



**NATIONAL AUDIT OFFICE OF THE GAMBIA**

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# **PERFORMANCE AUDIT REPORT**

**ON**

**THE PROVISION OF WATER IN URBAN, PERI-URBAN AND  
PROVINCIAL GROWTH CENTRES BY NAWEC**

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**NOVEMBER 2022**

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### List of Acronyms

Acronyms	Interpretation
3Es	Economy, Efficiency and Effectiveness
AFD	African Development Fund
BH	Borehole
Ca	Calcium
CCP	Central Control Panel (CCP)
Chlorine Gas	Cl <sub>2</sub>
CO <sub>2</sub>	Carbon Dioxide
COO	Chief Operation Officer
EWT	Elevated Water Tanks
Fe+2/3 mg/1	Iron
GBA	Greater Banjul Area
GDP	Gross Domestic Product
GIS	Geographical Information System
GUC	Gambia Utilities Corporation
HRWS	Human Right to Water and Sanitation
IMS	Information Management System
IWRM	Integrated Water Resources Management
Kg/h	Kilogram Per Hour
KMC	Kanifing Municipal Council
LLT	Low-Level Tanks
Mg/1	Milligram Per Liter
MoFWR	Ministry of Fisheries and Water Resources
MoPE	Ministry of Petroleum and Energy
MSG	Management Services Gambia Limited
NAWEC	National Water and Electricity Company
NO <sub>3</sub> - N mg/1	Nitrate Per Nitrogen
NRW	Non-Revenue Water
O <sub>2</sub>	Oxygen
pH	Potential of Hydrogen
PURA	Public Utilities Regulatory Authority
SDGs	Sustainable Development Goals
SOGEA	Single Order Generic Ethernet Access
UHC	Utilities Holding Corporation
UN	United Nations
WASIB	Water Supply and Sanitation in the Greater Banjul Area
WCR	West Coast Region
WHO	World Health Organization
WSP	Water Safety Plan
WTP	Water Treatment Plant

# 1 EXECUTIVE SUMMARY

## a. Background

The Human Right to Water and Sanitation (HRWS) is a principle that recognizes that safe drinking water and sanitation are essential to everyone's well-being. According to General Comment 15 of the United Nations Committee on Economic, Social, and Cultural Rights, drafted in 2002, *"the human right to water entitles everyone to sufficient, safe, physically accessible and affordable water for domestic uses"*; and in 2002, the United Nations General Assembly and Human Right Council declared water to be a human right. Safe and physically accessible water and sanitation service is a critical requirement for all people.

The Gambia is committed to achieving the United Nations' 2030 Agenda for Sustainable Development Goal (Goal 6), which aims to ensure universal access to water and sanitation.

The National Water and Electricity Company (NAWEC) also sometimes referred to in this report as the 'Company' is a state-owned enterprise that is responsible for the supply of pipe-borne water to households and industries in the urban, peri-urban, and provincial growth towns in the country. On the other hand, the Ministry of Fisheries and Water Resources is responsible for supplying water to the rural settlements. This performance audit focuses on areas which fall under the responsibility of NAWEC.

## b. Motivation

The audit was motivated by the following reasons:

### 1. Limited Water Coverage

By 2020, NAWEC served only approximately 60% of the population in the areas for which it is responsible.

### 2. Frequent Water Outages

There have been public outcries and newspaper publications that NAWEC customers go without water for hours, days, weeks, or even months, which is harmful to the health of the populace and defeats the HRWS principle. The situation was reported to be stressful, exhausting and made life difficult, particularly for women and children, who are often responsible for carrying water over long distances, exposing them to safety risks and exploitation.

### 3. Water Quality Deficiencies

Since the discovery of nitrates in NAWEC's water supply in 2016, there has been growing concern about the quality of water supplied by NAWEC to its customers over the years.

Thus, the concerns raised by citizens regarding the quality of water supplied by NAWEC motivated the National Audit Office (NAO) to investigate and carry out a performance audit on the coverage, quality and quantity of water supplied by NAWEC in urban areas, peri-urban areas, and provincial growth centres in The Gambia.

## **c. The Main Findings**

### **1. Water strategy and operational planning**

During the period under review, NAWEC did not adequately plan for the water it is required to supply to the residents within its jurisdiction. The company adopted a Water Master Plan effective 2005, which should be implemented within a 25-year period, however, the plan was deemed to be unrealistic as it did not capture the realities on the ground. Despite this, we noted that the management of the company did not review the plan to validate it and capture changing and prevailing circumstances of the water need demand for its residents within its jurisdiction. For example, during the period 2017 to 2021 the projected water demanded within the urban population was 252.67 million m<sup>3</sup>. Out of this, NAWEC was only able to produce an estimated water volume of 187.71 million m<sup>3</sup>. This left a serious water gap of 64.99 million m<sup>3</sup> between the quantity demanded and the quantity produced by the Company.

In addition, NAWEC did not have a strategic development plan for 2017-2018 that outlined what needed to be done and how it could be accomplished. This coupled with its inadequate water master plan, did not give guarantee for the company's swift response to adequately address the water supply issues/gaps both in the short and long term for residents within its jurisdiction

### **2. Water infrastructure and equipment**

During the period under review, we noted that some of the company's facilities were not well secured. For example, some of the facilities visited were not provided with security guards and others were not provided with full perimeter fence including proper gates. The security of these facilities relies on the operating staff during working hours. The facilities are left unprotected when these staff close work. This gives license to intruders such as unscrupulous person (thieves) and other domestic animals to access these premises causing some damages to these company infrastructures and equipment.

### **3. Water production and distribution**

During the period under review, the company was not able to produce and distribute the required water needed to meet the water demand of the residents within its jurisdiction.

From the discussions held with the company's management and officials responsible for the production and distribution of water, we were informed that as of 2020, the company has not covered 40% of the water demand for the urban, peri-urban and provincial growth towns, even though it had expanded slightly in recent years due to the company's reliance on donor-support and funding. This leaves over 60% of the residents within the jurisdiction of the company without access to safe and affordable drinking water. Most of these



uncovered residents mainly resort to digging their own boreholes or wells within their premises. This water extracted from these two sources are untreated and could lead to some health hazard.

In addition to this inadequate coverage, resident in areas that are covered continue to grapple with water shortage in most times of the day partly due to leakages and burst pipes which are either in adequately buried or dug out by erosion and can be seen lying about on the surface of the ground resulting to these pipes been tampered with causing serious water loses that are not swiftly responded to by the company. It should be noted that burst pipes and leakages are not only causes of water losses but also a source of water contaminations.

#### **4. Water Quality**

The water supplied by NAWEC's was not properly treated as most of the treatment plants we visited were either not operational or are operated under very unhygienic conditions. For example, in one of the stations that we visited, we observed a water monitor lizard swimming in the water treatment plant and algae found growing on the floor of the treatment plant.

In addition, we noted the company does not have the capacity to test the water it supplies to its residents/customers due to the lack of equipment and skilled staff. For example, during our visit to selected stations, we noted that offices that are designed as test laboratories are created at these stations but there was no equipment and qualified staff to operate them. The company mainly relied on water test samples conducted by the Department of Water Resources (DWR) which is one of the stakeholders in the provision of water in smaller settlements. It should be noted that the company and the Department of Water Resource operate at different jurisdictions or areas, therefore relying on these test samples conducted by the DWR could be misleading as it may not give a true reflection of the realities on the ground.

Furthermore, we also noted that key settlements within the jurisdiction of the company still battling with issues of highly concentrated iron and nitrate contrary to the WHO recommendations in the water supplied to them by the company which the company could not address during the period under review. From the look of things, the company is not likely to be able to deal with this issue in the soonest possible time as it grapples with the lack of qualified/skilled staff and unequipped laboratories to run these tests on the water it supplies to customers.

The absence or deficit of chlorine in water exposes it to a range of contaminants such as bacteria, mould and algae, which could cause diarrhoea, cholera, and other waterborne diseases.

## **d. Conclusion**

### **1. Water strategy and operational planning**

NAWEC has not updated the deficiencies in the water master plan since its development in 2005 to reflect current realities. In addition, the company did not put in place mechanisms to increase water production to meet the growing population's demand.

### **2. Water infrastructure and equipment**

Most of NAWEC's water facilities were not properly fenced, even those fenced were sometimes without gates to prevent unauthorised access therefore NAWEC has not adequately protected its water system and infrastructure risking the lives of over a million people.

### **3. Water production and Distribution**

NAWEC has not covered the entire mandated area, leaving majority of the citizenry without access to company's water supply.

Management failed to put efficient and effective maintenance measures in place resulting in inadequate maintenance of the water facilities such as irregular maintenance of the water tanks, reservoirs and pipes which led to serious leakages and in some instance caused contamination.

### **4. Water Quality**

NAWEC did not ensure that robust testing of the water is carried out regularly to determine the quality of the water before it is supplied to consumers. The company only rely on tests conducted by the Department of Water Resources which may not fully reflect the real situation in all the company's jurisdictions.

We observed that the company has been supplying contaminated water with a high amount of Nitrate and iron above WHO guidelines in some key towns within its jurisdiction during the period under review. Moreover, the company did not ensure that all the water it produces and distributes to its customers is properly chlorinated as chlorine deficits are consistently detected in the water it supplied to residents in two major towns within its jurisdiction.

## **e. Recommendation**

### **1. Water strategy and operational planning**

NAWEC should ensure the Water Master Plan reflect the current situation and should consider putting in place mechanisms to produce adequate water to meet the population demand. This would require developing and implementing a strategic development plan that outlines the water division's strategic objectives and how they will be achieved.

### **2. 3. Water infrastructure and equipment**

NAWEC should ensure water sources and their treatment plants are well protected/guarded.

### **3. Water production and distribution**

NAWEC should consider establishing strategies to extend its water coverage in areas under its mandate to accommodate and cater for the growing population's demand for clean water. The Management of NAWEC should ensure both preventive and periodic maintenance of the water distribution systems are prioritised.

### **4. Water Quality**

NAWEC should put in place strategies to reduce the iron and nitrate contents in its water supply to the WHO acceptable level. In addition, the company should consider setting up standard laboratories manned by competent lab technicians/skilled staff to carry out standard water quality test on a regular basis to ensure safe drinking water is supplied to its customers.

Furthermore, the company should ensure that all the water it produces is chlorinated in accordance with the WHO Guideline for Minimum Water Quality Standard.

## 1. CHAPTER ONE: INTRODUCTION

### 1.1 Background of the Audit

The Human right to Water and Sanitation is a principle that recognizes that safe drinking water and sanitation are essential to everyone's well-being. According to General Comment 15 of the United Nations Committee on Economic, Social, and Cultural Rights, drafted in 2002, *"The human right to water entitles everyone to sufficient safe, physically accessible and affordable water for domestic uses"*.<sup>1</sup> Safe and physically accessible water and sanitation service is a critical requirement for all people<sup>2</sup>. The United Nations General Assembly and Human Right Council declared water to be a human right<sup>3</sup> in 2010.

The Gambia is committed to achieving the United Nations' 2030 Agenda for Sustainable Development Goal (Goal 6), which aims to ensure universal access to water and sanitation.

National Water and Electricity Company (NAWEC) is a state-owned enterprise that is responsible for the supply of pipe-borne water to households and industries in the urban, peri-urban, and provincial growth towns in the country. On the other hand, the Ministry of Fisheries and Water Resources is responsible for supplying water to the rural settlements. This audit focuses on areas that are covered by NAWEC.

During the period, 2017 to 2018, NAWEC have spent GMD 149 million on the provision of water. Despite these huge expenses incurred; the company was unable to provide reliable water supply to its service areas.

### 1.2 Motivation

The audit was motivated by the following reasons:

#### a) Limited Water Coverage

By 2020, NAWEC was only able to serve approximately 60% of the population in the areas for which it is responsible<sup>4</sup>.

#### b) Frequent Water Outages

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<sup>1</sup> United Nations Department on Economic and Social Affairs (UNDESA)  
(UNCh[https://www.un.org/waterforlifedecade/human\\_right\\_to\\_water.shtml](https://www.un.org/waterforlifedecade/human_right_to_water.shtml))

<sup>2</sup> UNWATER: Human Rights to Water and Sanitation <https://www.unwater.org/water-facts/human-rights/>

<sup>3</sup> UN WATER article titled Human Rights to Water and Sanitation

<sup>4</sup> The Gambia: World Bank to Strengthen Access to Energy and Water JUNE 29, 2020

<https://www.worldbank.org/en/news/press-release/2020/06/29/the-gambia-world-bank-to-strengthen-access-to-energy-and-water>

There have been public outcries that houses, places of worship, health facilities, police stations, prisons, schools, among others, in NAWEC-mandated areas go without water for hours, days, weeks, or even months, which is harmful to the health of the populace. According to the Standard Newspaper Gambia (20 November 2020) the situation was stressful, exhausting and made life difficult, particularly for women and children, who are often responsible for carrying water over long distances, exposing them to safety risks and exploitation.

### **c) Water Quality Deficiencies**

Since the discovery of nitrates in NAWEC's water supply in 2016, there has been growing concern about the quality of water supplied by NAWEC to its customers over the years. Even though high levels of irons and nitrates were detected in NAWEC's water supply since 2016, the contaminated water is still flowing in areas with a combined population of more than 75,000<sup>5</sup> people.

Based on the issues raised above regarding the coverage, quality and quantity of water supplied by NAWEC in urban areas, peri-urban areas, and provincial growth centres in The Gambia, the National Audit Office decided to conduct a performance audit on the provision of water by NAWEC in The Gambia.

## **1.3 Audit Objective**

The objective of the audit was to assess measures put in place by NAWEC to ensure there is adequate production, treatment and distribution of water to its customers.

## **1.4 Main Audit Questions**

Our conclusions against the audit objective were based on the following audit questions.

- a) Has NAWEC ensured that an adequate quantity of water is produced for distribution to its customers?
- b) Has NAWEC ensured that there is a reliable distribution of water from its treatment plants?
- c) Has NAWEC ensured that the quality of water distributed to its customers meets safe drinking-water quality standards?

## **1.5 Assessment Criteria**

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<sup>5</sup> CCIJ – the Gambia water paradox how a country with plentiful water resources is failing to provide safe water to its people. <https://ccij.io/article/water-paradox-in-the-gambia/>

The assessment criteria were drawn from Public Utility Regulatory Authority Act 2001, PURA Minimum Quality Service Standard for Water and Sanitation 2008, and WHO Guideline for Quality Water Standards 2017.

**Appendix 1:** Audit questions and assessment criteria. Provides details of the criteria.

## **2 CHAPTER TWO: DESIGN OF THE AUDIT**

### **2.1 Introduction**

This chapter provides a detailed description of the scope of the audit, methods used to collect data, sampling techniques and methods used for data analysis.

### **2.2 Audit Scope**

The audit covered the supply of water by NAWEC in the Urban, Peri-Urban and provincial growth centres in the Gambia during the period from 1 January 2017 to 31 December 2021.

This period allowed the audit team to assess the trend of performance of NAWEC's water provision and to allow the team to make appropriate conclusions on the performance of NAWEC with regards to its water production and distribution services.

### **2.3 Audit Methodology**

#### **2.3.1 Sampling Techniques**

We visited all six (6) regions in the Gambia; the areas selected were based on those which get their water supply from NAWEC. We visited all the six (6) Water Treatment Plants in the country. We used purposive sampling techniques to select water facilities, boreholes, and customers to interview.

### **2.4 Methods for data collection**

#### **2.4.1 Document Review**

We reviewed various documents as shown in Appendix 2: Reviewed documents and purpose for reviews:

- To gather evidence on the performance of NAWEC in producing, treating, and distributing water to areas under its jurisdiction.
- To obtain comprehensive and reliable information on how NAWEC produces and distributes water to its service areas.
- To be able to identify the risks/impact and potential causes, as well as to gather evidence and come up with clear findings and recommendations

#### **2.4.2 Interviews**

We interviewed representatives from NAWEC, the Department of Water Resources and customers. **Appendix 3:** List of interviewed officials and customers.

The purpose of these interviews was:

- To gather more information and clarifications on NAWEC's current and previous practices in the provision of water to its serviced areas,
- To obtain perceptions from different stakeholders such as the audited entity and beneficiaries,
- To help corroborate or dispel data obtained through other data collection methods, and
- To obtain knowledge of NAWEC customers' experiences with the water service provided by NAWEC

### **2.4.3 Observations**

We visited NAWEC's treatment plants, boreholes, and other water facilities in the country to gain first-hand knowledge of the processes involved in NAWEC's water supply in various parts of the country.

### **2.4.4 Site visit and Physical Inspection**

We also inspected samples of selected Water Treatment Plants and stand-alone boreholes to physically inspect the equipment and conditions of the facilities. **See Appendix 4:**

### **2.4.5 Data Analysis**

Data were analysed quantitatively and qualitatively, and the results compiled to support the audit findings. Tables, figures, pictures, and graphs are among the techniques used to present audit findings.



### **3 CHAPTER THREE: SYSTEM DESCRIPTION FOR THE PROVISION OF WATER**

#### **3.1 Background of the audited entity - NAWEC**

NAWEC is a State-owned Enterprise mandated to provide water to the urban, peri-urban, and rural growth centres in the Gambia. The company manages two public service portfolios. Namely, supply of electricity and supply of water and sewage services.

The Water and Sewage Department's main functions are to supply water for both domestic and industrial use. However, their mandate or service areas are limited to urban, peri-urban, and rural growth centres.

- a) Urban areas (these are settlements in the Greater Banjul Area e.g Serrekunda, Kanifing and Abuko etc).
- b) Pre-Urban Areas (these are settlements closer to Greater Banjul Area and has a population over 5,000 e.g Tanji, Tujereng, Sanyang
- c) Provincial / Rural Growth centres (these are settlements far from GBA e.g Farafenni, Sibanor, Barra, Kanuma, Berending, Kerewan etc.)

Water is supplied to the rural settlements with a population of less than 5,000 people by the Ministry of Fisheries and Water Resources.

#### **3.2 Regulatory Framework for the Provision of Water by NAWEC**

##### **a) PURA Act 2001**

This Act specifies the regulations of all public utility's services including NAWEC.

##### **b) National Water Resources Council Act 1979**

This is the Act to establish a National Water Resources Council to formulate a water policy for the country and matters incidental thereto.

##### **c) National Environment Management Act 1994**

This Act sets standards and establishes criteria in environmental quality in particular water quality and set minimum standards for environmental quality in general and in particular for water quality, taking into account different uses including drinking water, water for industry, fisheries, wildlife and recreational purposes.

##### **d) The Gambia National Water Policy 2006**

The policy was originally sought to provide a legal framework for the orderly development, exploitation, conservation, and preservation of water resources.

**e) Minimum Quality Service Standard for Water and Sanitation 2008 by PURA**

This guideline established the minimum quality service standard for water and sewerage service providers in The Gambia.

**f) World Health Organization Guidelines for Drinking Water Quality 2017**

Sets minimum standard for drinking water quality for water and sanitation.

