MINISTRY OF HEALTH, LABOR AND WELFARE

PROJECT TO PROVIDE PLANNING GUIDANCE FOR
THE WATER SUPPLY PROJECT (PHASE-1)

PROJECT FOR WATER SUPPLY SYSTEM RECONSTRUCTION ASSISTANCE IN THE KINGDOM OF TONGA

FINAL REPORT

MARCH 2023

NJS CO., LTD.

PROJECT TO PROVIDE PLANNING GUIDANCE FOR THE WATER SUPPLY PROJECT (PHASE-1)

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FINAL REPORT

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EXECUTIVE SUMMARY

1. Background of the Project

The Kingdom of Tonga (hereinafter is called as" Tonga") is located in the South Pacific about 3,600 km northeast of Sydney, Australia and about 2,000 km north of Auckland, New Zealand. The country is an island country consisting of more than 172 large and small islands scattered across a vast sea area spreading about 1,000 km north to south and 500 km east to west. The country consists of 4 main islands of "Tongatapu", "Ha'apai", "Vava'u" and "Niuas" and their group islands, with a total land area of 747 km^2.

The national census (Tonga Census of Population and Housing 2021) mentions that the population of Tonga is 100,179 as of 2021, of which about 74 % or 74,320 people inhabit in Nukualofa, the capital of the country.

On January 15, 2022, a giant submarine volcano eruption occurred at Hunga Tonga-Hunga Ha'apai (HTHH) island, and the subsequent tsunami caused damage to the infrastructure and lifelines of Tonga. This event has highlighted the country's vulnerability to natural disasters. Disruption of the communication networks such as telephones and internet due to the disconnection of submarine cables, the closure of the international airport runway caused by the volcanic ash fall and the houses damaged by the tsunami, affected almost 84 percent of the total population.

Damages on the water supply facilities are; 1) volcanic ash accumulated in the rainwater storage tanks for drinking use and most of the Tongan people made it difficult to secure drinking water, and 2) the breakage of the water supply and distribution pipes due to the tsunami and also made it difficult to secure the domestic water. Ash falls from the volcanic eruption caused a damage to power supply such as adhesion to power lines triggered a flashover in the transformers, which resulted in damage to well submersible pump motors and electrical control panels. Furthermore, due to the severe damage to the communication network system, the Tonga Water Board (TWB), which operates the water supply in the major cities of Tonga consumed plenty of time to ascertain the detailed damage status of the water supply facilities on the remote islands.

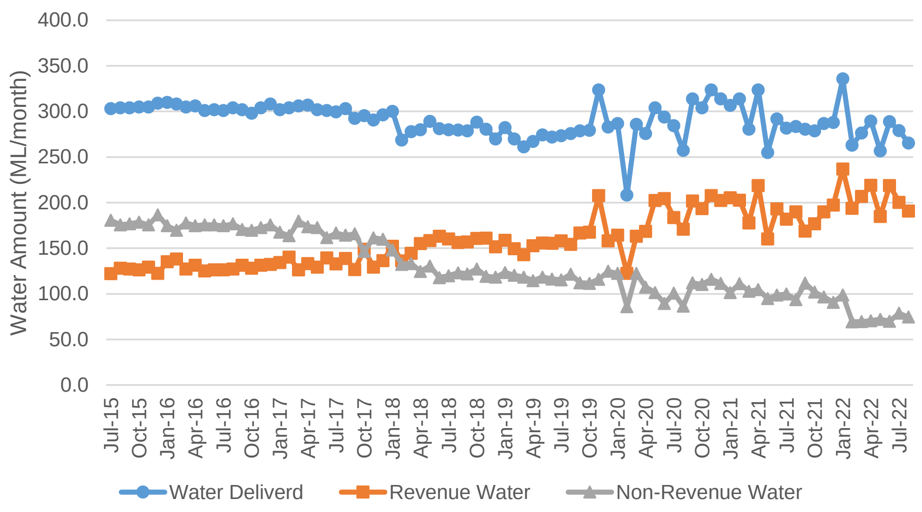
Based on the above background, the proposed project intends to carry out a survey the situation of the damage to water supply facilities caused by the submarine volcanic eruptions and tsunamis on the four (4) major islands of Tonga, and identify potential issues facing the country's water supply system especially on the vulnerability to the risks such as climate change and natural disasters. The survey team conducted a field survey for this purpose, and provided a guidance on a Water Supply Reconstruction Assistance Plan for the target areas of the four major islands described above.

2. Current Situation on Water Supply in the Project Area

Tongatapu Island, where Nuku'alofa, the capital of Tonga, is home to 74,320 people or about 74 % of the country's total population (Tonga Census of Population and Housing 2021). The population of the island is a major customer as a largest income source for TWB which accounts for about 78 % of the TWB's total customers in the country. Out of the total 13,565 households on Tongatapu Island (Tonga Census of Population and Housing 2021), TWB has water connections to 9,841 households (approximately 73% of that of the island) as of 2021, of which 7,819 households (approximately 58 %) connects to the TWB's water service. On the other hand, outside the water supply area of TWB, the water supply is operated by the Village Water Supply Committee (VWC) under the jurisdiction of the Ministry of Health (MOH).

Figure S-1 and Table S-1 show the TWB's water supply performance on Tongatapu Island. In the last seven (7) years, the amount of produced and revenue water has been increasing, the amount of water distributed has been maintained almost as flat, and the amount of non-revenue water (NRW) has been decreasing. In particular, the NRW rate is greatly decreasing by almost 27% from 58 % in FY2015 /16 to 31 % in FY2021/22 due to the construction of a water distribution network including the development of DMAs (District Metered Areas) and the introduction of smart meters that was supported by ADB and Australia. The TWB's performance in FY 2021/2022 were 13,665m^3/day for the water production, 9,341m^3/day for the water supply and 6,479m^3/day for revenue water on the basis of the daily amount, and about 31 % for NRW rate.

In the future, an increase of water consumption due to additional water supply for the new residents is expected from the government's plan to develop a new residential area on the outskirts of Nuku'alofa and to build a new village to accommodate the relocation of villagers affected by the tsunami in January 2022.



Source: Survey team based on data provided by TWB

Figure S-1 TWB's Performance on Water Supply Service on Tongatapu Island (monthly water volume, 2015/16 to 2021/22)

Table S-1 TWB's Performance on Water Supply Service on Tongatapu Island (average daily water volume, 2015/16 to 2021/22)

Fiscal Year	Water production (m^3/day)	Water delivered (m^3/day)	Revenue water (m^3/day)	Non-revenue water (m^3/day)	Non-revenue water rate
FY15/16	10,796	10,033	4,218	5,814	58%
FY16/17	10,772	9,970	4,328	5,642	57%
FY17/18	11,371	9,519	4,720	4,799	50%
FY18/19	12,326	9,051	5,102	3,949	44%
FY19/20	12,536	9,227	5,582	3,645	40%
FY20/21	14,427	9,777	6,350	3,427	35%
FY21/22	13,665	9,341	6,479	2,863	31%

Source: Survey team based on data provided by TWB

The water supply service in Nuku'alofa City was commenced by TWB from 1966. However, the water pressure was not sufficient and the water distribution facilities have deteriorated since then. After that, the pipes were replaced with those of larger diameter under the 2001 Japanese Grant Aid " The Project for Improvement of the Nuku'alofa Water Supply ", which has improved the water supply situation in the capital city of Nuku'alofa and realized a stable supply of the tap water. Approximately 41 km (φ50 to 500 mm in diameter) of water distribution pipes were constructed from the Mataki’eua Reservoir to the city center by the project. In addition, in December 2019, 16 new wells were drilled, 13 wells were repaired, a 3,000m^3 reservoir was constructed, and a 9.5 km transmission pipe was laid. Major facilities of the water supply have been almost completed.

Figure S-2 shows the locations of water supply facilities owned by TWB on Tongatapu Island. The current water supply system on Tongatapu Island consists of drawing of the water from the well field in Mataki’eua and pumping it to reservoirs (8 tanks totaling approximately 7,800m^3). After disinfection with chlorine, the water is distributed by gravity flow from the reservoirs to the city of Nukualofa and its surrounding areas.

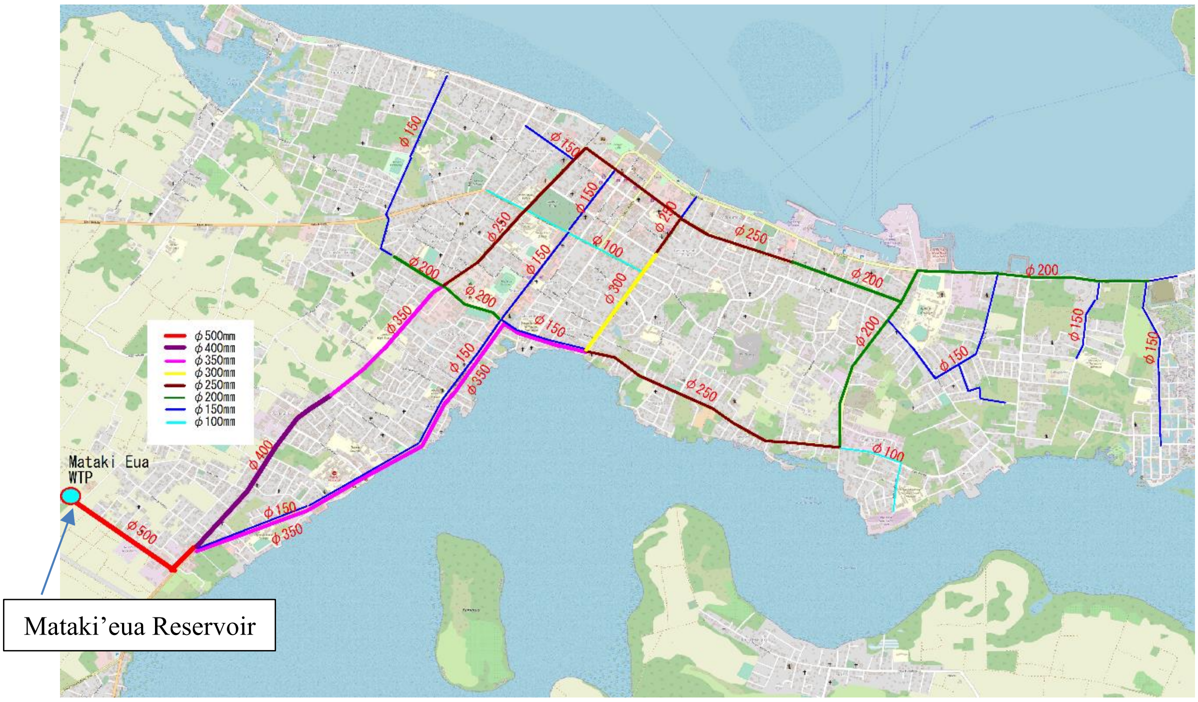


Figure S-2 Location of Existing TWB’s Water Supply System on Tongatapu Island

3. <u>Current Issues on Water Supply</u>

(1) National level

The following exhibits the current issues facing the water supply sector in the Kingdom of Tonga;

- Different plans for water supply development have been formulated. However, the plans have not been implemented, and the master plan for the water sector has not been revised since 1992.
- Management and financial risks such as a decrease in net income due to an increase in depreciation expenses associated with facility and equipment investment, an mandatory obligation to pay dividends

to the government of Tonga, and financial pressure from the government's request for reducing water charges makes TWB difficult to invest in facilities and equipment for the water supply development.

- A decrease in precipitation potentially caused by the recent climate change, sea water level rise due to global warming and the effects of tsunami is increasing the risk of sea water intrusion into the water source (freshwater lenses).
- Groundwater as a main water source containing a large amount of hardness constituent originating from the limestone geology and bad taste is traditionally unfavored by the people.
- TWB operators' insufficient capacity of operation and maintenance for the water supply facilities does not properly perform the water volume, quality, chemical dosing control, and equipment management.
- Sufficient budget is not allocated to the rehabilitation of water supply facilities and equipment, which increases their malfunctions and water leakage due to aging.
- Water supply service in village areas outside of TWB's service areas have problems in terms of finance and O&M capacity, which is also vulnerable to natural disasters.
- Response measures such as emergency water supply and emergency restoration activities against potential disasters are not taken sufficiently.

(2) Project Area

The current situation and the issues on the water supply service in the target area are 1) the vulnerability of the water supply system to large-scale natural disasters and 2) the vulnerability of the water supply service in the rural areas. For 1), the proposed project will enable to respond to the increase in water demand in the city center during a disaster through developing multiple water sources and laying a connection pipeline to existing reservoirs. In addition, the proposed a bypass pipeline to the existing pipe network will secure an emergency route to enable water supply even when the main distribution route is disrupted. In this way, the water supply system will be strengthened against natural disasters. As for 2), the distribution pipe network will be expanded to the surrounding villages of the new water source to be integrated into TWB's safe and stable water supply service will be planned.

4. <u>Outline of the Project</u>

(1) Goal of the Project

Considering the development policy and programm of Tonga and the recovery and reconstruction plan from the damage caused by the submarine volcanic eruption and tsunami that occurred in January 2022, the proposed project comprising development of multiple water sources through developing new well fields on Tongatapu Island, laying connection pipes to existing reservoirs and bypass connection pipes from existing reservoirs will improve the resilience of the water supply system and contribute to the stability of water supply in Tonga where is exposed to the threat of natural disasters and climate change.

(2) Outline of the Project

In order to achieve above goals, the proposed project will implement the development of new water sources, construction of necessary water supply facilities, and the soft component.

Table S-2 summarizes the outline of the proposed project.

Table S-2 Outline of the Project

Component	Contents of the Project
Basic Survey	Water source development survey
	Installation of groundwater observation wells
Facility Construction	Production wells: 7 locations (including 1 magnetic flow meter per well)
	Solar power generation system: 100 kVA ,1 set
	Emergency power generation system: 100 kVA, 1 set
	Reservoir: 1,000m^3
	Raw water transmission pipe: 5km
	Transmission pipe: 25 km
	Distribution pipe: 15km
	Bypass connection pipe: 5.5km
	Electromagnetic flow meter: 8 locations
Soft Component	Technical guidance on water source management
	Technical guidance on operation and maintenance of water supply facilities

Source: Prepared by the survey team

Development of New Water Sources

This component is to develop new water sources for the purpose of reducing the risk of sea water intrusion to the existing groundwater sources and resilience of the water supply system to overcome the intensification of natural disasters potentially caused by medium- to long-term global climate change.

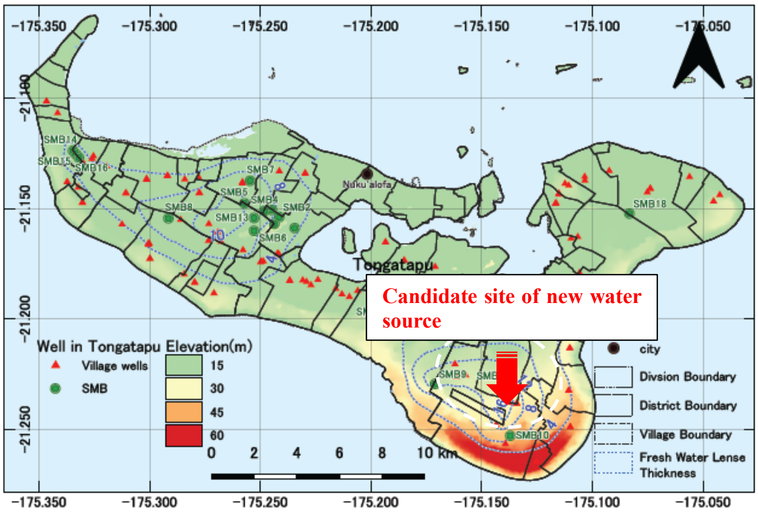


Figure S-3 Location of Candidate Site of New Water Source

Development of Water Supply Facilities

Figure S-4 shows the general overview on the proposed development of water supply facilities. A new water source will be developed in the Fua'amotu area in the southeastern part of Tongatapu Island, and a new reservoir at higher elevation is planned in the vicinity of Fua'amotu Airport, from where a connection pipeline to the existing Mataki'eua reservoir as a backup water supply in an emergency will be developed. Gravity flow can be applied from the new reservoir of G.L. 60 to 70 m to the existing Mataki'eua reservoir of G.L. 20 to 30 m. In addition, the water supply area will be expanded to the villages near the new reservoir, and the supplied water will be distributed by gravity flow. The target areas to be expanded by the proposed project are Fua'amotu, Nakolo and Ha'asini village at present, although the final decision will be made through further detailed survey.

