Denigomodu districts including the Location (refer section 0). A report was prepared in 2014 about restoring the seawater supply system using the Command Ridge tanks to supply the original area (Aremwa, 2014). While seawater supply is a possibility, a groundwater scheme is considered preferable for the supply to the Location for a number of reasons including (a) pumping to a nearby head tank rather than Command Ridge tanks and hence lower pumping costs, (b) reduced corrosion of any metal components including pumps due to lower salinity, and (c) if any overflow occurs there would be less negative impact on nearby groundwater.

Recommendations:

- Identify the location and current status of all groundwater pumping systems including those installed at Government and other buildings in 2009 and more recent schemes such as the one in the Meneng district.
- Design and install, as a high priority, a groundwater pumping system using nearby groundwater to supply toilet flushing water at the Location housing blocks.
- Implement additional groundwater pumping systems in other parts of the island including for houses in the Aiwo district which are situated above groundwater contaminated with oil and other hydrocarbons.
- Design all groundwater systems to ensure that groundwater salinity is well managed within reasonable limits and does not impact on nearby household groundwater supplies.
- Implement a regular groundwater monitoring program at existing and new groundwater pumping systems
- Reactivate a regular groundwater monitoring at the remaining monitoring boreholes drilled in 2008.

Other possible water supply measures

ix. Outline

Other possible measures to augment water supply on the island are:

- Large scale rainwater harvesting in mined-out areas
- Collection and treatment of runoff from the airport runway

- Groundwater pumping from selected open areas

These are considered briefly below. All are considered to be of lower priority than the three possible additional measures described in sections 0, 0 and 0

x. Large scale rainwater harvesting in mined-out areas

As mentioned in section 4.iv, large scale rainwater harvesting using “manmade large catchment areas” where mining has occurred was considered but rejected in the NWSMP on the basis of land ownership issues, possible secondary mining and high cost of removing pinnacles. A fourth and important issue not mentioned in the NWSMP is the high evaporation rate that would make such catchment areas unviable unless covered which would be very expensive.

This type of large scale rainwater harvesting is practiced on some small islands such as some of the Torres Strait islands, Australia. On some islands collection and storage areas of approximately 200 m by 100 m have been installed. The rainwater is supplemented with desalinated water and groundwater.

From a technical viewpoint this option could be further investigated but if land ownership issues arise, this option is not worth considering. However, this option is not seen as a high priority item compared with the proposed water supply system and improved household rainwater harvesting facilities.

Recommendations:

- Assess the feasibility of a large scale rainwater harvesting in mined-out areas from a land ownership perspective.
- If feasible, investigate this potential option from a technical and economic perspective using experiences from other islands including Torres Strait Islands, Australia.

xi. Collection and treatment of runoff from airport runway

A 2001 report on Nauru water supply and sanitation (WHO, 2001) considered the collection, storage and treatment of runoff from the airport runway as an option for additional water supply.

The 2011 Nauru Economic Infrastructure Strategy and Investment Plan (RoN, 2011b, Tables 1 and 10) identified a project for rainwater harvesting from the airport runway with an estimated cost of $8 million. No design details were shown to assess the basis of this costing. This potential project was seen as contingent on another project to resurface the runway. Ron (2011b) indicated that the runway rainwater harvesting project should be fully assessed in the water supply and sanitation master plan.

The 2019 Nauru Integrated Infrastructure Strategic Plan (RoN and PRIF, 2019, Table 4-1) listed the same runway rain water harvesting project again with the same cost estimate of $8 million. No further details were provided.

In the Pacific Islands, the only major rainwater harvesting scheme from an airport runway is the one on Majuro atoll, Marshall Islands. The rainwater is collected from the paved runway at the international airport with an area of 30 ha (Gale and deBrum, 2017) and pumped to a series of seven lined reservoirs with a total capacity of 130 ML and treated before entering the pipe network. This harvested rainwater is one of the main sources of water on the atoll with the others being rainwater harvesting at households and buildings and groundwater extracted from a freshwater lens at the western end of the atoll.

This potential project is not seen as a priority item but it should be considered in a revision version of the NWSMP, as recommended in RoN (2011b). It is considered that an amount of $8 million would be better spent on the proposed water supply system and improved household rainwater harvesting facilities.

Recommendation:

- Assess the feasibility and costs of a rainwater harvesting scheme using the airport runway including associated pumping, treatment and storage requirements in a revised version of the NWSMP as previously recommended.

11. Possible Alternative Sanitation Measures

Outline

As mentioned in section 0, the second objective for this review report is to "Consider alternate interventions or approaches more suited to Nauru's needs given the socioeconomic context to construct, operate and maintain, improved water and sanitation systems for Nauru."

It is noted that the list of 53 priority infrastructure projects in the Nauru Integrated Infrastructure Strategic Plan (RoN and PRIF, 2019) included only one sanitation/sewerage project i.e. a treatment plant for septic tank sludge. This is already incorporated into the proposed improvements in the NWSMP.

The NWSMP concluded that the best option for sanitation includes improvements to the on-site septic tanks, replacement of cess pits with septic tanks and installation of a small bore pipe system (Septic Tanks and Common Effluent Disposal System) to an STP at the Location with discharge of the treated effluent via irrigation in the centre of the island and emergency discharge, if necessary, via outfall to the ocean.

There are several components of the above system that could be modified as discussed below. These relate to:

- Type of sanitation system
- Possible option with three sewerage systems
- Outfall locations and designs.

Type of sanitation system

As mentioned in section 7.vi, a conventional gravity sewerage system could possibly be installed. This type of system has the advantage that existing septic tanks and cess pits could be removed and desludging would not be required. There are some examples of conventional sewerage systems in small Pacific Islands including:

- South Tarawa, Kiribati where three conventional sewerage systems operate in the main population centres of Betio, Bairiki and Bikenibeu using seawater as the flushing water. These systems were installed over a five year period between 1978 and 1980 and have been rehabilitated on two occasions since then. Another smaller system operates at the main hospital. No treatment is provided for the main systems other than maceration of the raw sewage by pumps before discharging to the ocean via outfalls which terminate at a depth of about 30 m below sea level on the southern (ocean) side of South Tarawa. In other parts of South Tarawa, on-site sanitation (septic tanks and pit toilets) are used.
- The main urban area of Majuro atoll and Ebeye Island on Kwajalein atoll, Marshall Islands which also use seawater for toilet flushing and discharge raw sewage via outfalls to the ocean (Majuro) and lagoon (Ebeye). The 400 mm diameter outfall on Ebeye island discharges at a depth of about 30 m at a distance of about 300 m from the island.

One potential major disadvantage regarding installation of a conventional gravity sewerage system is possible construction difficulties if limestone pinnacles are encountered during excavation for the piped sewerage system.

As mentioned in section 7.vi, there is the possible presence of limestone pinnacles in the coastal margin and the low lying Buada lagoon area where most sewerage pipes would be laid. However, no hard limestone (pinnacles or other) was encountered in the top 3-5 m of sediments in most boreholes drilled in the coastal margin and the Buada lagoon area in 2008-2009.

The other major potential problem is that land ownership may prevent construction. This potential problem also affects both the small bore piped system and indeed the piped water supply system recommended by NRW. If such issues arise, then a further option involving improved (polymer) septic tanks and improved on-site disposal via effluent disposal pipes or beds will need to be considered, as mentioned in section 7.vi. This method has been proposed for Kiritimati (Island) in Kiribati (Falkland and White, 2008) although other methods are currently being considered.

It is noted that compost toilets have not been considered as an option in this review report as other reports (e.g. Hara, 2010, White, 2012) mention there would be difficulties introducing these in Nauru due to preferences for flush toilets, as has been the case in other PICs.

Recommendation:

- Further consider the installation of a Conventional Gravity Sewerage System rather than the Septic Tanks and Common Effluent Disposal System based on available evidence of the type of sediments and possible presence of limestone pinnacles, particularly in the coastal margin where most sewerage pipes would be laid. This recommendation was also made in section 7.vi.

Possible option with three sewerage systems

The NWSMP has indicated that one piped sewerage system would be installed with all effluent being treated at a proposed STP installed at the Location. As the distance around Nauru's ring road is about 18 km, the length of two main sewer pipes commencing on the eastern side of the island and laid around both the north and south ends of the island to the STP on the west side of the island would be about 9 km each. There would also be main sewer pipes from other areas including the Buada district where a connecting pipeline would be at least 2 km long to the main pipeline adjacent to the ring road in Aiwo.

Rather than one piped sewerage system for Nauru, another possible option is to have three smaller sewerage systems each discharging to the ocean via separate outfalls. The three systems would be as follows:

- **Sewerage System No 1** would collect, treat and dispose of the sewage from the six districts between Boe and Baitsi and the Location on the western side of the island as well as Buada district and possibly the other locations in Topside. The percentage of the island's population in these districts and the Location is 59% based on Figure 11 of the NWSMP. This system would include a STP at the proposed Location site which would also process the sludge from all septic tanks on the island, assuming that the septic tanks are retained and a small bore (CED) system is installed. Disposal would be to the ocean via an improved outfall near the Location.
- **Sewerage System No 2** would collect, possibly treat and then dispose of the sewage from the five districts of Ewa, Anetan, Anabar, Ijuw and Anabare in the north and east of the island which represent a total of 19% of the island's population based on Figure 11 of the NWSMP. A smaller STP could be installed depending on need and available space. Disposal would be to the ocean via a new outfall near the northernmost part of the island, as discussed further in section 0.
- **Sewerage System No 3** would collect, possibly treat and dispose of the sewage from the Yaren and Meneng districts representing 8% and 14%, respectively, (i.e. a total of 22%) of the island's population based on Figure 11 of the NWSMP. As for system No 2, a smaller STP could be installed depending on need and available space. Disposal would be to the ocean via a new outfall near the southernmost part of the island, as discussed further in section 0.

The advantage of three systems would be smaller pipe and pump sizes in each system and smaller effluent discharges to the ocean at each site than at one site. They could be constructed over several years with the first being Sewerage System No 1. Experience with the first system would be useful regarding any modifications to the design for the second and third systems and would enable discussions with local communities and studies regarding outfall sites and designs to be conducted over more than a year (refer section 0).

Recommendation:

- Consider a possible alternative to the proposed single sewage collection, treatment and disposal system consisting of three separate systems.

Outfall locations and designs

The locations of the three outfalls mentioned above would be:

- Outfall No 1: near the Location as proposed in the NWSMP.
- Outfall No 2: near the northernmost part of the island. The approximate distance from the beach to the edge of the reef would be between about 250 m and 300 m.
- Outfall No 3: near the southernmost part of the island. The approximate distance from the beach to the edge of the reef would be between about 150 m and 200 m.

Examples of multiple outfalls on small populated islands are found on South Tarawa, Kiribati and Malé Island in the Maldives.

The northernmost and southernmost locations were selected because the predominant winds and currents are from the east to the west and these locations have the potential for sewage plumes, treated or not, to move away from the island to the west. This, however, needs further investigation as mentioned below.

The outfalls could be extended down below the edge of the reef to a depth of about 20 m to 30 m as has been done with rehabilitated outfalls at Betio, Bairiki and Bikenibeu on South Tarawa and on Ebeye Island, Marshall Islands.

The actual locations of the possible northern and southern outfalls should be decided after discussions with the local communities and hydrodynamic studies of ocean currents and background water quality studies near the edge of the reef. If these studies show that ocean currents combined with extension of these outfalls below the reef level will lead to dispersion of the sewage plume and movement away from the island, then there may not be a need for STPs at these locations. Decisions about possible installation of STPs at the northern and southern sites should be made after studies are conducted over at least a year at these locations and discussions are held with GoN and the local communities.

To prevent damage, the outfalls should be dug into the reef rather than being above the reef and covered with concrete, particularly for the northern and southern outfalls. The extensions of the outfalls from the edge of the reef to depths of 20 m to 30 m should be with MDPE pipe with suitable anchoring.

Recommendations:

- Consult with GoN and local communities about possible outfall sites in the north and south of the island.
- Conduct hydrodynamic studies of ocean currents and background water quality studies near the edge of the reef.
- Decide on whether STPs are required at the possible northern and southern outfall sites.

12. Conclusions and Recommendations

12.1 Main findings and conclusions

Updating the NWSMP

- Many sections of the Nauru Water and Sanitation Master Plan, 2017 (NWSMP) require updating. For example, the use of a planning horizon from 2015 to 2035 is now well outdated. Also, the population projections which are based on the 2011 Census should be reviewed.

Sources of water

- The NWSMP correctly acknowledges that the main sources of water are rainwater, desalinated water and groundwater.
- The NWSP states, again correctly, that "Rainwater is considered to be the lowest cost, high quality water source that is available on the island". However, during droughts, rainwater is not available at least for non-potable uses in most households and desalinated water becomes the primary source of freshwater.
- The NWSMP correctly points out that there is a need for rainwater tanks at all households and repairs or replacements of roofing and downpipes are required to improve rainwater harvesting potential.
- The NWSMP acknowledges that groundwater is a valuable source of non-potable water and can reduce the use of rainwater and desalinated water.
- The NWSMP recommends that groundwater be used only for toilet flushing due to health risks. However, it could also be used for garden watering depending on its salinity.
- The NWSMP has some misleading comments about groundwater status and availability including statements that the freshwater lens may be damaged by pumping (noting that most of the groundwater is brackish) and groundwater availability will diminish or "run out" in droughts (noting that this is not the case as the groundwater level is controlled by sea level and the groundwater will be available provided wells are sufficiently deep).
- While recognising that all three main sources of water are a valuable part of the total water resources, the NWSMP focuses primarily on desalinated water.