### **3.3 Objectives of NAWEC in relation to the provision of water**

- Equitable and affordable access to water by 2025
- Turning the organisation towards the customers by responding to their complaints in a timely manner.
- To ensure safe, effective provision of water and sewerage services in The Gambia<sup>6</sup>.

### **3.4 The Organizational Structure of the Water Division**

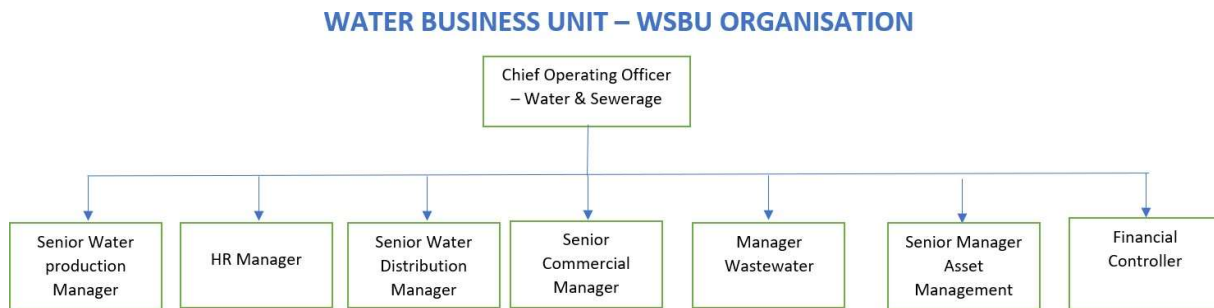
The company went through structural reform in 2020 and as such, the Water & Sewage division is now headed by a Chief Operations Officer (COO) responsible for the production and distribution of water to its customers. Henceforth, the Water and Sewage Division is responsible for its own profit and loss as well as its own planning and performance.

This division comprises six (6) units namely: Water Production, Water Distribution, Sewage, Commercial, Water Finance and Human Resources.

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<sup>6</sup> NAWEC Annual Report 2017 page 11 of 84

Chart 1: showing the organogram of the water division



Source: NAWEC Water Division.

### 3.5 Responsibilities of key units in the provision of water

#### a) Water Production

This unit falls under the responsibility of the Head of Water Production, who is responsible for all production boreholes, raw water transmission lines and all water treatment facilities. The Department is also responsible for repairing all production networks.

#### b) Water Distribution

This unit falls under the responsibility of the Head of Water Distribution, who is responsible for all water tanks, distribution networks and service connections. The Department is also responsible for repairing all distribution networks.

#### c) Commercial Water

This unit falls under the responsibility of the Head of commercial water, who is responsible for all aspects regarding customer accounting, revenue protection and loss reduction.

### 3.6 Role and Responsibilities of External Key Players

#### a) Ministry of Petroleum and Energy

This is the parent ministry, which oversees policy formulation and overseeing NAWEC's activities related to water provision<sup>7</sup>. As Chairman of the Board, the Permanent Secretary at the Ministry of Petroleum and Energy represents the Ministry on the Board of Directors.

<sup>7</sup> Interview with the permanent secretary MoPE.

**b) Public Utilities and Regulator Authority**

PURA establishes water tariffs across the country, monitors the quality and quantity of water supplied by NAWEC through quarterly water quality tests, and negotiates between NAWEC and its customers<sup>8</sup>. Customers can channel their complaints and dissatisfaction about the service of NAWEC to PURA.

**c) The Department of Water Resources**

This provides guidance for the proper utilization and management of the national water resources. On behalf of PURA, the Department of Water Resources conducts the NAWEC quarterly water quality tests<sup>9</sup>.

**d) World Health Organization**

WHO established international guidelines for minimum water quality standards, and NAWEC produces, treats and distributes water in accordance with WHO guidelines.

**e) Customers**

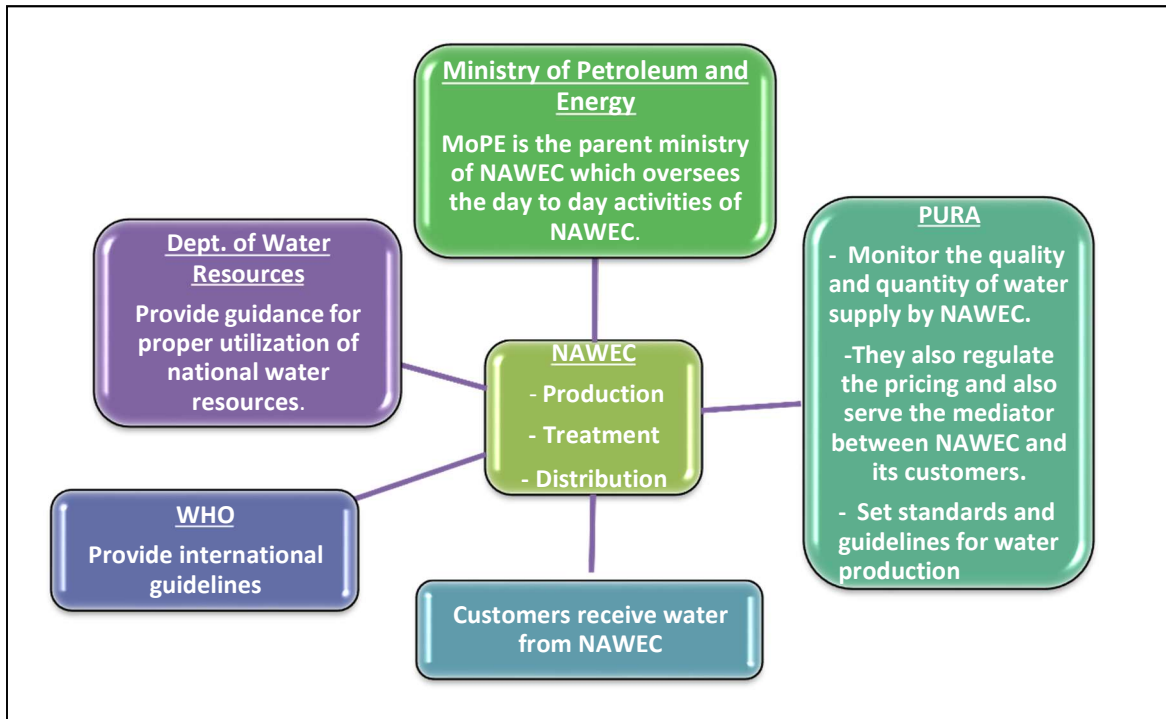
Customers are households, government institutions, and commercial users who rely on NAWEC for their water supply. They are end-users who are connected to the NAWEC water distribution channel and pay a monthly water bill based on the amount of water consumed.

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<sup>8</sup> Pura act 2001

<sup>9</sup> mofwr.gm

Chart 2: The relationship between NAWEC and relevant stakeholders in the provision of water.



Source: Auditor’s Analysis

### 3.7 Activities Carry Out by Water and Sewerage Division<sup>10</sup>

- Implementation of water projects
- Management of production facilities, treatment, and distribution of water
- Installation of water meters
- Routine and ad hoc maintenance of water facilities

### 3.8 Funding for the Provision of Water

National Water & Electricity Company Limited is a state-owned enterprise that funds its activities through the revenues generated from its operations and donor’s contribution. The budget is approved by their Board of Directors with a budget approval letter from the Ministry of Finance and Economic Affairs<sup>11</sup>.

<sup>11</sup> National Water and Electricity Company Ltd Budget approved by the Board

**Table 1: Approved budgets for NAWEC**

<b>Years</b>	<b>2017 (Million GMD)</b>	<b>2018 (Million GMD)</b>		<b>2019 (Billion GMD)</b>	<b>2020 (Billion GMD)</b>
<b>Water Production</b>	32.6	33.9	Budget estimates for both electricity and Water	5.0	2.9
<b>Water Distribution</b>	35.3	48.1			
<b>Total</b>	<b>67.9</b>	<b>82.0</b>		<b>5.0</b>	<b>2.9</b>

*Source: Approved budget for NAWEC (2017-2020)*

**Note:** Expenses for 2017 are the actual expenditure and 2018-2020 are budget estimates. The estimates for 2019-2020 consist of budgets for water and electricity services combined. They were not separated in the budget estimates prepared by NAWEC.

### **3.9 Process Description - Production of Water<sup>12</sup>**

#### **3.9.1 Feasibility study**

This is the first stage of the borehole development process, the study helps to identify underground water sources in terms of the quality, quantity, and the level of water available in aquifers.

#### **3.9.2 Water abstraction by boreholes**

This is the first stage of the water production cycle. Water is produced through the boreholes. The function of the boreholes is to extract groundwater and pump it to the treatment plant. The system is designed to operate in batches, i.e., groups of boreholes joined together at the entry point in the treatment plant. Depending on demand and water level in the lower-level tanks, these batches and Individual boreholes can be shut-down. The boreholes are controlled and monitored by control room personnel using the Central Control Panel (CCP). This panel indicates whether the boreholes are functioning at the designed capacity or not.

<sup>12</sup> NAWEC: Operating and Maintenance Manual

### **3.9.3 Treatment of Water**

#### **a) Aerator**

After extracting water from the boreholes water is sent through underground pipes to the aerator at the treatment plant. Aeration raises the pH value by removing carbon dioxide (CO<sub>2</sub>) from the water and increasing the concentration of oxygen (O<sub>2</sub>) in the water.

#### **b) Lime Dosing**

If the pH value after aeration is still insufficient, lime dosing is used to adjust the pH further. In the lime dosing building, lime, or calcium (Ca) is added to water in two mixing tanks. From these tanks the lime solution is pumped into the aerated water.

#### **c) Chlorination**

Chlorine gas (Cl<sub>2</sub>) is added to the water to disinfect the water for safe human drinking. The amount of chlorine injection is done manually based on the Water Treatment Plants' actual production rate and the desired concentration in the treated water. The system is designed for dosing 0.5 mg/l. The chlorine dosing rate can be adjusted to any WTP production rate. The chlorine dosing installation has a maximum capacity of 1 kg/h.

### **3.9.4 Distribution of Water**

#### **a) Low-Level Tanks**

The clean water that is treated with chlorine is stored in Low-Level Tanks (LLTs) after treatment in the treatment plants. These tanks primarily serve as buffers against fluctuations in demand. Furthermore, it allows the chlorine to meet the water and disinfect it. The required contact time, on the other hand, is negligible.

#### **b) Transmission Pumps**

The clean water is pumped from the LLTs into the clean water pipeline system. Transmission pumps are used to provide the mechanical force to push the water to the consumers and the elevated tanks are installed in the serviced areas.

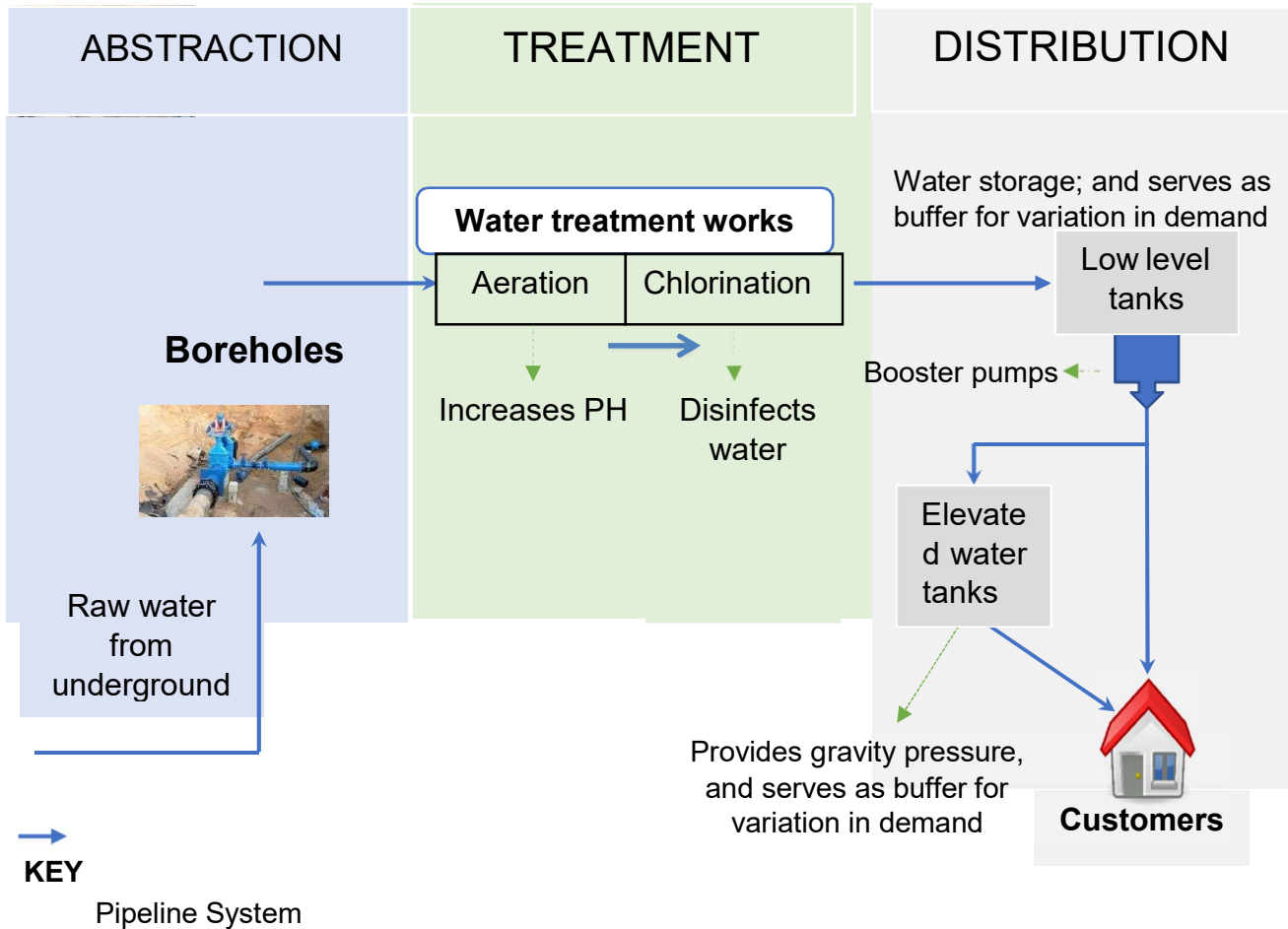
#### **c) Elevated Water Tanks**

At several locations along the clean water pipelines, Elevated Water Tanks (EWTs) are installed. EWTs have two functions; to act as a buffer for variations in demand and to provide gravity pressure for the distribution pipeline system. However, these tanks are fitted with valves that can put the tanks on bypass i.e., stopping the water from going into the tanks.

#### **d) Booster Pump**

The booster system operates automatically by measuring the water pressure on the discharge side. It will automatically adjust the flow by switching on and off pumps and regulates the speed of pumps in order to keep the outgoing pressure at a predefined level.

**Chart 3: Processes Involved in Water Provision**



*Source: Audit team based on NAWEC Operating and Maintenance Manual*



## 4 CHAPTER FOUR: FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

### 4.1 WATER STRATEGIC AND OPERATIONAL PLANNING

#### 4.1.1 Water Master Plan Does Not Reflect the Existing Condition

*According to the 2015 updated version of the Best Practice Master Planning Guidelines and Resources Document prepared by the Georgia Association of Water Professionals Integrated Master Planning Committee; it is best practice to keep master plans updated to ensure that the master plan reflects current conditions and thus can be used as a tool and resource when making decisions<sup>13</sup>.*

The Water Master Plan that came into existence in 2005 and valid for 25 years should be implemented through NAWEC on behalf of the Government of The Gambia. The primary functions of the Water Master Plan are to provide a framework and guide to authorities involved in the implementation, management and operations of sector services and development interventions. Additionally, the Master Plan is to act as a guide to financing agencies and other stakeholders concerning the staged implementation of the program components.<sup>14</sup>

Notwithstanding, the master plan was however deemed to be unrealistic because it does not capture the realities on the ground. According to the master plan, the projected water demand was supposed to be reviewed by 2015 (10 years from 2005) but up to the time of the audit, the projection was not reviewed.<sup>15</sup> However, the management of NAWEC's Water Division mentioned that under the African Development Fund (AFD) project, a new Master Plan will be developed.<sup>16</sup>

The management of NAWEC's Water Division informed us that they had not revised previous assumptions in the water master plan to identify deficiencies that required upgrading because the master plan was for 25 years, which had not yet expired, and thus did not deem it necessary.<sup>17</sup>

Changes over the years were not accounted for in the master plan, the company is having difficulty in connecting these additional locations and ensuring appropriate water supply. NAWEC's failure to update its Master plan to reflect the current situation caused the business to lose sight of its goal of providing adequate potable water to the population. As a result, the populace faced severe water shortages.

#### Conclusion

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<sup>13</sup> Best Practice Master Planning Guidelines and Resources Document prepared by the Georgia Association of Water Professionals Integrated Master Planning Committee last updated 2015.  
[https://cdn.ymaws.com/www.gawp.org/resource/resmgr/Master\\_Planning\\_Guidelines/GAWP\\_Master\\_Planning\\_Guide\\_eli.pdf](https://cdn.ymaws.com/www.gawp.org/resource/resmgr/Master_Planning_Guidelines/GAWP_Master_Planning_Guide_eli.pdf)

<sup>14</sup> NAWEC water master plan 2005

<sup>15</sup> NAWEC water master plan 2005

<sup>16</sup> Interview meeting with management of Water Division 3<sup>rd</sup> February 2022.

<sup>17</sup> Meeting with the management of NAWEC's Water Division on the 3<sup>rd</sup> February 2022

NAWEC has not updated the deficiencies in the water master plan since its development in 2005 to reflect current events.

### Recommendation

NAWEC should ensure the Water Master Plan reflects the current and projected situation.

### Management response

<b>Management Response</b>	<i>NAWEC recognizes that the masterplan of 2005 was not updated and or reviewed within the timeframe specified. However, it must also be recognized that a feasibility study was conducted into the water supply situation within the GBA between 2019/2020. As part of that study, demand projections were revised with recommendations for a new master plan to be developed.</i>  <i>This feasibility study was submitted to NAO at the time of the audit.</i>
<b>Action to be taken</b>	<i>As communicated to NAO, under the WASIB project funded by the Agence de France Developpement (AFD) a water supply and sanitation master plan is to be carried out and is expected to be completed by 2026 as part of phase 3 of that project.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>Upon Completion of the WASIB project – at this stage and providing all parameters remaining constant this is due for 2026</i>

#### 4.1.1 NAWEC Does Not Have Strategic Foresight to Cater for the Water Demand.

*The purpose of the NAWEC Strategic Plan is to guide the development of the business over the period between 2019 and 2025. The Management of NAWEC are aware of the critical role that NAWEC will play in the social and economic development of the Gambia. The plan is cognisant of developments in the sector and in the economy at large.<sup>18</sup>*

Strategic planning has been demonstrated to be an effective tool for long-term urban water management (Malmqvist et al. 2006). Strategic planning is the process of determining an organization's long-term direction based on sound predictions, options analysis, and key decisions about its future. Water utilities can become more commercially oriented by establishing strategic planning that asks, "Where are we now, where do we want to be, how might we get there, and how do we ensure success?" (Mugabi et al., 2007).