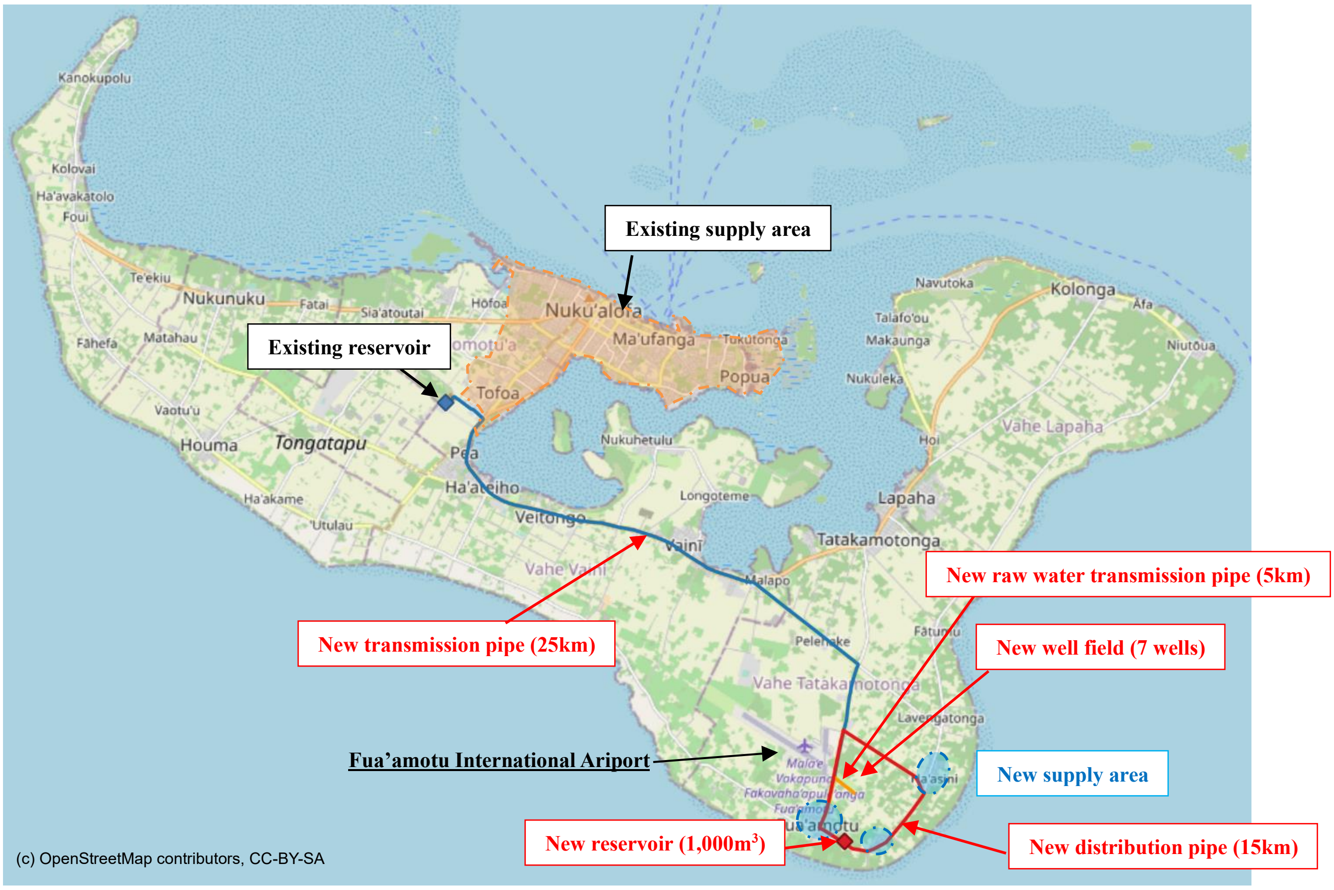


Figure S-4 Proposed Improvement Plan of the Water Supply Facilities

Development of Emergency Bypass Connection Pipe

A φ500 mm water distribution main from the existing Mataki'eua reservoir is currently partly a single pipeline. Securing a water distribution route in an emergency by attaining dual pipeline route through developing the bypass connection pipe as shown in Figure S-5 will improve the redundancy of the water supply system. The bypass connection pipe of φ300-500mm diameter totally with 5.5 km extension is planned. Improvement of the water pressure to the existing supply areas is also expected by using this bypass pipe even at normal operation.

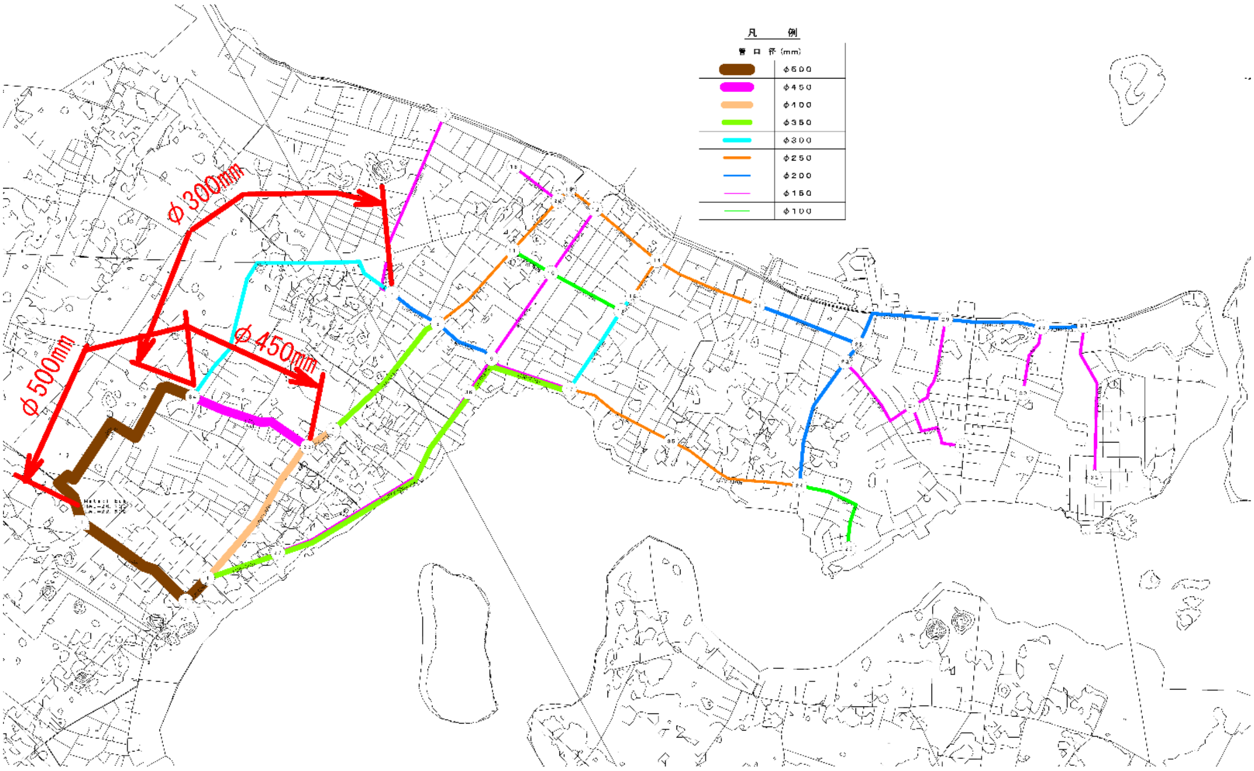


Figure S-5 Proposed Improvement Plan by Bypass Connection Pipe

<u>Implementation of Soft Component</u>

The main component of the proposed project will implement the facility development with the aim of strengthening the water supply system against natural disasters. However, TWB does not have sufficient knowledge and experience regarding operation and maintenance for new facilities. Technical guidance on operation and maintenance of the proposed facilities and support to their smooth operation and emergency response measures need to be carried out.

Table S-3 summarizes the proposed soft component.

Table S-3 Proposed Soft Components

Subject	Purpose
Technical guidance on operation and maintenance of water supply facilities	Capacity building toward efficient operation of the water supply system utilizing the facilities and equipment to be developed by the project and on emergency response measures
Technical guidance on water source management	Capacity building on operation and maintenance of water source for sustainable use of new and existing water sources

Source: Prepared by the survey team

5. <u>Conclusion</u>

Tonga has vulnerabilities to the external environment such as natural disasters and sea level rise due to climate change. The vulnerability was exposed this time by the event of the HTHH submarine volcano eruption combined with the tsunami triggered, and overcoming this problem is an essential issue for the social and economic development of the country. In particular, considering Tongatapu island is the political and economic center of Tonga together as well as placing of national capital city in Nuku'alofa, maintaining

of the functionality of the lifeline including water supply is a crucial issue. Among these, water supply is directly linked to the life support of people in an event of disasters, and is an indispensable element for ensuring hygiene, implementing necessary medical treatment, and social activities in the recovery stage.
The proposed project aims to "strengthen the water supply system for Tongatapu Island" by 1) developing multiple water supply source through new water source development, 2) developing an emergency bypass connection pipeline, and 3) providing technical guidance for operation and maintenance of water supply facility and water source management. The goal is to overcome the vulnerability of the Tongatapu water supply system to the external environment and improve the stability of the water supply over the medium to long term.
Supporting the stable water supply, which is one of the most important lifelines in an event of disasters, through the implementation of this project will bring safety and security to the lives of the people of Tonga and contribute to strengthening the foundation for economic development. Considering the past relationship between Japan and Tonga as well as the country's aid policy, the implementation of the project is considered to have great significance.

BASIC INDICATORS

Table-1 Key Economic Indicators of Tonga

	2020	1990
Population	10.64 thousand	10 thousand
GNI per Capita	4,300 US$	1,160 US$
Economic Growth Rate	0.7%	-2.00%.
External Debt Balance	194 million US$	54 million US$
DAC Category	Upper Middle Income Countries	Lower Middle Income Countries
World Bank Category	iii/Upper Middle Income Countries	IBRD Loan (Redemption Period 17 years) Eligible Country

Source: Ministry of Foreign Affairs Country Databook 2021, 2005.

Table-2 Millennium Development Indicators of Tonga

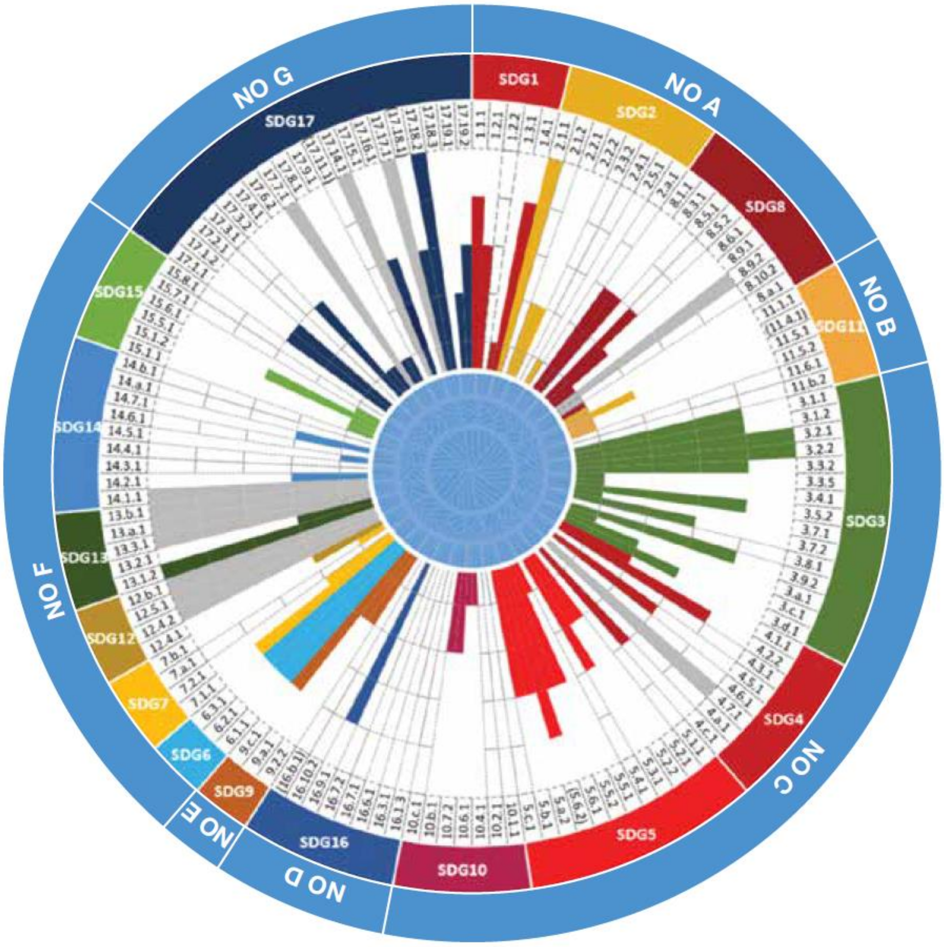
Millennium Development Indicators	Latest	Past
Goal 1: Proportion of population below $1.25 (PPP) per day: 5.9 % (2008)	—	—
Goal 2：Net enrolment ratio in primary education	84.6% (2013)	92.3% (1990)
Goal 3：Ratios of girls to boys in primary, secondary and tertiary education (Boy: 1.0)	1.00 (2013)	0.99 (1990)
Goal 4：Under-five mortality rate (per 1000 live births)	12.1 (2013)	22.8 (1990)
Goal 5：Maternal mortality rate (per 100 000 live births)	120 (2013)	71 (1990)
Goal 6：HIV prevalence among population aged 15-24 years	—	—
Goal 7：Proportion of population using an improved drinking water source (%)	99.6% (2015)	98.6% (1990)

Source: Japan's ODA Data by Country, 2016, Ministry of Foreign Affairs, Japan

Table-3 Infant, Under-five, Maternal Mortality and Life expectancy

	1990	2000	2010	2015	2019
Infant mortality per 1,000 live births	10	17	13	14	14
Under-five mortality per 1,000 live birth	22	18	16	17	17
Maternal mortality per 100,000 live birth	-	-	36 (2010)	124 (2015)	52 (2017)
Life expectancy at birth (years)	-	70	72	73	71