Water demand and future scenarios

- The adopted per capita water demand of 110 litres per person per day (Lpd) is considered reasonable for internal household uses. It is reasonably consistent with estimates for other Pacific Island Countries (PICs).
- The estimated allowance in the NWSMP for water losses (non-revenue water) in a water supply distribution network of 20% of water demand is reasonable for a well maintained piped water supply system. However, it is optimistic based on loss rates for water distribution systems in many other PICs and a minimum loss rate equal to 30% of demand is more appropriate.
- The six possible future water demand scenarios have some incorrect assumptions related to groundwater and rainwater availability which need correcting.

Water supply standards of service and design criteria

- The NWSMP correctly notes that there are no national standards of service for water supply. Further, it notes that the water supply system does not meet minimum standards that would reasonably be expected in most countries and the lack of a piped supply is indicative of an "emergency" supply system.

- The proposed installation of a piped water distribution system, including a ring main around the island, is supported as it would greatly improve the supply of desalinated water to consumers provided that land ownership issues can be resolved if they arise.
- Piped water supply systems have been operating in many small Pacific Islands including South Tarawa in Kiribati, Majuro and Ebeye in the Marshall Islands and several islands in the Cook Islands and Tonga. The piped water supply system on Ebeye uses desalinated water as would be the case on Nauru.
- If land ownership issues prevent the construction of all or part of the proposed piped water distribution system, it will be necessary to make changes to the NWSMP with a greater focus on ensuring that an adequate fleet of tankers, maintenance facilities and staff are available at all times.
- The maximum design water pressure of 50 m for the proposed distribution system is high compared with water supply systems on some other Pacific Islands. Higher pressures lead to higher losses due to leakage in water supply networks. This should be reduced to 30 m to minimise losses.
- The minimum design water pressure of 10 m for the proposed distribution system is also high. This should be reduced to 5 m, again to minimise losses.
- Other design criteria related to reservoir volumes, pumping hours and pipe diameters, materials and classes are all considered appropriate.
- The proposed fire fighting provisions including the number of fire hydrants and future use of the six large abandoned concrete tanks at the Golf Course to provide additional fire-fighting capacity are also considered appropriate.

<u>Water supply system design details</u>

- A number of design issues are raised in the detailed comments within this review report including:
    - The need to reduce the pressure from the Command Ridge tanks to Buada residents to no greater than the recommended maximum pressure of 30 m.
    - The need to reconsider the pipeline route as shown in the NWSMP from the Command Ridge tanks to the proposed Anetan tanks owing to the mining of much of the ridge road since 2017.
    - The need to consider extending the pipe network to include the facilities in Topside.

<u>Sanitation/sewerage supply standards of service and design criteria</u>

- The NWSMP correctly notes that there are no national standards of service for sanitation or sewerage systems.
- The proposed installation of a piped sewerage collection system is supported as it would greatly improve the current groundwater contamination problem provided that land ownership issues can be resolved if they arise.
- If land ownership issues prevent the construction of all or part of the proposed piped sewerage collection system, it will be necessary to make changes to the NWSMP with the focus on improved septic tanks and improved on-site effluent disposal systems. The present methods of desludging would need to continue with the sludge taken to a proposed sewage treatment plant.
- The selection of 130 Lpd for “unit household demand” for sewerage system design is not consistent with the adopted 110 Lpd for per capita water demand and should be reduced.
- The selection of pipe materials is considered appropriate.

Sewerage system design details

- The adoption in the NWSMP of the "Septic Tanks and Common Effluent Disposal" option in the NWSMP is considered reasonable but has the obvious disadvantage that desludging of septic tanks will need to continue into the future.
- It is considered there is not enough evidence in the NWSMP to reject the "Conventional Gravity Sewerage System" option from further consideration. This option was rejected in the NWSMP because deep trenching and additional pump stations would be required owing to the need for the gravity pipes to be straight and at a constant gradient. A further possible problem is that limestone pinnacles may be encountered during excavation which would make the construction work very difficult and expensive. However, no hard limestone (pinnacles or other) was encountered in the top 3-5 m of sediments in most boreholes drilled in the coastal margin and the low-lying Buada lagoon in 2008-2009.
- Conventional gravity sewerage systems with multiple pump stations and ocean outfalls have been operating on South Tarawa in Kiribati and on Majuro and Ebeye in the Marshall Islands for many years. These systems have all been installed on atoll islands where the predominant sediments in which the sewer pipes have been laid are unconsolidated sands and gravels.
- If the Septic Tanks and Common Effluent Disposal option is adopted:
  - Rather than having all wastewater from houses and other buildings flow through septic tanks as indicated in the NWSMP, consider bypassing the "greywater" from bathrooms and laundries while ensuring all "blackwater" from toilets and probably kitchens passes through septic tanks. This would relieve the "hydraulic load" on septic tanks.
  - The use of polymer double chamber type septic tanks is supported rather than current septic tanks using concrete blocks mortared together.
  - Septic tanks with capacities larger than 2,500 L should be considered for large households.
- The sewage flow calculations used for the "worst case scenario" in an example area need to be checked and revised as higher flows are likely to occur.
- A number of items in the Effluent Quality section of the NWSMP require checking and updating.

Sewerage treatment and disposal

- If either piped sewerage system option is installed, the NWSMP proposal to install a sewage treatment plant (STP) is supported. The selection of a conventional trickling filter treatment system to produce the Class C effluent is also supported.
- The preferred site in the NWSMP for a STP is at the Location due to its proximity to the serviced area, accessibility to ocean outfalls and the non-desirability of locating an STP on elevated ground due to groundwater contamination risks.
- The NWSMP concluded that the treated effluent from the STP should be disposed by irrigation of mine rehabilitation areas in the centre of the island and emergency discharge, if necessary, via outfall to the ocean. This land disposal option is problematic because it (a) would involve further major infrastructure to pump the effluent into the centre of the island, (b) would impose additional operation and maintenance requirements and costs on NUC and presumably the Nauru Rehabilitation Corporation, and (c) could present potential health risks during effluent disposal in the mine rehabilitation areas, particularly if problems with the treatment process arise.
- The NWSMP does not include a comparison of the advantages and disadvantages of effluent disposal options i.e. via irrigation on land or discharge to the ocean via outfall(s).

- The outfall disposal option has several advantages including much lower operational costs and maintenance requirements than land disposal in the centre of the island. This method of disposal has been successfully operating with conventional gravity sewerage systems on South Tarawa, Majuro and Ebeye and should be considered as the preferred option for Nauru.

Proposed capital works and timing

- The timings of the two implementation phases for water and sanitation improvements need to be changed to later years.
- The budget shown in NWSMP was updated in the later Nauru Priority Water Sector Development and Funding Needs Report, 2017 including a household rainwater harvesting improvement component.

Operation and maintenance

- The NWSMP section on O&M requirements and staffing to be updated with current information and would benefit from experiences with other utilities in other small PICs that operate and maintain water and sewerage systems.
- There is a need for a new section which considers fees for water and sewerage services and the ability of Nauruans to pay for these services.

Possible Additional Water Supply Measures

- Possible additional water supply measures include increased rainwater harvesting at households and at government, community and commercial buildings and increased use of groundwater supply systems. Other possible measures are also outlined.

(a) Increased rainwater harvesting at houses and other buildings

- The advantages of household rainwater harvesting are well known in Pacific islands including Nauru. The water is essentially free once the necessary rainwater harvesting components are installed and maintained. For Nauru, when rainfall is plentiful, rainwater can supply most, if not all, household needs depending on the sizes and conditions of roofs, gutters, downpipes and tanks and the number of people in the household. At times of plentiful rainfall, rainwater is conveniently available at household tanks and deliveries of desalinated water can be minimal. However, during droughts, rainwater is generally not available in most households and desalinated water becomes the primary source of freshwater.
- The NWSMP correctly points out that there is a need for rainwater tanks at all households and repairs or replacements of roofing and downpipes are required to improve rainwater harvesting potential. The Nauru Priority Water Sector Development and Funding Needs Report (NRW, 2017), prepared shortly after the NWSMP was published, mentions it is essential "that each and every household (and business) has a working rainwater tank that is connected to the guttering and provides a meaningful amount of storage so that it can become the primary water source at that location".
- Information about rainwater harvesting components (roofs, gutters, downpipes and tanks) from the 2011 Census, a 2019 NUC survey and a 2020 mini-census indicate that some households require adequately sized storage tanks while a significant number of households require repairs to or replacements of roofs, gutters and downpipes in poor condition.
- The total water storage capacity of 20.4 ML of the tanks at households and other buildings is very significant being about 3.2 times greater than the current total storage capacity of the large tanks (6.3 ML) within the public water supply system at Aiwo and Meneng. It is also slightly more than double the estimated storage capacity of 9.9 ML once additional tanks are installed. This shows the importance of storage tanks at households and other buildings to the total storage capacity on the island.

- Government of Nauru strategy and policy documents over the past 15 years indicate strong support for improvements to rainwater harvesting particularly at households including the need for incentive schemes to encourage households to improve and maintain roofs, gutters, downpipes and tanks.
- Despite this support, the Nauru Integrated Infrastructure Strategic Plan, 2019 does not include any household rainwater harvesting improvements in its list of 53 priority infrastructure projects. Also, a 2020 Project Design Document for installing water storage tanks for deliveries of desalinated water at 50 most vulnerable households dismisses rainwater harvesting. This is largely based on concerns about the quality of rainwater in relation to asbestos roofs and phosphate dust.
- Regarding asbestos roofs and the impact on rainwater collected from them, World Health Organisation drinking water guidelines states there is "no consistent evidence that ingested asbestos is hazardous to health, and thus it is concluded that there is no need to establish a health-based guideline value for asbestos in drinking-water. The primary issue surrounding asbestos-cement pipes is for people working on the outside of the pipes (e.g. cutting pipe), because of the risk of inhalation of asbestos dust". The same comments regarding asbestos cement pipes would apply to asbestos cement roofs and gutters. Based on this, there is no reason that rainwater collected from asbestos roofs and gutters cannot be used. Obviously, from the viewpoint of inhalation, asbestos roofs and gutters should be removed and replaced with suitable materials. A separate project to remove and properly dispose of asbestos roofs and gutters should be implemented especially at households.
- To examine the impacts of dust on rainwater quality ten rainwater samples were tested in 2010. The results showed that the concentrations of cadmium and lead were below the detection limit indicating no health risks from the dust. However, as mentioned in a 2014 report, dust seems to a taste issue and has led some households to completely abandon rainwater harvesting.
- This report includes results of rainwater harvesting simulations using the Nauruan rainfall data for typical households including number of people, per capita water demand, roof area and tank capacity. The results confirm findings in other locations that in many cases the most effective method of significantly increasing household rainwater harvesting potential is to repair, replace or install additional gutters and downpipes on existing roofs rather than increasing storage capacity.
- The results of rainwater harvesting analyses show there are significant average annual cost savings to be made by maximising the use of rainwater when available rather than relying solely on desalinated water. Using the NUC water rates for desalinated water in 2018-19, the average annual cost saving for typical households is in the order of $500 to $2,000.
- Further household rainwater harvesting analyses should be made to assess the optimal improvements for houses on Nauru.

(b) <u>Increased rainwater harvesting at government and other buildings</u>

- There is scope for increasing rainwater harvesting at government, community and commercial buildings.
- Activities that would assist are:
    - Preparation and introduction of a building code requiring all new government, community and commercial buildings to install appropriately sized gutters, downpipes and rainwater storage tanks.
    - Rehabilitation of concrete tanks C7 - C12 and installation of rainwater harvesting facilities to supply rainwater to these tanks

(c) Increased use of groundwater

- Groundwater pumping systems have been installed on the island to supply water primarily for toilet flushing at households, some government and other buildings and for part of the Meneng district.
- There is potential for additional groundwater pumping systems to be installed especially for densely populated areas such as the Location.

(d) Other possible water supply improvement measures

- These are:
  - Collection and treatment of runoff from the airport runway, as mentioned in previous reports including the Nauru Economic Infrastructure Strategy and Investment Plan, 2011.
  - Large scale rainwater harvesting in mined-out areas. This type of large scale rainwater harvesting is practiced on some small islands such as some of the Torres Strait islands, Australia. From a technical viewpoint this option could be further investigated but if land ownership issues arise, this option is not worth considering.

Possible Alternative Sanitation Measures

Possible alternatives were considered regarding the following aspects:

- Type of sanitation system (Conventional Gravity Sewerage System rather than the Septic Tanks and Common Effluent Disposal System), as previously mentioned.
- Three separate sewerage systems each covering part of the island rather than one system. The advantage of three systems would be smaller pipe and pump sizes in each system and experience with the first system would be useful regarding any modifications to the design for the second and third systems.
- Outfall locations and designs.