NAWEC did not have a strategic development plan for 2017-2018 that outlined what needed to be done and how it could be accomplished. However, it has drafted a strategic development plan for the years 2019 to 2025. Although no strategic objectives for the

<sup>18</sup> NAWEC Strategic Plan 2019 to 2025, page 2.

Water and Sewage Division were developed as part of the draft 2019-2025 strategic development plan, NAWEC's water division management claims they have been implementing the strategic objectives for the water and sewage division from 2019 to 2021, however, there was no evidence of this strategic objective in the strategic development plan.

The management of NAWEC's water division failed to explain why there was no strategic development plan for 2017-2018 and why the draft strategic development plan for 2019-2025 did not include a strategic objective for the water and sewage department and why the strategic development plan was not approved until 2022.

As a result of the weaknesses in the draft strategic development plan, NAWEC could not provide water for the growing population in their jurisdictions as there was no focus or future plans to cater for such population growth or settlement expansion.

**Conclusion**

From 2017 to 2021, NAWEC did not have an approved strategic development plan that clearly outlined the water division's strategic objectives and how they will be met.

**Recommendation**

NAWEC should develop a strategic development plan that outlines the water division's strategic objectives and how they will be achieved.

**Management response**

<b>Management Response</b>	<i>NAWEC is cognizant that a more robust Water Supply Strategy is required and is currently working to have that in place.</i>
<b>Action to be taken</b>	<i>Strategy to be developed</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>A strategy will be in place by March 2023</i>

**4.1.2 Risk of Water Contamination**

*According to World Health Organization (WHO) guideline for quality drinking water 2017; where a defined entity is responsible for a drinking-water supply, its responsibility should include the preparation and implementation of a Water Safety Plan (WSP).*

Water safety planning is a risk assessment and risk management strategy that extends across the entire drinking-water supply chain, from sources to consumers. A WSP's primary goal is ensuring good drinking-water supply to minimize contamination of source waters, reduce or remove contamination through treatment processes, and prevent contamination during storage, distribution and handling.

Contamination can occur at the source due to nitrate, iron, and fertilizer intrusion, among other contaminants. During distribution, pipe leakages or replacements can expose the water supply to pollution, allowing sewage and other contaminants to enter.

NAWEC has established a maintenance team; however, there is no documented safety procedure to guide their work. When maintenance issues emerge, the maintenance staff are given verbal instructions instead. We noted that NAWEC did not have a WSP for its water system that outlines all potential emergencies and the actions that must be taken if they occur.

Underground water sources, such as Bakau, Bansang and Gunjur, have significant quantities of nitrates and irons. NAWEC has no mechanism in place to treat nitrates in water. Despite developing ways to remove or reduce the iron content of water to an acceptable level, these strategies have failed, since the water delivered to the residents of Gunjur and Bansang still contain significant levels of iron as shown in **chart 10**. The residual chlorine in NAWEC's water supply is deficient, as shown in **chart 11**, and so will not be able to eliminate contaminants if contamination occurs during storage, distribution, or handling.

According to NAWEC's water division management, the failure to develop a WSP for its water system was due to capacity and resource availability. However, during our interview with the Water Division Management, this was identified as a risk and management promised to develop a WSP over time.<sup>19</sup>

In the absence of a WSP, contamination emergencies cannot be swiftly and easily controlled, putting the lives of many at risk. For example, in 2020, garbage in the Bakau gutters infected NAWEC's water pipes, resulting in the contamination of taps in Bakau residents' homes. This lasted for months and caused health worries among the locals.<sup>20</sup>

## Conclusion

NAWEC has not developed a WSP for its water network to provide guidance to the company on appropriate response and preventive measures of contamination.

## Recommendation

NAWEC is recommended to create a Water Safety Plan that outlines steps to be taken to help mitigate emergencies when they occur.

## Management response

<b>Management Response</b>	<i>NAWEC is aware that water safety plans play an important role in the management of a water supply system, not only to react to</i>
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<sup>19</sup> Interview meeting with management of Water Division 3<sup>rd</sup> February 2022

<sup>20</sup> The standard newspaper, June 15 2020 titled Nawec faults Bakau in contaminated water issue. By Alagie Manneh.

	<i>emergencies but also to prevent a risk eventuating and also to implement measures to minimize the impact of the risk if an emergency does occur.</i>
<b>Action to be taken</b>	<i>As part of our priorities Water safety Plans are to be developed</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>Water Safety plans for our facilities will be developed for all facilities within the next 2 years.</i>

## 4.2 WATER PRODUCTION AND DISTRIBUTION

### 4.2.1 Water Production Does Not Meet the Demand

NAWEC is mandated to provide water for Urban, Peri-Urban and Provincial growth Centres in The Gambia.<sup>21</sup> The standard water needs in urban areas is usually considered to range from 100 to 150 liters per capita per day.<sup>22</sup>

The daily water production of NAWEC during the period under review was approximately 102,851 m<sup>3</sup> (102,851,000 liters) per day. The water produced by NAWEC is insufficient for the urban area, let alone the peri-urban and provincial growth areas. The daily production of 102,851 m<sup>3</sup> is only sufficient to provide approximately 69 liters per capita per day to the 2021 urban population of 1.48 million people as shown in table 2 below. NAWEC has drilled 17 production boreholes between 2017 and 2021, but there has been no significant improvement in the volume of water produced by NAWEC between 2017 and 2021.

**Table 2: Population water demand for GBA versus Nationwide water estimates by NAWEC water**

Year	Projected Population for GBA (In millions)	Population water demand for GBA [projected population x 36.5] (In millions m <sup>3</sup> )	Nationwide NAWEC projected Water demand (In millions m <sup>3</sup> )	Nationwide NAWEC estimated quantity of water produced (In millions m <sup>3</sup> )	Gap (In millions m <sup>3</sup> )
2017	1.26	46.08	36.64	37.14	8.95
2018	1.32	48.05	38.23	36.44	11.61
2019	1.37	50.	37.93	39.90	10.11
2020	1.49	54.38	44.04	40.89	13.49
2021	1.48	54.16	43.36	33.34	20.83

**Source:** GBOS population census 2013 and NAWEC projected Water demand for its coverage area.

**Note:** 2013 population census by The Gambia Bureau of Statistics (GBoS) revealed a population of 1,857,181 people and an annual growth rate of 3.1%. 2017-2020. Urban population projection was

<sup>21</sup> NAWEC Annual Report 2017.

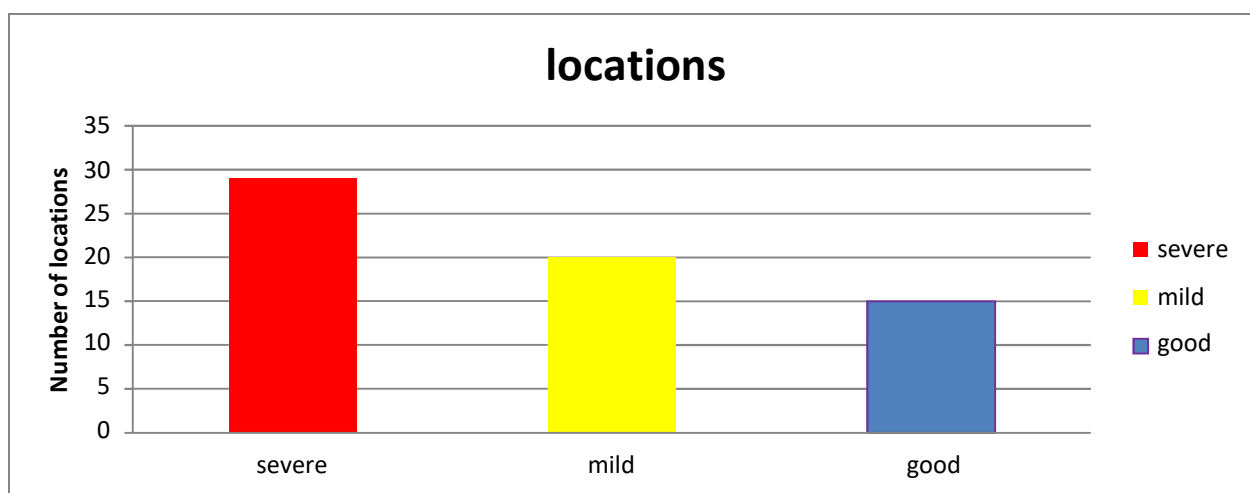
<sup>22</sup> WASIB Feasibility Report 2020.

extracted from World Bank website and 2021 urban population was extracted from Knoema website.  $36.5 \text{ m}^3 = (100 \text{ liters} \times 365 \text{ days}) / 1000$ .

As shown in table 2 above, the water produced by NAWEC from 2017 to 2021 does not meet the population's demand. From 2017 to 2021 the projected urban population water demanded was 252.67 million  $\text{m}^3$  and NAWEC estimated water produced was 187.71 million  $\text{m}^3$  therefore the demand and supply gap are 64.99 million  $\text{m}^3$ . Analysis has shown that the gap between the quantity demanded, and the quantity produced has been increased from 2017 to 2021.

According to PURA 2008 Minimum Quality of Service Water and Sanitation Guideline, the average daily water supply at connections in towns with more than 100,000 inhabitants should be 24 hours and for other towns a minimum of 16 hours. Opening hours of the public distribution system is 12 hours/day, 7 days a week.<sup>23</sup> We have found that NAWEC does not have adequate water to supply its customers, the chart 4 below shows customers' responses on the availability of water supply at different location.

**Chart 4 : NAWEC customers' response on how often they get water supply from the company.**



**Source:** auditors' analysis of information gathered from the customers

**Key:**

**Severe:** Absence of piped water supply for more than three days.

**Mild:** Water supply is available part of the day/night but not up to 24hrs.

**Good:** There is 24hrs regular water supply

As shown in chart 4 above, our analysis of the responses from the customers interviewed showed that only 23% of the 64 locations interviewed said that they have 24-hour access to regular water supply from NAWEC. 77% of the locations interviewed therefore live without access to an uninterrupted water supply. **Appendix 5:** Availability of water to selected location

<sup>23</sup> Minimum quality of service standard for water and sanitation. PURA

During interviews at treatment centres, we were informed by NAWEC personnel that the population was not having access to 24-hour water supply because the quantity of water produced by their boreholes was less than the population demand.

NAWEC's strategic and operational planning does not provide an estimate of how much water is required by its service areas. In addition, NAWEC's Internal Audit team carried out an audit on water production, treatment, and distribution in April 2015; however, a follow up was carried out in 2017 which revealed and confirmed that there was no mechanism in place to determine the actual water demand of the population, so demand was estimated based on the amount of water supplied previously rather than the actual demand.

As there was no strategic foresight to capture the water demand of the population in the serviced areas, NAWEC focuses on increasing water production capacity mainly when it is confronted with severe water shortages. For instances, during the early days of Covid-19 when the customers were faced with water shortages in some service areas, NAWEC dug borehole Brikama N5, Old Yundum Tank Borehole and Sukuta Tank Borehole. Just 2 months after its commissioning Sukuta Tank Borehole was eventually decommissioned due to quality issues. Furthermore, to respond to the Covid-19 pandemic, GMD 4.6 million was spent by NAWEC to install water tanks at various settlements that experienced severe water shortage. However, the NAWEC Internal Audit Report on Covid-19 response water tanks revealed a daily gap of 78,000 litres, representing 38% of the 126,000 litres that should have been filled by the bowser trucks.<sup>24</sup>

As a result, NAWEC does not know the quantity of water to produce in order to meet the growing population demand thus causing water shortages. In certain cases, schools such as Gambia High School, Bundung Lower Basic School, and St. Peter's Technical Junior and Senior Secondary School occasionally ask students to go home during school hours due to lack of water in the schools, thus interfering with the students' education. Similarly, hospitals such as Edward Francis Small Teaching Hospital, Essau District Hospital, and Serekunda Health Centre frequently struggle to carry out day-to-day operations such as dialysis, maternal delivery and even water to use for sanitation.

## **Conclusion**

NAWEC did not put in place mechanisms to increase water production to meet the growing population's demand.

## **Recommendation**

NAWEC should ensure it puts in place mechanisms to produce adequate water to meet the population demand.

## **Management response**

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<sup>24</sup> Covid-19 Taskforce Clarification to Internal Audit page 5 to 8.

<b>Management Response</b>	<p><i>It must be recognized that to be able to put in place the right mechanisms the funds must also be available to fund these.</i></p> <p><i>Over the years and with the exception of the EXIM Bank Asbestos replacement project there has been no investment in the water sector- this has significantly impacted NAWEC's ability to implement the required solutions that could have minimize the water shortages.</i></p> <p><i>There are 2 projects in the pipeline that will help in bridging the supply demand GAP however the master plan to be developed will also assist in directing how future needs are to be met.</i></p>
<b>Action to be taken</b>	<i>Master Plan to be developed that will drive how existing and future demand will be met</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>Upon Completion of the WASIB project – at this stage and providing all parameters remaining constant this is due for 2026</i>

#### **4.2.2 The Distribution System is Unable to Maintain the Pressure Needed to Reach Certain Areas**

*According to the PURA Act 2001; NAWEC shall make repair, change, extension, or improvement to its service necessary for the efficient provision of the service.*<sup>25</sup>

Elevated tanks are used to supply water through gravity pressure and serve as buffers in the water network. Inspection of elevated tanks showed that 44% of the 27 elevated tanks (as shown in table 3) visited was bypassed for more than 5 years ago i.e., water was supplied directly to the customers without passing through the water tanks.

**Table 3: Total number of elevated tanks that are bypassed**

<b>Treatment plant</b>	<b>Total number of</b>	<b>Tanks bypassed</b>	<b>Tank bypassed</b>	<b>Tank bypassed</b>	<b>Functional Tanks</b>	<b>Quality of</b>
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<sup>25</sup> PURA Act 2001.



	tanks the water treatment plant should supply		due being faulty	due to not having enough water		service in areas
Brikama	3	0	-	-	3	Not Good
Sukuta	6	4	1	3	2	Not Good
Serekunda	9	5	4	1	4	Not Good
Gunjur	1	1	1	0	0	Good
Fajara	3	1	1	0	2	Not Good
Mansakonko	1	0	-	-	1	Fairly Good
Bansang	1	0	-	-	1	Not Good
Kanuma	1	0	-	-	1	Not Good
Basse	1	1	1	0	0	Not Good
Farafenni	1	0	-	-	1	Fairly Good
<b>Total</b>	<b>27</b>	<b>12</b>	<b>8</b>	<b>4</b>	<b>15</b>	

Source: inspection at NAWEC elevated tanks and customer interviews

As shown in table 3 above, 44% of the elevated tanks were bypassed due to the excess demand, faulty liners, structural problems, and old age. Some of these causes were corroborated by the water and sanitation in the Greater Banjul Area (WASIB) project feasibility study. Picture 1 shows the non-functional elevated tanks at Basse and Serekunda water treatment plants.

Picture 1: Non-functional water tank at Basse water facility and Serekunda Treatment Plant



Sources: Pictures taken from 22<sup>nd</sup> to 26<sup>th</sup> November 2021.

Consequently, the distribution system was unable to maintain the pressure needed to reach certain areas, thus, resulting in few hours of water supply or no water supply in most of the service areas. In most areas water is available during the night or mornings lasting for an hour or two. Furthermore, the bypass affects the efficiency of the booster pumps as they are used continuously to pump water.

### Conclusion

Forty-four percent (44%) of NAWEC elevated water tanks which are used as buffers and designed to provide gravity pressure in distributing water to the network were bypassed.

### Recommendation

NAWEC should establish mechanisms in place to ensure elevated water tanks are not bypassed.

### Management response

<b>Management Response</b>	<i>Noted – As NAWEC review how systems are operated and maintained we will implement robust strategies to address growth, renewal and operations and maintenance, this practice will reduce the frequency at which tanks are bypassed.</i>  <i>The first step of this process was to implement An Asset Management team that will be responsible for ensuring appropriate strategies to address, growth, renewal and operations are implemented and carried out.</i>
<b>Action to be taken</b>	<i>Robust Asset Management plans and operational plans to be developed</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>The process will start in December 2022.</i>

### 4.2.3 NAWEC's water System and infrastructure were not well secured

*NAWEC is mandated to provide safe drinking water to urban, peri-urban and provincial growth Centres in The Gambia.* <sup>26</sup>

During site visits, we discovered that the water treatment plants in Mansakonko and Kanuma did not have security guards, thus the facilities are left unprotected when the people in charge close from work. Additionally, the property boundary fences in the provincial treatment plants, such as Farafenni, Mansakonko and Basse were short, and some parts had fallen off.

In addition, in Farafenni, animals such as pigs and goats were found intruding in the treatment plant and the operator disclosed that children and animals do cause damages to the cables of the boreholes. During the inspection of the boreholes, we found out that 35 out of the 60 boreholes inspected were not well protected as the gates were damaged or left open as shown in pictures below.

**Picture 2: The unprotected water facility at Farafenni (Left) and Mansakonko water facility (right)**



**Sources: Pictures taken from 22nd to 26th November 2021.**

Furthermore, during site visits, we found that some of the older boreholes had their copper cables exposed to theft and/or vandalism. NAWEC has started burying these cables in new boreholes but has failed to do the same for the older ones. Consequently, people continue to cause damages to these cables that resulted in hours of no water production. For instance, NAWEC has recently announced that four (4) other boreholes in Latriya and Jambur were vandalized in 2021 by cutting the copper cables and rendering them non-

<sup>26</sup> NAWEC Annual Report 2017.

operational<sup>27</sup>. In addition, it reported that three (3) boreholes in Brikama Forest were vandalized in 2018 by cutting off their cable causing the company to lose 4.5 million liters of water per day<sup>28</sup>.

NAWEC’s management informed us that due to financial constraints they were unable to ensure that all the gates and fences of the boreholes and treatment plants are maintained.

## Conclusion

Most of NAWEC’s water facilities were not properly fenced, even those fenced were sometimes without closed gates. Therefore, NAWEC has not adequately protected its water system and infrastructure risking the lives of over a million people who consume/utilizes the water.

## Recommendation

NAWEC should ensure water sources and their treatment plants are well protected/guarded.

## Management responses

<b>Management Response</b>	<i>Noted and concur – NAWEC is currently assessing ways to secure its facilities and is currently embarking on ensuring that planned improvements works are carried out to secure the facilities. In a nutshell this has already started.</i>  <i>Examples of facilities that have already being worked on are Boreholes B4 and PN3 – Facility where fencing is underway is Farafenni.</i>
<b>Action to be taken</b>	<i>NAWEC will ensure facilities are secured over time.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>Improvements are currently underway however this will be done over time.</i>

### 4.2.4 Difficulties in Locating Underground Water Leakages

<sup>27</sup> Interview with the management of water division on 3<sup>rd</sup> February 2022.