Source: The State of the World's Children, 2002, 2012 and 2016, UNICEF

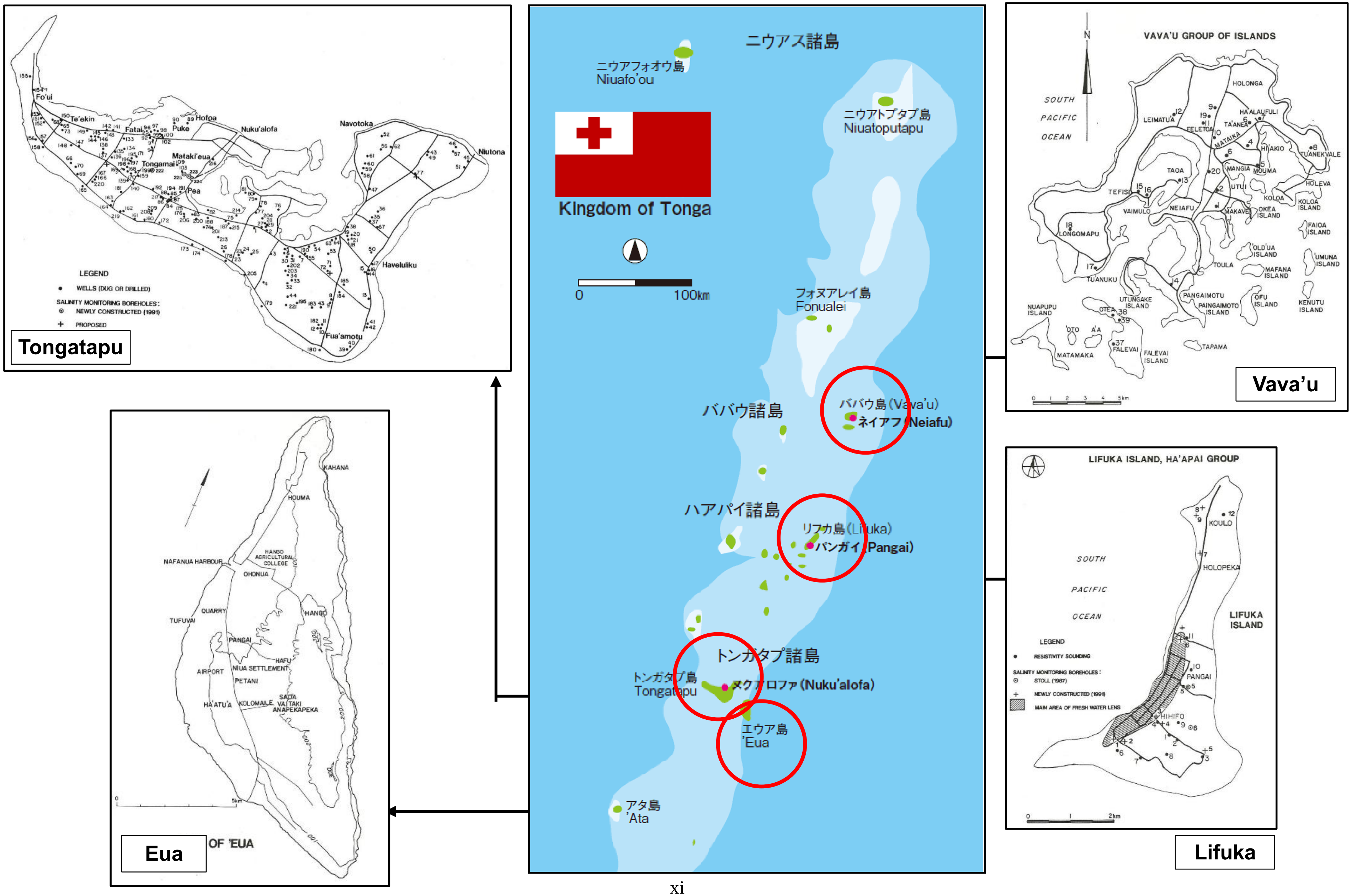


	BAR TYPE	VALUE
	Grey Bar	Tier 3 indicator. No established methodology
	Dashed Bar	None, or insufficient country data
	No colour bar	No achievement against the goal
	20% of colour bar shaded	Minimal achievement
	40% of colour bar shaded	Some achievement
	60% of colour bar shaded	Average Progress
	80% of colour bar shaded	Good Progress
	Full colour bar	Goal is fully achieved

Source: Voluntary National Review 2019, Kingdom of Tonga.

Figure-1 Progress on Sustainable Development Goals (SDGs) in Tonga

LOCATION MAP



PHOTOS

Photo-1: Fern Valley spring source, Eua Island.
The water source on Eua Island consists of spring water and groundwater (wells). The electrical conductivity is low, but during the rainy season it can become highly turbid, exceeding 200 NTU, and its treatment is a challenge.

Photo-2: Matavai WTP, Eua Island.
1,000 m^3 /day scale water treatment plant (WTP) with ordinary sedimentation + filtration system. The water is pumped up from Matavai Cave, which has the largest possible intake, and is energy inefficient.

Photo-3: Failed membrane filtration system, Eua Island.
Membrane filtration systems were installed in 2008 with New Zealand assistance to treat high turbidity during the rainy season, but have failed and malfunctioned due to significant membrane blockages.

Photo-4: Broken filtration units, Eua Island.
The membrane filtration system failed and a filtration unit was installed in 2013, but is not currently operational. The installation height is lower than clear water reservoir and water cannot be stored in it.

Photo-5: Clear Water Reservoir, Eua Island.
During the dry season, groundwater is pumped supplementary to the clear water reservoir (capacity 563 m^3) due to the reduced volume of surface water.

Photo-6: Matavai production well, Eua Island.
The water is pumped to the clear water reservoir during the dry season. The electrical conductivity of 664 µS/cm indicates no problem for the water quality (August 2022).

Photo-7: Remaining asbestos pipes, Eua Island.
Approximately 1 km of asbestos pipes remain and need to be renewed.

Photo-8: Pressure reducing tank, Eua Island.
The water supply area on the Eua island has two pressure reducing tanks due to the difference in altitude of approximately 120 meters.

Photo-9: Water distribution pipes damaged by the tsunami, Eua Island.
Water distribution pipes damaged by the tsunami that followed the submarine volcanic eruption. It already has been restored.

Photo-10: Relocation sites for suffered residents in Ha'apai Islands, Eua Island.
Relocation sites prepared for the inhabitants of the Ha'apai Islands affected by the submarine volcanic eruption and the tsunami triggered.

Photo-11: Pumping facility of infiltration gallery (1), Lifuka Island.
Diesel-driven pump (No. 116) located at the corner of a U-shaped infiltration gallery with an extension of approximately 100 m and a depth of 30 m in the Pangai area. The electrical conductivity was as high as 5,200 μS/cm (August 2022), significantly exceeding the WHO's threshold limit.

Photo-12: Pumping facility of infiltration gallery (2), Lifuka Island.
Pumping pump (No. 115) driven by solar power located at the corner of a infiltration gallery in the Hihifo area. Electrical conductivity was 1,380 μS/cm (August 2022), which is below the WHO's threshold limit.

Photo-13: Pumping facility of infiltration gallery (3), Lifuka island.
Pump opposite No. 115 (No. 114). The infiltration gallery is approximately 100 m long, 25 m deep, U-shaped and the ground surface is cleared. Wild pigs hang out around the site.

Photo-14: Production well, Lifuka Island.
Production well (No. 118) in the Hihifo area. Electrical conductivity is 1,590 µS/cm (August 2022), exceeding the WHO' threshold limit. Pumping rate 3 l/sec.

Photo-15: Potential relocation site of water source (Lifuka Island).
Potential relocation site of existing water source located next to the hospital in the northern part of Lifuka island. It is expected to have a thicker freshwater lens than the current water source location.

Photo-16: TWB Ha'apai branch office, Lifuka Island.
Reservoirs, elevated tanks and other facilities are located on the premises of the branch office, as well as a customer tariff payment counter.

Photo-17: Reservoirs, Lifuka Island.
The reservoirs consist of five polyethylene tanks (45 m^3 / tank), four of which are currently in operation.

Photo-18: Elevated tank, Lifuka Island.
After pumping into an elevated tank, the water is distributed to the city by gravity. The electrical conductivity of the distribution water was 2,800 µS/cm (August 2022), exceeding the WHO's threshold limit.

Photo-19: Chlorination with hypochlorite tablets (Lifuka Island).
On Lifuka Island, hypochlorite tablets (imported from New Zealand) are contained in plastic bottles and placed in the reservoirs by manual for disinfection of raw water.

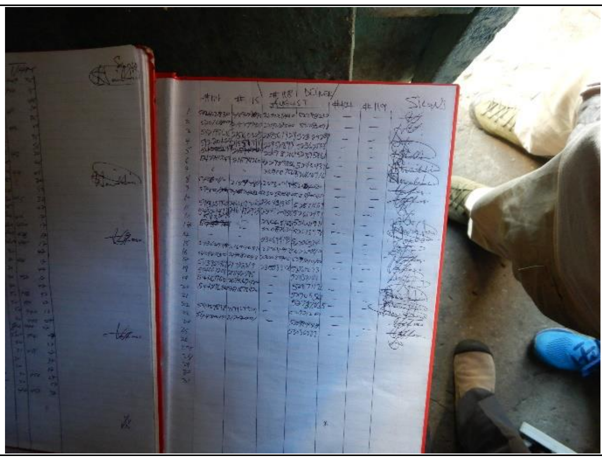


Photo-20: Daily report of TWB Ha'apai branch office, Lifuka Island.
On the remote island branches of the TWB, not only on Lifuka Island, the inflow and outflow of water is managed daily by reading the flow meter and by hand-writing in a notebook.

Photo-21: Rainwater harvesting facility at accommodation, Ha'apai Islands.
Rainwater harvesting facility at the accommodation on Foa Island, adjacent to Lifuka Island. There is no water supply, and people rely on rainwater for domestic use, including drinking water.

Photo-22: New well (1) in workshop, Vava'u Island.
A new production well (No. 119) constructed in 2020 on the TWB workshop site. Pumping rate: 3.5 l/sec, depth 35 m, electrical conductivity of 2,167 μS/cm (August 2022), exceeding WHO's threshold limits.

Photo-23: New well (2) in workshop, Vava'u Island.
A new production well (No. 120) constructed in 2020 on the TWB workshop site. Pumping rate of 3.4 l/sec, a depth of 35 m and an electrical conductivity of 1,385 μS/cm (August 2022), slightly lower than the WHO's threshold limit.

Photo-24: Workshop, Vava'u Island.
Equipment inside a TWB workshop.

Photo-25: Existing reservoir, Vava'u Island
RC on ground reservoirs on Vava'u Island (three ponds totaling 1,400 m^3). The electrical conductivity of 1,620 µS/cm (August 2022), higher than the WHO's threshold limit, and a residual chlorine of 0.1 mg/l.

Photo-26: Leimatua village intake pump, Vava'u Island.
Solar-powered intake pumps for village water supply in Leimatua. Installed with grant assistance for grassroots human security by Japan. The electrical conductivity of 874 µS/cm (August 2022).

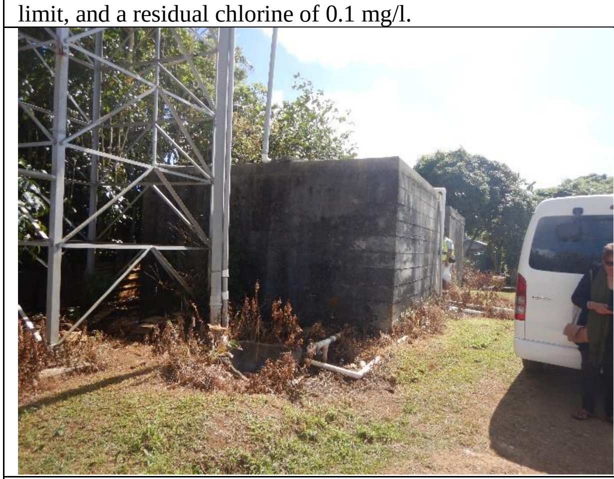


Photo-27: Existing reservoir for Leimatua village water supply, Vava'u Island.
Existing reservoir for village water supply in Leimatua. On-site measurements showed a good electrical conductivity of 665 µS/cm and a residual chlorine concentration of 0.2 mg/l.

Photo-28: Production well in Prison area, Vava'u Island.
Wells installed within the Prison area near the proposed new water source. Water quality test results show that the electrical conductivity is good at 874 µS/cm and there is no evidence of sea water intrusion.

Photo-29: Potential new water source site, Vava'u Island
Potential site for new water source near Prison area. Currently the site is vacant area with no buildings, etc.

Photo - 30: Geological strata composed of limestone, Vava'u Island.
The geological strata of Vava'u Island is composed of limestone of coral origin.

Photo-31: Existing well field, Tongatapu Island.
Existing well field in Mataki'eua, Nuku'alofa, the capital city. The entire TWB water supply on Tongatapu Island rely on the well field and its average daily production is approximetely1.44 million m^3 /day.

Photo-32: Existing reservoir, Tongatapu Island.
TWB's existing reservoirs located in Mataki'eua, Nuku'alofa, the capital city. A total of eight (8) reservoirs, large and small, is operating with a total capacity of approximately 7,800 m^3.

Photo-33: Water testing laboratory, Tongatapu Island.
The sole TWB laboratory at the reservoir site. Test samples are airlifted in once a month from each remote island. Only parameters of fecal coliform, electrical conductivity and residual chlorine can be measured.

Photo-34: Well drilling machine, Tongatapu Island.
Well drillers owned by TWB. As well as drilling its own wells for its own water supply, it also receives requests from MLNR to drill wells. The machine is capable of drilling to a depth of 50 m.

Photo-35: Broken seawater desalination unit, Tongatapu Island.
RO equipment provided by Australia in 2009, capable of producing 18 m^3 /day of water. The equipment is currently out of service due to a breakdown, but before the breakdown it was transported to a remote island during the cyclone..

Photo-36: Village water supply facility in Peah Village, Tongatapu Island.
A village locating near the current TWB water supply area is planned to be served by the TWB water service to be incorporated into its water supply area.

Photo-37: Smart meter near TWB headquarters, Tongatapu Island.
TWB fully replaced mechanical meters with smart meters on Tongatapu Island from October 2019 to March 2020. The good practice has been highly praised within the TWB as a significant increase of the revenue water.

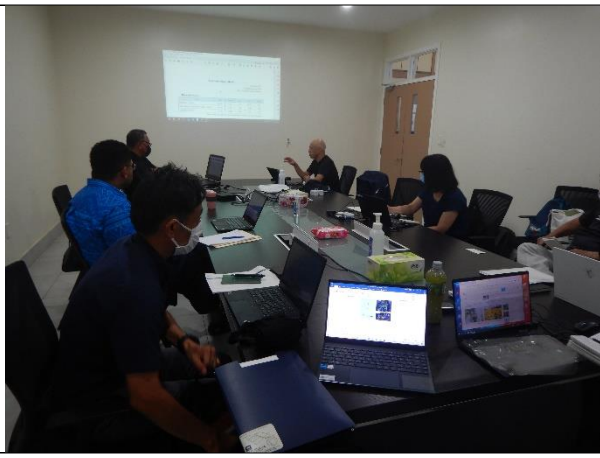


Photo-38: Discussions at TWB HQ on the filed survey results
After returning to Tongatapu Island from the field survey on the remote islands, discussions were held on the issues and proposed measures in each remote island based on the results of the field survey.

Photo-39: Consultations with the MLNR
The Ministry of Land and Natural Resources (MLNR) was requested to share and exchange views on the content and results of the field survey and to provide the data of the groundwater, observation wells and related data.

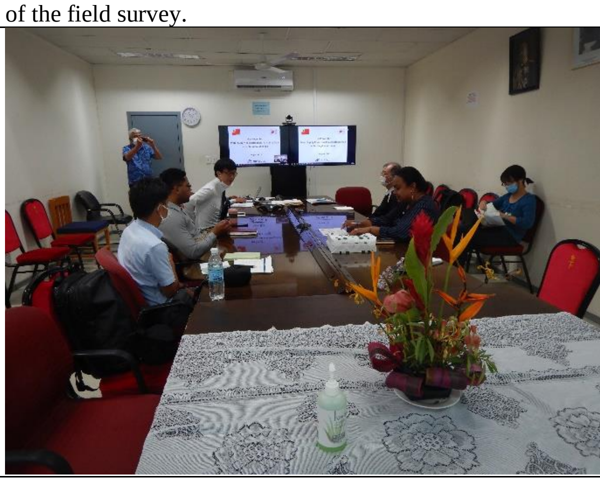


Photo-40: Consultation with the MEIDECC.
The contents and result of the field survey was shared with the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Communication and Climate Change (MEIDECC) and exchange views on those.

Photo-41: Consultations with the MOH.
The field surveys contents and results were shared with the Ministry of Health (MOH) and exchange opinions on water supply in rural areas.

Photo-42: Wrap-up meeting with TWB
In the presence of the CEO of TWB, a report on the results of the field survey, issues and recommended support were discussed before returning to Japan.