Community consultations

- It will be necessary to conduct community consultations about the proposed water supply and sewerage system designs to determine any land ownership or other issues that may arise including locations of water and sewer pipelines, additional water storage tanks, sewage treatment plant(s) and ocean outfall(s).
- It will also be useful to conduct community consultations regarding household rainwater harvesting improvements and maintenance and the type of incentive schemes that would assist implementation.

Report format

- There are a number of spelling, grammatical and other errors in the text (e.g. regarding units) which require correcting in a revised version of the NWSMP.
- Details of some reports referred to in the NWSMP are not provided and there is no section containing a list of references.
- It is evident that the NWSMP was not thoroughly proofread before publishing.

12.2 Summary of recommendations

Detailed recommendations are provided at the end of each section and sub-section of this report. As these are too numerous to be repeated in this section, a summary of the main recommendations are provided below:

Planning horizons and population projections

- Change the 20 year planning horizon from 2015 - 2035 to 2021 - 2040 or a later period depending on when improvements are likely to commence.
- Review and, if necessary, revise the population projections for water supply and sanitation planning purposes based on the estimated Nauruan population in 2020 and the most likely future scenario regarding the Refugee Processing Centres.

Infrastructure details

- Update the NWSMP with:
  - Current desalination plant and water storage capacities at both the Aiwo and Meneng sites and the arrangements for delivery of water based on current information.
  - Current operational arrangements for the desalination plants and deliveries of desalinated water.
  - Current sewage treatment plant details including the current methods of effluent disposal and disposal/treatment of septic tank sludge.

Groundwater status and use

- Revise the NWSMP to recognise that groundwater is not limited at houses and other buildings that have wells but rather that it is mainly brackish and will be available for use in droughts at least for toilet flushing.
- Revise the part of the NWSMP referring to a freshwater lens that may be damaged by pumping, noting that most groundwater is brackish.
- Provide comments about monitoring and management of groundwater pumping including upper limits on pumping rates to minimise impact on groundwater salinity.

Water demand and future scenarios

- Accept the estimate of 110 Lpd for average per capita demand for internal household water use in households as reasonable using all sources.
- Revise the loss rate from a potential piped water supply distribution system to a minimum of 30% of demand.
- Recalculate or delete the possible future water demand scenarios which are based on incorrect assumptions related to groundwater and rainwater availability.
- Recalculate the adopted future water demand scenario for the 20 year period 2021 to 2040 or a later period depending on when improvements are likely to commence and also take account of (a) groundwater use for at least toilet flushing and (b) non-residential demands if not already included.
- Revise the water supply estimates that NUC are supplying as a percentage of "real demand" under "normal" and drought conditions. Losses in pipelines should be deleted from the calculations to enable valid comparisons and the data should be updated to the year 2020.
- Revise the water supply estimate to the RPCs based on their current and expected future use.

Water supply standards of service and design criteria

- Adopt the proposal to install a piped water distribution system, including a ring main around the island, provided that land ownership issues can be resolved if they arise.
- Reduce the maximum design water pressure from 50 m to 30 m and the minimum design water pressure from 10 m to 5 m in the proposed water distribution system.
- Adopt other design criteria related to reservoir volumes, pumping hours and pipe diameters, materials and classes as specified in the NWSMP.

Water supply system design details

- Design the water supply system components for target years later than 2025 and 2035 as specified in the NWSMP.
- Outline the preferred measure to control the maximum pressure to Buada residents at 30 m rather than 50 m.
- Investigate alternative route option(s) for the proposed pipeline from the Command Ridge tanks to the proposed Anetan tank.
- Consider extending the pipe network to include the facilities in Topside.

Sanitation/sewerage supply standards of service and design criteria

- Adopt the proposal to install a piped sewerage collection system provided that land ownership issues can be resolved if they arise.
- Reduce the 130 Lpd for "unit household demand" for sewerage system design to be consistent with the adopted 110 Lpd for per capita water demand.
- Correct the errors in the average dry weather flow and peak flow values and units.
- Justify the inflow/infiltration estimate of 5% of the average dry weather flow which seems low.

Sewerage system design details

- Further consider the installation of a "Conventional Gravity Sewerage System" rather than the "Septic Tanks and Common Effluent Disposal System" based on available evidence of the type of sediments and possible presence of limestone pinnacles, particularly in the coastal margin and the low lying Buada lagoon area where most sewerage pipes would be laid. Any drilling logs additional to those drilled in 2008-2009 and geotechnical information should be checked to assess the type of sediments and likelihood of encountering limestone pinnacles.
- If the Septic Tanks and Common Effluent Disposal System is adopted:
    - Consider bypassing septic tanks for "greywater" from bathrooms and laundries while ensuring all "blackwater" from toilets and probably kitchens passes through septic tanks.
    - Revise the NWSMP to recommend that double chamber polymer septic tanks be used for all new and replacement installations.
    - Revise the NWSMP to recommend that septic tanks larger than 2,500 L (e.g. 3,000 L and 4,000 L) be used for large households.
- Check and revise the sewage flow calculations used for a "worst case scenario" example area.
- Update the Effluent Quality section based on the recommendations shown in that section of this report.

Sewerage treatment and disposal

- Adopt the proposal to install a sewage treatment plant using the conventional trickling filter treatment method provided that land ownership issues can be resolved if they arise.
- Adopt the disposal option of discharge to the ocean via outfall(s) rather than irrigation of mine rehabilitation areas in the centre of the island as proposed in the NWSMP.

Proposed capital works and timing

- Revise the timings of the two implementation phases for water and sanitation improvements to appropriate later years than shown.
- Update all tables, figures and associated text in the NWSMP with the additional items, including a household rainwater harvesting improvement component, and the revised budget as presented in the Nauru Priority Water Sector Development and Funding Needs Report, 2017.

Operation and maintenance

- Contact utilities in other small PICs that operate and maintain water and sewerage systems to gain a more accurate assessment of typical staffing levels required.
- Update the organisational structure based on anticipated O&M requirements for the water and sewerage systems including RO plants and STP(s).
- Include a new section which considers fees for water and sewerage services and the ability of Nauruans to pay for these services.

Possible Additional Water Supply Measures

(a) Increased rainwater harvesting at houses and other buildings

- Update the NWSMP with:
  - The most recent data regarding status of rainwater harvesting systems at households and other buildings.
  - Comments regarding the considerable support for household rainwater harvesting improvements in Government of Nauru strategy and policy documents over the past 15 years and the need for incentive schemes to encourage households to improve and maintain roofs, gutters, downpipes and tanks.
  - Comments regarding asbestos roofs and phosphate dust in relation to rainwater quality based on the latest (2017) World Health Organization guidelines and a 2010 report on rainwater sample testing.
  - A household rainwater harvesting improvement component and revised budget for the 20 year capital works program based on the Nauru Priority Water Sector Development and Funding Needs Report, 2017.
- Analyse all household rainwater harvesting systems and assess best strategies to improve rainwater harvesting which in many cases will be replacing existing gutters and downpipes and/or installing them on parts of house roofs where they are not already fitted.
- Due to the significant cost savings to households from using rainwater, when available, rather than purchasing desalinated water, conduct further consultations with the Government of Nauru and the Nauruan community about the need to include new or improved rainwater harvesting components with any project that focuses on installation of household water storage tanks, including the proposed project in the 2020 Project Design Document for installing water storage tanks for deliveries of desalinated water at 50 most vulnerable households.
- Develop guidelines for design and instructions for maintenance of rainwater harvesting systems for households and other buildings using readily available information that has been used in

other PICs. Items of particular importance are the use of high capacity gutters and overflow pipes directed to groundwater wells where possible.

- Prepare and implement a building code with mandatory requirements for rainwater harvesting facilities (gutters, downpipes and tanks) to be installed at all new houses and government, community and commercial buildings.
- Collect and test 10 rainwater samples from selected households in each of the 14 districts and include the results in education and awareness programs.
- Include training of households in maintenance procedures in any future rainwater harvesting improvement projects.
- Reactivate community and school education programs about the need to maintain rainwater harvesting systems for the benefit of households, especially due to significant cost savings that can be made by using rainwater, when available, rather than expensive desalinated water.
- Introduce financial incentives for the maintenance, repair and enhancement of household rainwater harvesting using schemes such as subsidised rainwater harvesting materials and a revolving fund for loans to purchase rainwater harvesting components.
- Advise the authors of the 2020 Project Design Document (SPC and RoN, 2020) to update the document with consistent terminology about the definition of a water storage tank in relation to its capacity.
- Prepare and introduce regulations requiring all new government and community buildings to install appropriately sized gutters, downpipes and rainwater storage tanks.
- Rehabilitate and install liners in concrete tanks C7 - C12, construct a roof over these tanks and install appropriately sized gutters and downpipes.
- Implement a separate project to remove and properly dispose of asbestos roofs and gutters especially at households.

(b) <u>Increased use of groundwater</u>

- Identify the location and current status including groundwater salinity of all groundwater pumping systems installed at Government and other buildings in 2009 and more recent schemes such as the one in the Meneng district.
- Design and install, as a high priority, a groundwater pumping system using nearby groundwater to supply toilet flushing water at the Location housing blocks.
- Implement additional groundwater pumping systems in other parts of Nauru including for houses in the Aiwo district which are situated above groundwater contaminated with oil and other hydrocarbons.
- Design all groundwater systems to ensure that groundwater salinity is well managed within reasonable limits and does not impact on nearby household groundwater supplies.
- Implement a regular groundwater monitoring program at existing and new groundwater pumping systems.
- Reactivate a regular groundwater monitoring at the remaining monitoring boreholes drilled in 2008.

(c) <u>Other possible water supply improvement measures</u>

- Assess the feasibility and costs of a rainwater harvesting scheme using the airport runway including associated pumping, treatment and storage requirements in a revised version of the NWSMP, as previously recommended in the Nauru Economic Infrastructure Strategy and Investment Plan, 2011.

- Assess the feasibility of a large scale rainwater harvesting in mined-out areas from a land ownership perspective. If feasible, investigate this potential option from a technical and economic perspective using experiences from other islands including Torres Strait Islands, Australia.

Possible Alternative Sanitation Measures

- Further consider the installation of a Conventional Gravity Sewerage System rather than the Septic Tanks and Common Effluent Disposal System, as recommended above.
- Consider a possible alternative to the proposed single sewage collection, treatment and disposal system consisting of three separate systems.
- Consult with GoN and local communities about possible outfall sites in the north and south of the island.
- Conduct hydrodynamic studies of ocean currents and background water quality studies near the edge of the reef.
- Decide on whether STPs are required at the possible northern and southern outfall sites.
- Consider alternatives to a piped sewerage system if land ownership issues prevent a piped sewerage system from being implemented. One alternative is to install improved septic tanks and improved on-site disposal via effluent disposal pipes or beds.

Community consultations

- Conduct community consultations about the proposed water supply and sewerage system designs including locations of water and sewer pipelines, additional water storage tanks, sewage treatment plant(s) and ocean outfall(s).
- Conduct community consultations regarding household rainwater harvesting improvements and maintenance and the type of incentive schemes that would assist implementation.

Report format

- Correct all spelling, grammatical and other errors in the text (e.g. regarding units)
- Include a references section
- Thoroughly proofread the revised document.

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Annex A1.1

Comments regarding the NWSMP text

A number of problems were noticed with the text of the NWSMP during this review including those listed below. The document should be improved with the use of spell checking software as well as a thorough proofread.

Errors in spelling and grammar were noticed while reviewing the NWSMP including the following:

- "Nuaru" (section 4.2.4 (a) and section 7.3)
- The first sentence in section 4.2.1 reads "The remain little available information on the existing water demand usage and patterns as currently customers are unmetered as they are not on a piped water supply system." The first part of the sentence does not make sense and "water demand usage" needs to be re-written as either "water demand" or "water usage" (or preferably "water use").
- The first and unfinished second sentence in section 4.2.5 should be deleted, as they repeat the same words as used at the start of section 4.2.4.

The following problems were also noticed with the NWSMP:

- The (List of) Abbreviations on page 9 of the Pdf file do not include some abbreviations used in the text (e.g. MDPE, RPC) and includes many not used in the text (e.g. CI, DSS, EP, ET, HLZ, L/ET/d, LLZ, MD, MDMM, MH, NRW, PE, PRV and PSV).
- The acronym RFC which occurs in several parts of the document should be RPC
- Appendices B and C are not cited in the report
- There is no references section.

Recommendations:

- Correct all spelling, grammar errors and other errors in the text (e.g. regarding units).
- Include a references section
- Thoroughly proofread the revised document.