<sup>28</sup> Gambia: Nawec attributes recent water shortage to sabotage by unscrupulous people; says the company loses 4.5 million liters of water per day due to cable theft by thieves - (gambianewstoday.com)

*The Public Utilities and Regulatory Authority's (PURA) Minimum Quality of Service Standard Guidelines for Water and Sanitation of 2008 states that a water provider should maintain up-to-date maps and plans and records of its entire transmission and distribution or collection and interception system, with such other information as may be necessary to enable the water provider to advise prospective customers and others entitled to the information, as the facilities available for services in any locality<sup>29</sup>.*

A review of the WASIB project's feasibility study final report 2020 revealed that the company had a Geographic Information System (GIS) which was designed to map out underground water pipes in the water system and help locate leakages in the water network. Trial GIS software was used by NAWEC from 2009 to 2010 and was never purchased after its expired date due to funding problems. During an interview with the management of the water division, they acknowledged that there was no GIS system operational during the period under review.<sup>30</sup>

The WASIB project's feasibility study final report 2020 further highlighted that the non-functionality of the GIS was as a result of the limitations of the Ikonos geographic satellite imagery, and the failure of field operators to document for each network intervention performed such as alteration or extension.

A non-operational GIS can result in long days, weeks, and months of underground water leakage that the company would be unable to easily locate. Furthermore, NAWEC cannot provide advice on the water distribution facilities available to prospective customers and others who are entitled to information because the water distribution facilities available for services in any locality are not mapped in the absence of a GIS.

## **Conclusion**

From 2017 to 2021; NAWEC did not have a functioning GIS which should have mapped out its entire water network.

## **Recommendation**

NAWEC should put in place strategies to ensure that it maintains an up-to-date and functioning GIS.

## **Management Responses**

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<sup>29</sup> (PURA) minimum quality of service standard for water and sanitation 2008 page 28.

<sup>30</sup> Meeting with the management of NAWEC on 7<sup>th</sup> July 2021

<b>Management Response</b>	<i>Noted and concur – As part of the WASIB (AFD) project a GIS of the water supply network will be developed – NAWEC has already started to collect data to assist with this process.</i>
<b>Action to be taken</b>	<i>GIS to be further developed under the WASIB project</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>Upon the completion of the WASIB project in 2026</i>

#### 4.2.5 Limited Access to NAWEC's Pipe Water

*NAWEC is mandated to provide water for Urban, Peri-Urban and Provincial growth Centres in The Gambia<sup>31</sup>.*

During an interview with the Water Division management, we were informed that as of 2020, the company was yet to cover 40% of its coverage area, even though it has expanded slightly in recent years due to the company's reliance on donor support. However, this claim is not documented.<sup>32</sup>

The WASIB feasibility study report 2020 stated that NAWEC has only covered 38% of the GBA area.

Interviews with NAWEC's customers revealed that there were instances where one side of a street had access to water while the opposite side did not. Some parts of Yundum, Busumbala, Jalongba, Batukungku, Tanji, Sukuta, Mariamakunda, Mamuda, and Basse Mansajang were yet to receive NAWEC water supply as NAWEC had not expanded to some of these areas at the time of this audit.

NAWEC's water supply capacity has not kept pace with the demand coupled with the late implementation of proposed expansion projects<sup>33</sup>. The AFD project, for example, has been approved since 2019 but was yet to be implemented, likewise the OIC.. As a result, the size of the unserved population continued to grow, surpassing current water infrastructure and putting pressure on the water utility's capacity to connect the increasing number of households. According to the company, they rely heavily on donor funding for expansion.

People who do not have access to NAWEC's pipe water dig boreholes/wells or find other ways to obtain water, which is not only expensive but also frustrating.

## Conclusion

<sup>31</sup> NAWEC 2017 Activity Report.

<sup>32</sup> Meeting with the management of water department on the 7<sup>th</sup> of July 2021

<sup>33</sup> Interview with management of water department 7<sup>th</sup> July 2021.

NAWEC did not cover the entire mandated area, leaving majority of the citizenry without access to NAWEC’s water supply.

### Recommendation

NAWEC should establish strategies to extend its water coverage in areas under its mandate to catch up with the growing population demand.

### Management responses

<p><b>Management Response</b></p>	<p><i>It must be recognized that to be able to put in place the right mechanisms the funds must also be available to fund these. This includes having the right tools for example a hydraulic model.</i></p> <p><i>Over the years and with the exception of the EXIM Bank Asbestos replacement project there has been no investment in the water sector- this has significantly impacted NAWEC’s ability to implement the required solutions that could have minimize the water shortages.</i></p> <p><i>There are 2 projects in the pipeline that will help in bridging the supply demand GAP however the master plan to be developed will also assist in directing how future needs are to be met.</i></p> <p><i>It must also be noted that the right financial response is also required and government will need to ensure appropriate tariffs are set to be able to generate the right revenue for re-investment.</i></p>
<p><b>Action to be taken</b></p>	<p><i>Once the WASIB project is implemented and NAWEC is provided with the appropriate tools developed through these projects we will be better able to plan and project where and how systems can be extended to cater for future demand.</i></p>
<p><b>Officer Responsible for remedial action</b></p>	<p><i>Chief Operating Officer - Water and Sewerage Business unit</i></p>
<p><b>Date when the situation will be regularized</b></p>	<p><i>Upon the completion of the WASIB project in 2026</i></p>

#### 4.2.6 Water rationing – managing the limited production

*According to PURA’s Minimum Quality of Service for Water and Sanitation 2008, during times of threatened or actual water shortage, the water provider shall equitably apportion its available water supply with due regard to public health and safety<sup>34</sup>.*

Rationing is the equitable allocation of limited water supplies in order to maintain public health and safety. During an interview, it was brought to our notice that NAWEC does not practice water rationing<sup>35</sup>.

<sup>34</sup> PURA’s minimum quality of service for water and sanitation 2008 page 40.

<sup>35</sup> Interview with NAWEC’s water department on 3<sup>rd</sup> February 2022

This is because NAWEC did not establish any water rationing procedures that will serve as a guide to help address its water shortage problem.

As a result, areas under NAWEC's mandate a times goes for hours, days, months and even years at a time without water supply from NAWEC.

### Conclusion

NAWEC did not put in place any water rationing procedures to help address its water shortage problem and ensuring equal distribution of water to customers.

### Recommendation

NAWEC should equitably apportion its available water supply with due regard to public health and safety.

### Management responses

<b>Management Response</b>	<i>NAWEC provides water to the communities taking into consideration the limitation of the water supply system.</i>
<b>Action to be taken</b>	<i>When possible NAWEC will ensure water can be supplied to communities on a more regular basis.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - Water and Sewerage Business unit</i>
<b>Date when the situation will be regularized</b>	<i>When possible NAWEC will ensure water can be supplied to communities on a more regular basis.</i>

#### 4.2.7 Lack of Preventive Maintenance and Water Losses

*NAWEC has a target to maintain its water loss at fifteen percent (15%)<sup>36</sup>.*

Preventive maintenance can be one of the solutions to avoid water loss by leakages resulting from pipe bursts. Preventive maintenance may include periodic survey on the distribution and supply lines, water piping etc. Pipes exposed on the surface are at risk of bursting when people, animals, and automobiles trample on them.

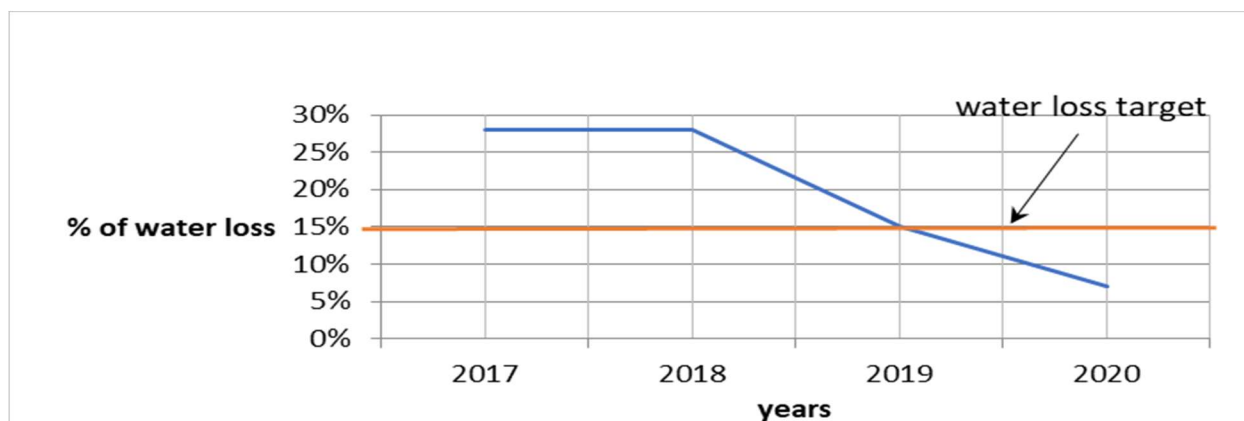
From the review of the water production figures provided by NAWEC Water Division, we noted that the company has improved on mitigating water losses to meet its 15% target. The trend over the years is shown in the chart below.

Chart 5: Amount of water loss between 2017 and 2020 <sup>37</sup>

<sup>36</sup> NAWEC Activity Report 2017 page 12.

<sup>37</sup> NAWEC water production figures from 2017 to 2020





Source: data provided by NAWEC

From the chart above it can be seen that from 2017 to 2020, the water loss percentage had decreased from 28% to 7%. However, it is important to note that these production figures were based on estimates because only about half of the boreholes were metered correctly as highlighted in section 4.2.2. This could have an impact on the accuracy of the reported water losses.

Water losses are mainly caused by leakages and burst pipes, illegal connections, non-registered meters and old distribution networks<sup>38</sup>. During our site visits and inspections, we have seen evidence of water leakages and pipes exposed to damages. The table below shows list risk of water loss.

Table 4: List of NAWEC WTP and boreholes that were found leaking during site visit.

site	Evidence/risk of water loss
Serrekunda WTP	Its reservoir was continuously leaking during the times of visits, and this led to water loss.
Kanuma WTP	Elevated tank was continuously leaking during the time of our visit
Farafenni WTP	The elevated tank was continuously leaking during the time of our visit.
Boreholes N3, E15, E3, E5, PN6, BH17	These boreholes were also leaking through their air valves and the non-return valves which resulted to water loss.

Source: Auditors inspection from 22<sup>nd</sup> to 26<sup>th</sup> November 2021.

During our interview with the water division management, we were told that service pipes should be at a minimum of 60 centimeters and the main pipe 1 meter underground<sup>39</sup>. However, we discovered pipes that were supposed to be at a minimum of 60cm (service pipes) and 1meter (main pipes) underground lying on the surface in areas including Bakoteh borehole, Jarra Karantaba, Basse Manneh Kunda, Bansang, and Kololi Tavan.

<sup>38</sup> Interview with the NAWEC management of Water Division 7<sup>th</sup> June 2021.

<sup>39</sup> Interview with the management of Water Division on 07/07/2021

During an interview with the residents, we were informed that these pipes have been on the surface for over a year and that they frequently experience pipe bursts and leakages. People, animals, and automobiles trample on distribution water pipes, causing bursts and leakages.

The pictures below show some of the areas affected with water leakages due to burst pipes, leakages at the boreholes and exposed pipes on the surfaces of the sand.

Picture 3: Burst pipes in Farafenni (top) and Mansakonko (down)



Source: Audit pictures taken from 22<sup>nd</sup> to 26<sup>th</sup> November 2021

Picture 4: NAWEC's exposed distribution pipe (top Left), main pipe (top right) in Bundung and exposed distribution pipe (Bottom left) exposed distribution pipe at Jarra Karantaba (Bottom right)



Sources: Audit pictures taken 22<sup>nd</sup> to 26<sup>th</sup> November 2021.

NAWEC’s Water Division Management informed us that the exposure is sometimes caused by soil erosion, or the pipes were not laid at the appropriate depth during installation. This assertion was confirmed during our site visits as seen in the above pictures (3 and 4) that pipes were not properly buried as required. In addition, during an interview, the management of Water Division acknowledged that NAWEC has not set up a monitoring team to follow up on its ground works.<sup>40</sup>

During a meeting with the management of NAWEC Water Division, it was shared that NAWEC’s response time for leakages is within 1 hour for transmission lines and 24 hours for the distribution network,<sup>41</sup> but NAWEC has failed to provide us with a maintenance log to verify this information.

NAWEC takes 6 to 14 days to respond to burst pipes, according to 84% of the consumers we interviewed. We requested for the customer complaint logbook. However, NAWEC has failed to provide it for our review. The table below shows the range of NAWEC’s response time to pipe bursts in the locations interviewed. **Appendix 6:** Response time of NAWEC to pipe bursts at selected areas per Customer interview.

Table 5: Range of response times experienced by NAWEC customers.

Range of response time	Number of places interviewed	Percentage %
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<sup>40</sup> Interview with NAWEC water division management on 7<sup>th</sup> July 2021.

<sup>41</sup> Interview with the management of Water Division on 07/07/2021

24hrs	17	27%
More than 24hrs	47	73%

*Source: Auditors customer survey from November 2021 to 17<sup>th</sup> March 2022.*

Analysis of the table above shows that NAWEC takes a lot of time before responding to pipe bursts. However, the Customer Service Department Officials at NAWEC stated that most of those reports/complaints do not go formally to them as a result they were unaware of some of the complaints.

NAWEC estimated Non-Revenue Water (NRW) rate of about 35% to 45%. However, this rate is unreliable as NAWEC does not have a systematic way of measuring actual and physical losses in its coverage area<sup>42</sup>.

Leakages cause a lot of water losses which affects both NAWEC and its customers. When pipes bursts and water leaks, NAWEC suffers from economic loss because no revenue is collected from the water that passes through leakages. Customers also suffer from water shortage, water contamination and low water pressure.

### **Conclusion**

Management failed to put efficient and effective maintenance measures in place resulting to inadequate maintenance of the water facilities such as irregular maintenance of the water tanks, reservoirs and pipes which led to serious leakages. From the evidence obtained from the fieldwork, pipes were not well buried as required by the criteria. Sometimes, it takes time to rectify technical faults like burst pipes and leakages within the distribution lines.

### **Recommendation**

The Management of NAWEC should ensure both preventive and periodic maintenance of the water distribution system is prioritized.

### **Management response**

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<sup>42</sup> NAWEC website

<b>Management Response</b>	<p>NAWEC do implement preventative and routine maintenance however with buried assets it is not always possible to know that an asset will fail especially if the type of material implies that you will get certain operational years.</p> <p>It must be noted that a significant portion of failure within the network is as a result of pipe burst due to erosion lessening the cover over the pipe. In recent times NAWEC have engaged NRA on addressing some of these erosions especially in areas where the erosion is more than 1m, however, to date they are yet to come on board to get these addressed.</p> <p>Where it is feasible for NAWEC to address these issues, we have and will continue to do so.</p>
<b>Action to be taken</b>	NAWEC have and will continue to implement the appropriate strategies in order to sustainably manage the water supply assets.
<b>Officer Responsible for remedial action</b>	Chief Operating Officer
<b>Date when the situation will be regularized</b>	This is a continuous process

### 4.3 WATER INFRASTRUCTURE AND EQUIPMENT

#### 4.3.1 Inaccurate Information about Water Production and Usage of Water Meters

According to the PURA Act 2001; NAWEC shall make repair, change, extension, or improvement to its service necessary for the efficient provision of the service. According to PURA minimum quality of service standard guidelines for water and sanitation of 2008, a water provider should test installed meters according to its size<sup>43</sup>.

During water production, NAWEC fits boreholes with water reading meters. These metres measure the volumes of water produced and distributed to the population. The Table below shows the functionality of the boreholes.

Table 6: Details of boreholes that have functional meters and non-functional meters.

Plant	Number of boreholes visited	Number of borehole metres not functional	% Of borehole metres not functional
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<sup>43</sup> (PURA) minimum quality of service standard for water and sanitation 2008 page 12.

Sukuta	16	1	6%
Brikama	17	5	29%
Serekunda WTP	11	1	9%
Fajara	5	0	0%
Gunjur	1	0	0%
Kanuma	1	0	0%
Farafenni	1	0	0%
Bansang	1	1	100%
Basse	2	0	0%
Mansakonko	1	1	100%
Others	4	2	50%
<b>Total</b>	<b>60</b>	<b>11</b>	<b>18%</b>

*Sources: Inspection of NAWEC boreholes and elevated tanks 22 November 2021 to 17 March 2022.*

As can be seen in the table above, 18% of NAWEC borehole meters have been faulty for more than five years ago.

According to WASIB Feasibility Study Report 2020, NAWEC Water Division estimated that only 30% of the boreholes were correctly metered. However, our visit to the boreholes came after the replacement of metres of boreholes connected to the Sukuta Water Treatment Plant in 2020 through the Exim Bank-funded project.

However, a review of the NAWEC Water Division Raw Water Operational Statistics 2021/22 document revealed that NAWEC was unable to obtain total monthly production figures from boreholes connected to Brikama, Sukuta, and Brusubi standalone boreholes between October 2021 and January 2022 due to its faulty meters.

According to NAWEC's Water Division's management, these meters were not replaced or repaired because they do not have the required budget to do so, however, table 7 below shows that from 2017 to 2020, meters were budgeted. Thus, NAWEC uses the past readings as a reference to estimate the flow.