ABBREVIATIONS

AC	Asbestos Cement Pipe
ADB	Asian Development Bank
AS	Australian Standard
ASTM	American Society for Testing and Materials
AusAID	Australian Agency for International Development
AWWA	American Water Works Association
BCP	Business Continuity Plan
CEO	Chief Executive Officer
Covid-19.	Coronavirus Disease 2019
DMA	District Metered Area
DTH	Down The Hole Hammer
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EM	Electromagnetic
ENSO	El Niño Southern Oscillation
EU	European Union
EWSUP	Eua Water Supply Upgrade Project
FRP	Fibre Reinforced Plastics
FS	Feasibility Study
HTHH	Hunga Tonga-Hunga Ha'apai
IPCC	Intergovernmental Panel on Climate Change.
ISO	International Organization for Standardization
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
JOCV	Japan Overseas Cooperation Volunteers
KPI	Key Performance Indicator
MCA	Multi Criteria Assessment
MDGs	Millennium Development Goals
MEIDECC	Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications
MLNR	Ministry of Lands and Natural Resources
MOF	Ministry of Finance
MOH	Ministry of Health
MOI	Ministry of Infrastructure
MPE	Ministry of Public Enterprises
NEMO	Tonga National Emergency Management Office
NGO	Non-Government Organization

NPAT	Net Profit After Tax
NRW	Non-Revenue Water
NTU	Nephelometric Turbidity Unit
NZAID	New Zealand International Aid and Development Agency
NZS	New Zealand Standard
ODA	Official Development Assistance
PALM	Pacific Islands Leaders Meeting
PEC	Pacific Environment Community
PIF	Pacific Islands Forum
PRIF	Pacific Region Infrastructure Facility
PVC	Poly Vinyl Chloride
RWH	Rainwater Harvesting
SDGs	Sustainable Development Goals
SOPAC	South Pacific Applied Geoscience Commission
SPCZ	South Pacific Convergence Zone
SPREP	South Pacific Regional Environment Programme
TCC	Tonga Communications Corporation
TDS	Total Dissolved Solids
TEPB	Tonga Electric Power Board
TERM	Tonga Energy Road Map
TMS	Tonga Meteorological Service
TOP	Tongan Pa'anga.
TVB	Tonga Visitor's Bureau
TWB	Tonga Water Board
UNICEF	United Nations Children's Fund
VES	Vertical Electric Survey
VWC	Village Water Committee
WASABI	Water and Sanitation Broad Partnership Initiative
WatBal.	Water Balance
WHO	World Health Organization (Organization)

Chapter 1

Introduction

Chapter 1 Introduction

1.1 Background and Objective of the Survey

1.1.1 Background

One of the Millennium Development Goals (MDGs) adopted in 2000 – "to halve the proportion of people without access to safe drinking water by 2015 compared to 1990 levels" - was achieved in 2010, and a significant improvement in the situation of access to safe drinking water has been achieved globally since 2000.

However, the access to such drinking water with the safe quality and water supply service depends on the region, income level and other factors, and according to UNICEF, as of 2020, two (2) billion people worldwide does not have access to safe, controlled drinking water, among whom 490 million people (7% of the global population) have to take untreated water from wells, lakes, rivers and irrigation canals that may be contaminated by external pollutants.

On the contrast, Japan is working towards achieving Goal 6 of the "Sustainable Development Goals (SDGs)" adopted in 2015: "By 2030, ensure access to and sustainable management of water and sanitation for all people." To achieve this goal, Japan has been continuously supporting developing countries by constructing water supply facilities through ODA-funded cooperation and dispatching water supply experts through technical cooperation projects, making use of the experience and knowledge gained through the successful expansion of water supply service in domestic projects.

Japan's water supply system has expanded rapidly throughout the country since 1952 and now has achieved the water supply coverage rate of 98.1% (Basic Statistics on Water Supply 2019, Ministry of Health, Labour and Welfare), and has formed a world-leading water supply system with low leakage rates and earthquake preparedness.

In the process of its service expansion, Japan overcame many challenges such as the deterioration of water quality, lack of water sources and high non-revenue water rates (NRW) due to rapid economic and population growth, and contributed significantly to the reduction of waterborne diseases such as cholera and typhoid, and it is recognized that water supply is also important in the fight against infectious diseases.

During the global outbreak of the coronavirus infection (COVID-19) since 2019, although washing hands with soap and clean water was recommended at the time of the pandemic as a general infection control measure based on the official announcement of WHO, it is estimated that approximately 30% or 2.3 billion people of the world's population were unable to perform basic hygiene behavior.

Furthermore, in recent years, the effects of climate change, such as rising of the average temperatures potentially caused by the global warming, rising sea water temperatures and levels, have led to more severe and frequent weather disasters such as heavy rainfall, floods and droughts, which have already brought an impact on water supply systems worldwide in terms of both water quantity and quality.

As water supply systems is a basic core infrastructure and lifelines for human life, the disruption of water services due to the weather-related disasters will cause extensive damage to the lives of people and business activities in different regions / areas of the world. WHO, therefore, has called for countries to prepare water safety plans considering climate change impacts and also seeking for resilience to their impact.

Global environmental problems are becoming more important on a global scale for taking its measures an issue, and their growing seriousness may also cause a major impact on waterworks which use water as a recyclable resource. For this reason, many countries, including Japan, have announced their aim to create 'carbon neutral' society that reduces GHGs (Greenhouse Gas) emission to zero by 2050, and the water supply sector is also required to take different measures for environmental conservation to build a low-carbon and recycling-oriented society.

The situation surrounding the water supply sector, considering the need to support developing countries in achieving the SDGs and to overcome climate change and infectious diseases that most developing countries are facing, the support to these countries is expected from the experience of Japan's water supply business and the utilization of Japanese technology.

Under these circumstances, utilizing Japan's advanced technology and knowledge to support to the water supply sector in the countries described above is a key responsibility as a member of the international community, also to encourage Japanese companies, local governments and other water utilities to expand overseas business activities.

Japan's ODA is in principle implemented based on the requests from the developing countries. However, most of the water supply project plans are immature in their content when the recipient countries requests assistance from the Japanese Government, which has become an obstacle to the formation of promising water supply projects.

Therefore, surveys toward examining specific measures to solve problems in collaboration with water supply administrators and water utility staff in developing countries are needed as a matter of practice to improve the capacity of central and local governments in these countries to prepare water supply project plans, formulate water supply policies and operate water supply services.

1.1.2 Objective

The purpose of the survey is to provide advice and guidance that contributes to the preparation of plans for solving problems from a professional and technical perspective viewpoint, based on the information on specific issues (facility development, operation and maintenance, human resources development, etc.) and potential needs in the water supply sector in developing countries that are independently identified by Japanese companies, local governments and other Japanese water supply entities. Implementation of such advice and guidance under a public and private partnership will aim to improve the planning capacity of the recipient country and promote the formation of more promising and maturated projects that can fully utilize Japan's knowledge and experience.

1.2 Schedule and Contents of the Survey

The schedule of the survey works is shown in Table 1.1. The period of the work is approximately 10 months and the timeframe for submission of the reports is also shown in Table 1.1. The main contents of the survey are shown in Table 1.2.

Table 1.1 Survey Schedule

Item \ Year	2022							2023		
	June	July	August	September	October	November	December	January	February	March
1.Preparation in Japan	◄	─	►							
(1) Submission of planning documents	▼									
(2) Preparation for water supply project planning guidance			▼							
2.Survey in Tonga			◄	►						
(1) Study on current/future issue			▼							
(2) Discussion on water facility development plan				▼						
3.Reporting in Japan				◄	─	─	─	─	─	►
(1) Preparation of draft report and discussions							▼			
(2) Preparation of draft request form and discussions								▼		
(3) Preparation of the final report and its executive summary									▼	
(4) Submission of the final report										▼

Source: prepared by the survey team

Table 1.2 Contents of the Survey

Date / Month	Task	Contents
Mid-June, 2022	Preparation of Implementation Plan	・Purpose of the Project ・Basic Policy of the Project ・Contents of the Survey Works ・Work plan
Late June to mid-August., 2022	Preparation of implementation of guidance on water supply project planning.	・Collection and Analysis of Data and Information ・Preparation and Submission of Questionnaire ・Data gathering on the damage caused by volcanic eruptions and tsunami ・Schedule coordination with related organizations, etc. ・Logistical coordination at the destination
Late August to Early September, 2022	Technical Guidance on the Water Supply Project	・Fact finding on the current situation ・Current and future problems and issues ・Data gathering and analysis of relevant information on the current situation and future project plans ・Review and discussion on the contents of the project
Mid-September to Early December, 2022	Preparation of draft report and discussions	・Analysis of current and future problems and issues ・Review of project contents ・Preparation of draft reports and discussion
Late January, 2023.	Preparation of draft request form and discussions	・Guidance on drafting request forms ・Discussion on draft request forms
Early -to Late February, 2023	Preparation of the report and its executive summary	(Implementation of post-guidance).
Late March, 2023	Submission of the final report	・Submission of the final report ・Submission of the project performance report

Source: prepared by the survey team

1.3 Survey Team

The survey team consists of the following members.

Table 1.3 Survey Team Members

Name	Job Title	Occupation
Dr. Moeko YOSHITOMI	Project Superintendent	Ministry of Health, Labour and Welfare
Mr. Daisuke YASHIRO	Chief Consultant	NJS Co., Ltd.
Mr. Tadashi SATO	Water supply planning and design (Water Source)	Earth System Science Co., Ltd.
Mr. Kenta HAYASHI	Water supply planning and design (Facilities)	NJS Co., Ltd.
Mr. Keita SHINJO	Water supply planning and design (Pipeline)	Ryusei Consultant Co., Ltd.
Mr. Sampei NAKANISHI	Procurement of water supply material and equipment	NJS Co., Ltd.
Mr. Motomu TAKARA	Water supply facilities operation and maintenance	Ryusei Consultant Co., Ltd.

Chapter 2

Findings on the Current Situation on the Project

Chapter 2 Findings on the Current Situation on the Project

2.1 Outline of the Country and the Project Area

2.1.1 Outline of the Country and the Project Area

Tonga is located in the South Pacific about 3,600 km northeast of Sydney, Australia and about 2,000 km north of Auckland, New Zealand. The country is an island country consisting of more than 172 large and small islands scattered across a vast sea area spreading about 1,000 km north to south and 500 km east to west. The country consists of 4 main islands of "Tongatapu", "Ha'apai", "Vava'u" and "Niuas" and their group islands, which has a total land area of 747 km^2.

Tonga is basically a volcanic archipelago, the western islands are geologically newer, the eastern islands were formed from coral reefs caused by the subsidence of volcanic islands, and most of the subsurface layer of Tongatapu Island is covered with uplifted limestone. The climate of the island is subtropical and oceanic, with the highest temperature from December to March and a cooler climate from June to October due to the southeast monsoon, and the average temperature is 21.3 degree Celsius in July. Cyclone usually occurs frequently in the summer season from December to April, and tend to be concentrated in January and February.

According to the national census (Tonga Census of Population and Housing 2021), the population of the Tonga as of 2021 is 100,179 inhabitants. Table 2.1 shows the population of Tongatapu, Vava'u, Ha'apai and Eua Island, which are the survey areas.

Table 2.1 Population by Island

Island	Male (person)	Female (person)	Total (person)	%
Tongatapu	35,959	38, 361	74, 320	74.2
Vava'u	7,044	7,1 38	14, 182	14.2
Ha'apai	2,787	2,878	5,665	5.6
Eua	2,386	2,478	4,864	4.9
Niuas	574	575	1,1 48	1.1
Total	48,749	51,43 0	100, 179	100.0

Source: Tonga Census of Population and Housing 2021

2.1.2 Occurrence of Submarine Volcanic Eruptions

A volcanic eruption occurred at Hunga Tonga-Hunga Ha'apai (HTHH) around am 9:35 on December 20, 2021 (Tonga local time), and a volcanic plume rose up to an altitude of 18 km. Volcanic activity continued after that, and a satellite image taken on December 25 confirmed that the area of the island had expanded. The volcanic activity weakened once on January 5, 2022. However, it resumed around 4:00 on January 14, causing a large-scale eruption, and an ash plume reached an altitude of 17 km. The Tongan government has issued a tsunami warning to the people. Around this time, the residents of Tongatapu and Eua Island were affected by the smell of sulfur. The tsunami warning issued by the country's National Tsunami Warning Center was lifted on the evening of the 14th for Vava'u and Ongo Niua Islands, and on the morning of the 15th for the entire island.

Then, around 17:00 on January 15th (around 13:00 Japan time), a huge magnitude of eruption occurred in Tonga as well as in Fiji which is located more than 500km away from the volcano. And also, a sound of explosion was reported even further afield in New Zealand and Australia. The volcanic plume rose to an altitude of approximately 16,000 m and spread to a radius of 260 km. About 400,000 tons of sulfur dioxide were released according to the satellite observations.

In a massive eruption on the January 15th, explosion sounds were observed in the capital Nuku'alofa, 65 km away from the volcano. Ash fall was also observed on the islands of Batoa and Ono-i-Lau in Fiji, which are relatively close to Tonga. Observations from space by meteorological satellites indicated that a huge volcanic plume rose up and a shock wave (air shock) propagated across the Pacific Ocean. Scientists at the University of Auckland, New Zealand reported that the volcano eruption was a once-in-a-thousand-year event.

2.1.3 Effects of Submarine Volcanic Eruptions and Tsunami

The massive eruption and its subsequent tsunami that occurred on January 15, 2022 have once again highlighted the vulnerability of Tonga's infrastructure and lifelines to natural disasters. Communication networks such as telephones and the Internet were disrupted due to the disconnection of submarine cables, and the international airport runways was closed due to the accumulated volcanic ash fall, and damage to houses was caused by the tsunami.

Similar impacts were found on the water supply facilities from the information that 1) volcanic ash accumulated in the rainwater storage tanks for drinking use of most of the Tongan people made it difficult to secure drinking water and that 2) the breakage of the water supply and distribution pipes due to the tsunami also made the affected residents difficult to secure the domestic water. Ash fall from the volcanic eruption caused a damage to power supply such as adhesion to power lines triggered a flashover in the transformers, which resulted in damage to well submersible pump motors and electrical control panels. Furthermore, due to the severe damage to the communication network system, the Tonga Water Board (TWB), which operates the water supply business in the major cities of Tonga took it a lot of time to ascertain the detailed damage status of the water supply facilities on the remote islands.

Based on the above background, the survey intends to acquire more information on the damage to the water supply facilities caused by the submarine volcanic eruptions and tsunamis on the four major islands of Tonga, and identify potential issues facing the country's water supply sector against the risk including climate change and natural disasters. The survey team conducted a field survey for this purpose, and provided a guidance on a water supply recovery support plan for the target areas of the four (4) major islands described above.

2.2 Current Situation and Issues on the Water Supply of the Country

2.2.1 Current Situation on the Water Supply Sector (National Level)

(1) Overview of the Water Supply Sector

Water supply in Tonga is roughly divided into urban water supply for city areas and rural water supply for villages. Urban water supply is implemented by TWB under the jurisdiction of the Ministry of Public Works (MPE), which provides water supply services and operation/maintenance management services to major cities on Tongatapu Island, Vava'u Islands, Ha'apai Islands, and Eua Island. doing. Table 2.2 shows the outline of the water supply service by TWB.