A2 – Review of Existing Policy and Governance Arrangement by Professor Ian White

Review of the Nauru Water and Sanitation Master Plan: Relation to Existing Policy and Governance Arrangements

Ian White

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19 August 2020

Summary

This review examines how the Nauru Water and Sanitation Master Plan (NWSMP) supports and promotes the application of Nauru's policy and governance provisions and recommends additional actions that will assist implementation of the MWSMP. A review of relevant policies, strategies, plans and institutional arrangements, as well as broader sectoral information, was carried out. Nauru, the third smallest independent nation in the world, faces large challenges in water and sanitation. Currently water supply is precarious and vulnerable, with frequent La Niña-related droughts and sanitation is unsatisfactory.

The NWSMP, when implemented, will fulfill Nauru's commitments to the UN's 2030 Sustainable Development Goal no. 6 and to Pacific Regional Action Plan for Sustainable Water Management, 2003. Nauru's National Sustainable Development Strategy, 2005-2015 (NSDS, revised 2009) is the overarching Government Policy determining national priorities and directing government resources. Its sector goal for water and sanitation : "*Provide a reliable, safe, affordable, secure and sustainable water supply to meet socio-economic development needs*" and for waste and sewerage: "*Effective management of waste and pollution that minimizes negative impacts on public health and environment*" are consistent with the overall goals of the NWSMP. The 2011 Nauru Infrastructure Strategy and Investment Plan (NISIP) identified the priority infrastructure necessary to fulfill the NSDS. NISIP recognised that: *The Water & Sanitation Sector Master plan is essential for the comprehensive assessment of the sectors, and the detailed analysis of investment alternatives.* One policy objective of the National Water, Sanitation and Hygiene Policy, 2012 was *Water Master Plan for the long-term development of Nauru's water sources and associated storage and supply infrastructure produced.* The National Infrastructure Investment Strategic Plan has three projects within the top 52 which are also contained in the NWSMP. In broad thrust, NWSMP supports and promotes the application of Nauru's policies, plans and strategies. It however fails to address the 2025 targets in the NSDS that rain and ground water harvesting comprise 50 percent of total water production and that rainwater harvesting production be increased by 50 percent.

There is no current legislation to protect, conserve and manage Nauru's public water resources and the designated lead agency has no statutory powers in the regulation of water. A draft Environment Bill in various forms has been before Parliament since 2011 and is currently being further amended. It is recommended that this be passed as soon as possible, and regulations be drafted and passed on water quality standards, theft and misuse of public water and tampering with water meters.

The Land Act 1976 represents a major cost to the NWSMP and will delay its implementation. The Government does not own land in Nauru. Land for public use must be leased from extended family landholder groups. This involves lengthy negotiations. The NSDS recommended a "*Review of land tenure system and land legislation to be more investor friendly and market driven*" because of the negative impact of the current system on development projects. This has not occurred, and requires determined leadership otherwise projects vital to the health well-being and development of all Nauruans, such as NWSMP, could be excessively delayed or abandoned. a "*Review of land tenure system and land legislation to be more investor friendly and market driven*" because of the negative impact of the current system on development projects.

Introduction

The objectives of this report are to:

1. Review how the Nauru Water and Sanitation Master Plan (NWSMP) supports and promotes the application of existing water and sanitation policy and governance arrangements of Nauru, and
2. Recommend what additional considerations and interventions may be required to improve the implementation of the NWSMP with a focus on the policy, legislation and institutional structural aspects.

To achieve these objectives a review of the NWSMP (NRW, 2015; RoN, 2017) and relevant policies, legislation and institutional arrangements has been carried out. The difficulty of supplying water and sanitation services in Nauru in an affordable way are large. As the NWSMP acknowledges, Nauru sources water from rainwater harvesting, mostly contaminated groundwater, desalination and imported bottled water. It also points out that Nauru's current water supply and sanitation services are precarious and vulnerable. The Appendix provides a summary of some of the challenges Nauru faces in the water and sanitation sector and which the NWSMP aims to address.

Progress in Water and Sanitation in Nauru

In 2009 the situation was described succinctly as (Hebblethwaite, 2009):

> "*Nauru currently has no institutional, legislative or policy frameworks for the management of water and sanitation, leaving the country with no specific objectives or agreed targets for the management of its water resources, and no clear lines of responsibility for water resources planning and decision making. A further difficulty is that, despite a common concern about water, the citizens of Nauru are not effectively engaged in the protection of their water resources, and there is no clear mechanism in which to facilitate their participation in planning and management decisions*."

Since then, the Government in 2009 has revised the National Sustainable Development Strategy, 2005-2025, (NSDS, RoN, 2009b) which sets out Nauru's long-term vision, message and goals. It recognised that the way in which electricity and water services are delivered in Nauru were not sustainable.

Building on the NSDS, the Government developed in 2011 a 10-year Nauru Infrastructure Strategy and Investment Plan (NISIP, RoN, 2011a) which assessed current status and needs in each infrastructure sector and used this assessment to review proposed projects. NISIP noted that in 2010, 80% of desalinated water was unaccounted for water, deliveries of 12 L/person/day were only 12% of estimated demand and the cost of production of water was \$AUD20/m^3 compared with the price charged for water of \$AUD2.50/m^3. For sanitation in 2008, NISIP noted that only 50% of Nauruans had access to improved sanitation while less than 5% population had access to uncontaminated groundwater in 2010.

Cabinet in February 2012 endorsed the National Water, Sanitation and Hygiene Policy (NWSHP, RoN, 2012). Consistent with the NSDS, the vision of Nauru's NWSHP is:

> "*Reliable, safe, affordable, secure and sustainable water supplies to meet socio-economic development needs and appropriate sanitation systems for healthy communities and environments*."

The 2018 Annual Report of the Nauru Utilities Corporation (NUC, 2018) showed that non-revenue water in 2017-18 has been reduced to 13% with residential supplies around 14 L/person/day. Water tariffs are \$8.40/m^3 for residential, \$9.70/m^3 for Government and \$11.80/m^3 for commercial/industrial uses with delivery charges of \$5 for volumes < 5m^3 and \$10 for volumes > 5m^3. The cost of production by reverse osmosis remains at \$20/m^3.

In late 2019, Government updated the NISIP with the introduction of the Nauru Integrated Infrastructure Strategic Plan 2020-2030 (NIISP, RoN & PRIF, 2019). The NIISP was initiated in 2017 to ensure that investment levels are correctly prioritized to achieve required service levels and that assets are well managed to meet the financial, social, cultural and environmental needs of Nauru in a sustainable manner. NIISP ranked 53 infrastructure projects across all sector. Included in the list were relining four C water tanks (priority 4 estimated price, \$150,000), a replacement pipeline from AIWO to the RoN Hospital (priority 17,\$500,000), a new septage treatment plant for the country (priority 20, \$6,000,000), and s water remineralisation plant, (priority 42, \$160,000). Apart from the last, all are included in the NWSMP.

In both governance arrangements and in infrastructure management there have been major advances in Nauru. The Nauru Water and Sanitation Master Plan can be seen as another much-needed advance but it needs to meet Government objectives and be implementable.

Consistency with Policy and Governance Arrangements

- **3.1 International and Regional Agreements and Treaties**

The NWSMP is in line with Nauru's commitment to and is consistent with the overall thrust of the United Nation's 2030 Sustainable Development Goal 6*: To ensure access to safe water sources and sanitation for all*". It also recognises regional commitments made under the Pacific Regional Action Plan for Sustainable Water Management, 2003 which was endorsed by all Pacific Island Nations Heads of State during the Pacific Island Leaders meeting in Auckland in 2003.

- **3.2 NSDS, 2005-2025**

The NSDS is viewed as overarching Government Policy determining national priorities and directing government resources. One of the five long-term goals of the NDSD (RoN, 2009a) is: "Provision of enhanced social, infrastructure and utilities services." The main thrust of the NWSMP is enhanced services in water and sanitation. The sector goal given by the NDSD for water and sanitation is: "*Provide a reliable, safe, affordable, secure and sustainable water supply to meet socio-economic development needs*." For waste and sewerage, the sector goal is: "*Effective management of waste and pollution that minimizes negative impacts on public health and environment*". Both are consistent with the overall goals of the NWSMP.

The strategies identified in the NSDS for the water and sanitation sectors were:

a. Develop a national water resource management policy to guide the sustainable use and management of water resources in Nauru,
b. Improve water storage capacity and infrastructure,
c. Ensure optimal use of groundwater resources, and
d. Provide cost-effective measures for water supplied through reverse osmosis.

Those recognised under waste and sewerage were:

a. Strengthen the waste and sewerage sector by enhancing the capacity to manage solid and hazardous waste and sewerage, and
b. Develop marine pollution management strategies.

The NWSMP directly addresses strategies b. and c. under water and sanitation and a. under waste and sewerage.

The medium-term milestones (2015) identified by the NSDS under water and sanitation were:

a. Regular supply of water available to all households and businesses.
b. Water use and sanitation guidelines developed and implemented.
c. Assessment of recycled water completed.
d. Long-term sustainable options developed to ensure water is available during drought periods.
e. Water catchment and storage capacity expanded.
f. Water losses and leakage reduced.
g. Improvements made to groundwater harvesting infrastructure.
h. Cost-effective sustainable options for addressing water supplied through reverse osmosis implemented.

The NWSMP addresses a., d., e., f., and h. Two of the long-term milestones (2025) of the NSDS under water and sanitation are:

a. Rain and ground water harvesting comprised 50 percent of total water production.
b. Rainwater harvesting production increased by 50 percent.

While the NWSMP acknowledges the importance of rainwater harvesting and groundwater use in Nauru it does little to improve either, even though it acknowledges that rainwater harvesting in Nauru is sub-optimal. Groundwater in the NWSMP is pragmatically assigned to be used for toilet flushing and no limits are set for the extraction rate from groundwater.

• 3.3 NISIP, 2011-2020

In consultations, the NISIP (RoN, 2011a) found that all stakeholders emphasised the urgent need for a coordinated water supply master plan that comprehensively assesses sustainable demand, production and storage requirements; develops options for investment, tariffs and delivery; and garners political and community support for a detailed and sustainable strategy. NISIP also found that a major problem with the water sector was maintenance, particularly of household water harvesting systems.

NISIP believed that the main issue in the sanitation and waste management sector is the lack of policy and regulations, allowing the environment to be degraded, and placing public health in jeopardy and noted that a water and sanitation sector policy process was about to be commenced. It concluded:

> "*The Water & Sanitation Sector Master plan is essential for the comprehensive assessment of the sectors, and the detailed analysis of investment alternatives. It should begin with filling in the baseline information gaps (such as volumes of water produced, stored and delivered; household usage benchmarks, etc) so that policy can be based on realistic figures. A range of investment alternatives (such as rainwater tanks; reticulated supply, gravity-fed supply lines) can be analyzed using economic, financial and community criteria and integrated into an overall master plan for implementation. Government would approve each stage of the planning process and ensure that cost recovery and tariff structures are adequate for ongoing maintenance and sustainable future investment*."

The imperative for a Water and Sanitation Master Plan is very clear, although not all aspects envisaged in the NISIP are included in the current NWSMP, particularly in terms of tariffs and garnering political and community support for a detailed and sustainable strategy. In the absence of quantitative data on household rainwater or groundwater uses, the NWSP has taken a conservative approach to water supply by assuming that all household rain tanks will be empty and groundwater use is restricted to those with pumps. It does not address the critical issue of limiting the maximum groundwater pumping rate.

• 3.4 NWSHP, 2012

The NWSHP declares the Government's commitment to provide reliable, safe, affordable, secure and sustainable water supply and to facilitate appropriate sanitation systems to meet health and socio-economic development needs of all Nauruans and to provide direction to Government Departments, agencies and corporations."

NWSHP has seven policy goals:

1. Adaptation to climate variability and change incorporated in all aspects of water and sanitation management.
2. Reliable, safe, affordable, secure, efficient and sustainable water supply systems established.
3. Sanitation systems introduced to meet appropriate sanitation needs, minimise impacts on the environment and encourage improved hygiene.
4. Equitable and fair systems created for controlling demand, conserving water and minimising waste and losses.
5. Clear, consistent and transparent system of water and sanitation policy, plans and laws established that identify lead organisations, and their roles, responsibilities for managing, conserving and protecting water resources.
6. Appropriate resources, capacity, skills training, information and organisations available for managing water and sanitation systems sustainably.
7. Community aware of the issues and actively engaged in planning, protection and conservation of water and improvements to and maintenance of household water and sanitation facilities.

A set of policy objectives was listed in the NWSHP under each policy goal and included:

1.1 Water Master Plan for the long-term development of Nauru's water sources and associated storage and supply infrastructure produced.

The NWSMP can be seen as part fulfilment of a policy objective of the NWSHP.

The NWSHP identified Department of Commerce, Industry and Environment (CIE) which was designated as the lead agency, assisted by Department of Health, Nauru Utilities Corporation, Nauru Rehabilitation Corporation, Department of Education, Department of Finance and Sustainable Development, Department of Home Affairs and Disaster Risk Management Office. CIE currently has no statutory powers to regulate water.

The NWSHP also called for the establishment of a two-person water unit within CIE to coordinate implementation of the goals and objectives of NWHSP, undertake monitoring, planning and management of Nauru's water resources and their use and to oversee the development of a long-term water master plan and develop incentive schemes for increased community participation in water conservation and protection, improved rainwater harvesting and sanitation systems. It is uncertain whether this water unit has been formed.