**Table 7: NAWEC approved budget 2017, 2019 and 2020 and NAWEC budget for board approval 2018 for water meters.**

<b>Meters</b>	<b>2017 Board Approved</b>	<b>2018 For Board Approval</b>	<b>2019 Board Approved</b>	<b>2020 Board Approved</b>

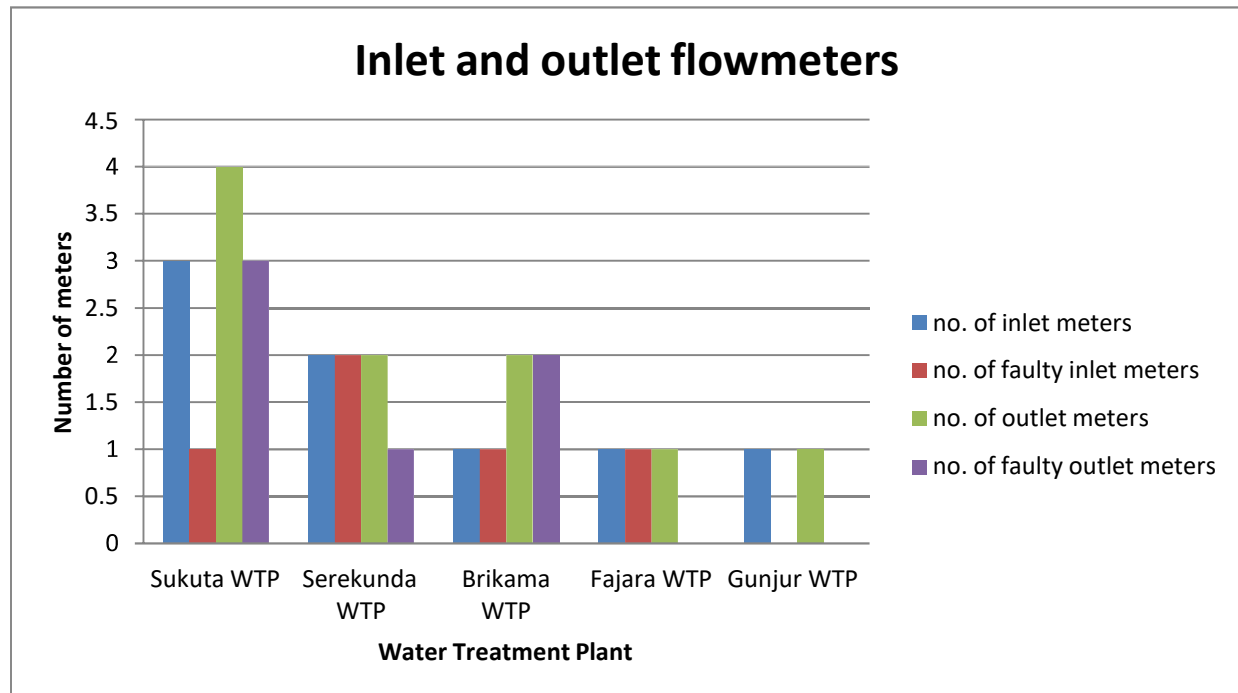
	Qty	(D)	Qty	(D)	Qty	(D)	Qty	(D)
DN300 bulk meter	6	360,000	6	360,000	12	720,000	0	0
DN200 Raw water meters	5	275,000	10	550,000	20	1,100,000	0	0
DN150 Bulk water meters	4	160,000	4	160,000	8	320,000	0	0
Digital Bulk meters for BWTP	4	400,000	4	400,000	2	200,000	1	100,000

Sources: NAWEC approved budget 2017, 2019 and 2020 and NAWEC budget for board approval 2018.

Inaccurate readings result in wrong information about water production and distribution, water usage, system audits and leak detection efforts. The lack of functional reading meters hampers future water projections. Placing water metering tool at the source and at the service point is an essential component of efficient and conservation management, as it is a requirement for accounting for water usage and lost control, cost savings, and evaluating the efficiency of the water system.

Furthermore, during an inspection of the inlet and outlet bulk water meters at the water treatment plants, the audit team noted that 11 out of 18 meters were faulty (5 inlets and 6 outlets). The functionality of flowmeters is shown in chart 6.

Chart 6 : Number of fault outlet and inlet flowmeters at water treatment plants and elevated tanks.



Additionally, an inspection of the inlet and outlet meters of 27 elevated tanks revealed that 15 elevated tanks had faulty inlet meters, 5 did not have inlet meters and 19 had faulty outlet meters.

The Feasibility Study for a Water supply and sanitation in the Great Banjul Area project (WASIB) Final report 2020 noted that 28 flow meters (representing 53%) of the elevated tanks were faulty. According to the report, more than 85 percent of the bulk meters needed replacement.

Furthermore, the WASIB report also highlighted that all electromagnetic flowmeters installed at water treatment plants or elevated tanks were faulty. The report also stated that the electromagnetic flowmeters are not robust enough for use in the Gambia, and that the difficulties with electricity power supply may explain this. Additionally, the management of NAWEC's water department informed us that failure to repair or replace all faulty inlet and outlet flowmeters at treatment plants and elevated tanks was due to lack of funds. However, nothing was submitted to us to substantiate this claim.

Due to the low accuracy of water flow meters, NAWEC is not able to determine the volume of raw water sent to the treatment plant from its boreholes and the quantity distributed to the customers.

### **Conclusion**

NAWEC has relied on the readings of its faulty meters in its water production system and distribution thus miscalculating the total amount of water produced and distributed. NAWEC has been miscalculating the total amount of water it produces and distributes.

### **Recommendation**

NAWEC should establish a mechanism to ensure water produced and distributed are adequately metered.

### **Management Response**

<b>Management Response</b>	<i>Note and concur. In general, meters are installed when a new system is commissioned however not in all cases are meters replaced once they become faulty. As part of the WASIB project (Phase 1) inlet and outlet meters will be installed at boreholes and treatment plants.</i>
<b>Action to be taken</b>	<i>Inlet and outlet meters to be installed during the implementation of the WASIB project</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>Upon completion of the WASIB project in 2026</i>

#### **4.3.2 No Production, Treatment and Distribution of Water during Power Outages.**

*Each water and sanitation provider shall furnish permanently installed gasoline, diesel, propane-fuelled, natural gas, or oil-fired standby power equipment at such facility*



*locations as are necessary to provide sufficient standby power capacity<sup>44</sup>. Furthermore, the public utility to which this part applies shall make any repairs, changes, extension or improvement to regulated public service necessary for the efficient provision of the service<sup>45</sup>.*

NAWEC's water production and treatment is powered by electricity solely generated by the company itself. Power is needed to operate all the boreholes and machinery involved. Since the power supply in the country is not stable, NAWEC can only reliably produce, treat, and distribute water using stand-by-generators anytime there is power outage.

During our inspection at Brikama Water Treatment Plant on 15th November 2021, which is linked to 17 boreholes, we found that there was no functional standby generator since 14th November 2020 (Picture 5 below shows the non-functional standby generators). At Serekunda Treatment Plant, we found that 5 out of 11 of its boreholes were not linked to any standby generator. In the absence of electricity, there cannot be any production, treatment and distribution at these treatment plants.

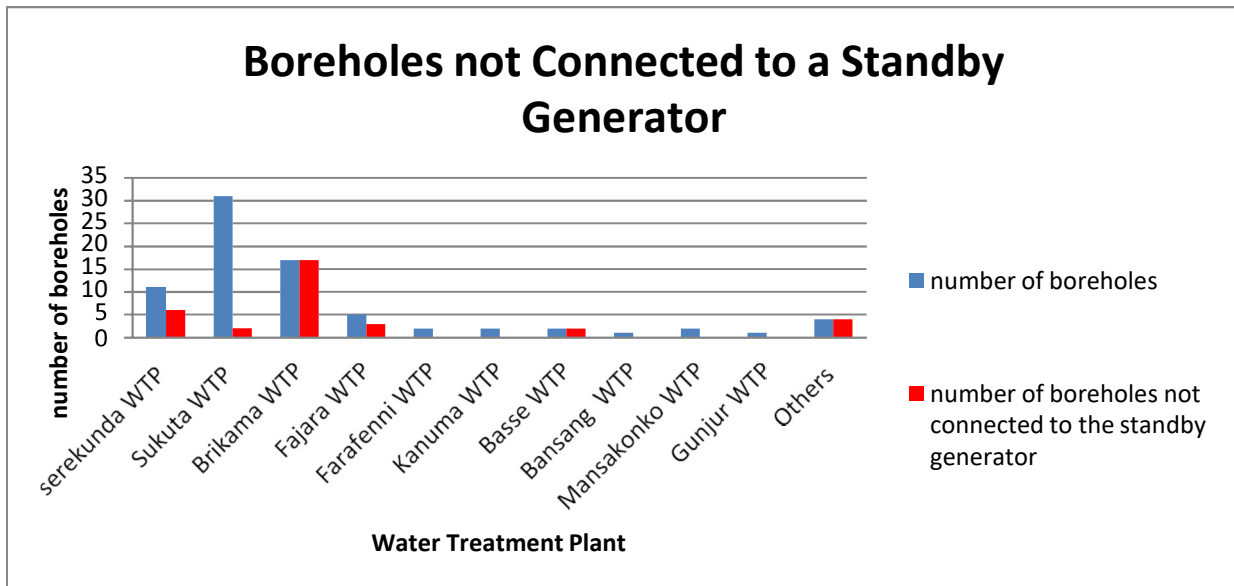
During our inspections at the rural NAWEC water production facilities, we confirmed that the Generator at Basse Water Production Facilities which is responsible for almost 7 villages was not functional at the times of our visit on 24 November 2021. We also learnt that only 2 out of the 5 boreholes at Fajara water treatment plant were linked to the standby Generator. Through interviews and physical verifications, we found that 44 out of the 60 boreholes visited were not linked to any generator as shown in chart 7 and therefore leads to service interruption whenever there is power outage.

**Chart 7: Boreholes link to Standby Generators and those that are not linked.**

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<sup>44</sup> Minimum quality of service standard for water and sanitation. PURA

<sup>45</sup> PURA Act: PART VII, 31. (c)



Source: from the site visit conducted to all NAWEC treatment plants and its other water production facilities

Picture 5: Non-functional Standby Generators at Brikama and Basse water treatment plant.



Sources: Pictures taken from 22<sup>nd</sup> and 26<sup>th</sup> November 2021

According to the Water Division management, NAWEC has failed to repair its generators due to financial constraints. However, the audit team was not provided with any document to back this claim.

Due to frequent power outages Water Treatment Plants and Standalone Boreholes which are not linked to any standby generator will not produce, treat or distribute water as required.

### Conclusion

NAWEC has failed to provide its water production facilities with functional standby Generators to ensure there is continuous production during power cuts.

### Recommendation

NAWEC should ensure all its facilities are connected to a functional Stand-by-Generator to ensure adequate production, treatment and distribution of water for its customers. Additionally, NAWEC should ensure all its faulty Stand-by-Generators are repaired.

### Management response

<b>Management Response</b>	<i>Noted – NAWEC recognizes the importance of ensuring service continuity during emergency and more importantly during a power outage. It must be noted that it is not financially feasible for NAWEC to have every facility equipped with its own generator and hence the approach is to have all boreholes serving a particular treatment plant connected to a generator. This is the approach taken within the GBA and similarly for some facilities within the provinces. Currently there are standby generators that have malfunctioned beyond the capacity of our internal maintenance crew and for these systems, sourcing competent service providers have proved difficult.</i>
<b>Action to be taken</b>	<i>NAWEC where financially feasible will install standby genset and where the technical service can be sourced will repair malfunction genset.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>When and as required.</i>

### 4.3.3 Risk of Pipe Burst Due to Unmonitored Pressure

*According to the PURA act of 2001; NAWEC shall make repair, change, extension, or improvement to its service necessary for the efficient provision of the service.*

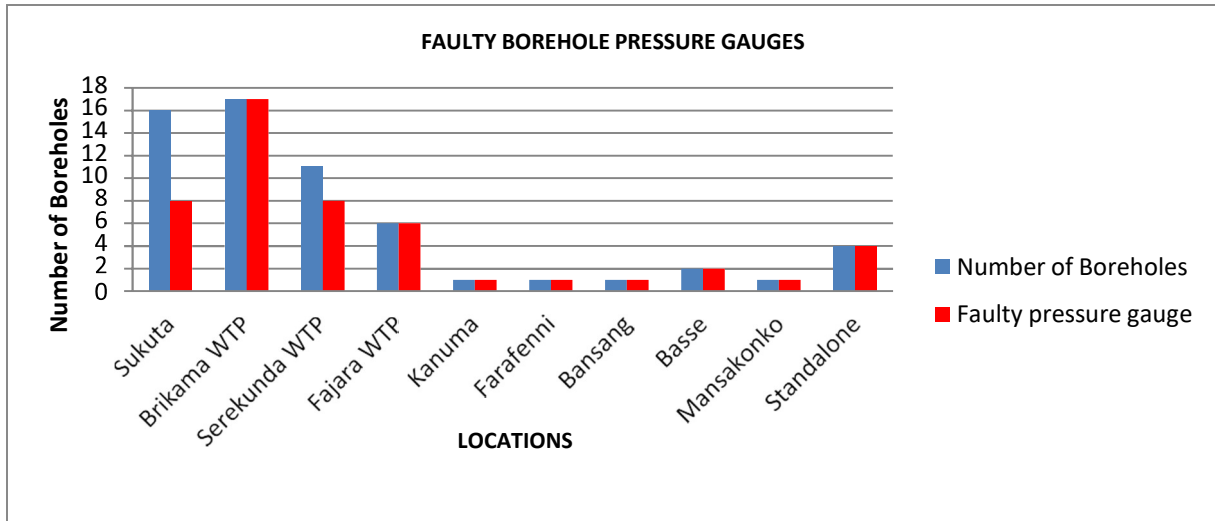
Pressure gauges measure the pressure at which the borehole pumps water. During inspection of the boreholes. We were informed that from 2017 to 2020 none of the pressure gauge was functioning. <sup>46</sup>

However, the Exim Bank funded project in 2020 replaced the gauges at boreholes linked to Sukuta Treatment Plant. Therefore, the pressure of the water pumped can be monitored from the control panel at the Sukuta Treatment Plant.

Thus indicating that NAWEC is unaware of the pressure at which the rest of its boreholes are pumping water to the treatment plants or elevated tanks. The chart below shows the functionality of borehole pressure gauges.

**Chart 8: Number of NAWEC boreholes pressure gauges and the faulty pressure gauges.**

<sup>46</sup> Inspection of NAWEC boreholes and Elevated tanks from 23<sup>rd</sup> February- 17<sup>th</sup> March 2022



Source: audit team data collected from site visits

Analysis of chart 8 above shows that 49 (representing 82%) of the pressure gauges installed at the boreholes were not working

This is a result of the failure of NAWEC to replace or repair faulty pressure gauges on its boreholes. NAWEC does not know the pressure at which most of its boreholes pump water to WTPs and elevated tanks.

NAWEC's inability to monitor its water pressure may cause pipe burst which could lead to loss of water and eventually revenue losses. There is a risk of the boreholes pumping water at a low pressure that might affect the daily water production as well.

### Conclusion

82% of the 60 borehole pressure gauges were faulty of which more than half were faulty for more than 3 years.

### Recommendation

NAWEC should put in place strategies to ensure pressure gauges are functional.

### Management response

<b>Management Response</b>	<i>Noted and NAWEC is currently in the process of doing just this. At the same time it must be mentioned that the water supply network in NAWEC is not operated at excessive pressures that leads to significant burst but we do recognize that pressure monitoring is important for the operations.</i>
<b>Action to be taken</b>	<i>Functional pressure gauges to be installed as and where required</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>When and as required.</i>

#### 4.3.4 Risk of Water Service Interruptions Due to Aged Infrastructure

*According to the PURA act of 2001; NAWEC shall make repair, change, extension or improvement to its service necessary for the efficient provision of the service.*

NAWEC has relied on repair rather than replacement of its aging water system over the years. We discovered through an interview with the company's management that some water infrastructures such as boreholes, pipes etc, have outlived their useful lives but are still in use.<sup>47</sup>

During our meeting with the Water Division Management, we were informed that the useful life of a borehole is 25 years. Analysis of a sample of 74 boreholes revealed that 37 (50%) of them outlived their useful lives, ranging from 29 (Sukuta) to 63 (Fajara) years old as shown in chart 9 below. We discovered that aging infrastructure is a serious issue affecting the company during inspections of water plants and boreholes, with many of its infrastructures severely corroded as shown in picture 6.

Even though NAWEC's water infrastructure has been in place since the 1970s, there has been no major replacement within the period under review except for about 81 kilometers of Asbestos pipes and ten (10) transmission pumps replaced under the Exim Bank project. In addition, we were informed during Interviews with customers in Bakau, Sanchaba, Gunjur and Banjulinding that sometimes they have particles in the water supplied from NAWEC as a result of corroded pipes especially in early morning hours.

**Picture 6: Corroded boreholes at Bansang water facility (top left) and Mansakonko (top right), some of the replaced asbestos pipes placed at Faraja water treatment plant and reservoir at Serekunda water treatment plant (bottom right)**

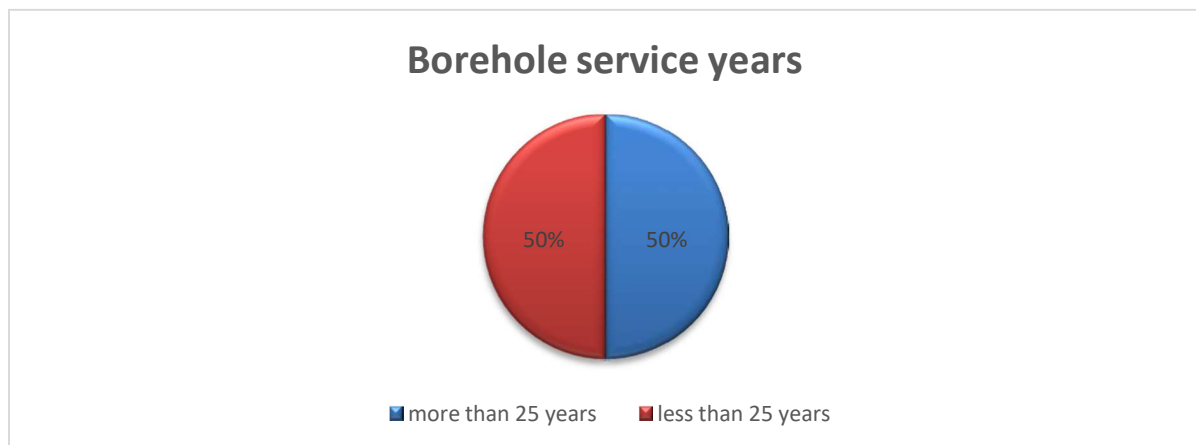
<sup>47</sup> Interview with the management of Water Division on 07/07/2021



Sources: Pictures taken from 22<sup>nd</sup> and 26<sup>th</sup> November 2021

This was due to the company's failure to establish strategies for replacing old infrastructures. Corroded aged infrastructures pose a high risk of failure, resulting in service interruptions and water quality with a bad taste, colour and contamination. **Appendix 8:** Showing 74 boreholes and their ages their ages.

Chart 9: Borehole service years of 74 boreholes.



Source: Auditors analysis from the data collected from site visits.

## Conclusion

Half of the existing NAWEC water infrastructures have outlived their useful life and require replacement. The total number of infrastructures replaced, as well as the rate at which they were replaced, is extremely low. The old infrastructure affects the quality of water supplied thus putting the lives of citizens at risk as the bulk of the water supplied are consumed internally by the population.

### Recommendation

NAWEC’s water infrastructure requires an upgrade, and the company should ensure infrastructure sustainability; thus, setting strategies to gradually replace all aging infrastructures in the system over a given period of years is recommended.