Table 2.2 Overview of TWB's Water Supply Service

Island Group	Total Population	No. of Households	Active Connection	Temporarily Disconnected	Long Disconnected	Plugged	Total	Coverage
Tongatapu	74,320	13,565	7,819	699	1,317	6	9,841	58%
Vava'u	14,182	2,723	1,126	0	170	0	1,296	41%
Ha'apai	5,665	1,136	387	0	77	0	464	34%
ʻEua	4,864	913	777	1	107	0	885	85%
Ongo Niua	1,148	262	-	-	-	-	-	0%
Totals	100,179	18,599	10,109	700	1,671	6	12,486	54%

Source: Tonga Water Board Business Plan 2022-2027, Tonga Census of Population and Housing 2021

"Tonga Water Board Business Plan 2022-2027 " (hereinafter referred to as the "Business Plan") reports the number of households connected to the water supply business by TWB will be 12,486 as of 2021, of which 10,109 will be in operation and 2,377 non-operating. In the 2021 version, the water supply coverage rate for the entire country for the total number of 18,599 households (operating/total number of households = 10,109 / 18,599) will be approximately 54 %. Most of the households not connected to TWB 's water supply service use the village water supply that is operated by the Village Water Supply Committee (VWC).
Table 2.3 shows the current status of the efforts to achieve the SDGs (Target 6: Clean Water and Sanitation) in Tonga.

Table 2.3 Current Status on the Achievement of SDGs (Goal 6) in Tonga

Goal 6: By 2030, achieve universal and equitable access to safe and affordable drinking water for all

SDG Global Targets	SDG Global Indicators	2000 (%)			2015 (%)		
		Nationwide	Urban	Rural	Nationwide	Urban	Rural
6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1 Proportion of population using safely managed drinking water services	98	97	99	100	100	100
6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1 Proportion of population using a) safely managed sanitation services and b) a hand-washing facility with soap and water	89	99	86	93	97	92

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1 Proportion of domestic and industrial wastewater flow safely treated	—	—	—	—	—	—
	6.3.2 Proportion of bodies of water with good ambient water quality		—	—	—	—	—
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water use efficiency over time	—	—	—	—	—	—
	6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	—	—	—	—	—	—
6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1 Degree of integrated water resources management implementation (0-100)	—	—	—	—	—	—
	6.5.2 Proportion of transboundary basin area with an operational arrangement for water cooperation	—	—	—	—	—	—
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes”	6.6.1 Change in the extent of water-related ecosystems over time	—	—	—	—	—	—
6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, seawater intrusion, water efficiency, wastewater treatment, recycling and reuse technologies	6.a.1 Amount of water- and sanitation-related official development assistance disbursements	—	—	—	—	—	—
6.b Support and strengthen the participation of local communities in improving water and sanitation management	6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	—	—	—	—	—	—

Source: WHO UNICEF JMP, Progress on Drinking Water, Sanitation and Hygiene 2017

(2) Water supply facility

TWB's water supply system is composed of the pump-up at well fields from the freshwater underground aquifer called "freshwater lens" as a water source, followed by the chlorination and distribution to the service areas by gravity flow. TWB has been working on the expansion of their water supply service with assistance from different donors mainly on Tongatapu Island, where Nuku'alofa, the capital of Tonga is located. However, in the surrounding remote islands, the obstacles to the proper operation of water services are found as shown in the emergence of multiple challenges such as aging water supply facilities, sea water intrusion into existing water source, shortage of drawn water amount , remaining asbestos pipes, frequent leakage of water coming from aging distribution pipes and accompanying high rate of NRW (Non-Revenue Water), and also malfunction of the equipment such as chlorine dosing purpose and water meter.

Rural water supply, on one hand, which is under the jurisdiction of the Ministry of Health (MOH), serves their water only for about three (3) hours a day and causes water-borne diseases several times due to lack of chlorination facilities. In addition, insufficient management for the water source has become a cause of concern about water contamination for their satisfactory water supply service in terms of water quality and quantity.

(3) Impact on water supply due to submarine volcanic eruption and tsunami

The survey results on the impact on TWB's water supply business by the volcanic eruption and tsunami that occurred on January 15, 2022 is summarized as below and its detail by the main islands is shown in Table 2.4. As a result, no major fatal impact on water supply facilities nor event that may cause an obstacle to the future water supply services was confirmed during the survey.

- No damage to the distribution network by the tsunami, while water pipes damaged for 265 coastal households in Nuku'alofa, 57 households on Eua Island and 25 households on Lifuka Island
- Increase of water consumption exceeding production capacity after the eruption at the urban areas of the remote islands.
- Ash-induced blackouts were a major factor for the obstacle to water production and supply after the eruption.
- The use of tap water to remove volcanic ash caused water shortages and pressure drops in the distribution network.
- Volcanic ash deposits caused flash over at the transformers in the wells, resulting in the failure of two (2) intake pumps and one (1) backup generator on Vava'u Island.
- The tsunami intruded near the TWB's infiltration gallery on the coast area of Lifuka Island. However, it did not affect the water source. Seawater intruded into the observation wells in the coastal area, causing a temporary increase in EC (Electrical Conductivity) after the disaster, and it has currently recovered to normal levels.
- The water supply system on Eua Island, which uses surface water as raw water, was suspended due to the risk of volcanic ash flowing into the water treatment plant.
- Recovery of the entire water system needed two (2) weeks of January 16 to 30

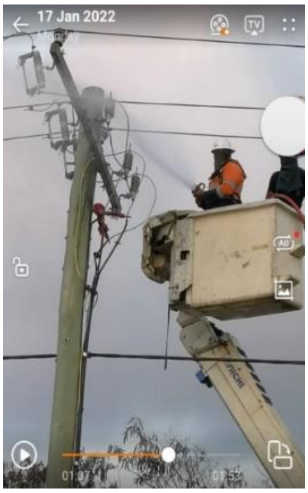
Table 2.4 Damage to Water Supply Facilities

No.	Island Name	Overview of Damage
1	Tongatapu	Damage to the rainwater storage tanks for drinking due to the accumulation of the ash fall was reported at some households. However, whether it can be used depended on the degree of the accumulation. No major impact has occurred for the water source at the well fields that is far from the coastal area.

No.	Island Name	Overview of Damage
		In rural areas, both parameter of pH value and TDS as an index of salination were below the WHO guideline values and no effects have been confirmed. .
2	Eua	Spring water as one of the water sources may be affected by ash fall and may not be suitable for drinking, but there is no problem for its use for other purposes (washing clothes, washing dishes, etc.). On the other hand, the water from the wells was considered safe because they were not affected by ash fall or tsunamis.
3	Vava'u	Main water source is located about 3 km north of the urban area, and the impact of ash fall and tsunami inundation is small, and the damage from volcanic eruptions is a minimal among the four (4) islands.
4	Lifuka	Well fields locating along the coast of the western part of the island (Pangai district) was affected by the tsunami, and there are causes of concerns that the well water sources have been affected.

Source: The survey team based on information obtained from TWB

Distribution pipes damaged by the tsunami (‘Eua)



Removal of ash fall on power lines (Tongatapu)

Repairing of distribution main damaged by the tsunami (Tongatapu)

Source: TWB

Figure 2.1 Status of Damage caused by Submarine Volcanic Eruption and Tsunami

2.2.2 Issues on Water Supply (National Level)

(1) Issues in Water Supply Business in General Aspect

Table 2.5 summarises the issues of the water supply business in Tonga.

Table 2.5 Issues in water supply business in Tonga

Category	Issue	Expected Magnitude of Issue Level			Rationale for Evaluation of Issue Level
		Small	Middle	Large	
Institutional / Organizational	Their policy toward encouragement of self-efforts is not confirmed.		○		TWB relies on the external financial support for a development of a new project, but the O&M is normally run by TWB's allocated budget.
	Insufficient staff number or human sources for the requirement of the water supply service operation.		○		There is no problem with the number of the technical staffs, but more skilled engineers are needed.
Planning / Coordination	Upper-level plan such as a Master Plan on water supply has not formulated yet.			○	The current master plan for water supply facility development was developed in 1992 and has never been revised. Although individual facility development plans exist, a master plan that will serve as the basis for these plans needs to be developed.
	Coordination among the assistance of donors or international institution for water supply projects is not confirmed.		○		The funding and technical assistance to be required for new development and improvement of water supply systems are requested by TWB on a case-by-case basis for each project, which requires a coordination between the central government level and individual donors.
	Balance of the water supply service level (e.g. water supply amount, progress of improvement of facilities) has not been achieved.		○		TWB provides urban water supply services, while in rural areas village committees provide water under the jurisdiction of the Ministry of Health. Unbalance of the service level has been confirmed as shown in the fact of the shorter supply of only 3 hours per day in rural areas compared to those of the urban water supply.
	Balanced coordination with other relevant sectors (e.g. water resources management, sewerage and urban plan) is not made.		○		The Ministry of Land and Natural Resources is the centralized authority for water source management, and TWB develops water sources under permission from the Ministry and provides water supply services. There are no significant problems regarding the balance in these jurisdictional aspects. However, in terms of pollution control of water sources, environmental considerations such as prevention of contamination of water sources should be taken as found in the facts of free-ranging wild pigs.
Business Operation / Financial Management	Insufficient budget for development of water supply projects			○	As a public enterprise, TWB is able to manage its business operation as an independent accounting system. However, the fund for the development of the new facilities cannot be provided only by TWB, and it needs a support of fund from donors.
	Water tariff system or policy has not been established.		○		Regarding the business management of TWB, not only is the business income from collecting water charges, but it also provides a wide range of services such as plumbing work and education and training services. is not sufficiently disseminated, and appropriate tariffs based on the pay- as-you-go system have not been collected. Furthermore, when expanding the water supply service to rural areas, it is necessary to educate the residents and build a consensus on the disparity in water charges from before the service was provided.

Category	Issue	Expected Magnitude of Issue Level			Rationale for Evaluation of Issue Level
		Small	Middle	Large	
Operation & Maintenance	A guideline or manual of the maintenance of the water supply facilities has not been established.	○			The standard of the maintenance works that was formulated in New Zeeland is used in TWB.
	Proper maintenance works is not done.		○		Efforts are being made to maintain the aging water supply facilities. Especially, the quantity of maintenance-related equipment is not sufficient.
	Data (e.g. water quality) or asset management is not conducted.			○	Data management in a Digital Transformation for the water quantity and quality is not carried out.
	Number of skilled maintenance staffs enough for the quantity or quality of the maintenance works is not sufficient.		○		No problem has encountered with the number of engineers, but skilled engineers are required.
Technical Aspect	Water source is vulnerable to the natural condition (e.g. topography, geology, disaster, climate change)			○	Aquifers formed by the hydrogeological conditions in coral reef geology are susceptible to natural conditions such as storm surges, tsunamis and climate change.
	Seawater intrusion is progressing to the current water source and drinking water cannot be supplied.			○	The freshwater lens, which is the main water source, has become a state in which seawater intrusion to the water source is progressing due to concentrated pumping from the water in the hydrogeological conditions caused by repeated failures of pump units, clogging of wells, etc. In addition, even in case of spring water as a water source, the water is easily affected by rainfall. Turbidity is high in the rainy season and the amount of water decreases in the dry season, which has become an obstacle to the operation of existing water treatment plants. There is concern that climate change will further progress salinization in the future.
	Enough water cannot be distributed due to the deteriorated water supply facilities.			○	Asbestos pipes still remain and the pipes are aging, and water leakage is progressing. In addition, the NRW (Non-Revenue Water) rate is still high.
	The basic facilities for disinfection for tap water are not functioning due to their malfunctions and may causes hygienic problems on its water supply.			○	Due to the difficulty in procuring chlorine gas, the existing disinfection equipment is not functioning and the supply of safe tap water is not possible. Disinfection is not mechanized, and appropriate disinfection is not practiced.
	Design manual or criteria has not been established in the Kingdom.			○	In Tonga, design standards related to water supply facilities have not been established, and internationally accepted standards are applied in project.
	The technical level of the staffs does not reach the target level of facility planning, design and project management		○		Capacity development in facility planning, design and project management is required.
	The technical level of the staffs appropriate does not reach the target level of O&M.	○			Capacity development in the facility O&M is required.

Source: Prepared by the survey team

(2) Lack of Viable Long-Term Plan

TWB formulated the "Tonga Water Supply Master Plan" in 1992 to shape the future direction of water supply in Tonga. However, the plan has never been updated since then. On one hand, toward commencing redevelopment of the water supply facilities on the remote islands under delayed development, "Outer Islands Water Supply Improvement Project" was formulated in 2012 aiming to develop water supply facilities in Vava'u, Lifuka, and 'Eua Islands. Furthermore, according to "Draft Investment Proposals" which was formulated in October 2016 with the support of the Pacific Region Infrastructure Facility (PRIF), the following two (2) investment plans for the water supply sector are proposed.

a) Improvement of TWB's water supply operation composing of improved asset management, groundwater source management, water quality improvement, reduction of NRW, revised water tariffs and improved meter reading and billing (Investment Plan 1)
b) Expansion of TWB's water supply service area to the rural areas of Tongatapu and part of the remote island area (Investment Plan 2)

In addition to above, the "Tonga Water Board Business Plan 2022 - 2027 " also formulates an investment plan for the future five (5) years.
Above investment plans, however, have not yet been implemented.

(3) Business / Financial Risks and Insufficient Investment Funds for Facility Development

Table 2.6 shows the TWB's financial balance for the recent five (5) years. The balance has shifted in the black since 2012. The annual water charge revenue (sales) and gross profit have been in increasing tendency since FY2016 against the increase in the numbers of customers despite the impact of the revised water tariff, which will be described later. On the other hand, selling, general and administrative expenses have been increasing, of which an increase in depreciation costs associated with facility and capital investment is one of the reasons is, and resulted in the decreasing net profit since 2017. As described above, TWB's revenue coming from the water tariff collection has been growing steadily with the expansion of water supply areas, while the net profit decreasing from the reason of the increased expenditure for the rapid development for the water supply facilities.
In addition, the central government has ordered public enterprises in Tonga to pay dividends to the government, and the burden of paying dividends is putting pressure on TWB 's finances. The obligation to pay dividends is stipulated in the Public Enterprises Act 2002, which prescribes that the amount to be paid for the year is determined within six (6) months after the end of the fiscal year through an assembly with the Minister.
The actual dividends paid by TWB to the Government is determined based on the net profit after tax by taking the cash flow and financial capacity of the current fiscal year into consideration. The amount varies each year, however, from the survey of "Project for Improvement of Water Supply System in Vava'u, the survey team obtained the fact on new bill that public entity's obligation of 100% dividend of the net profit should be paid to the government being acted. In fact, the dividend in 2019 accounted for about 98 % of the net profit. On the other hand, in fiscal 2021, the dividend is expected to be set as 75% of the net profit, and it is expected that 40 % of the net profit will be the target dividend in the future due to a change in

government policy according to the interview with TWB. As described above, the dividend rate is easily affected by politics, and it is possible that dividend payments will continue to become a financial threat to TWB.

Table 2.6 TWB's Fiscal Balance (5 years from 2017 to 2021)

(Unit: TOP $)

ITEMS	FY 2016/2017	FY 2017/2018	FY 2018/2019	FY 2019/2020	FY 2020/2021
Operating Revenue	6,311,631	6,386,174	6,808,915	7,857,679	7,679,560
Cost of Sales	(2,132,520)	(2,116,363)	(1,960,865)	(2,759,756)	5,924,474
(Depreciation)	(586,895)	(586,895)	(586,895)	(755,673)	
Gross Profit	**4,179,111**	**4,269,811**	**4,848,050**	**5,097,923**	
Other Income	1,828,099	2,011,227	2,125,348	2,345,468	2,342,887
Administrative Expenses	(4,366,310)	(4,604,454)	(5,464,881)	(6,162,395)	5,924,474
(Depreciation)	(1,382,649)	(1,366,030)	(1,622,196)	(1,724,934)	
Profit from Operations	**1,640,900**	**1,676,584**	**1,508,517**	**1,280,996**	
Finance Income	38,234	38,234	38,234	7,907	
Finance Costs	(14,531)	(17,488)	(120,924)	(69,551)	
Net Profit before Tax	**1,664,603**	**1,697,330**	**1,425,827**	**1,219,352**	1,425,827
Income Tax Expenses	(416,151)	(424,333)	(332,002)	(304,838)	332,002
Net Profit after TAX	**1,248,452**	**1,272,997**	**1,093,825**	**914,514**	1,093,825
Dividend	1,030,000	323,663	1,067,074		
Dividend % to NPAT	82.50%	25.43%	97.55%		

*1 The figures of FY2020/2021 are based on TWB's Business Plant, and the breakdown of the profit and loss was not available.
*2 The amount of the dividends for FY2019/2020 and FY2020/2021 are set to blank space because it was not available
*3 NPAT: Net Profit after Tax
Source: Created based on TWB Audit Account 2017-2018, 2018-2019, 2019-2020, Tonga Water Board Business Plan 2022-2027

Table 2.7 and Figure 2.2 show the changes in TWB's water charges by island. Sufficient water tariff revenue is a basic requirement for sound water supply business operation, and it should be set at a level that TWB can pay operation / maintenance, depreciation cost for the facilities and equipment and necessary investment.