• 3.5 Nauru Infrastructure Review Report, 2018, NIRR

The NIRR (Clear Horizon, 2018) was prepared for the Australian High Commission, Nauru to undertake an in-house end-of-term review of the DFAT-funded Nauru Infrastructure and Services investment and to help guide future programming decisions. The review was limited to investments since 2014. It found that DFAT's household water tank program was inadequate in terms of effectiveness, efficiency and monitoring and evaluation. The NIRR identified of currently foreseeable need for priority infrastructure investment in Nauru:

- Renewable energy;
- Water and sanitation;
- Drainage and roads;
- Health (community health clinics and stage 3 of the hospital, including nurses quarters);
- Information and Communications Technology, including access for educational purposes;
- Education (additional TVET facilities for staff and students, classrooms at primary and secondary
- levels if attendance rates increase);
- Waste management; and
- Land rehabilitation and associated infrastructure (including water catchments and land use planning).

The NIRR also pointed out that the Government of Nauru has established a Nauru Infrastructure & Asset Management Steering Committee to develop a Nauru Infrastructure Asset Management Framework (NIAMF) and the National Infrastructure Investment and Management Strategy[1] to set the direction for infrastructure investments and asset management for the next 5 to 10 years.

NIRR found that the investment in household rain tanks was unsuccessful and recommended investment in public infrastructure was a better option.

• 3.5 NIISP, 2020-2030

NIISP supersedes NISIP and is of a different character. It does not provide a sector by sector detailed analysis of past performance or governance needs. Instead it prioritized 53 infrastructure investment opportunities of various sizes using a multi-sectoral, multi-criteria quantitative assessment, applicable to all infrastructure sectors. The NIISIP acknowledges that in 2016/17 Nauruans were supplied on average 6L/pers/day of desalinated water while in 2017/18 average supply had increased to

[1] These were unable to be found on the internet. The Nauru-News web site mentions the launch on 7 August 2020 of a PRIF supported National Integrated Infrastructure Investment Plan but is unavailable on the PRIF web site.

15L/pers/day. NIISP's target for 2025 is > 20 L/pers/day. Despite the obvious shortage of per capita fresh water in Nauru, the assessment criteria used by NIISIP, and the obvious unsatisfactory state of septage disposal, only one water and sanitation project was listed within the top 10 priorities, the relining of four of the C tanks which receive desalinated was direct from RO units. A new Septage system did just make it into the top 20 priority projects, while a replacement pipeline from AIWO to the RoN Hospital made it within the top 50 projects. These are all included within the NWSMP.

3.5 Legislation

The NWSMP makes no actual mention of relevant government policies or strategies and only one mention of law regarding the number and placement of fire hydrants: *"... it was proposed to limit the number of network access points for fire hydrants to avoid unlawful access to the network."* Currently there is **no law** limiting access to public water supplies.

In 2009, Hebblethwaite (2009), identified the absence of a legislative framework for the management of water and sanitation as a key impediment to sector improvements in Nauru. That is still the case. Two policy objectives in the NWSHP were:

2.12 Law passed to protect water sources from misuse and theft.

5.6 Review of all legislation, regulations and policy relevant to water and sanitation conducted to determine the need for water and sanitation legislation or regulations to manage, conserve and protect fresh water.

These have yet to be done. Water in Nauru is unprotected from misuse, pollution, theft, and there are no water quality standards, and, in a country with frequent severe water shortages, no incentives for conservation.

In 2011, a draft Environment Act, draft Public Health Act Water Regulations, and draft Waste Regulations were in preparation for presentation to Parliament. No record can be found on the On-line Legal Database (RoN, 2020) of any water or waste regulations. Currently the DEMCC, has been returned by Parliament for further amendment, so it is not law.

The DEMCC does address some of the issues raised above and identifies CIE as being responsible for water and waste management, sanitation and natural disasters, including droughts. DEMCC also permits Cabinet to make regulations and a suite of these are needed including water quality standards, theft and misuse, and water conservation. It would seem imperative for the success of the NWSMP that DEMCC be enacted as soon as possible and that water regulations be specified as well.

3.6 Legal Impediments to the NWSMP

The Government does not own land in Nauru, all public spaces are rented from landowner extended family groups. The NSDS identified the urgent need for a revised land tenure system by 2015. It concluded that land issues and land disputes are the cause of many delays in achieving progress and that more attention and community awareness are needed together with a sound legal and regulatory framework.

The Lands Act 1976 (Amended April 2011, RoN, 2011d) specifies the payment of lease fees to landowners for land used for public use. The lease schedule depends on whether the land is phosphate-bearing, non-phosphate-bearing, or mined-out former phosphate land (RoN, 2014).

The MWSMP did not pursue the creation of manmade large catchment areas for rainwater harvesting on the island, particularly where mining activities have been previously undertaken. It recognised that land ownership issues were one of the major obstacles to building large catchment rainwater harvesting systems in Nauru. In addition, one of the criteria used by MWSMP to select the location of future water storages was where past water infrastructure had been previously constructed to reduce potential land ownership and conflict issues.

It is clear that the construction of pipelines around the island, under the existing Lands Act could incur continuing lease payments, a cost not considered in the NWSMP and a process causing extensive delay[2].

Recommendations

The Nauru Water and Sanitation Master Plan addresses Nauru's international and regional commitments in the water and sanitation sector and broadly fulfils the policy directives in the NWSHP, the NSDS and the NISIP. It is a professional, pragmatic attempt to address the urgent water and sanitation issues in Nauru. While it acknowledges that rainwater harvesting, groundwater and desalinated water as well as imported bottled water are all used as sources of water, it concentrates on planning a reticulation system for desalinated water and a partial reticulated sewage system. In a pragmatic approach it adopts a planning regime for water supply in which rain tanks have run dry and there is minimal groundwater use. In Nauru, which experiences severe droughts of 6 months duration, every 5.2 years, with average rainfall of 90 mm, this uses the precautionary principle; however, it would have been more consistent with the NSDS to have had some planning for large rainwater catchment and for groundwater. Large catchment rainwater harvesting was not pursued due to complications of leasing even mined-out land from traditional owners.

The NWSMP assumes that rainwater is "*considered to be the lowest cost, high quality water source that is available on the island*…" This is only the case in well-managed household rainwater systems. Many of the household systems are in disrepair on the island and the NWSMP does not address this need or the potential of a large-scale rainwater catchment. The NWSMP assumes that all the local coastal groundwater is too polluted for any use but for toilet flushing yet the Census 2011 results still show multiple uses for groundwater. One of the critical issues here, not addressed by the NWSMP, is to limit the maximum pumping capacity of groundwater pumps used, since excessive pumping can not only salinize a household's well but the wells of many of its neighbours.

The NWSMP does not recognise that the current absence of legislation on the regulation, management, conservation and protection of water is a major impediment to its implementation. Nor does it recognise that the Lands Act 1976 imposes a major financial cost and time-impost to its implementation.

It is recommended that the Nauru Government enact as soon as possible the draft Environment Management and Climate Change Bill 2020 and that the Bill include regulations on water quality standards, theft of water, tampering with water meters and misuse of water, water conservation, and specifying the maximum pumping capacity of groundwater pumps. The establishment of a water unit within CIE, as recommended by NWSHP would be also beneficial.

Land tenure is the elephant in the room. The NSDS recommended a "*Review of land tenure system and land legislation to be more investor friendly and market driven*" because of the negative impact of the current system on development projects. The Lands Act 1976 potentially represents a major impediment to improving water supply in Nauru. Although this is a politically complex task because of deep-seated traditional customs, it appears for the common good that some changes to the Act to specifically exempt a basic and essential water supply and sanitation plan and allow it to proceed would be of immense benefit to Nauru. This will require extensive consultation and purposeful leadership. It does not involve negating all tenure, merely allowing two vital services to be delivered to all Nauruans.

[2] The NIISP claims that it is expected to result in improved land use to provide public services in regard to land tenure claims. There is no mechanism in NIISP to achieve this.

Appendix

• Water and Sanitation Challenges in Nauru

The NWSMP final report provides a plan for supplying water and sanitation to the Pacific Island nation of Nauru, the third smallest independent country in the world, for the next 20 years. The difficulty and complexity of that task needs to be recognised. Nauru's single 22 km^2 raised coral island lies about 60 km north of the equator and is home to about 12,000 Nauruans. It also hosts an undisclosed number of asylum seekers housed in Australia's Regional Refugee Processing Centre (RPC)[3]. It is important to recognise that although a small island, Nauru has 15 different and distinct communities centred on 14 districts and the Location, each with different identities and loyalties. Most communities are located on a low, relatively narrow coastal fringe. A very large portion of the higher elevation interior has been mined for phosphate and requires rehabilitation.

Nauruans have survived under difficult circumstances for more than 3,000 years. One of the greatest and continuing challenges has been the periodic scarcity of freshwater, caused by El Niño-Southern Oscillation (ENSO) events which impact both rainfall and the island's fragile, variable quality groundwater. Although Nauru's average rainfall is around 2,100 mm, with on average about 56% of rainfall occurring in the November to April wet season, the historic rainfall record for the period 1947-2010 shows that major 6-month droughts, averaging only 90mm of rain, occur on average every 5.2 years (White, 2012).

Prior to 1995, Nauruans relied on multiple sources of water including rainwater harvesting, groundwater and water imported as ballast in phosphate ships or shipped directly from Kosrae in FSM. In droughts people also adapted and used seawater for bathing, washing and toilet flushing. In 1995, a thermal desalination unit was commissioned using excess heat from the electricity generator. Currently, water is sourced from imported bottled water, shallow groundwater, desalination from reverse osmosis units, rainwater harvesting and continuing use of seawater (Bouchet, 2011).

During the peak of phosphate mining, a reticulated system supplied water from an array of large storage tanks with water imported from ships and rainwater harvested from large buildings and delivered to household cisterns also used for rainwater harvesting. The public system has fallen into disrepair and water supply is now precarious and has been for almost two decades (SOPAC, 2007). Not all houses have rainwater harvesting systems[4], those that do are in variable states of repair. Desalination plants supply freshwater to the remaining storage tanks from where water is trucked to consumers and the NRC. The system is vulnerable to breakdowns in desalination plants, power plants, road tankers[5] and to fuel shortages.

The rainfall record suggests that, during the May to October dry season, domestic rainwater harvesting systems will fail on average once every 4.5[6] years. Even more challenging, during the October to April wet season, domestic rainwater harvesting systems will fail once every 6.0 years. Many of the domestic rainwater harvesting systems are sub-optimal.

During these severe dry times, there is heavy reliance on desalination, which can consume up to 30% of the island's expensive, mostly diesel-fuelled energy production. Shallow groundwater in the coastal fringe, because of uncontrolled extraction as well as non-optimal extraction methods, also becomes brackish at most locations. The former limited sewage systems on the island, with one or two exceptions, are now inoperable. Households rely on septic tanks or pit latrines. Discharge from these

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[3] Water and sanitation at the RPC are the responsibility of the Australian Government.

[4] The NISIP estimated that only 40% of household rainwater harvesting systems were maintained adequately (RoN, 2011a)

[5] NUC (2018) states that water tankers were only available 65% of the time and that 83.4% of water deliveries were completed within two days of the order being placed.

[6] Based on the percentile of rain less than or equal to 360 mm over the 6-month season.

has caused wide-spread pollution of groundwater in the coastal and significant public health challenges (Bouchet and Sinclair, 2010). Sewage treatment and disposal is a significant challenge in small islands with limited land area, limited water supply and surrounding coral reefs. In the coastal area in Nauru groundwater is accessed via vertical wells, a sub-optimal method in small, low islands, and is frequently brackish especially during dry periods. There are no current controls on the rate of groundwater extraction which, if excessive, can salinize groundwater.

The above summary illustrates the complex interconnections of issues relating to water and sanitation in Nauru: geographic isolation: people: water: energy: sanitation: health: climate variability: governance (Hebblethwaite, 2009). An additional challenge to water supply and sanitation planning in Nauru is the changing climate.

Changing Climate

Projections based on CMIP5 climate model results (ABoM and CSIRO, 2014) indicate that Nauru will continue to be impacted by ENSO events (very high confidence); annual mean temperatures and extreme high daily temperatures will continue to rise (very high confidence); mean rainfall will increase (medium confidence), along with more extreme rain events (high confidence); and droughts are projected to decline in frequency (medium confidence). No projections were given for potential evaporation. These suggest that water demand might be expected to increase with increasing temperatures, but this may be offset by the projected increase in mean rainfall and decrease in drought frequency.

The projected decrease in drought frequency, however, appears to be at odds with more recent model results which project that the frequency of severe ENSO events will double over the twenty-first century (Cai *et al*., 2014; 2015, IPCC, 2019). While incomplete monthly rainfall records at Nauru are available from 1893, other climate data is not available or is sparse. Sea surface temperatures (SST) surrounding Nauru have increased over the past 70 years at a rate of 1.0±0.1^{o}C/century[7], suggesting that air temperatures on Nauru have increased by a similar amount (ABoM and CSIRO, 2014). There are no significant trends ($p>0.1$) in annual, or wet and dry season rainfalls over the period 1894 to 2010 or over the period 1946 to 2010. In addition, the frequency of apparent dry season rain harvesting failures between the first half of the rainfall record (1893 to 1952) is less frequent (one in 7.7 years) than in the second half of the record (1953 to 2010, one in 4.8 years). Both the lack of a trend in rainfall and the increase in frequency of dry periods appear to contradict the climate model projections.