### Management response

<b>Management Response</b>	<i>As mentioned in our clarifications, assets will be replaced at the right time and not necessarily when it has reached its theoretical life. Assets will be replaced when the condition deems it necessary and or the asset is not serving its purpose – this could result in an asset being replaced/upgraded before it reaches its theoretical life or well after its theoretical life has been reached.</i>
<b>Action to be taken</b>	<i>Assets to be replaced as and when required</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>Assets to be replaced as and when required</i>

## 4.4 WATER QUALITY

### 4.4.1 Healthy Risk Due to High Iron Content in Water

*According to WHO Guideline for Drinking Water Quality 2017, acceptable level of iron in drinking water is a maximum of 0.3 mg/l.* <sup>48</sup>

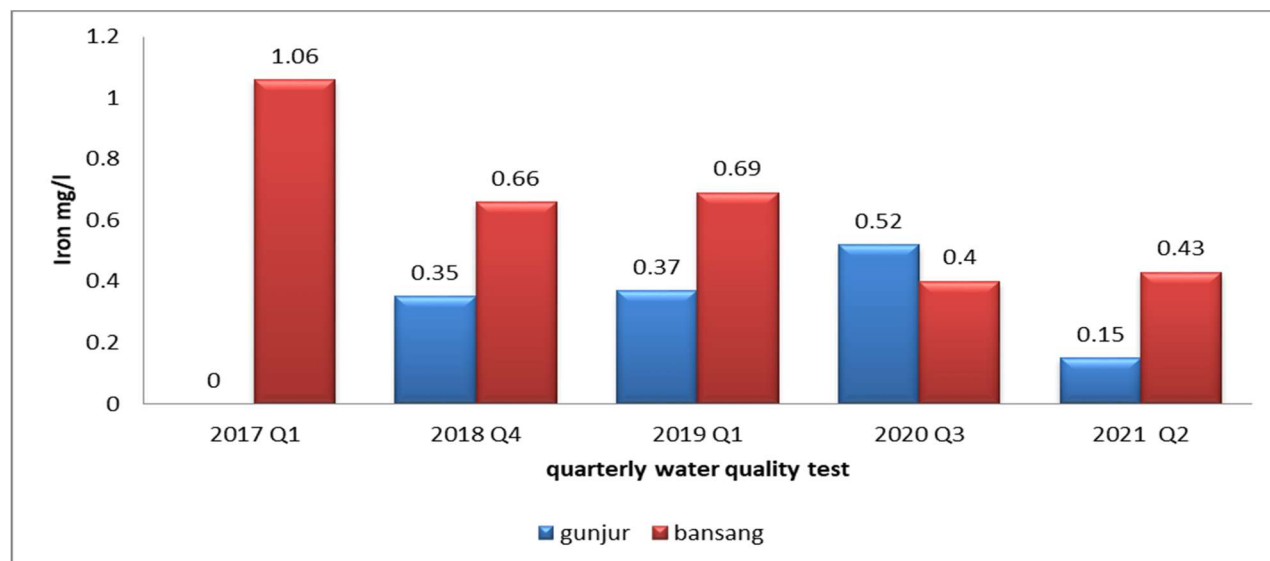
We found that apart from Bansang and Gunjur, all other locations were within the acceptable standard. Review of a sample of the Quarterly Water Quality Test Reports by DWR during the period under review showed that the iron content in water supplied by NAWEC in Bansang consistently exceeded 0.3mg/l.

The lands in Bansang and Gunjur contain high levels of iron, resulting in iron levels in their water that exceed the WHO acceptable level as shown in chart 10 below. NAWEC, on the other hand, has installed an iron filtration system in Bansang to address this issue. Additionally, in an attempt to reduce the high levels of iron in Gunjur’s water supply, NAWEC decommissioned one of the boreholes with high iron content in Gunjur,

<sup>48</sup> Principles and Practices of Drinking-water Chlorination. A guide to strengthening chlorination practices in small- to medium-sized water supplies (WHO).

but no iron filtration system was installed in Gunjur's Water Treatment Plant. However NAWEC said they plan on taking water from another source mainly Busuranding.

**Chart 10: Iron content in the water supplied to Bansang and Gunjur**



**Source: Quarterly Water Quality Report from 2017 to 2021, Department of Water Resources**

The review of a sample of Quarterly Water Quality Test Reports by DWR during the period under review revealed that, despite the iron filtration system in Bansang, the water in Bansang continued to contain high levels of iron above the WHO standard for drinking water quality. Meanwhile in Gunjur, the iron content has been higher than the acceptable level in 2018 to 2020. However, in 2021 both the first and second quarter Water Quality Test Reports by DWR showed that the iron content in the water sample tested from Gunjur were below the acceptable level.

According to the management of NAWEC's WD, the iron filtration system in Bansang was not functional since 2020 due to maintenance issues. NAWEC budgeted GMD6.3 million for iron removal treatment in Gunjur from 2017 to 2019, however, there was no filtration system in Gunjur. According to NAWEC, filtration system at Bansang is difficult to maintain and NAWEC is seeking alternative solution through the World Bank sponsored project underway.<sup>49</sup>

**Table 8: Budget for iron removal treatment**

Budget for iron removal treatment for Gunjur			Budget for iron removal treatment
2017	2018	2019	2020

<sup>49</sup> Interview with the management of Water Division 3<sup>rd</sup> February 2022.



Board Approved (D)	For Board Approval (D)	Board Approved (D)	Board Approved (D)
3,300,000	1,000,000	2,000,000	4,000,000

Source: NAWEC approved budget for 2017, 2019 and 2020 and for board approval 2018.

During the inspection of the Bansang Water Treatment Plant, the audit team collected a water sample from a tap inside the Treatment Plant as shown in Picture 7.

Picture 7: Water obtained from the tap in the Bansang water treatment plant



Sources: Picture taken 24th November 2021.

High iron content in water promotes bacterial growth in water production and distribution system, iron overload can cause hemochromatosis in humans which causes damage to the heart, liver and pancreas.<sup>50</sup> Additionally, high iron content causes stains to clothes during laundry.

## Conclusion

<sup>50</sup> <https://www.peninsulawater.com/is-iron-in-drinking-water-harmful->

The iron content in water supplied by NAWEC is mainly within the acceptable range. However, high iron content that supersedes the WHO acceptable standard of 0.3 mg/l has been detected consistently in water supply to Bansang and Gunjur during the period under review. The health and lives of the citizenry is put at risk as the water supplied by NAWEC in those regions contained iron levels that are not within the acceptable range

### Recommendation

NAWEC should put in place strategies to reduce the iron content in its water supply to the WHO acceptable level.

### Management response

<b>Management Response</b>	<p><i>There are 2 main facilities that are affected by elevated iron, that is Bansang and Gunjur. In May 2022 in a bid to ensure water with elevated iron is not supplied we have decommissioned the boreholes that served the Gunjur Water Treatment Plant and have re-directed a borehole from the Brikama wellfield free of elevated iron to now serve Gunjur.</i></p> <p><i>With respect to the Bansang water supply, the World bank project will look to improve the water quality at this facility. Until this project materializes NAWEC Water Business unit will be cleaning the tanks at least twice annually and flushing the lines at least once annually. This is the operational strategies that will be employed to ensure bio-films with iron gets dislodged from the system.</i></p>
<b>Action to be taken</b>	<i>Under the World Bank Project, the Bansang facility will be upgraded and while we await its implementation, we will ensure the system is flushed regularly.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>Once the physical works are implemented – feasibility study now underway</i>

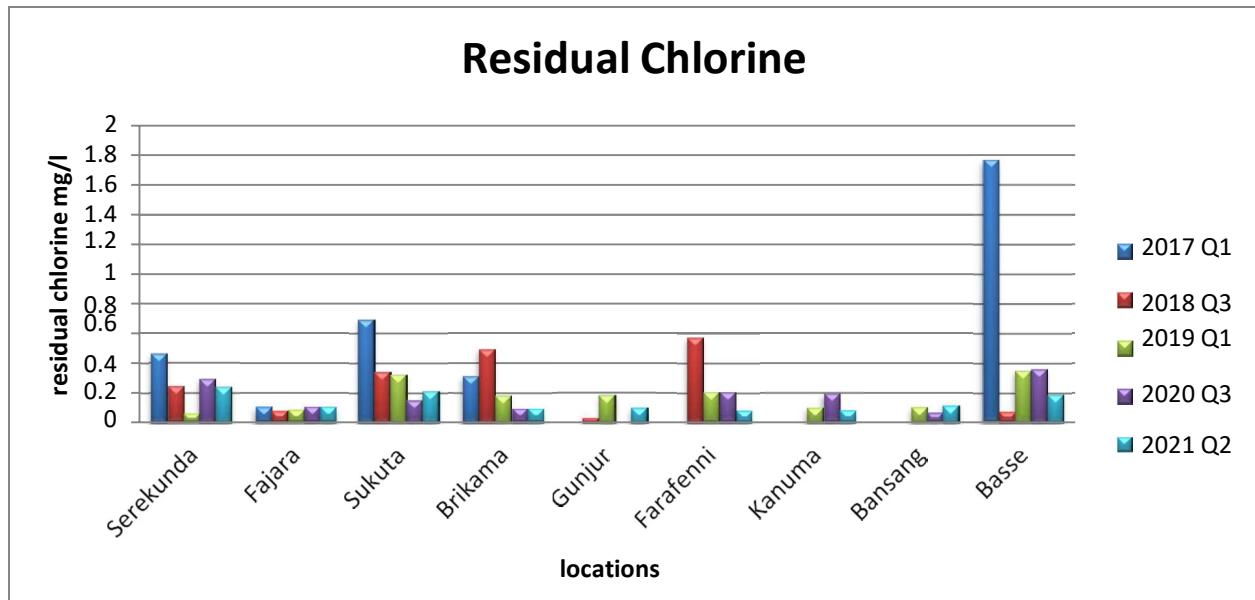
#### 4.4.2 Health Risk Due to Inappropriate Chlorination Methods

*According to the WHO Guideline for Drinking Water Quality 2017, residual chlorine concentration of 0.2 mg/l to 0.5mg/l should be maintained to the point of consumer*

delivery and chlorine levels in drinking water should not exceed 5 mg/l at the point of injection<sup>51</sup>.

Review of a sample of the Quarterly Water Quality Monitoring Reports prepared by the Department of Water Resources between 2017 to 2021 showed that an average of 76% of 100 locations tested did not meet the required minimum standard of residual chlorine in the water samples. Analysis of 5 samples of quarterly water quality tests presented is in the chart below.

Chart 11: Residual chlorine test result in 85 locations in 2017 and 100 locations from 2018 to 2021.



Source: PURA quarterly water quality test report 2017-2021

Further analysis of the quarterly water test results during the period under review showed that the water sample of an average of 16 locations had no residual chlorine.

During an interview with NAWEC's Chief Operations Officer, it was confirmed that not all the water produced by the company is treated. Some wells are pumped directly into the water supply system because they assume the underground water in The Gambia is of good quality. Secondly, during site visits, we discovered that inappropriate chlorination methods were used in some NAWEC facilities, such as the Brikama Kabafita standalone borehole, where we discovered that the facility does not conduct chlorination and instead relies on the chlorinated water supplied to the facility from the Brikama water treatment plant to 'mix with the raw water' and disinfect. In the same way, Kanuma and Basse water facilities had two boreholes each, but only one of them was connected to the chlorine injection point.

<sup>51</sup> Principles and Practices of Drinking-water Chlorination. A guide to strengthening chlorination practices in small- to medium-sized water supplies (WHO).

Furthermore, the treatment plants and water facilities did not have chlorine test kits to test the chlorine in the water before distribution. Therefore, NAWEC obtains no concrete knowledge of its chlorine level before water is distributed to consumers.

The absence or deficit of chlorine in water exposes it to a range of contaminants such as bacteria, mould and algae which could cause diarrhoea, cholera, and other waterborne diseases. According to the WHO, 3.4 million people, mostly children, die every year from water-related diseases<sup>52</sup>.

### Conclusion

NAWEC has not ensured that all the water it produces and distributes to its customers was properly chlorinated as chlorine deficits were consistently detected in the water supplied by NAWEC in most of the locations tested from 2017 to 2021.

### Recommendation

NAWEC should ensure that all the water it produces is chlorinated in accordance with the WHO Guideline for Minimum Water Quality Standard.

### Management response

<b>Management Response</b>	<i>Chlorination is required to treat bacterial contamination within the water supply. From PURA sampling results it is not shown where there is elevated bacteriological contamination at the source nor within the distribution network. Accordingly, NAWEC will ensure that the water supplied meets the required standard and not necessarily implementing chlorination at all the facilities.</i>  <i>We will however ensure there is residual chlorine at the extreme of the network at all times.</i>
<b>Action to be taken</b>	<i>Chlorination will be installed as required.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>As and when required</i>

### Auditor Comment

As a water utility company, NAWEC is responsible for ensuring the safety of the water it produces and distributes. Having the required level of residual chlorine in the water protects it from recontamination during storage and distribution. Preventive measures should be implemented regardless of whether PURA sampling results show that the water is contaminated with bacteria or not. Furthermore, because these tests are performed on a quarterly basis, NAWEC should not wait until there is bacteriological contamination at

<sup>52</sup> <https://waterandhealth.org/safe-drinking-water/wp/>

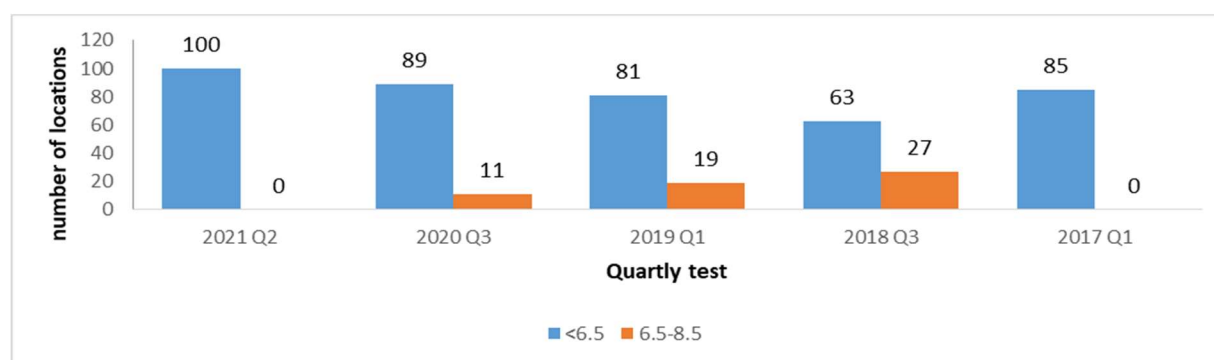
the source or within the distribution network to ensure that all water produced and distributed is chlorinated in accordance with WHO guidelines.

#### 4.4.3 Health risk due to Low pH Level in Water

*World Health Organization recommended pH level for water is 6.5 to 8.5.*

Review of Water Quality Reports by Department of Water Resources during the period under review showed significant number of locations that do not fall within the appropriate PH range. The analysis is presented in the chart below.

**Chart 12 : Number of locations with pH level below/above WHO guideline of 6.5 to 8.5. in 85 locations in 2017 and 100 locations were tested from 2018 to 2021**



**Source: PURA Quality Water Quarterly Report 2017 to 2021**

As shown in chart 12 above, more than half of the locations water supply have pH levels below the WHO standard. Aeration is carried out to regulate the pH level to an appropriate range. According to NAWEC’s Greater Banjul Area Water Supply System Operating and Maintenance Manual; in case the pH value after aeration is not yet sufficient, lime dosing is applied for further pH adjustment. Therefore, the main purpose of lime dosing is to raise the pH level of water and precipitate the ions (e.g calcium, magnesium, and iron) that cause hardness in water<sup>53</sup>.

We noted that aeration is carried out in 4 out of 6 WTPs, however, lime dosing is not practiced in any of these treatment plants. There are lime dosing systems installed in Serrekunda and Brikama Water Treatment Plants, but they were both not in use at the time of our visits. The table below shows the availability of aeration and lime dosing in the visited facilities.

Furthermore, during our visit, we noted that there was no aeration taking place at the Serekunda and Bansang Water Treatment Plants. We also found that none of the water production facilities in the provinces and other standalone boreholes within the GBA conduct aeration or lime dosing.

<sup>53</sup> WHO guides to drinking water quality.

**Table 9: List of the treatment plant and standalone boreholes which conduct aeration and lime dosing.**

Treatment plant	Aeration	Lime dosing
Sukuta	V	X
Serekunda	X	X
Brikama	V	X
Gunjur	V	X
Fajara	V	X
Bansang	X	X

**Source:** During our site visits from 22<sup>nd</sup> November 2021 to 17<sup>th</sup> March 2022.

**Note:** The **V** sign means its functioning. The **X** sign means not functioning.

Review of DWR Quarterly Water Quality Monitoring Report revealed that in the third Quarter of 2018, the Bansang water PH level was calculated at 6.57 and this was when aeration was already carried out. However, it was calculated at 5.89 during the second quarter of 2021 when no aeration was carried out during the period. The picture below shows the abandoned aerator at the Bansang Water Treatment Plant.

**Picture 8: Abandoned aerator at Bansang Water Treatment Pant**



**Source:** pictures taken 24 November 2021.

NAWEC officials informed us that they were not using lime dosing because the pH level of the water from their boreholes has a pH level within the WHO standard. This assertion was contradictory to the Water Quality Report by the Department of Water Resources as indicated in the chart above. According to Kelli Mcgrane, September 16, 2020, water contained heavy metals which can be dangerous, potentially leading to heavy metal poisoning and toxic symptoms which include diarrhea, nausea, vomiting and shortness of breath and organ damage. Children have been shown to have more side effects from heavy metal exposure, including an increased risk of developmental delays, behavioral disorders, certain forms of cancer and heart disease.

In addition to harming your body, acidic water corrodes pipes. Water with low pH can start to dissolve metal pipes over time, causing leakages and further increasing the presence of heavy metals in the drinking water supply<sup>54</sup>.

## Conclusion

NAWEC has not been able to effectively treat its water to the appropriate pH level during the period under review. Though aeration is available in many treatment plants, the system has failed on many occasions to regulate the pH level. Lime dosing, which is supposed to correct any deficiency in case aeration is not enough to regulate the pH, was not used by NAWEC. Therefore, water with inappropriate pH level has consistently been supplied to the consumers.

## Recommendation

NAWEC must ensure proper aeration takes place in all its water facilities to increase the pH of water produced before distribution.

## Management Response

<b>Management Response</b>	<i>NAWEC will ensure that the pH of the water supplied meets the required standard and not necessarily implementing aeration at all the facilities as the quality water dictates whether or not aeration is required.</i>
<b>Action to be taken</b>	<i>NAWEC will ensure that the pH of the water supplied meets the required standard and not necessarily implementing aeration at all the facilities as the quality water dictates whether or not aeration is required.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer - WSBU</i>
<b>Date when the situation will be regularized</b>	<i>As and when required</i>

### 4.4.4 Unhygienic Conditions of the Water Facilities pose health risk to customers and staff

*NAWEC has the mandate to supply potable drinking water to its customers, in doing that all their facilities should be well maintained and clean so that their customers can have water fit for human consumption<sup>55</sup>.*

During an inspection of NAWEC's water treatment plants, the infrastructures at the Brikama, Sukuta, Fajara, Gunjur, and Bansang aerators in use were found that algae were significantly present on the floor, pipes and the wall in the aerator; this is shown in Picture 9. However, there was no aeration carried out at the Serrekunda treatment plant

<sup>54</sup> Acidic Water: Risk, Benefits, and More By Kelly McGrane, MS, RD on September 16, 2020- Medically reviewed by Miho Hatanak, RDN,L.D.