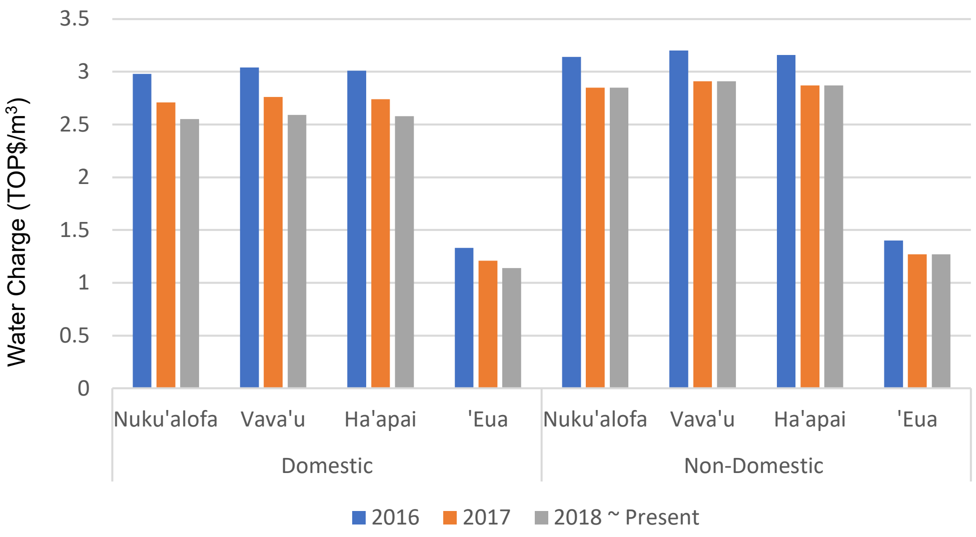
Tongan government has repeatedly requested TWB to reduce water tariff, and TWB has reduced it by 25 % from 2016 to 2018, resulting in an annual loss of 1.4 million TOP $. Requests for further reductions in water tariffs in the future may put pressure on TWB's finances.

Table 2.7 TWB's Water Charge by Island

(Unit: TOP $ /m^3)

Branch / Year	Household Use				Non-household			
	Nukualofa	Vava'u	Ha'apai	Eua	Nukualofa	Vava'u	Ha'apai	Eua
2016	2.98	3.04	3.01	1.33	3.14	3.20	3.16	1.40
2017	2.71	2.76	2.74	1.21	2.85	2.91	2.87	1.27
2018 ~ present	2.55	2.59	2.58	1.14	2.85	2.91	2.87	1.27

Source : Prepared by the survey team based on Tonga Water Board Business Plan 2022-2027



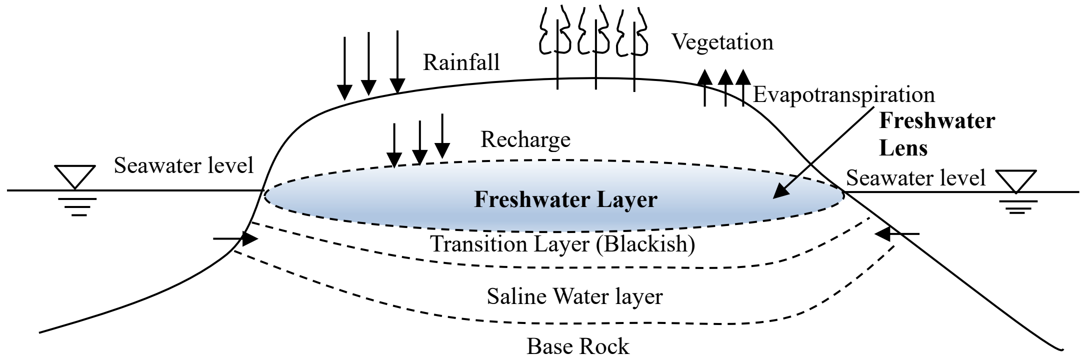
Source: Prepared by the survey team based on Tonga Water Board Business Plan 2022-2027

Figure 2.2 Annual Change of TWB's Water Tariff by Island

As described above, due to the mandatory legal requirement for TWB as a public enterprise, TWB's financial status is easily affected by the government policies such as setting water tariffs and the amount of dividend payments. TWB is unable to invest new construction of facilities and equipment from their own budget. In addition, although water supply facilities and equipment have been developed with the support of different donors, failures of equipment (filters, chlorinator, water intake pumps, flow meters, water meters, etc.) has been becoming apparent due to these insufficient investment for the renewal and repair of water supply facilities.

(4) Seawater Intrusion to Water Sources

Groundwater of island nations is formed of fresh water recharged from the ground surface and saline water invading from the sea depending on their geological conditions with a boundary of salt and fresh water in the aquifer. The depth of this boundary is determined by the density difference between the freshwater, saline water and the pressure balance, and the freshwater aquifer is thick in the center of the island and thin at the edge, and is called a "freshwater lens" due to its formed shape of a lens. (See Figure 2.3), and the tap water in Tonga uses this freshwater layer as the main water source.



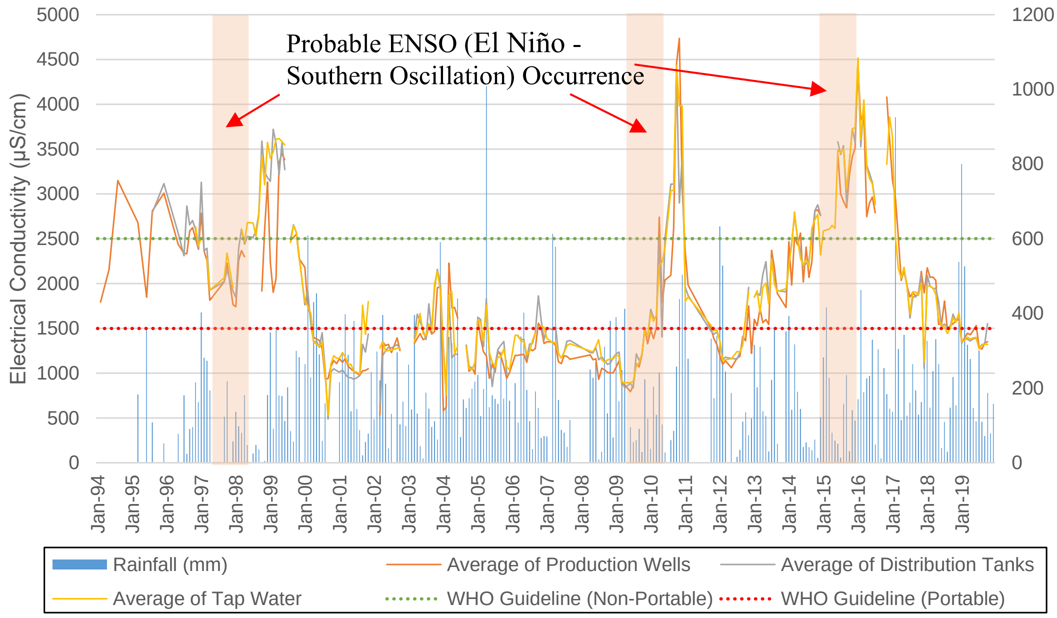
Source: Prepared by the survey team

Figure 2.3 Hydrogeological Schematic Diagram of Freshwater Lens in Tonga

The water has to be pumped up from the wells and infiltration galleries installed at the upper level of the freshwater aquifer in order to use fresh groundwater. However, the decreased water pressure of the surrounding aquifer caused by the concentrated or excess pumping of multiple wells will cause a phenomenon called "up-corning" in which saltwater flows up from the bottom of the aquifer toward the well and the aquifer gradually becomes saline.

Tonga has been affected by a decrease in rainfall possibly due to recent climate change, sea level rise by global warming, and tsunamis due to its location in the Pacific Rim seismic belt, which has increased the risk of sea water intrusion into the freshwater lens.

Figure 2.4 shows the past annual variation of the average monthly precipitation and electrical conductivity (EC) of intake wells, reservoirs and tap water in TWB over the past 26 years on Vava'u Island. In the South Pacific near Tonga, El Niño phenomenon is thought to have occurred in 1997 to '98, 2009 to '10, and 2015 to '16. From the fact that the amount of rainfall was extremely low and the EC value increased sharply during and immediately after the period during these periods, it can be seen that the intake wells were affected by salt water intrusion caused by the insufficient recharge from the ground surface due to the decreased precipitation at the past climate change (El Niño phenomenon). The frequency of occurrence of El Niño in Tonga has increased from about once every 20 years to once every 10 years during the 21st century, and the impact on groundwater has increased and been getting stronger.



Source: Survey team based on data provided by TWB

Figure 2.4 Past Annual Change of Precipitation, Electrical Conductivity and El Niño on Vava'u Island

(5) Use of Rainwater for Drinking instead of Tap Water

Photo 2.1 Rainwater Harvesting in Schools

In Tonga, rainwater is traditionally used as drinking water, and even now most of the households and public facilities such as schools and hospitals use FRP (fiber reinforced plastic) or concrete tanks next to or underground in buildings. The rainwater is collected from the gutter on the roof into the tank and used for drinking (Photo 2.1).

"Tonga Census of Population and Housing 2021" reports that about 65% of the entire country uses rainwater as drinking water, namely, about 58 % in Tongatapu, 79 % in Vava'u, 90 % in Ha'apai. and 81% on Eua Island with a stronger trend of its use on remote islands. On the other hand, the percentage of the use of the tap water for drinking is very small at around 6% throughout the country, indicating that tap water is mainly used for the purposes (e.g. cooking, bathing, washing, etc.) other than drinking. One of the reasons for this is that groundwater, the main source of the tap water in the country, contains a large amount of calcium as a hardness constituent with bad taste originating from the limestone geology and is not preferred by the residents. However, relying on rainwater as a drinking water source has the risks related to safety and stability as shown in the table below, and therefore the use of safe tap water needs to be promoted.

Category of Risks	Potential Risks by Using Rainwater
Climate change	・ Sufficient amount of water cannot be taken at droughts caused by decrease in rainfall or El Niño phenomenon
Natural disasters	・ During the volcanic eruption in January 2022, the inside of the tank was contaminated with ash fall and could not be used for drinking until the tank was washed. ・ Seawater blown up by the wind mixes into the tank at passing of cyclones makes it unusable for drinking.
Hygiene	・ Fecal contamination caused by small animals and contamination caused by dead leaves of trees. ・ Growth of bacteria in tanks.

(6) Insufficient Capacity for Operation and Maintenance of Facilities

Flowmeters were not installed where they were needed, and some flowmeters were not functioning due to malfunctions and most of the water meters are broken. In addition, well pumps are not properly managed and facilities for flow rate control are not well prepared. In addition, the method of the daily flow rate control on remote island areas is managed by handwritten notes, and the data cannot be utilized for daily operation management (Photo 2.2). Such TWB's current practice should be improved through appropriate flow management and grasping of flow performance are basic information for water supply business management.

Only chlorine disinfection is currently being carried out for chemical dosing process. In the past, chlorination facilities were introduced including on remote islands with assistance from international donors. However, all of them are out of order at present (Photo 2.3). In addition, residual chlorine is not managed on a daily basis, and depending on the time of day, the necessary amount of residual chlorine cannot be secured, and unsterilized tap water is distributed, which poses a safety risk.

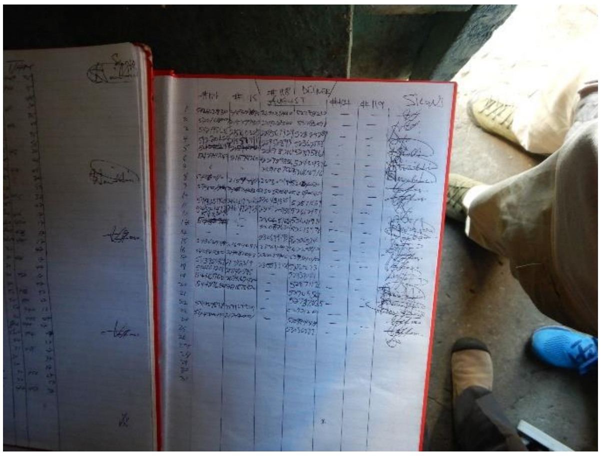


Photo 2.2 Handwritten Operation Management Daily Report

Photo 2.3 Disinfection with Hypochloride Tablets

Dailly water quality measurement for the parameters such as residual chlorine, turbidity, pH, and electrical conductivity are not controlled. TWB owns a water quality testing laboratory adjacent to the Matakieua Reservoir on Tongatapu Island. TWB cannot carry out the measurement of hazardous substances such as heavy metals of iron and Manganese, and chloroethylene, and they have insufficient function of their only water quality testing laboratory (Photo 2.4). TWB's branch offices on the remote islands does not own water quality measurement equipment, thus samples are transported by air to Tongatapu Island once a month, the chemist in the laboratory in above Matakieua Reservoir conducts water quality testing only for above three (3) parameters, and collect the results by e-mail.

Water treatment facility using water filtration process is developed only on Eua Island, and other islands use a simple system consisting of only water intake, transmission and distribution facilities. Therefore, most of the types of mechanical and electrical equipment are simple system only with composing of basic equipment such as pumps, electric panels, chlorine dosing equipment, flow meters, and water meters. Equipment maintenance is basically conducted as post-incident measures just after an accident occurs, and planned preventive maintenance management is not carried out. In addition, post-maintenance measures against failures are insufficient, and as mentioned above, most of the flowmeters and water meters are left as in a state of failure (Photo 2.5). When equipment breaks down and spare parts are needed, in many cases they are needed to be procured from overseas. Filtration equipment, rapid filters, etc. have not been repaired after they broke down. Most recently, Australia provided seawater desalination equipment for emergency water supply in an event of disasters in 2019. However, the equipment is also out of order and is not currently in operation. As mentioned above, due to Tonga's geographical factors, Tonga has serious problems related to the maintenance of the equipment from the actual fact that even expensive equipment cannot be continuously used once they are broken.

Photo 2.4 Water Testing Laboratory (Tongatapu)

Photo 2.5 Broken Flow Meter

Photo 2.6 Broken Desalination Equipment

(7) Deteriorated Facilities and Equipment

TWB's commenced their water supply service on Tongatapu Island in 1966, and with the support of different donors, the water supply facilities have been developed and the revenue base has been expanded through expanding the water supply area. On the other hand, sufficient budgets have not been allocated for the renovation of facilities and equipment that already have been developed, and problems associated with deterioration of facilities and equipment are becoming apparent. In addition, TWB intends to expand the water supply area to the urbanized areas in the future, and the importance of asset management is increasing as to how to appropriately manage the increasing water supply assets. TWB's water supply assets are currently managed using the Excel database "TWB Fixed Asset Register 20-21", and a dedicated management system has not yet been introduced.

Increase in water leakage due to the aging of the distribution network should be considered as a peculiar issue. “Tonga Water Board Business Plan 2022 - 2027” reports that the most recent NRW (Non-Revenue Water) rate in Tongatapu, Vava'u and 'Eua Islands is 30 to 40 % , and about 20 % on Lifuka Island from the leakage as the main cause. Asbestos pipes still remain in some parts of the distribution mains on Vava'u and 'Eua Islands, and immediate replacement is required from the viewpoint of water leakage and durability. " Business Plan 2022 - 2027 " also mentions that the water distribution pipe network owned by TWB is u

PVC or ductile cast iron pipe with a diameter of 40 mm to 500 mm and total extension of about 270 km, while "TWB Fixed Asset Register 20 - 21" reports that the distribution networks account for about 40 % of total assets on a historical cost basis. Therefore, it is necessary to systematically secure a budget and implement renewal of pipelines as a long-term effort.