It would seem from the above that increasing temperatures in Nauru may result in a very modest increase in demand for water. In general, however, planning based on the historic frequency of dry periods in Nauru appears to be the best strategy for coping with the impacts of future climate on water availability and has been adopted in the NWSP.

Besides climate variability, governance and institutional issues are important factors which can determine the success of water and sanitation planning

The Hierarchy of Factors Relating to Water Governance and Planning

Bredehoeft (1997), reflecting on his long experience in applying science and technology to solve water supply challenges, concluded that there are broader and often more weighty contributors that take precedence over technical and scientific issues, despite their importance. In his hierarchy of factors contributing to decisions about water, legal aspects come first followed by political and economic factors. He placed technical at the lowest level.

Bredehoeft's original hierarchy has been modified in Figure 1 to include health and social-cultural issues, both of importance in the Pacific. A key thrust of integrated water resource management is recognition

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[7] SST in the Nino4 region

of the significance and inter-dependences of the factors in Figure 1. Failure to accommodate them in any water and sanitation policy or planning process can derail the process.

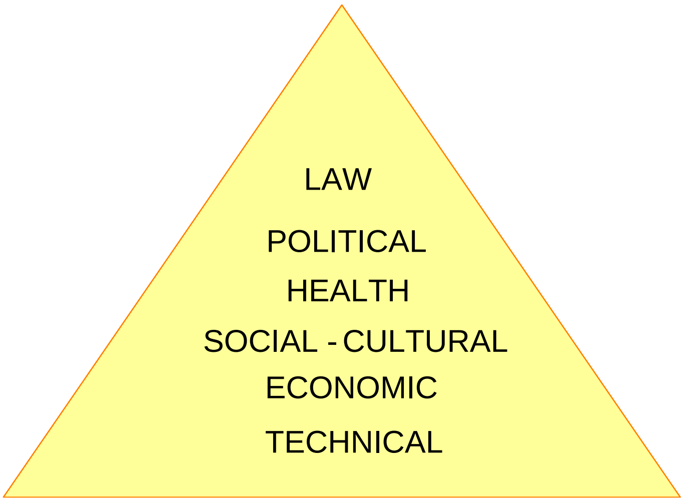

Figure 1 The hierarchy of factors contributing to water resources management (modified from Bredehoeft, 1997).

Normally the political, health, social-cultural and economic factors are encapsulated within government policy and are also reflected in enacted laws. Figure 1 emphasises the fundamental importance of law as a basis for water resources planning and management. In Pacific Island countries statutory law is often complemented by customary law. In some situations, customary law can predominate. Before considering relevant customary and statutory law, Nauru Government policy initiatives are considered.

Water, Sanitation and Hygiene Policy Initiatives

4.1 National Sustainable Development Strategy, 2005-2025, NSDS

The NSDS, revised in 2009 (RoN, 2009a,b) sets out Nauru's long-term vision, message and goals. Following the review of NSDS (RoN, 2009a), the current way in which electricity and water services are delivered in Nauru were recognised as not sustainable. NSDS identifies clear goals for the water and sanitation and waste and sewerage sectors directly relevant to the NWSMP, which are:

5 Provide a reliable, safe, affordable, secure and sustainable water supply to meet socio-economic development needs.
6 Effective management of waste and pollution that minimizes negative impacts on public health and environment.

The strategies identified under water and sanitation were:

- e. Develop a national water resource management policy to guide the sustainable use and management of water resources in Nauru,
- f. Improve water storage capacity and infrastructure,
- g. Ensure optimal use of groundwater resources, and
- h. Provide cost-effective measures for water supplied through reverse osmosis.

Those recognised under waste and sewage were:

- c. Provide cost-effective measures for water supplied through reverse osmosis, and
- d. Develop marine pollution management strategies.

The NSDS envisaged significant progress in all strategies by 2015, however, the NSDS did not define specific programs or activities to achieve the milestones nor their budgetary requirements or implications. These were the tasks of the National Infrastructure Strategy and Investment Plan, NISIP (RoN, 2011a).

4.2 National Infrastructure Strategy and Investment Plan, NISIP

The relation of the NISIP (RoN, 2011a) to the NSDS and to budgeting, Ministries, State Owned Enterprises and service delivery is shown in

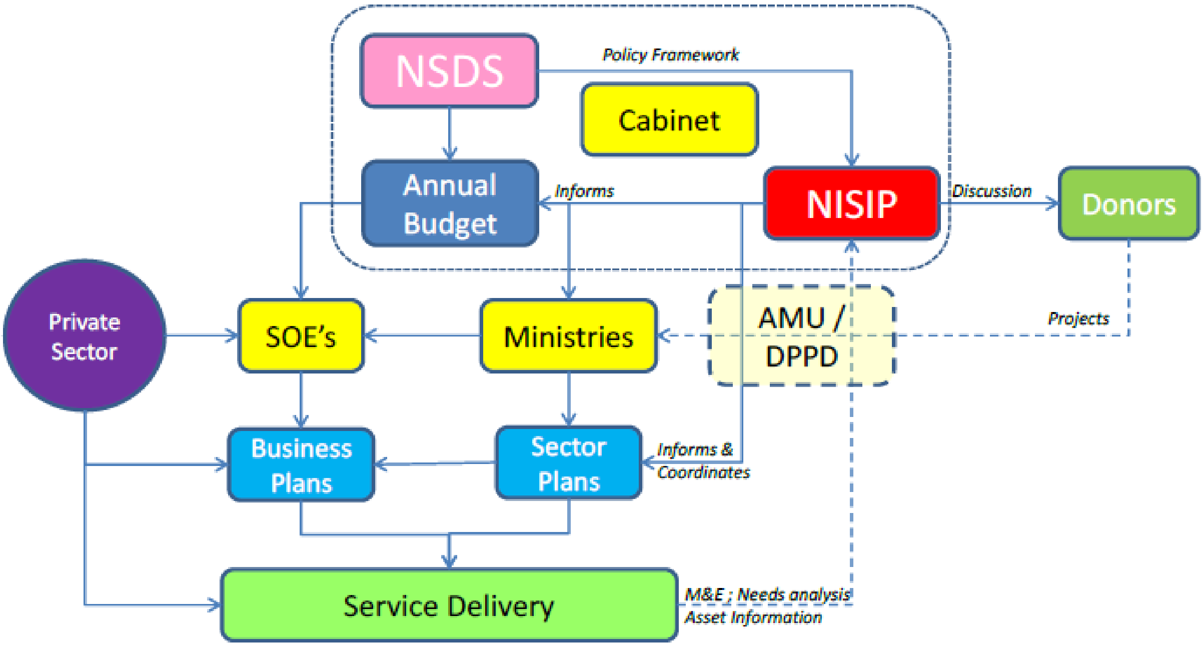

Figure 2 The relation of NISIP to Nauru's planning Structure (RoN, 2011a)

The NISIP (RoN, 2011a) noted that in 2010, 80% of desalinated water was unaccounted for water, deliveries of 12 L/person/day[8] were only 12% of estimated demand and the cost of production of water was \$AUD20/m^3 compared with the price charged for water of[9] \$AUD2.50/m^3. For sanitation in 2008, NISIP noted that only 50% of Nauruans had access to improved sanitation while less than 5% population had access to uncontaminated groundwater in 2010.

In consultations, the NISIP found that all stakeholders emphasised the urgent need for a coordinated water supply master plan that comprehensively assesses sustainable demand, production and storage requirements; develops options for investment, tariffs and delivery; and garners political and community support for a detailed and sustainable strategy. NISIP also found that a major problem with the water sector was maintenance, particularly of household water harvesting system.

NISIP believed that the main issue in the sanitation and waste management sector is the lack of policy and regulations, allowing the environment to be degraded, and placing public health in jeopardy and noted that a water and sanitation sector policy process was about to be commenced. It concluded :

> *"The Water & Sanitation Sector Master plan is essential for the comprehensive assessment of the sectors, and the detailed analysis of investment alternatives. It should begin with filling in the baseline information gaps (such as volumes of water produced, stored and delivered; household usage benchmarks etc) so that policy can be based on realistic figures. A range of investment alternatives (such as rainwater tanks; reticulated supply, gravity-fed supply lines) can be analyzed using economic, financial and community criteria and integrated into an overall master plan for implementation.*

[8] NUC(2018) reported non-revenue water in 2017-18 as 13% with residential supplies around 14 L/person/day.
[9] From NUC (2018), water tariffs are \$8.40/m^3 for residential, \$9.70/m^3 for Government and \$11.80/m^3 for commercial/industrial uses with delivery charges of \$5 for volumes < 5m^3 and \$10 for volumes > 5m^3.

Government would approve each stage of the planning process and ensure that cost recovery and tariff structures are adequate for ongoing maintenance and sustainable future investment."

4.3 National Water, Sanitation and Hygiene Policy, NWSHP

Nauru Cabinet endorsed the National Water, Sanitation and Hygiene Policy in February 2012 (RoN, 2012). The Policy was developed through consultations with all relevant government ministries, agencies and enterprises and with community and NGO representatives and through the National Development Committee that oversees implementation of the NSDS and NISIP. The purposes of Nauru's NWSHP are:

> "…to declare the Government's commitment to provide reliable, safe, affordable, secure and sustainable water supply and to facilitate appropriate sanitation systems to meet health and socio-economic development needs of all Nauruans and to provide direction to Government Departments, agencies and corporations."

Consistent with the NSDS, the vision of Nauru's NWSHP is:

> "*Reliable, safe, affordable, secure and sustainable water supplies to meet socio-economic development needs and appropriate sanitation systems for healthy communities and environments*."

NWSHP has seven policy goals:

1. Adaptation to climate variability and change incorporated in all aspects of water and sanitation management.
2. Reliable, safe, affordable, secure, efficient and sustainable water supply systems established.
3. Sanitation systems introduced to meet appropriate sanitation needs, minimise impacts on the environment and encourage improved hygiene.
4. Equitable and fair systems created for controlling demand, conserving water and minimising waste and losses.
5. Clear, consistent and transparent system of water and sanitation policy, plans and laws established that identify lead organisations, and their roles, responsibilities for managing, conserving and protecting water resources.
6. Appropriate resources, capacity, skills training, information and organisations available for managing water and sanitation systems sustainably.
7. Community aware of the issues and actively engaged in planning, protection and conservation of water and improvements to and maintenance of household water and sanitation facilities.

A set of policy objectives were listed in the NWSHP under each policy goal and included:

2.1 Water Master Plan for the long-term development of Nauru's water sources and associated storage and supply infrastructure produced.

2.12 Law passed to protect water sources from misuse and theft.

5.6 Review of all legislation, regulations and policy relevant to water and sanitation conducted to determine the need for water and sanitation legislation or regulations to manage, conserve and protect fresh water.

The designated government organisations identified to implement the NWSHP were:

Department of Commerce, Industry and Environment (designated lead agency)

Department of Health

Nauru Utilities Corporation

Nauru Rehabilitation Corporation

Department of Education

Department of Finance and Sustainable Development

Department of Home Affairs

Disaster Risk Management Office

The Policy adopted by Cabinet recognised the necessity to develop a Master Plan and to ensure there was a solid legal basis for managing and protecting water resources and improving sanitation.

4.4 National Water, Sanitation and Hygiene Policy, NWSHP

In late 2019, Government updated the NISIP with the introduction of the Nauru Integrated Infrastructure Strategic Plan 2020-2030 (NIISP, RoN & PRIF, 2019). The NIISP was initiated in 2017 to ensure that investment levels are correctly prioritized to achieve required service levels and that assets are well managed to meet the financial, social, cultural and environmental needs of Nauru in a sustainable manner. NIISP supersedes NISIP and is of a different character. It does not provide a sector by sector detailed analysis of past performance or governance needs. Instead it prioritized 53 infrastructure investment opportunities of various sizes been using a multi-sectoral, multi-criteria quantitative assessment, applicable to all infrastructure sectors. NIISP ranked 53 infrastructure projects across all sector. Included in the list were relining four C water tanks (priority 4 estimated price, \$150,000), a pipeline from AIWO to the RoN Hospital (priority 17,\$500,000), a new septage treatment plant for the country (priority 20, \$6,000,000), and s water remineralisation plant, (priority 42, \$160,000). Apart from the last, all are included in the NWSMP.