<sup>55</sup> 2016 annual report of NAWEC.

Aeration is often the first major process at water treatment plants which brings water and air into close contact to reduce the hardness of the water before the next phase of treatment.

Furthermore, the aerators at Fajara and Bansang were not roofed and fenced as in other NAWEC treatment plants, and as such these aerators were exposed to people, animals, reptiles and birds. For instance, during the inspection at the Fajara Treatment Plant, we found a monitor lizard lying inside the aerator during treatment as shown in Picture 9.

According to the management of NAWEC's WD aerator in Bansang Water Treatment Plant has not been use since 2020 due to maintenance issues. However, the audit team was not provided with the maintenance log by NAWEC for review upon request to show evidence as maintenance work being carried out on the infrastructure

The unhygienic condition of the water facilities poses a high risk to the health of the consumers as the water is exposed to contaminants such as disease-causing microbes (bacteria). Exposed and unenclosed aerators attract birds, animals, reptiles, harmful objects, and bacteria; these can lead to water contamination and a high risk of supplying contaminated water to the population.

**Picture 9: Condition of the aerator at Brikama Water Treatment Plant (Top left and top Right) and aerator condition at Fajara Water Treatment Plant showing a reptile (Monitor Lizard) inside the aerator.**



Sources: Pictures taken from 11<sup>th</sup> November to 26<sup>th</sup> November 2021.

Furthermore, we found that the grasses surrounding the aerators at Gunjur, Brikama and Bansang almost covered the reservoirs where water is kept after treatment before distribution.



NAWEC does not regularly clear grasses within their facility to avoid reptiles making it a shelter. We were informed that cleaning of the infrastructures is done only when deemed necessary instead of on a routine basis. During an interview with the officials at the Brikama, Fajara and Mansakonko Water Treatment Plants, it was revealed to us that the staff have seen several snakes within the treatment plants, thus exposing the staff to snake bites, which could lead to death.

## Conclusion

NAWEC has not ensured the proper upkeep of its facilities in the water treatment plants. As there is neither routine cleaning of its aerators nor clearing of grasses surrounding the plants and this could pose a health risk to the water produced and consumed.

## Recommendation

NAWEC should ensure hygienic condition of its water facilities is maintained.

## Management Response

<b>Management Response</b>	<i>Noted and Concur – NAWEC is currently in the process of cleaning up its facilities however this will take some time to achieve an acceptable level of compliance.</i>
<b>Action to be taken</b>	<i>Facilities to be regularly monitored and where improvements are required this will be done.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>Improvements have already started, and will be a continuous process</i>

### 4.4.5 High Nitrate Levels in Water Pose Health Risk to the Customers

*The WHO guideline states that the nitrate level of water to be supplied to the population should not pass 10mg/l.<sup>56</sup>*

We found in all the Quarterly Water Quality Reports by DWR from 2018 to the first quarter of 2021 that high Nitrate above WHO Guideline for drinking water has continuously been tested from the water supplied to Bakau areas. We were informed by the Deputy Director of Department of Water Resources that NAWEC were advised by his department to decommission the contaminated borehole (BH5) at Latrikunda. We were informed by the Operator at Fajara Water Treatment Plant that this specific borehole has been decommissioned since 15 September 2018. However, nitrate levels above WHO Guidelines are still detected in NAWEC's water supply to Bakau areas even after this specific borehole was decommissioned (shown in table 10). All the other areas are within WHO acceptable water quality standards.

<sup>56</sup> WHO drinking water quality guidelines.

According to the Deputy Director of DWR, NAWEC did not consult them to conduct feasibility studies for the identified sites before borehole drilling. This was confirmed by the Chief Operations Officer of the Water Division at NAWEC.

**Table 10: Sample of High amount of Nitrate in the water supply to the Bakau areas by the Fajara Water Treatment Plant.**

Locations	Nitrate per nitrogen NO3-- N mg/l				
	2021 2 <sup>nd</sup> Q	2020 3 <sup>rd</sup> Q	2019 1 <sup>st</sup> Q	2018 3 <sup>rd</sup> Q	2017 2 <sup>nd</sup> Q
Fajara treatment plant tank	<b>12.0</b>	<b>13.0</b>	<b>13.0</b>	<b>14.4</b>	8.00
Tap inside the treatment plant complex	<b>12.1</b>	<b>14.0</b>	<b>14.2</b>	<b>16.8</b>	8.00
Bakau Mamakoto, near the big tree	7.0	<b>14.0</b>	<b>12.0</b>	<b>13.2</b>	8.50
Bakau old cape point/Banana bar	7.0	<b>14.0</b>	7.4	7.0	8.5

*Source: A random sampling of the quarterly water quality report by DWR from 2017 to 2021.  
Note: The figures in BOLD represent the levels of nitrate above the WHO acceptable standard 10m/g*

According to NAWEC, high nitrate levels are caused by encroachment of settlements to the boreholes. NAWEC’s management recommends that settlements should be at least 50m away from where NAWEC boreholes are stationed to avoid water contamination.

However, there was no regulation in place to ensure this is the case on the ground<sup>57</sup>. During site inspections we observed that 31% of NAWEC's boreholes were 10 meters or less away from settlements and a total of 92% were either encroached or at risk of being encroached soon, as shown in the picture below.

**Picture 10: NAWEC boreholes encroached by settlements (Top left PN6(Sinchu), Top right BH12 (Jola Kunda) and BH 18(Latrikunda) all link to the Serekunda WTP and down right is SS6 of Sukuta WTP.**

<sup>57</sup> Interview with the management of Water Division 7<sup>th</sup> July 2021



Latrikunda



Jola Kunda



Sinchu

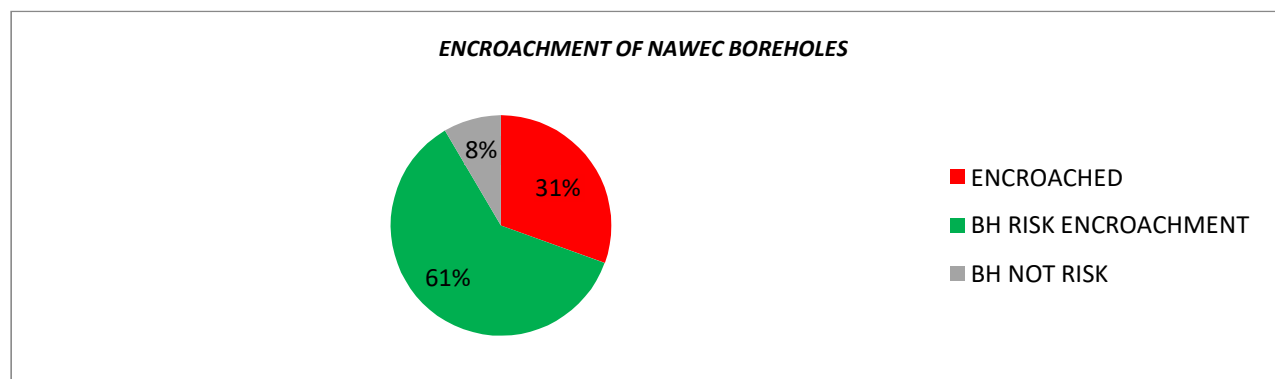


Jabang

Sources: Sites visits from 22<sup>nd</sup> November 2021 to March 2022

According to the Deputy Director of DWR, human activities such as the digging of toilets and soakaways deeper than two meters, and improper waste disposals by encroachers lead to borehole contamination by nitrate. However, Fajara Treatment Plant is getting some of its water supply from Sukuta Treatment Plant. Additionally, NAWEC does not have any nitrate treatment procedure in place to reduce the level of nitrates in its water. The chart below shows the percentage level of boreholes encroached.

Chart 13: Percentage of boreholes encroached, those that are on risk and those that are free from encroachment.



Source: Sources: Sites visits from 22<sup>nd</sup> November 2021 to March 2022

**Encroached:** We discovered that 31% of the NAWEC boreholes shared a fence with residents.

**Borehole Risk to Encroachment:** We also discovered 61% are at risk been encroached.

**Boreholes not at Risk to Encroachment:** We also discovered that 8% are not risk being encroached

During an interview with the Deputy Director of Department of Water Resources, it was revealed that consumption of nitrate in drinking water can be very dangerous to health,

especially for infants and pregnant women. Consuming too much nitrate can affect how blood carries oxygen and can cause methemoglobinemia (also known as a blue baby syndrome). Methemoglobinemia can cause the skin to turn to bluish colour and can result in serious illness or death. Bottle-fed babies under six months old are highest at risk of getting methemoglobinemia. Other symptoms connected to methemoglobinemia include decreased blood pressure, increased heart rate, headaches, stomach cramps, and vomiting<sup>58</sup>.

## Conclusion

NAWEC has been supplying contaminated water with a high amount of Nitrate above WHO Guidelines to Bakau and Fajara areas during the period under review.

## Recommendation

NAWEC should establish strategies to reduce the level of nitrate in its water supply to the WHO acceptable level. Instead of supplying drinking water from contaminated boreholes, NAWEC could sell the contaminated water to industries or companies that will use it for non- drinking purposes, such as construction, gardening etc.

## Management response

<b>Management Response</b>	<i>This is one aspect that NAWEC had discussed with NAO into possibilities and one area that NAWEC is currently assessing. Recently one measure taken is to have water with low nitrates mixed with the water containing elevated levels of nitrate. This has proved successful in limiting the concentration to levels below the WHO recommended guidelines.</i>
<b>Action to be taken</b>	<i>NAWEC will ensure that appropriate strategies are in place to mitigate water having elevated nitrate (above the WHO Guideline) does not get distributed to customers</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer</i>
<b>Date when the situation will be regularized</b>	<i>NAWEC to implement strategies as and when required.</i>

### 4.4.6 NAWEC Does Not Test the Quality of Water Produced and Distributed to Customers

*Water service providers shall furnish the regulator quarterly test reports and if a test failed the set standards, PURA shall be immediately informed of such abnormalities<sup>59</sup>.*

<sup>58</sup> <https://www.medicalnewstoday.com/articles/321955>

<sup>59</sup> PURA Minimum quality of service standard for water and sanitation 2008.

During the period under review NAWEC has not furnished PURA with any quarterly water quality report. NAWEC instead relied on the water quality test that is conducted by the Department of Water Resources on behalf of PURA for the past 10 years.

During the inspection at Serekunda, Brikama, and Sukuta treatment plants, we learned that offices were designed as laboratories, but these laboratories were no longer functional due to lack of equipment and qualified staff to operate them. NAWEC therefore did not monitor the water quality produced, due to the absence of equipped laboratories. Additionally, the company did not outsource it to any other organisation that can do it on its behalf.

During a meeting with PURA officials, it was revealed that it is difficult to regulate a monopolistic institution like NAWEC, which is responsible for providing water to more than half of the population. PURA is aware of the water shortage and quality concerns. Regarding the water scarcity issue, PURA advised NAWEC to increase investments and accelerate project implementation. In terms of water quality issues, some boreholes have been decommissioned, but the problem still exists.

Over the years, PURA has fined NAWEC for violations and has given them directives to help them solve their problems, but the problems still exist. They went on to say that PURA, as a Regulator, is torn between upholding standards and attempting to alleviate problems on the ground. Asking NAWEC to halt operations in Bansang, Gunjur, and Fajara due to poor water quality will only exacerbate the shortage problem, so PURA will let it slide if the water does not kill the people<sup>60</sup>.

Without a functional Laboratory to carry out water quality tests and/or outsourcing such services, there is a risk that NAWEC may supply the population with water that is not fit for consumption.

## **Conclusion**

NAWEC has not ensured effective monitoring of the water was done before supplying to consumers. Department of Water Resources did conduct regular testing of water supplied by NAWEC on behalf of PURA as part of its regulatory functions. However, this testing is not real time, and the quarterly report only conveys periodic quality report.

## **Recommendation**

NAWEC should setup laboratories and ensure that competent lab technicians carry out standard water quality tests on regularly basis to ensure safe drinking water is supplied to its customers.

## **Management Response**

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<sup>60</sup> Meeting with PURA 3<sup>rd</sup> August 2022.

<b>Management Response</b>	<p><i>NAWEC is aware that regular monitoring of water quality is important however the way in which this is done is left to NAWEC – that is NAWEC can decide to do it inhouse or have this activity outsourced. Outsourcing this activity does not require NAWEC to have its own lab.</i></p> <p><i>NAWEC has taken a step in the right direction to have this task carried out. It must be noted that at the start of 2022 DWR was engage re conducting sampling and analysis of NAWEC supply however to date we are yet to receive confirmation that this will be done – and hence to date we are unable to implement the budget set aside for this as DWR is yet to facilitate this.</i></p>
<b>Action to be taken</b>	<i>NAWEC will continue to engage DWR until we are in a position to set up our own lab.</i>
<b>Officer Responsible for remedial action</b>	<i>Chief Operating Officer – WSBU</i>
<b>Date when the situation will be regularized</b>	<i>When required</i>

## Appendix 1: Audit questions and assessment criteria.

Audit question and sub-questions	Audit Criteria
<b>QUESTION 1</b>	
Has NAWEC ensured that adequate quantity of water is produced (extracted) for distribution to its customers?	
a. What plans has NAWEC made to ensure an increase in the levels of water production?	According to PURA's Minimum Quality Service for Water and Sanitation 2008; each utility shall make all reasonable efforts to prevent interruptions of service and when such interruptions occur shall endeavour to re-establish service with the shortest possible delay consistent with the safety of its customers and the public. Where an emergency water service interruption affects fire protection service, the water provider shall immediately notify the fire chief or other responsible local official
b. Has NAWEC ensured timely implementation of water projects?	According to PURA Act: PART VII, 31. (c) Public utility to which this part applies shall make any repairs, changes, extension, or improvement to regulated public service necessary for the efficient provision of its service. Review of the annual activity reports of 2017 stated NAWEC targets a water loss of 15 % for both technical and commercial losses.
c. Does NAWEC have the manpower in place to be able to produce enough water for its customers?	According to PURA: minimum quality service standard for Water and Sanitation 2008, Page 12. A maximum of 12 years will be given to the providers to reach a level of 75-90% coverage (depending on alternative resources used by the population in the service area)
d) Has NAWEC ensured cost-effectiveness of its water production infrastructure?	According to the GPPA bill 2014 30(1) A procuring organization is responsible for the administration of procurement contracts into which it enters and shall establish procedures for contract administration and provide the necessary material and human resources for their implementation.
e. Has NAWEC conducted effective feasibility studies to ensure sustainability of water production	<i>According to PURA Act: PART VII, 31. (c) Public utility to which this part applies shall make any repairs, changes, extension, or improvement to regulated public service necessary for the efficient provision of the service. Review of the annual activity reports of 2017 stated NAWEC targets a water loss of 15 % for both technical and commercial losses.</i>
<b>QUESTION 2</b>	
Has NAWEC ensured that there is a reliable water distribution system for the water produced from its boreholes?	
a. Has NAWEC put in place measures to ensure reduction of water loss in the process of distribution?	<i>According to PURA Act: PART VII, 31. (c) Public utility to which this part applies shall make any repairs, changes, extension, or improvement to regulated public service necessary for the efficient provision of its service. Review of the annual activity reports of 2017 stated NAWEC targets a water loss of 15 % for both technical and commercial losses.</i>
b. Has NAWEC ensured cost-effectiveness of its water distribution infrastructure?	According to the GPPA Bill 2014 30(1) A procuring organization is responsible for the administration of procurement contracts into which it enters and shall establish procedures for contract

	administration and provide the necessary material and human resources for their implementation.
<b>QUESTION 3</b>	
Has NAWEC ensured that the quality of water distributed to its customers meet safe water quality standards? (Explained extensively)	
Has NAWEC ensured all its Water Treatment Plants are equipped to carry out water treatment before distribution?	Quality of service standards: set of rules and guidelines – both substantive and procedural – governing all stages: potablewater production, potable water distribution, sewage collection, and sewage disposal.
Has NAWEC ensured all its standalone boreholes conduct chlorination before distribution?	<i>WHO recommends that a minimum residual chlorine concentration of 0.2 mg/l and a maximum of 0.5mg/l should be maintained to the point of consumer delivery, chlorine levels in drinking water should not exceed 5 mg/l at the point of injection</i>
Has NAWEC ensured there is a functional laboratory to test the quality of water provided?	<i>Water service providers shall furnish the regulator quarterly test reports and if a test failed set standard, PURA shall be immediately informed of such abnormalities</i>
Has NAWEC ensured water contamination is mitigated?	<i>Sustainable Development Goal target 6.1 calls for universal and equitable access to safe and affordable drinking water. The target is tracked with the indicator of “safely managed drinking water services” – drinking water from an improved water source that is located on premises, available when needed, and free from faecal and priority chemical contamination</i>
Has NAWEC ensured proper and timely maintenance of its water equipment?	<i>According to PURA Act: PART VII, 31. (c), Public utility to which this part applies shall make any repairs, changes, extension or improvement to regulated public service necessary for the efficient provision of the service.</i>



## Appendix 2: Reviewed documents and purpose for reviews

Name of the Document reviewed	Purpose for review
<b>Policy documents</b>	
Operation and maintenance Manual, 2020	To know how, boreholes, treatment plants, and standalone are operated and maintained
Gambia National Water Policy ,2006	To understand water, use, and management in the Gambia.
Public Utility Regulatory Authority (PURA) Act, 2001.	To know the regulations put in place regarding water provision.
National Water Resources Council Act ,1979	To know the responsibilities of the water resource council.
National environment, Act 1994	To know the standards and guidelines for water
<b>Guidelines</b>	
World Health Organization (WHO) water quality guidelines	To understand WHO water quality standards.
Minimum quality of service standard for water and sanitation of 2012	To know the minimum quality of service standard put in place to guide the provision of water in the Gambia.
<b>Performance Report / strategies</b>	
NAWEC Organogram	To understand the organizational structure of NAWEC.
NAWEC Strategic Plan 2019 to 2025	To understand the company's objective and vision and mission statement
Annual Activity Reports of NAWEC 2017	To know the company's activities and financial performance throughout the period under review. To understand the achievements, challenges, proceedings policies during the period under review.
Sustainable Development Goal: (6)	To identify goals and objectives that can be used as a source of criteria Spelled out measures put in place by the Government to ensure availability and sustainability management of water and sanitation for all by 2030.
<b>Research and publication</b>	
Quarterly water quality report nationwide. First quarter of March 2021	To access current data on the quality of water produce by NAWEC and to know the parameters use in testing NAWEC water.
Research and Publications Newspapers	To know some of the public outcries in relation to the provision of water by NAWEC and researches done on water.
Feasibility study for a Water supply and sanitation in the Great Banjul Area project (WASIB), Final report 2020	To know the outcome of the feasibility studies conducted by NAWEC
NAWEC Master Plan Volume 7 – Legal / Institutional Study (Volume 7 of 8) December 2005	The know the legal and institutional framework of the water supply and sanitation sector of The Gambia