(8) Vulnerability of Water Supply Services in Rural Areas

In Tonga, VWC operates and manages the water supply business under the jurisdiction of the Ministry of Health outside the water supply service area of TWB. As shown in Photo 2.7, the VWC water supply facilities generally consisting of wells and elevated water tanks have the following issues.

Photo 2.7 Water Suppl Facilities in Village Areas

- The quality of water supply services and the setting of water tariffs differ depending on the operating VWC in village areas, in the same way, the capacity of the finance and O & M are different depending on the scale of the village. In particular, the lack of O & M capacity and morale is a major problem, and capacity development and training will be needed.
- TWB has achieved 24-hour water supply, while VWC supplies only hours per day or about 3 hours in some village areas.
- A risk of contamination of water sources exists by the infiltration of night soil from domestic septic tanks and feces of animals such as wild pigs into the ground. In addition, insufficient chlorine disinfection may cause potentially high risk of outbreaks of water-borne diseases.
- Use of pesticides and fertilizers in agricultural activities is another risk of contamination of the groundwater sources.
- Their vulnerability to natural disasters in taking water has become a highlight when the submarine volcanic eruption and tsunami occurred in January 2022 as shown in the fact that water intake pumps could not operate in village areas at the power supply outage because of their operation with no their own generators

(9) Disaster Response

1) Emergency water supply at the disaster

At the event of the volcano eruption and tsunami on January 15, 2022, the water demand consumption was concentrated in the water supply area of TWB, and the reservoir remained almost empty for 16 to 27 days after the disaster. It is also reported that the water demand continued to exceed the water production capacity in the urban areas of each remote island. Remote islands are particularly vulnerable to natural disasters and climate change, and once they are affected, it is difficult to secure drinking water, thus the emergency water supply has become a high need. Securing backup water sources by developing new water sources and providing seawater desalination equipment, etc., building a redundant water supply system by temporarily increasing the amount of water produced in an event of disasters, and deploying the necessary water trucks and emergency services will be necessary to strengthen the emergency water supply system by improving the supply system and developing an emergency water supply manual.

2) Emergency restoration at disaster

The submarine volcanic eruption and tsunami in January 2022 damaged water supply pipes for 265 coastal households on Nuku‘alofa, 57 households on Eua, and 25 households on Lifuka Island. Volcanic ash deposits also caused transformers to flash over, causing failures in well intake pumps, electrical panels, and generators. As a result, two (2) weeks was needed to recover all water supply systems in TWB. Furthermore, the cut-off of the submarine cable caused severe damage to the communication network system in the entire country, and as a result, the TWB headquarters was only able to obtain fragmentary information on the damage to the water supply facilities on the remote islands, and could not provide the detailed information on the damage and consumed a lot of time to figure it out. In addition to such disaster of the volcanic eruptions and tsunamis, the water supply in Tonga is also prone to large-scale earthquakes and cyclones.
As mentioned above, rapid acquisition of the data / information of the damage to the water supply system after a disaster and its restoration measures against such disasters will be a big challenge for the water supply sector in Tonga which is vulnerable to natural disasters. At present, TWB has formulated their BCP (Business Continuity Plan), whereas their manuals for emergency response have not been sufficiently prepared.

2.2.3 Hygiene-related Issues and Waterborne Diseases (National Level)

No sewerage system has not been developed in Tonga, and only the treatment using septic tanks is commonly practiced. Most of the septic tanks have small size, lack capacity, and have inappropriate structures, so the contaminated water flowing out of septic tanks during heavy rainfall is thought to be the cause of the overgrowth of algae along the coast and in lagoon areas, which is a potential concern about the impact on the ecosystem. TWB does not have authority over sewage treatment, and there is no clear definition of an organization in Tonga regarding the jurisdiction over wastewater treatment.
With regard to water-borne diseases, data related to health and hygiene are managed by the MOH (Ministry of Health), while the number of cases of water-borne diseases is not systematically managed.

2.2.4 Current Situation of Water Supply by Islands

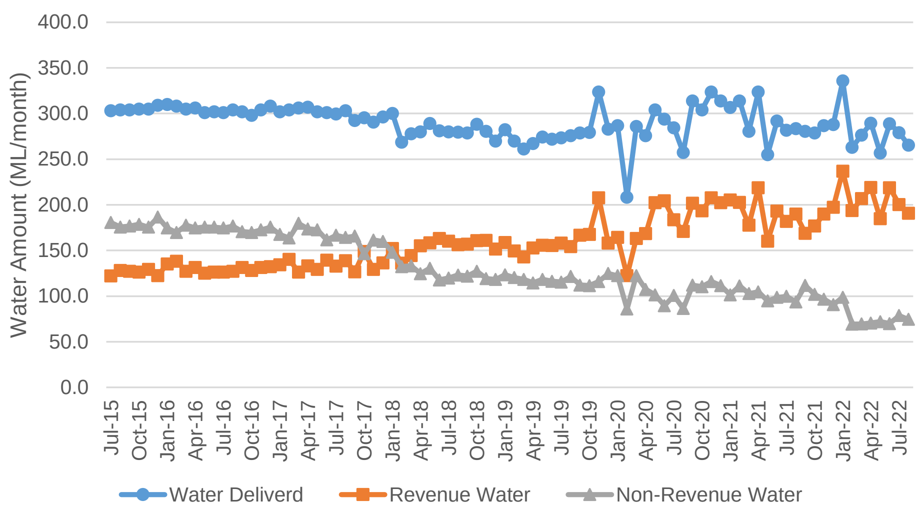
(1) Tongatapu Island

1) Current situation of water supply

Tongatapu Island, where Nuku'alofa, the capital of Tonga, is home to 74,320 people or about 74 % of the country's total population ("Tonga Census of Population and Housing 2021"). The population of the island is a major customer as a largest income source for TWB which shows about 78 % of the TWB's total customers in the country. Out of the total 13,565 households on Tongatapu Island (Tonga Census of Population and Housing 2021), TWB has water connections to 9,841 households (approximately 73% of that of the island) as of 2021, of which 7,819 households (approximately 58 %) connects to the TWB's water service. On the other hand, outside the water supply area of TWB, the water supply is operated by the Village Water Supply Committee (VWC) under the jurisdiction of the Ministry of Health (MOH).

Figure 2.5 and Table 2.8 show the TWB's tap water supply performance on Tongatapu Island. In the last seven (7) years, the amount of produced and revenue water has been increasing, the amount of water distributed has been maintained almost flat, and the amount of NRW (Non-Revenue Water) has been decreasing. In particular, the NRW rate is greatly decreasing by almost 27% from 58 % in FY2015 /16 to 31 % in FY2021/22 due to the construction of a water distribution network including the development of DMAs (District Metered Areas) and the introduction of smart meters that was supported by ADB and Australia. The TWB's performance in the year of 2021/2022 shows that average daily water volume in 2021/22 was 13,665 m^3/day for the water produced, 9,341m^3/day for the water distributed, 6,479 m^3/day for revenue water and about 31 % for NRW rate.

In the future, an increase of water consumption for the water supply for the new residents is expected from the government's plan to develop a new residential area on the outskirts of Nuku'alofa and to build a new village in January 2022 to accommodate the relocation of villagers affected by the tsunami.



Source: Survey team based on data provided by TWB

Figure 2.5 Water Supply Performance on Tongatapu Island (FY2015/16 to FY2021/22)

Table 2.8 Water Supply Performance on Tongatapu Island (FY2015/16 to FY2021/22)

Year	Water Production (m^3/day)	Water Delivered (m^3/day)	Revenue Water (m^3/day)	Non-Revenue Water (m^3/day)	Non-Revenue Water Rate
FY15/16	10,796	10,033	4,218	5,814	58%
FY16/17	10,772	9,970	4,328	5,642	57%
FY17/18	11,371	9,519	4,720	4,799	50%
FY18/19	12,326	9,051	5,102	3,949	44%
FY19/20	12,536	9,227	5,582	3,645	40%
FY20/21	14,427	9,777	6,350	3,427	35%
FY21/22	13,665	9,341	6,479	2,863	31%

Source: Survey team based on data provided by TWB

The survey results by the team in 2022 provides no any significant problem with regard to the water quality of Tongatapu Island, namely, the measured quality indicated low EC and confirmed appropriate dosing of chlorine (see Appendix-4 for details). On the other hand, the tap water indicated the constituent of high hardness due to its raw water originating limestone geology, and residents has become unwillingness to use it as drinking water.

2) Overview of water supply facilities

The water supply service in Nuku'alofa City was commenced by TWB in 1966. However, the water pressure was low and the water distribution facilities have deteriorated since then. After that, the pipes were replaced with those of larger diameter under the 2001 Japanese Grant Aid "Nuku'alofa Water Supply Development Project", which has improved the water supply situation in the capital city of Nuku'alofa and realized a stable supply of the tap water. Approximately 41 km (φ50 to 500 mm in diameter) of water distribution pipes were constructed from the Mataki’eua Reservoir to the city center by the project. In addition, in December 2019, 16 new wells were drilled, 13 wells were repaired, a 3,000 m^3 reservoir was constructed, and a 9.5 km transmission pipe was developed. Major facilities of the water supply have been almost completed.

Figure 2.6 shows the locations of water supply facilities served by TWB on Tongatapu Island. The current water supply system of the island consists of drawing of the water from the well field in Mataki’eua and pumping it to the reservoirs (8 reservoirs totaling approximately 7,800 m^3). After disinfection with chlorine, the water is distributed by gravity flow from the reservoirs to the city of Nukualofa and its surrounding areas.

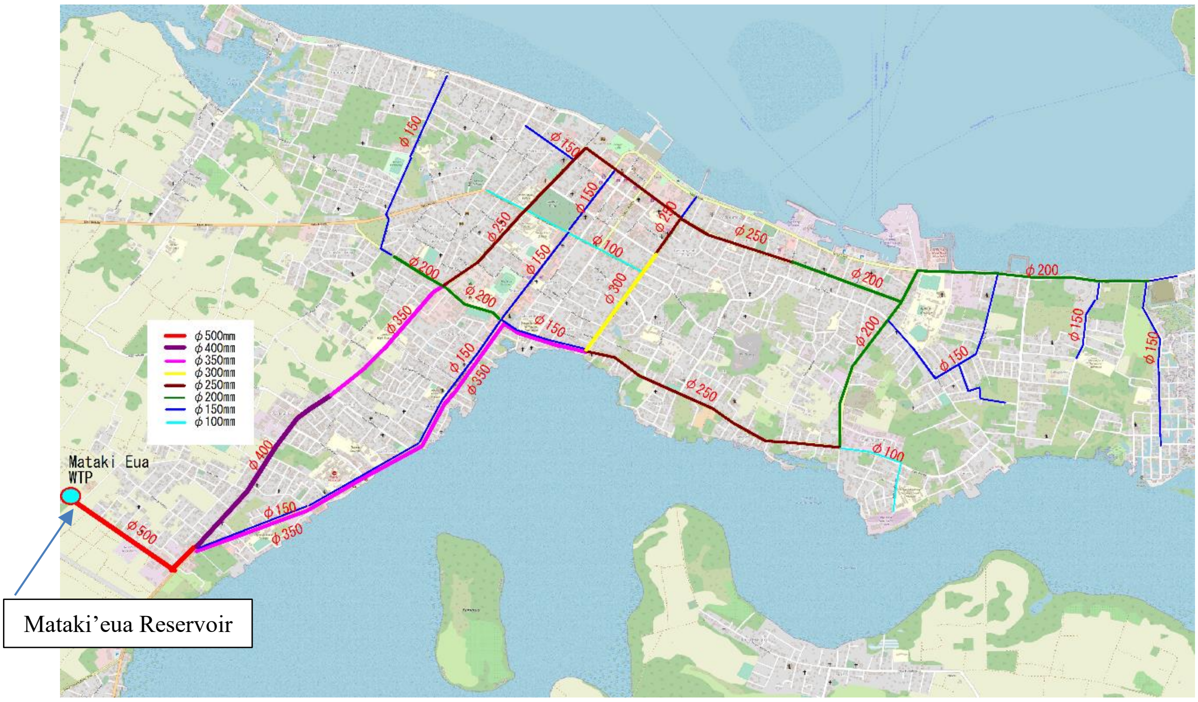


Figure 2.6 Location of Existing Water Supply Facilities on Tongatapu Island

In 2019 to March 2020, TWB completely replaced mechanical the water meters for each house with smart meters. The high degree of hardness of the tap water in Tonga has brought a breakage to the mechanical meters one after another due to the occurrence of scales caused by hardness contained such as calcium and they were replaced with the smart meter (Durable years of the smart meters is 15 years and its battery should be replaced every 5 years). Since the introduction of this smart meter increased the amount of revenue water and water tariff revenue, this successful case has been highly evaluated within TWB, and TWB plans to introduce it to the remote islands.

Photo 2.8 Conventional mechanical meter

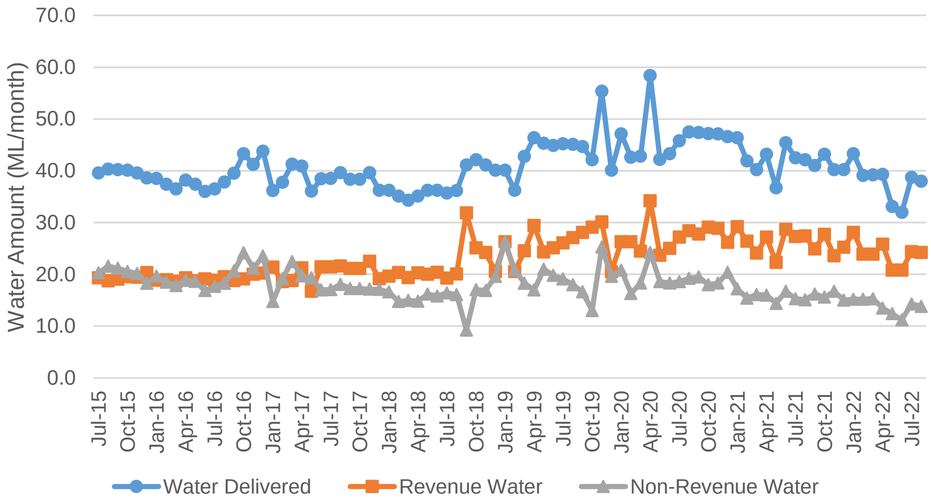
Photo 2.9 Newly Introduced Smart Meter

(2) Vava'u Island

1) Current status of water supply

Vava'u Island is a main island of the Vava'u Archipelago, located approximately 200 km north of Tongatapu Island, and is home to 14,182 people, about 14% of the total population of the entire country (Tonga Census of Population and Housing 2021). Neiafu, the center of Vava'u Island, is the second largest city in Tonga after the capital, Nuku'alofa, and is home to approximately 38 % of the population of Vava'u Island. Out of 2,723 households on Vava'u Island (Tonga Census of Population and Housing 2021) mainly in Neiafu, TWB has its water supply connections to 1,296 households (approximately 48 % for total households in Vava'u) as of 2021, of which 1,126 households (approximately 41 %) are provided with TWB's water service. Outside the water supply area of TWB, the water supply is operated by VWC as in Tongatapu.

Figure 2.7 and Table 2.9 show TWB's tap water supply performance on Vava'u Island. In the last seven (7) years, although there have been fluctuations in the amount of water produced and distributed, both figures have remained almost flat, while the amount of revenue water has increased slightly and the amount of NRW has been decreasing. One of the reasons why the amount of water produced and distributed had been increasing until the end of 2019 and decreased slightly after 2020 is that Vava'u Island is a world - famous port for yachts and a tourist place. Therefore, travel restrictions due to the COVID-19 may have caused such impact. The average daily water volume in 2021/22 was 1,621 m^3/day for the water produced, 1,302 m^3/day for the water distributed and 630 m^3/day for the revenue water, and about 37 % for the NRW rate.