The Statutory Legal Basis

As part of the development of the NWSHP a briefing note was prepared on legal issues that needed to be addressed (White, 2011a). These included:

I Climate variability and change and water resource vulnerability

1. Legal processes and implications of drought declarations and restrictions
2. Legal implications of making seasonal rainfall predictions
3. Legal responsibilities in local flooding and groundwater pollution increases in heavy rains

II Water quality and supply

1. No drinking or secondary water quality standards
2. No legal protection from contamination of water sources
3. No legal control of groundwater access or extraction rates
4. No building codes for rainwater harvesting or storage especially on government and public buildings.
5. Lack of regulation of water production
6. No law to prevent theft of water from public or private water storages and particularly schools

III Sanitation and Environment

1. No building codes for the design and construction of sanitation systems
2. No regulations for the pumping out of cess pits and septic tank sludge
   No regulations for the disposal of sewage sludge and sewage outfalls to the reef and ocean
3. No regulation preventing the use of potable water for toilet flushing

IV Demand

1. Imperfect, very limited, inequitable system for managing RO water demand
2. No system for controlling equitable water use from community water storages
3. No legal control of groundwater use

V Governance

1. No or limited statutory basis for organisations in the water or sewage disposal sector
2. No water or sanitation legislation

3. No legal requirement for reporting on the state of the Nation's water resources or sanitation services

VI Capacity

1. No national water resource and climate data base
2. No coordinated systematic and regular water resource monitoring, analysis and reporting program

VII Community awareness and engagement

1. Limited community participation in the planning, protection and conservation of water resources and in promoting improved sanitation systems (statutory basis)
2. No incentives for encouraging the improvement of household rainwater harvesting and sanitation systems

Nauru's On-Line Legal Database (RoN, 2020) provides up-to-date details of all enacted legislation in Nauru. A search of that reveals the following legislation of relevance to water and sanitation.

4.5 Public Health Ordinance, 1925, Revised 1983, PHO

The emphasis on water in the PHO (RoN, 1983) focusses on the control of mosquito breeding:

- No stagnant water shall be allowed to lie in such grounds for more than 24 hours unless treated to the satisfaction of the Government Medical Officer by efficient drainage, or with petroleum or other suitable oil.
- No tins, bottles, coconut shells or husks, or other receptacles capable of holding water shall be allowed to remain upon such premises or grounds.
- Water tanks or vessels to be covered or treated. All tanks and vessels used for retaining water shall be efficiently covered with mosquito-proof gauze or shall be treated with kerosene or other suitable oil to the satisfaction of the Government Medical Officer.
- If mosquito larvae be found in any receptacle of any kind, or in any stagnant water, it shall be accepted as proof that the provisions of sections 8, 9 and 10 (above) of this Ordinance have not been satisfactorily complied with.
- The Administrator in Council, on the recommendation of the Government Medical Officer, may order the destruction of trees or plants which retain water.

The PHO also contains a regulation on rainwater harvesting:

- The guttering and down pipes connected with the roofs of all houses and premises shall be kept clean and efficient.

Sanitation is only mentioned once in PHO where the Administrator in Council may make regulations providing for and in relation to sanitation in respect of any place, premises, vehicle or receptacle.

The Sanitary Inspectors Ordinance, 1921, in force 26 December, 1967 (RoN, 1967) specifies "the duty of the Sanitary Inspector (SI) to make systematic inspections of the district at certain periods and at intervals as occasion may require to keep himself informed of the sanitary condition of the Island". In the event of insanitary premises, the SI may direct the owner to return the premises to a sanitation condition.

In 2011, the Ministry of Health's new Public Health Bill was being drafted (White, 2011b). It was planned to include a series of regulations on Water, Waste and Vector Control. The purpose of the water component of the regulations was to ensure the safety and safe use of:

(a) water intended for human consumption;

(b) potable water being carted, trucked or stored or in reticulated supplies; and

(c) water in swimming pools and swimming places.

These draft regulations were focused on the important aspect of water quality. An examination of the Legal Database (RoN, 2020) has failed to find any new Public Health Act.

4.6 Education Act, 2011, EA

The EA (RoN 2011c) under Section 26 School environment, specifies that the principal of a school must ensure that:

(a) the school environment is clean, safe and secure; and

(b) the school has an adequate supply of clean running water during school hours; and

(c) sufficient toilet and bathroom facilities for students are in working order during school hours.

If these cannot be fulfilled, the principal "must recommend to the Secretary (Education) that the school be temporarily closed."

4.7 Nauru Utilities Corporation Act 2011, NUCA

The NUCA (RoN, 2011) specifies the functions of the Corporation in relation to water are:

(a) to acquire, store, treat, distribute, market and otherwise supply water for any purpose;

(b) to undertake, maintain and operate any works, system, facilities, apparatus or equipment required for any purpose mentioned in paragraph (a);

(c) to do anything that the Corporation determines to be conducive or incidental to the performance of a function mentioned in paragraph (a) or (b).

NUCA has been amended in 2016 and 2019. None of the amendments change the NUC's functions related to water.

4.8 RONPHOS ACT 2005, in force 1 March 2013, RA

The RA specifies that the objectives of the RONPHOS Corporation are:

1. Maintain and operate the phosphate industry on Nauru in a safe, efficient and profitable manner.
2. To establish, maintain and operate such activities as are or may be ancillary to the maintenance and operation of the phosphate industry on Nauru.
3. To establish, maintain and operate such other activities, including those recommended to the Board by the Minister, as the Board shall, with the approval of Cabinet, from time to time determine.

In the past, Egidu was responsible for septic tank pump outs although RONPHOS has also been employed for waste collection, sewage pump out and disposal. It is unclear whether that is still the case

4.9 Lands Act 1976, Amended 15 April 2011, LA

The LA (RoN, 2011d) amongst other things establishes the rights of the Government or public corporations to lease land on Nauru for phosphate mining or other public purposes for 77 years. Amendments in 2014 (RoN, 2014) provide the schedule of lease fees to be paid depending on whether land is phosphate land, non-phosphate land, or mined-out land. As it stands, it is clear that the establishment of a piped water and sewage system would incur substantial rental costs.

4.10 Draft Environmental Management and Climate Change Bill 2020, DEMCC

In 2011, a draft Environment Act, draft Public Health Act Water Regulations, and draft Waste Regulations were in preparation for presentation to Parliament. No record can be found on the On-line Legal Database (RoN, 2020) of water or waste regulations. Currently the DEMCC, has been returned by Parliament for further amendment, so it is not law.

The multiple objectives of the DEMCC include:

(a) coordinating the role of the Government and the public in relation to all environmental management and protection decision making processes;
(b) environment conservation while applying principles of sustainable use and development of natural resources;
(c) promoting meaningful public and civil society involvement in relation to issues of environmental management and protection;
(d) taking necessary measures to ensure that the Republic meets its international and regional obligations relating to the management or protection of the environment;
(e) facilitating assessments and regulation of environmental impacts of any activity likely to affect it, prior to a proposed activity taking place;
(f) taking any action necessary as will control or minimise pollution;
(g) ensuring the proper collection, transportation and disposal of waste;
(h) ensuring the protection of natural resources from pollution;
(i) establishment of the Climate Change and Environment Protection Fund;
(j) providing for arrangements and procedures including measures for accessing biological and genetic resources, their products and derivatives for scientific research, commercial and any other purposes and ensuring equitable sharing of benefits accruing therefrom;
(k) formulating policies and issuing of guidelines;
(l) promoting the understanding, management, conservation and protection of biological diversity; and
(m) facilitating the implementation of necessary measures to strengthen the environmental resilience of the Republic to climate change.

The DEMCC applies the precautionary approach by applying appropriate measures and activities for removal of the danger where a certain activity relating to the environment has potential to cause harmful effects on the environment, human life and health. In the DEMCC ***'water'*** includes lake, lagoon, waterway, groundwater, coastal water and tank[10].

DEMCC establishes the Department responsible for Environment and Climate Change as the responsible agency for carrying out any act required to be done which is deemed to be authorised and directed by the Secretary[11]. Focussing on water, the Secretary has the following powers:

i. monitor any activity that has or is likely to have any environmental impact in any area of land or water;
ii. prepare and implement national environment management and protection plans and policies;
iii. ensure and promote the use of sustainable technologies and renewable energy;
iv. promote public awareness and education in relation to environmental management and protection issues;
v. collect information and establish record keeping, monitoring and reporting requirements as necessary to carry out the principles and objectives of this Act;
vi. provide information and education to the public regarding the protection and improvement of the environment;
vii. review, implement and enforce any written laws relating to the management and protection of the environment;
viii. review and approve environmental impact assessments submitted in accordance with this Act or any other written law.

The DEMCC identifies powers of the Secretary in relation to the management of the environment shall include matters relating to:

[10] The DEMCC does not specify whether "tank" refers to public water tanks only or includes both public and household tanks.
[11] Currently the Department of Commerce, Industry & Environment is the responsible Department.

i. climate change by providing guidance in the formulation and implementation of environmental and climate change policies, plans and programmes;
ii. the movement or disposal of hazardous wastes and substances;
iii. desertification and drought relief;
iv. the management and protection of coastal areas;
v. the preservation of biological diversity;
vi. waste management;
vii. promoting environmentally sound technologies and renewable energy;
viii. sustainable land use management;
ix. water management;
x. natural disasters;
xi. sanitation.

Importantly, the DEMCC identifies the Department as being responsible for water and waste management, sanitation natural disasters, including droughts.

In addressing climate change, DEMCC charges the Secretary, in conjunction with other Government Departments, relevant international and regional agencies and all stakeholders to formulate and implement strategies and programs to protect water resources and coastal areas and to address the environmental impacts of climate change on water resources, and coastal areas and their vulnerability to natural disasters.

A particular strength of the DEMCC is that it allows the Cabinet to make regulations which may include the management, protection and conservation of freshwater resources. This is particularly important. In 2011, theft of water from school rain tanks was a major issue. It also permits making regulations to prescribe measures and related purposes for the discharge of sewage into the waters and to prescribe measures and related purposes that the operator of a plant shall undertake for the treatment of sewage before it is discharged into the water.

DEMCC also establishes a Climate Change and Environment Protection Fund which can be used for the protection from pollution of and removal of pollution from land, water and air.

Land Tenure and Customary Land Ownership

It is important to recognise that land ownership in Pacific Island Nations is fundamentally different from land ownership elsewhere. For most Pacific Island people, customary land ownership is fundamental to identity and involves kinship and inherited rights. Land ownership instils a sense of belonging, often enables subsistence and imposes rights such as the ownership and use of everything on and beneath the land, including groundwater. Most land in Nauru is owned not by individuals, but by large family groups. Any lease transactions for land require consensus among owners, which is often difficult to achieve Customary land ownership has served subsistence communities well for generations, and when water supply and sanitation were family responsibilities. Problems arise, however, in transitioning to modernity, such as when governments assume responsibility for water and sanitation services.

Infringing the rights of customary landowners, imposing restrictions on land use, or intrusion of public infrastructure are anathemas and can lead to compensation claims or even vandalism of public infrastructure (White *et al*., 1999). Payment of compensation itself can lead to inequities and conflicts in and between island communities and can increase costs of public water supply and sanitation service options to the extent that they are not economically viable (GoK, 2011).

In Nauru, the government does not own land. Instead it leases land from traditional landowners for the public use of their land[12]. This has created an expectation that any public use for any purpose of

[12] NUC(2018) shows that the Nauru Utilities Corporation paid $AUD 1,016,666 in land lease rental in 2018.

traditionally owned land will involve payment of compensation[13]. As an example of the public/private dilemma on Nauru: rehabilitation of the phosphate-mined topside has in the past been delayed by picketing by landowners seeking compensation for the use of their land, a common problem with many public infrastructure projects. An additional complication is that identifying the traditional owners is a lengthy process that often leads to community disputes. The NSDS 2005-2025 (RoN, 2009) identified the urgent need for a revised land tenure system by 2015. It concluded that land issues and land disputes are the cause of many delays in achieving progress and that more attention and community awareness are needed, together with a sound legal and regulatory framework.

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A2 – Review of Nauru Institutional Capacity by Dr Louis Bouchet

Attention:
Peter Sinclair
Water Resources Assessment and Monitoring Coordinator
Geoscience, Energy, and Maritime Division (GEM)
Pacific Community
SPC - Private Mail Bag - Suva, Fiji

RE:

Peer Review of Nauru Water and Sanitation Master Plan

Dear Peter,

Please find below the review of the Nauru Water and Sanitation Master Plan (NWSMP), with consideration to the capacity for Nauru institutions, and government agencies to implement, maintain, and operate the proposed interventions regarding the existing environmental and social context of Nauru.

1 Introduction

The primary objective of the assignment is to undertake a peer review to help verify the validity, and draw accurate conclusions on the suitability of the NWMSP, with a specific focus on:

1. A review of NWSM plan with consideration to the capacity for Nauru institutions, and government agencies to implement, maintain, and operate the proposed interventions regarding the existing environmental and social context of Nauru.
2. Considerations for alternate improvements given Nauru's current institutional capacity and socio-economic context.

It is noted that the following review focuses on the feasibility and sustainability of the proposed plan, regarding Nauru's socio-economic context. The technical aspect of the proposed infrastructure is not reviewed here.
The approach taken included a desktop review of the latest national and regional documents relevant to the water sector, and a critical review of the NWSM plan with consideration for alternative solutions.