### Appendix 3: List of interviewed officials and customers.

#### A: Officials interview and Discussions

NO.	NAME	DESIGNATION
1.	Marlene Roberts Saidy	Chief Operations Officer NAWEC
2.	Alhagie Dibba	Director of Water Division
3.	Mbacke Jaiteh	Water Production Manager
4.	Ebrima Seckan	Water Distribution Manager
5.	Demba Chune	Senior Commercial Manager Water Business Unit
6.	Tijan Williams	Head of Internal Audit
7.	Musa Kora	Financial Controller WBU
8.	Foday Janneh	NAWEC Internal Audit
9.	Simon Gomez	Internal Audit Office
10.	Ndongo Sillah	Engineer NAWEC
11.	Yunusa Colley	Distribution Engineer
12.	Ngoneh Jallow	Group Customer Service Director
13.	Joseph B Mendy	Senior Revenue Protection Officer
14.	Habibou Bah	Senior Credit Officer
15.	Hassan Bah	Senior Regional Manager
16.	Matarr Manjang	Senior Regional Manager
17.	Alasan Jagne	Meter Reader Manager
18.	Maimuna G. Coke	Senior Regional Manager
19.	Mamat Sowe	Senior Data Verification Officer
20.	Foday Conteh	Deputy Director DWR
21.	Buba Sanyang	Operator (Serekunda)
22.	Alieu K. Njie	Senior superintendent (Sukuta)
23.	Idrissa Njie	Pump attendant (Kanuma)
24.	Modou Lamin Camara	Diesel Engine Operator (Mansakonko)
25.	Buba Marreh	Pump attendant (Mansakonko)
26.	Omar Gagigo	Pipefitter (Bansang)
27.	Ousman Sowe	Station Operator (Farafenni)
28.	Omar J Gray Johnson	Superintendent (Fajara)
29.	Ousman Nyassi	Station officer (Fajara)
30.	Ebun K. Bayo	Operator (Gunjur)
31.	Ebrima Sanyang	Senior operator (Brikama)
32.	Tombong Jawara	Electrician (Brikama)
33.	Abdou Bah	Electrician (Brikama)
34.	Tijan Ceesay	Station Operator (Basse)
35.	Saikou Jarra	Pipefitter (Basse)
36.	Dawda Jallow	Borehole Operator (Basse)
37.	Momodou Lamin Sompo Ceesay	Director of Petroleum, water and Electricity (PURA)
38.	Solo Sima	Director of Consumer Affairs (PURA)
39.	Burama Jammeh	Director of Economic Regulation (PURA)

## B: Customers

No.	Location	Number of customers interviewed
1.	Abuko	3
2.	Bakau (Police station)	2
3.	Bakau Mama Koto	1
4.	Bakau primary school	1
5.	Bakau Sanchaba	1
6.	Bakoteh (Borehole)	3
7.	Bakoteh Tippa Garage	3
8.	Banjul (EFSTH)	3
9.	Banjul GPS	1
10.	Banjul GSSS	3
11.	Banjulinding Libya	2
12.	Bansang	1
13.	Bansang General Hospital	4
14.	Barra	3
15.	Basse (Alunhari)	2
16.	Basse (Mansajang Kunda)	2
17.	Basse Kaba Kama	2
18.	Brufut	4
19.	Bundung (Borehole)	2
20.	Bundung Primary school	1
21.	busumbala	1
22.	Dipa Kunda	1
23.	Essau General Hospital	5
24.	Fajara Barrack	3
25.	Fajikunda (Church)	1
26.	Farafanni (Mauritani)	2
27.	Farafenni Ecobank	1
28.	Farafenni General Hospital	5
29.	Farato	1
30.	Farato Church Junction	1
31.	Farato Mingdaw	1
32.	Gunjur	1
33.	Jabang	1
34.	Jambangjelly	1
35.	Jarra Karantaba	3
36.	Jarra Pakalinding	1
37.	Jarra Soma	2
38.	Kanifing Estate	1
39.	Kanifing South	1
40.	Kololi (Tavan)	1
41.	Kololi Central police station	1
42.	Kotu Fire Service	4
43.	Lamin Sanchaba	1
44.	Lamin Temasu	1
45.	Latrikunda German	2
46.	Latrikunda Sabiji	2
47.	Latrikunda yirri nyanya	1
48.	London corner	1
49.	Manjai	2
50.	Pipeline	3

51.	Sanchaba (Touba)	2
52.	sanyang	1
53.	Serekunda hospital	3
54.	Serekunda police station	2
55.	Sinchu Alagie	1
56.	Sukuta Health Centre	1
57.	Talinding Fana Fana Garage	1
58.	Talinding Kunjang	2
59.	Talinding Supersonic Junction	1
60.	Tanji	2
61.	Tujereng	2
62.	University of The Gambia	1
63.	Wellingara Central	1
64.	Yundum Gambia Civil Aviation	1

## Appendix 4: Visited sites

### A: Treatment plants and water facilities

1. Brikama Water Treatment Plant
2. Fajara Water Treatment Plant
3. Sukuta Water Treatment Plant
4. Bansang Water Treatment Plant
5. Gunjur Water Treatment Plant
6. Serekunda Water Treatment Plant
7. Basse water facility
8. Kanuma water facility
9. Mansakonko water facility
10. Farafenni water facility

### B: Boreholes connected to water treatment plants and water facilities

Brikama boreholes	Serekunda boreholes	Sukuta boreholes	Gunjur borehole	Fajara	Kanuma	Mansa konko	Farafenni borehole	Basse borehole	Bansang borehole
E1	B8	A2	Borehole 1	1A	Borehole 1	Borehole 1	Borehole 1	Borehole 1	Borehole 1
E2	B10	A3		1B					
E3	B11	A4		B5					
E5	B12	B1		B6					
E6	B17	B3		B14					
E7	B18	Jah oil		B16					
E9	PN2	SS2							
E12	PN3	SS3							

E13	PN4	SS6							
E14	PN5	SS7							
E15	PN6	SP1							
N1 A		SP2							
N2		SP3							
N3		SP4							
N4		SP5							
N5		SP6							
N6									

### C: Standalone boreholes

1. Brikama kabafita standalone borehole
2. Brusubi tank standalone borehole
3. Brufut ward tank standalone borehole
4. Brufut village standalone borehole

### Appendix 5: Availability of water to selected location

Locations	Conditions	Remark
1. Abuko	Mild	Supply comes late at night until hours of morning low pressure.
2. Bakau Mama Koto	Severe	Poor water quality Sometimes we go for 2months without water.
3. Bakau Police Station	Severe	Three years of water outages. Poor water quality and they could go days without drip of water. Low pressure
4. Bakau primary school	Good	The supply is good.
5. Bakau Sanchaba	Mild	Mostly late at night till early morning with low pressure. Sometimes 24hrs without water.
6. Bakoteh Borehole	Good	The supply is indeed good
7. Bakoteh Tippa Garage	Good	Our water supply is very good, its 24 hours supply.
8. Banjul EFSH	Severe	7years now the hospital is facing frequent water outages. Sometimes they will pay fire service to supply them water
9. Banjul GPS	Severe	Lack of drinking water to prisoners and officers. Poor sanitation Facing outages 10 years now

10. Banjul GSSS	Severe	7years now the hospital is facing frequent water outages. The science could not be use. Poor sanitation
11. Banjulinding Libya	Severe	Sometimes they stayed for 3days without water supply. Sometimes we have water late at night
12. Bansang General Hospital	Mild	Supply comes late at night until hours of morning low pressure.
13. Bansang Residents	Good	We do not normally face water shortage here, but the water quality is very poor.
14. Barra	Severe	Sometimes five days without drop of water. Sometimes very late at night with low pressure
15. Basse Alouhare	Severe	They could go for 2 weeks without water supply. Low pressure as well.
16. Basse Kaba Kama	Good	The water supply is very good and palatable to drink.
17. Basse Mansajang	Severe	Sometimes 3 days without water. Some parts of Basse Mansajang do not have water almost a year now.
18. Brufut	Mild	No 24 hours water supply
19. Bundung borehole	Severe	Sometimes 3 days without water.
20. Bundung Primary school	Severe	A complete 3 days without drop of water. Low pressure
21. Busumbala	Good	The supply is good.
22. Dipa Kunda	Severe	This house goes more than 4days without water supply. Sometimes night with low pressure as well
23. Essau General Hospital	Severe	Sometimes 5days without drip of water from NAWEC.
24. Fajara Barrack	Severe	Poor water quality sometimes we go for 2months without water.
25. Fajikunda (St Charles Iwanga church)	Severe	The rev Father confirmed to us that the church is without water for the past 2years.
26. Farafenni Ecobank	Mild	Supply comes late at night until hours of morning low pressure.
27. Farafenni General Hospital	Good	They do not face water shortage because the hospital is also using it private borehole.
28. Farafenni Mauritania	Good	The water supply here is very good the only problem we face is burst pipes and these could sometimes contaminate our waters.
29. Farato	Mild	Supply comes late at night until hours of morning low pressure.
30. Farato Church Junction	Severe	We are without water sometimes 1 week. We rely on private borehole owners.
31. Farato Mingdaw	Mild	Supply comes late at night until hours of morning low pressure.
32. Gunjur	Good	They supply is very good, I used to have it 24hrs
33. Jabang	Mild	Water supply comes at night
34. Jambangjelly	Good	The supply is good

35. Jarra Karantaba	Severe	Sometimes 5 days without water supply. We rely on borehole owners.
36. Jarra Pakalinding	Mild	Supply comes late at night until hours of morning low pressure.
37. Jarra Soma	Mild	Supply comes late at night until hours of morning low pressure.
38. Kanifing Estate	Mild	Supply comes late at night until hours of morning low pressure.
39. Kanifing South	Mild	Supply comes late at night until hours of morning low pressure.
40. Kololi Central police station	Severe	Lack of drinking water to prisoners and officers. Poor sanitation Facing outages 3 years now
41. Kololi Tavan	Severe	Experiencing water shortages They could go up to weeks without drip of water
42. Kotu Fire Service	Mild	Supply comes late at night until hours of morning low pressure.
43. Lamin Sanchaba	Mild	Supply comes late at night until hours of morning with low pressure
44. Lamin Temasu	Mild	The supply is low
45. Latrikunda German	Mild	Supply comes late at night until hours of morning low pressure.
46. Latrikunda Sabiji	Severe	We could sometimes face lack of water for more than 3 days.
47. Latrikunda yirri nyanya	Severe	One (1) year without water supply.
48. London corner	Mild	Supply comes late at night until hours of morning with low pressure
49. Manjai	Severe	They are without water supply since April 2021.
50. Pipeline	Severe	It's been 6months without a drop of water. They still bill by NAWEC
51. Sanchaba Touba	Severe	Lack of drinking water to prisoners and officers. Poor sanitation Facing outages 10 years now
52. Sanyang	Good	The water supply is good
53. Serekunda hospital	Severe	Weeks without water from NAWEC
54. Serekunda police station	Mild	Water supply only at night
55. Sinchu Alagie	Mild	Mostly late at night till early morning with low pressure, Sometimes 8 hrs without water.
56. Sukuta health Centre	Good	The water supply is good
57. Talinding Fana Fana Garage	severe	Sometimes 3 days without water.
58. Talinding Kunjang	Severe	Poor water quality sometimes we go for 2months without water.

59. Talinding Supersonic Junction	Good	The water supply is good we do not face outages.
60. Tanji	Good	The water supply is good
61. Tujereng	Good	The water supply is good
62. University of The Gambia	Mild	Supply comes late at night until hours of morning low pressure.
63. Wellingara Central	Severe	This place is without drip of water since 2016 to date.
64. Yundum Gambia Civil Aviation	Severe	More than 2 years without water from NAWEC. We are even digging our own borehole.

**Key:**

**Severe:** Absence of pipe borne water supply for more than three days.

**Mild:** Water supply is available part of the day/night but not up 24hrs.

**Good:** There is 24hrs regular water supply



**Appendix 6: Response time of NAWEC to pipe bursts at selected areas per Customer interview.**

Location	Timely Response	Untimely Response
1. Abuko		✓
2. Bakau (Police station)		✓
3. Bakau Mama Koto		✓
4. Bakau primary school	✓	
5. Bakau Sanchaba	✓	
6. Bakoteh (Borehole)		✓
7. Bakoteh Tippa Garage	✓	
8. Banjul (EFSTH)	✓	
9. Banjul GPS	✓	
10. Banjul GSSS	✓	
11. Banjulinding Libya		✓
12. Bansang		✓
13. Bansang General Hospital		✓
14. Barra		✓
15. Basse (Alunhari)		✓
16. Basse (Mansajang Kunda)		✓
17. Basse Kaba Kama	✓	
18. busumbala	✓	
19. Bundung (Borehole)		✓
20. Bundung Primary school	✓	
21. Brufut		✓
22. Dipa Kunda		✓
23. Essau General Hospital	✓	
24. Fajara Barrack	✓	
25. Fajikunda (Church)		✓
26. Farafanni (Mauritani)		✓
27. Farafenni Ecobank		✓
28. Farafenni General Hospital	✓	
29. Farato		✓
30. Farato Church Junction		✓
31. Farato Mingdaw	✓	
32. Gunjur		✓
33. Jabang		✓
34. Jambangjelly		✓
35. Jarra Karantaba		✓
36. Jarra Pakalinding		✓
37. Jarra Soma		✓

38. Kanifing Estate		✓
39. Kanifing South		✓
40. Kololi (Tavan)		✓
41. Kololi Central police station		✓
42. Kotu Fire Service	✓	
43. Lamin Sanchaba		✓
44. London corner		✓
45. Lamin Temasu		✓
46. Latrikunda German		✓
47. Latrikunda Sabiji		✓
48. Latrikunda yirri nyanya		✓
49. Manjai		✓
50. Pipeline		✓
51. Sanchaba (Touba)		✓
52. Sinchu Alagie		✓
53. Serekunda hospital		✓
54. sanyang		✓
55. Sukuta Health Centre	✓	
56. Talinding Fana Fana Garage		✓
57. Talinding Kunjang		✓
58. Talinding Supersonic Junction		✓
59. Tanji		✓
60. Tujereng		✓
61. University of The Gambia	✓	
62. Wellingara Central		✓
63. Yundum Gambia Civil Aviation	✓	
64. Serekunda police station		✓

## Appendix 7 : List of boreholes that are not connected to standby generators

No.	Treatment Plant	No Boreholes	Connected to Standby Generator	Remarks
1	Serekunda Water Treatment Plant	11	5	Only five Boreholes are linked to the treatment plant.
2	Sukuta treatment Plant	31	29	Only BH 16 and B14 are not linked to the Generator
3	Fajara Water Treatment Plant	6	2	Only BH 6 and BH16 are linked to the generator due to its capacity.
4	Gunjur Water Treatment Plant	1	1	The borehole is linked to the standby generator.
5	Brikama Water Treatment Plant	17	0	The generator at the treatment plant is faulty since March 2020.
6	Kanuma	2	2	Both boreholes are connected to a standby generator.
7	Mansakonko	2	2	Both boreholes are connected to a standby generator
8	Farafenni	2	2	The Generator is working perfectly and both BH1 and BH2 are linked.
9	Bansang	1	1	The Generator is working perfectly and linked to the borehole.
10	Basse	2	0	The Generator is faulty since November 2021.

## Appendix 8: Showing 74 boreholes and their ages

Treatment plant	Number of boreholes connected	Years commissioned	Age as of 2021
Brikama	17	2009	12
Sukuta	12	1992	29
	2	2002	19
	5	2012	9
	10	2020	1
	2	2021	0
Serekunda	6	1992	29
	5	1979	43
Farafenni	2	1992	29
Mansakonko	2	1990/1991	30/31
Gunjur	1	2014	7
Bansang	1	1990/1991	30/31
Kanuma	2	1992	29
Basse	2	1991/1992	29/30
Fajara	1	1958	63
	2	1966	56
	2	1977	45

## Glossary

**Non-Revenue Water (NRW):** Water that has been produced and is lost before it reaches the customer. Losses can be real losses or apparent losses. High levels of NRW are detrimental to the financial viability of water utilities, as well as to the quality of water itself. NRW is typically measured as the volume of water lost as a share of net water produced. However, it is sometimes also expressed as the volume of water lost per km of water distribution network per day.

**Elevated Water Tank:** Is a water storage tank in which water is stored at atmospheric pressure and distributed by gravity flow in a down feed system; the tank is usually elevated above the roof of a building and is filled by a booster pump.

**Low-Level Tank/Reservoir:** Is a tank primarily served as a buffer/storage against fluctuation in demand.

**Aeration:** Is the process of raising the pH value by removing carbon dioxide from increasing the concentration of oxygen in the water or maintaining the oxygen saturation of water in both natural and artificial environments. Aeration techniques are commonly used in pond, lake, and reservoir.

**Lime Dosing:** Is used to adjust the pH further in water or a system which is designed for low flow rates and comprises of a mixing tank with a geared mixer. Here the lime is mixed with makeup water. The makeup water is added to the tank via solenoid valve and water meter with a contacting head.

**Chlorination:** This is a very popular method of water disinfection that has been used in different water treatment plants for many years. It has shown to be effective for killing bacteria and viruses in the water during its process.

**pH (power of hydrogen):** Is a measure of hydrogen ion concentration, a measure of the acidity or alkalinity of a solution. The pH scale usually ranges from 0 to 14. Aqueous solutions at 25°C with a pH less than 7 are acidic, while those with a pH greater than 7 are basic or alkaline.

**Nitrates:** Occurs naturally in drinking water. However, if there are high levels of nitrates in the water, it is probably caused by human activities such as the overuse of chemical fertilizers and improper disposal of human and animal wastes. These fertilizers and wastes contain nitrogen compounds that are converted to nitrates in the soil.

**Iron:** Is a mineral in which high quantities in water can harm skin cells, leading to infection and wrinkles. Moreover, such water does not rinse off the soap residue from the body. Water with a high quantity of iron flowing through the pipes leads to buildup, causing the pipes to clog. This can, in turn, clog up the sinks and toilets and result in low water pressure in your home. Too much iron in water also causes the accumulation of reddish-brown slime in your pipes.

**Ikonos:** A commercial earth observation satellite, and was the first to collect publicly available high-resolution imagery at 1- and 4-meter resolution.

**Electromagnetic Flowmeter:** Simply known as mag flow meter is a **volumetric flow meter** which is ideally used for wastewater applications and other applications that experience low pressure drop and with appropriate liquid conductivity required. The device doesn't have any moving parts and cannot work with hydrocarbons and distilled water.

**Methemoglobinemia:** A condition of elevated methemoglobin in the blood. Symptoms may include headache, dizziness, and shortness of breath, nausea, poor muscle coordination, and blue-colored skin.