Supporting documents included: *Nauru Priority Water Sector Development and Funding Needs Report* (2017); *Rapid Review of Water Knowledge for Pacific Small Islands Developing States* (World Bank June 2018); *ADB Strategic Country Analysis* (2014); *National Water, Sanitation and Hygiene Implementation Plan*, (2012). *National Integrated Water Resource Management Diagnostic Report Nauru* (2007); *Nauru Water, Sanitation and Climate Outlook* (2011); *Groundwater as a social-ecological system: A framework for managing groundwater in Pacific Small Island Developing States* (Bouchet et.al., 2019); *Water, Sanitation and Hygiene Interventions in the Pacific: Defining, Assessing and Improving 'Sustainability* (Clarke et.al., 2014).

2 Summary of findings

Overall, the review found that the NWSMP is primarily technical and lacks consideration for the local socio-cultural and economic context, which is critical for the sustainability of any water and sanitation

project in the Pacific Region. As described in Bouchet et. al. (2019), command and control approaches (technical fixes) to water management in the Pacific Region are often not well fitted to local contexts. In many PSIDS such as Nauru, there is a central authority responsible for water and sanitation (e.g. NUC) but it has limited in-house technical and financial capacity. The authority is thus strongly tied to regional agencies and donors who offer technical assistance through consulting experts. Experts may have professional motivations in proposing certain interventions over others. Technical fixes (institutional and technological) are often led by consulting experts, through short term donor projects (Clarke et al., 2014). Solutions are often based on the replication of measures efficient in other contexts or on the assumption that local socio-cultural and economic settings do not play a critical role in water and sanitation infrastructures management. The NWMSP is a clear example of a command and control approach to water and sanitation management in the region.
It is noted that the proposed infrastructure is not "new" to Nauru. A similar reticulation network of desalinated water was already proposed by a team of engineers from JICA in the early 2000 and was never considered further by the government, for reasons that are discussed in this letter.

Key considerations that are missing from the NWSMP are:

- Sustainability of the proposed infrastructures:
  - is the current institutional system robust enough to fully support the development of the proposed infrastructures, which challenge status Quo?
  - If the Nauru Utilities Corporation (NUC) oversees Maintenance and Operation (M&O) of the proposed network, how will the M&O be funded (e.g. government alone, bilateral support from donor country?). Can the cost of M&O be covered by the water service fee? If yes, can households afford the proposed fee?
- Consideration for the many lessons learnt from AID projects operating in the Pacific over the past decades:
  - Are reticulated water networks currently in operation in any other Pacific Small Island Developing State (PSIDS). If yes, how successful are they? What are the issues and how will it be different in the Nauru context?
  - What happened to previous water and sanitation infrastructure in Nauru, both in time of prosperity and economic hardship? Why did they fail? How and why will it be different this time?
- Identify the risks and possible obstacles to the implementation, operation and ongoing funding due to Nauru's current institutional capacity, socio-economic context and customary laws (e.g. Land Ownership):
  - Is it likely that the implementation of a reticulated network will be challenged by local landownership?
  - Is it likely that, without long term commitment from donor partners, NUC will have enough capacity (technical and financial) to operate and maintain the proposed infrastructure?

With regards to the key missing considerations above, the reviewer agrees that:

a. The installation of septic tanks in each household is a sound investment as it should significantly reduce groundwater contamination provided that the technology selected, size and installation are appropriate.

b. A larger sewage treatment plant is needed.
c. Increasing water storage capacity is vital, both for bulk storage and at household level.

With regards to the key missing considerations above, the reviewer disagrees on:

d. The use of reticulated sewage because of landownership issues, operation and maintenance issues and potential for additional point source pollution if leakages were to occur.
e. The issue of reticulated water supply given the low success of such infrastructures in the region, operation and maintenance and potential social issues (land ownership)
f. The use of desalinated water in a reticulated water supply for the reasons detailed in point e. and the added fact that desalinated water is expensive to produce.

3 Review of the Nauru Water and Sanitation Master Plan

3.1 Overview

The NWSMP is a technical document that defines a strategy to meet current and future water demand and improve the disposal/treatment of sewage. The strategy is primarily technical and essentially proposes an engineering solution (reticulation of desalinated water to every household in Nauru and reticulation and treatment of sewage) to meet Nauru's future water and sanitation needs.

The bulk of the document focus on the design of both the reticulated desalinated water system and sewerage system (100 pages). Capital cost (i.e. initial cost of infrastructures) is also detailed for both systems. Finally, O&M is briefly mentioned, with a proposed telemetry system to operate the system and a proposed organisational chart with required staff. An estimated annual operation and maintenance costing is also detailed.

3.2 Critical analysis

3.2.1 Basis for the proposed infrastructure

3.2.1.1 Alignment with the Water and Sanitation Policy

The introduction of the report mentions the NSDS key performance indicator as the basis to be met by the master plan. It is noted that although the NSDS is the overarching policy document for Nauru, it was developed prior to the Water and Sanitation Policy. The Water and Sanitation Policy is the overarching document for water and sanitation and the master plan should have refer to this document instead.

The Water and Sanitation Policy and implementation plan also strongly advocate conjunctive use of water for Nauru. Although it is mentioned in the report, the report is mainly about the installation of reticulated desalinated water and sewage disposal network to all households in Nauru, which is not proposed anywhere in the water and sanitation policy as a viable option for Nauru.

3.2.1.2 Interpretation of data

The NWSMP was supported by a previous document "status report" developed by the same consultancy. There are several statements that the reviewer disagrees with in this report and that ultimately support the master plan:

1. "*Most of Nauru's drinking and washing water is supplied to households by water tankers which are filled up with treated (desalinated) water by the Nauru Utilities Corporation (NUC) […] It can be observed from the figure above that desalination supply is critically important for meeting drinking water needs and constitutes nearly 70% of the drinking water supply*". This is based on the 2011 census, from answering a single question about the primary source for drinking water. Another way to look at it, is to look at another parameter from that same census: The % of HH who have their roof (gutters) connected to their water storage tank was 92.5%. Although the census also details that 30% of households had no gutters at all, the total percentage of HH with a connected water tank is about 65%, which indicate that at least 65% of houses in Nauru collect rainwater. Therefore, rainwater is most likely to be the primary source of drinking (and general) water rather than desalinated water. This is in line with the findings of Bouchet and Sinclair (2010).

2. *"Older assets such as the pipe reticulation system were abandoned some years ago and the exclusive use of pipe materials such as Asbestos Cement and Galvanised Iron for the entire old network has made rehabilitation of the pipe network unviable."* The document appears to suggest that a water reticulation system was previously in place in Nauru. Even during time of prosperity, there never has been a reticulated network around the island. The mentioned reticulation system

was a seawater reticulation system and only fed the NPC worker quarters (above Location area) with seawater to fill swimming pools and use for toilets.

3.2.2 Identified risks with the proposed infrastructure

The following risks have been identified with the proposed infrastructure:

3.2.2.1 Reticulated network installation

The implementation of the proposed system requires that kilometres of piping be installed all around the island, through to each house. The sole planning of the installation of the pipe network around the island is likely to be highly complicated, as the government must seek permission from landowners prior to the installation of any infrastructure on their land. This huge task will require the government to carefully consider where to place infrastructures, not only from a technical or costing point of view, but also to limit potential for dispute arising between neighbours and/or the government.

Local institutions are likely to come short in case of dispute between landholders and government. Even if a law was to be put in place to protect such infrastructure, customary law of landownership will likely prevail, and the government may not be willing to take the matter to court.

A talk with NUC general manager Mr Ali in 2017 revealed that a project to have a reticulated water supply from NUC to the hospital have been in the pipeline for years but is not going ahead due to landholder issue. NUC is located less than 1km from the hospital.

3.2.2.2 Reticulation of desalinated water

There are very few countries who use reticulated desalinated water as their primary source of water. The main reason for that is that desalinated water is expensive to produce, and reticulated networks do incur losses (the NWSMP account for potential 20% loss).

According to World Bank (2018) on reticulated network in the Pacific Islands Region: *"some reticulation systems are unable to meet demands (especially because leakage is typically significant); therefore, water is supplied for only a few hours per day as de facto demand management. Because of uncertainty of supply, people leave taps open to intercept the supply. This greatly increases losses."*

According to World Bank (2018) on desalination in the Pacific Islands Region: *"The success rate of desalination has been poor in Pacific Island countries because the equipment is expensive to operate and maintain […] The development of desalination facilities is an option for supplementing water supplies during times of drought, but in most instances the high costs prevent this being a widespread adaptation option".*

The two extracts above from World Bank (2018) highlight that there are high risks with the proposed approach. The risks are primarily associated with the O&M needs of such infrastructure, which are high and requires both sufficient funding and technical capacity (staff).

3.2.2.3 Operation and Maintenance

O&M of government owned infrastructure has long been an issue in Nauru. The underlying root of the problem is insufficient funding, although lack of technical personal and insufficient planning of OM activities are also to blame.

Funding for O&M

Funding for O&M for a reticulated desalinated network is critical. Although the document provides a rough costing for O&M, it is unclear where the funding will be sourced. A funding agreement is necessary not only for the capital cost but also for the ongoing cost of O&M.
Households are unlikely to be able to afford the fee required for NUC to recover O&M costs. Thus, a subsidy system must be in place and guaranteed on the long term for it to viable. At present, the production of desalinated water is subsidised, and the proposed infrastructure will increase the pressure on the government and it's donor partners.
It is also noted that setting up the fees for water and sewage service will require considerations for what households may be able to afford. If the subsidised fees are too low, households that can afford to pay for it may waste water at the government expense. If the fees are too high, some households may decide to tap the water illegally. Again, without a solid institutional framework that enable the government to act, householders may argue that the infrastructure is on their land and therefore, they may use it as they see fit. At a small scale these issues may be manageable but at a larger scale, it would have disastrous effects and will likely halt the entire operation.

Technical capacity for O&M

Technical capacity could also be an issue given that qualified engineers in Nauru are in high demand. It is likely that a supervisor from oversea, with experience with similar systems will have to run the operation for several years while training a sufficient number of Nauruan to eventually take charge of the O&M. Although this is a risk, it is manageable and will provide upskilling and employment for Nauruan.

4 Considerations for alternate improvements

Based on the above considerations, the reviewer recommends:

1. Government and donor partner participation in funding household water and sanitation infrastructure be clearly defined. Government participation in maintenance and replacement of water assets at domestic level is ill defined but substantial. At present, the government and AID projects provide assistance to households somehow on a needs basis, mainly based on AID project objectives, timelines and budget. This is unsustainable and make water and sanitation planning virtually impossible. If the government and donor partners are to assist households with their water and sanitation infrastructure, a clear budget and long-term plan should be defined, with the objective to satisfy a minimum standard per household (i.e. storage per capita and on-site treatment of sewage). This way, donors can pick up the plan and funds parts of it.

2. Increasing rainwater catchment and storage capacity at Household level. Rainwater is currently the main (and virtually the only natural source of freshwater in Nauru) and rainfall is predicted to increase. There is now at least one rainwater tank manufacturing plant on the island and each household should aim to meet a minimum storage requirement per capita (to be defined base on rainfall[1], tank size, roof size ect..). As stated in point a. this can be done by planning ahead and clearly stating the level of involvement in Households infrastructures from the government and donor partners.

3. Increasing bulk water storage capacity and rainwater harvesting. Bulk water storage is necessary to act as a buffer during drought periods. Considering the planned increase in rainfall, bulk storages with a large diameter are preferred as the roof can be used to collect rainwater. Bulk storages are thus filled with rainwater and can be topped up with desalinated water based on tailored schedule. Preferably, bulk storage are to be installed on government land near NUC so a small reticulation system between the Desalination plant and the storage can be implemented.

4. The delivery of water produced by NUC (rainwater and desalinated water) should remain via tanker. The distances between the plant and each household is small and it is likely cheaper than a reticulated network to maintain and operate. It is easy to increase the delivery capacity by purchasing new truck when needed. The maintenance and operation of mechanical vehicles is not an issue in Nauru and several, competent mechanics can be found on the island. Furthermore, a reticulated network does not improve the water standard in Nauru if households don't have a pump and a reticulated network from their tank to their house (most don't).

5. Regarding sewage, the easiest and likely more sustainable option is to improve on site-treatment with adequate septic tank (not cesspit). A trial was done by the Pacific-IWRM project and if the design tested for the project appear to be efficient, then that design might be adopted. Pumping of septics when full should be planned (and probably subsidised) via tanker and redirected to a suitable sewage treatment facility.

6. Regarding the sewage treatment facility, this review did not look at technical specificity, but it should be kept as simple and easy to operate and maintain as possible. A study was done by Kassenga Hara for the Pacific-IWRM project and it might useful to compare it with the plant proposed in the NWSMP.

The reviewer recommends that critical observations, risks related to the proposed infrastructure and proposed alternative solutions in this letter be further discussed with local Nauruans, involved in the water and sanitation and infrastructure planning sector.

Sincerely,

Louis Bouchet.

[1]The NWSMP state that no local rainfall records are available. I do have records for up to 2016 (with some gaps) and have replaced the gauge battery in 2016