Source: Survey team based on data provided by TWB

Figure 2.7 Water Supply Performance on Vava'u Island (FY2015/16 to FY2021/22)

Table 2.9 Water Supply Performance on Vava'u Island (FY2015/16 to FY2021/22)

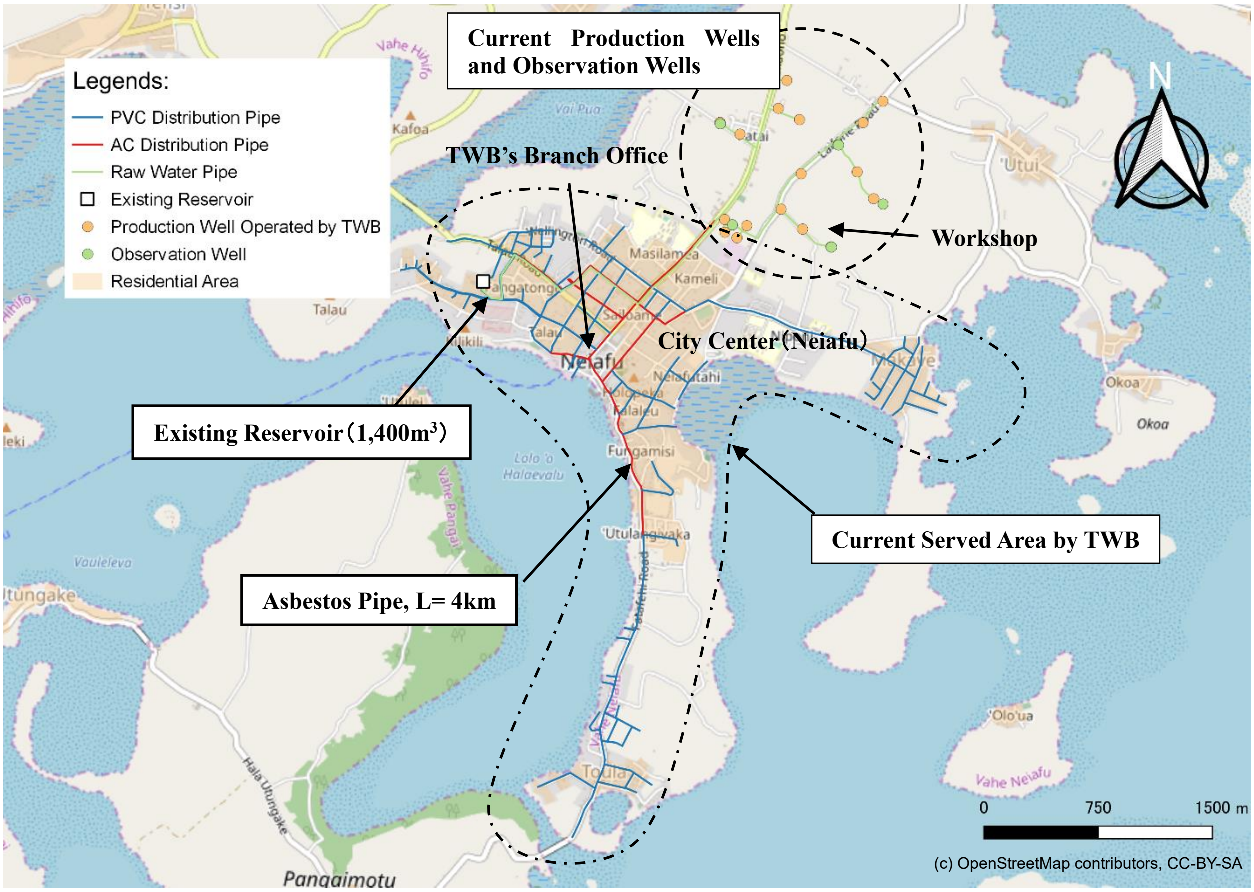
Year	Water Production (m^3/day)	Water Delivered (m^3/day)	Revenue Water (m^3/day)	Non-Revenue Water (m^3/day)	NRW Rate
FY15/16	1,638	1,267	630	636	50%
FY16/17	1,763	1,295	643	652	50%
FY17/18	1,987	1,216	677	540	44%
FY18/19	1,984	1,348	798	598	42%
FY19/20	2,113	1,504	879	625	41%
FY20/21	1,822	1,467	892	575	39%
FY21/22	1,621	1,302	820	484	37%

Source: Survey team based on data provided by TWB

2) Overview of water supply facilities

In the 1970s, the water supply service on Vava'u Island was commenced with drilling five (5) intake wells as water sources and development of the water distribution main of 1,000 m^3 and a reservoir of 1,000 m^3. However, these water supply facilities have not been renovated since then. Since 2000, the number of TWB's wells in operation has been gradually decreased due to the failure of the pumps and clogging of wells. In addition, and also approximately 4 km of asbestos pipes still remain in the distribution pipes in Neiafu City.

Figure 2.8 shows the water supply system on Vava'u Island consistinh of drawing the raw water from the wells in Neiafu City and pumping it to reservoirs (3 tanks of totaling approximately 1,400m^3 capacity), followed by the disinfection process and distribution by gravityflow to the city center of Neiafu and the surrounding areas.



Source: The final report "Project for Improvement of Water Supply System in Vava'u, the Kingdom of Tonga", 2019

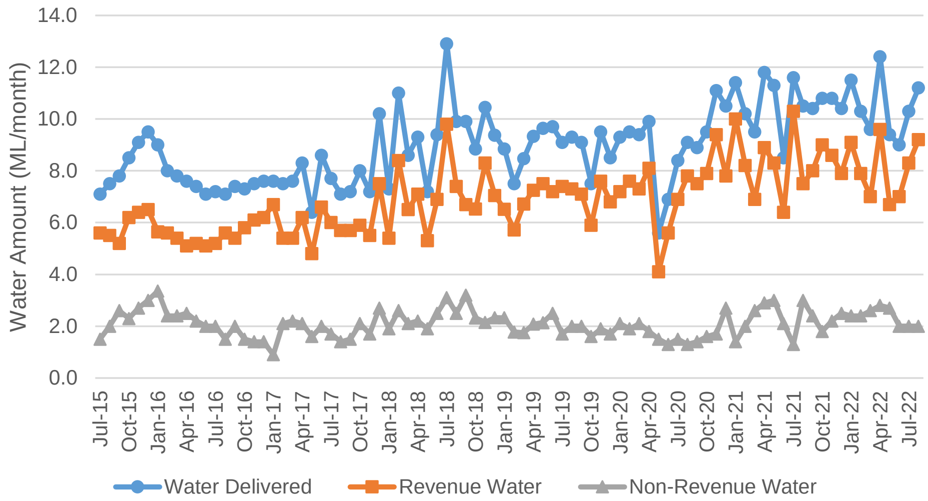
Figure 2.8 Location Map of Existing Water Supply Facilities on Vava'u Island

(3) Lifuka Island

1) Current status of water supply service

TWB supplies the water to the Pangai and Hihifo districts of Lifuka Island in the Ha'apai Islands. 4646 households or about 41 % of the total 1,136 households of the islands ate connected to the water supply service of TWB , of which 387 households (about 42%) are provided with its water service. Outside the water supply area of TWB, on one hand, the water supply is operated by VWC under the jurisdiction of MOH.

Figure 2.9 and Table 2.10 shows TWB 's water supply performance on Lifuka Island. In the last seven (7) years, the amount of water produced, water delivered and revenue water have increased, and the amount of water distributed has increased by about 31% from that of FY201/16 to FY2021/22. The amount of non-revenue water has maintained flat, while the NRW rate has decreased by about 8 % from 30 % in FY2015 /16 to 22 % in FY2021 /22. The average daily water volume in 2021/22 was 690 m ^{3}/day of water produced, 347 m^3/day of water distributed and 270 m^3/day of revenue water.



Source: Survey team based on data provided by TWB

Figure 2.9 Water Supply Performance on Lifuka Island (FY2015 /16 to FY2021 /22)

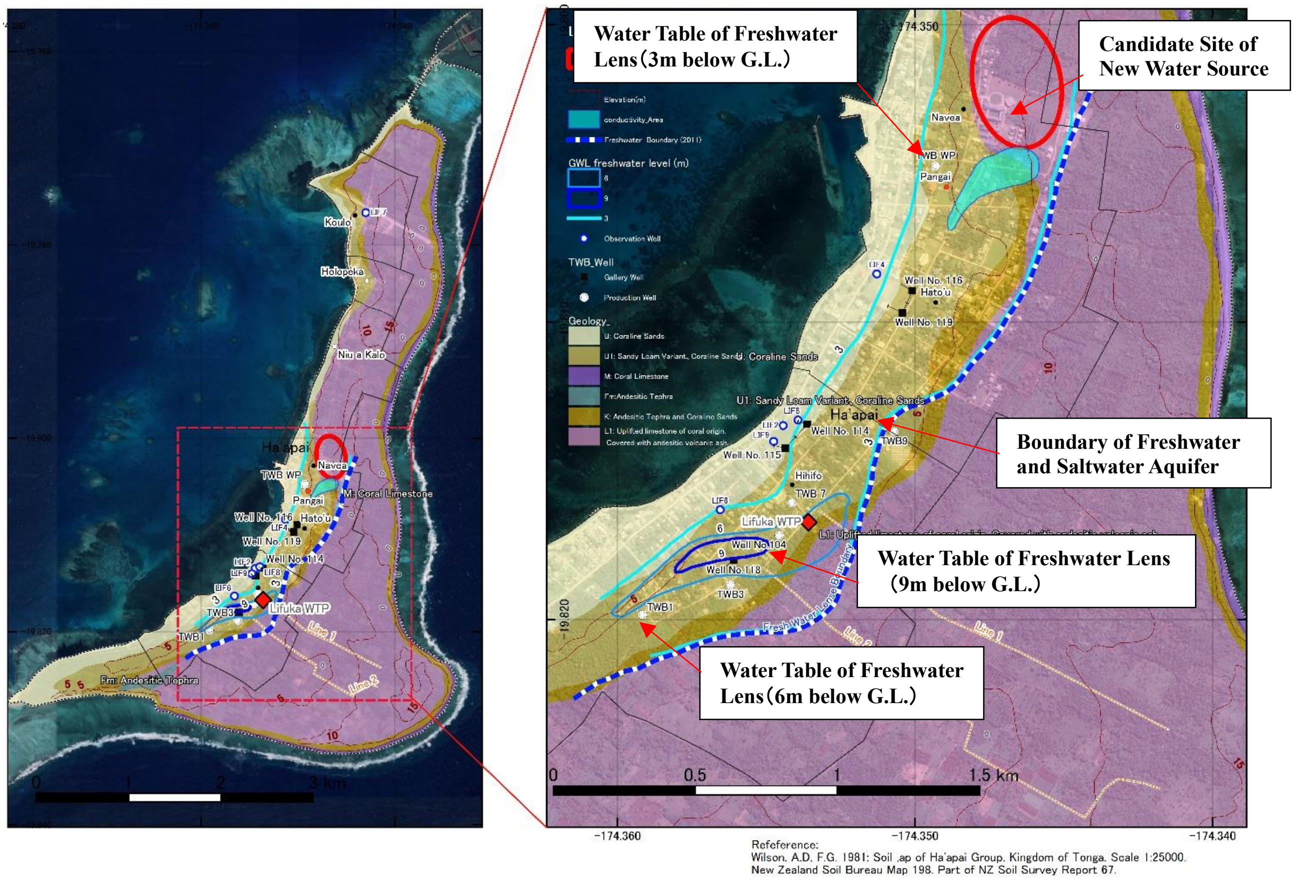
Table 2.10 Water Supply Performance on Lifuka Island (FY2015 /16 to FY2021 /22)

Year	Water Production (m^3/day)	Water Delivered (m^3/day)	Revenue Water (m^3/day)	Non-Revenue Water (m^3/day)	NRW Rate
FY15/16	520	264	185	79	30
FY16/17	552	247	190	57	23
FY17/18	581	275	208	67	24
FY18/19	813	315	237	77	25
FY19/20	685	284	225	59	21
FY20/21	570	329	263	66	20
FY21/22	690	347	270	77	22

Source: Survey team based on data provided by TWB

2) Overview of water supply facilities

Figure 2.10 shows the location of the existing water supply facilities on Lifuka Island. Lifuka Island's water source depends on a freshwater lens (groundwater) that is easily affected by the external environment. The drawn water at three (3) infiltration galleries and one (1) shallow well is pumped up to three (3) reservoirs in higher elevation (approximately 200 m^3 of total capacity) and followed by the chlorination process, pumping to the elevated tank installed within the premise of TWB Ha'apai branch office and the distribution to the city center by gravity. The distribution main was developed in 1996 and renewed to PVC pipes in 1999, and leakage has been progressed repeatedly for the twenty-three (23) years since then due to high water pressure and deterioration. Above TWB Ha'apai branch office also has a counter for collection water fee from the customers.



General Map of the Facilities — Enlarged Map of Details of the Facilities

Source: Prepared by survey team

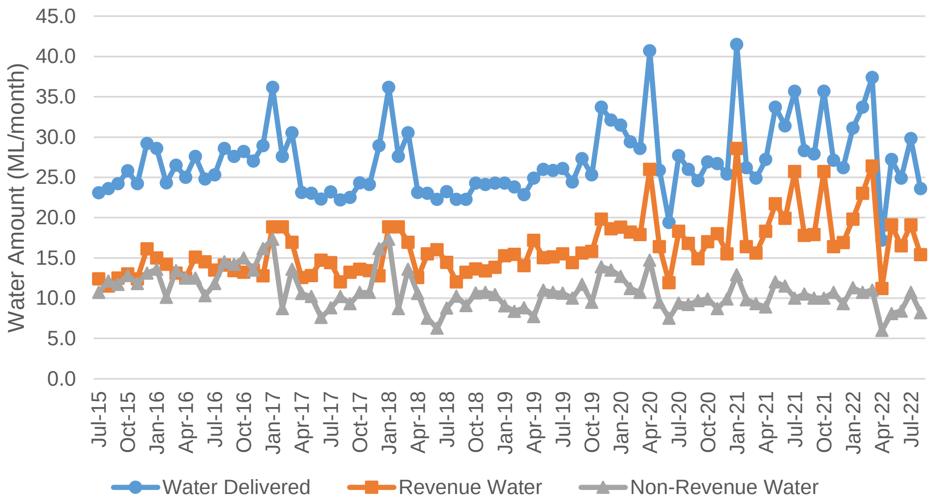
Figure 2.10 Location Map of Existing Water Supply Facilities on Lifuka Island

(4) Eua Island

1) Current status of water utilities

Eua Island is located south-west of Tongatapu Island where the capital Nukualofa is located, and is home to 4,903 people and 913 households (Tonga Census of Population and Housing 2021). As of 2021, 885 households (about 97% for the total households in entire Eua Island) were connected to TWB water supply, of which 777 (about 85%) were provided with its water services. The coverage rate of the TWB's water supply is the highest among the four islands.

TWB's water supply performance on Eua Island is shown in Figure 2.11 and Table 2.11. Over the last seven years, water production, water delivered and water received have increased slightly, with slight fluctuations, and water distribution has increased by approximately 15% from FY 2015/16 to FY 2021/22. Non-revenue water has decreased slightly with about 14% as a NRW rate from 47% in 2015/16 to 33% in 2021/22.The average daily water consumption in 2021/22 was 1,162 m^3/day for the produced water, 965 m^3/day for the distributed and 648 m^3/day for revenue water.



Source: Survey team based on data provided by TWB

Figure 2.11 Water Supply Performance on Eua Island (FY2015/16 to FY2021/22)

Table 2.11 Water Supply Performance on Eua Island (FY2015/16 to FY2021/22)

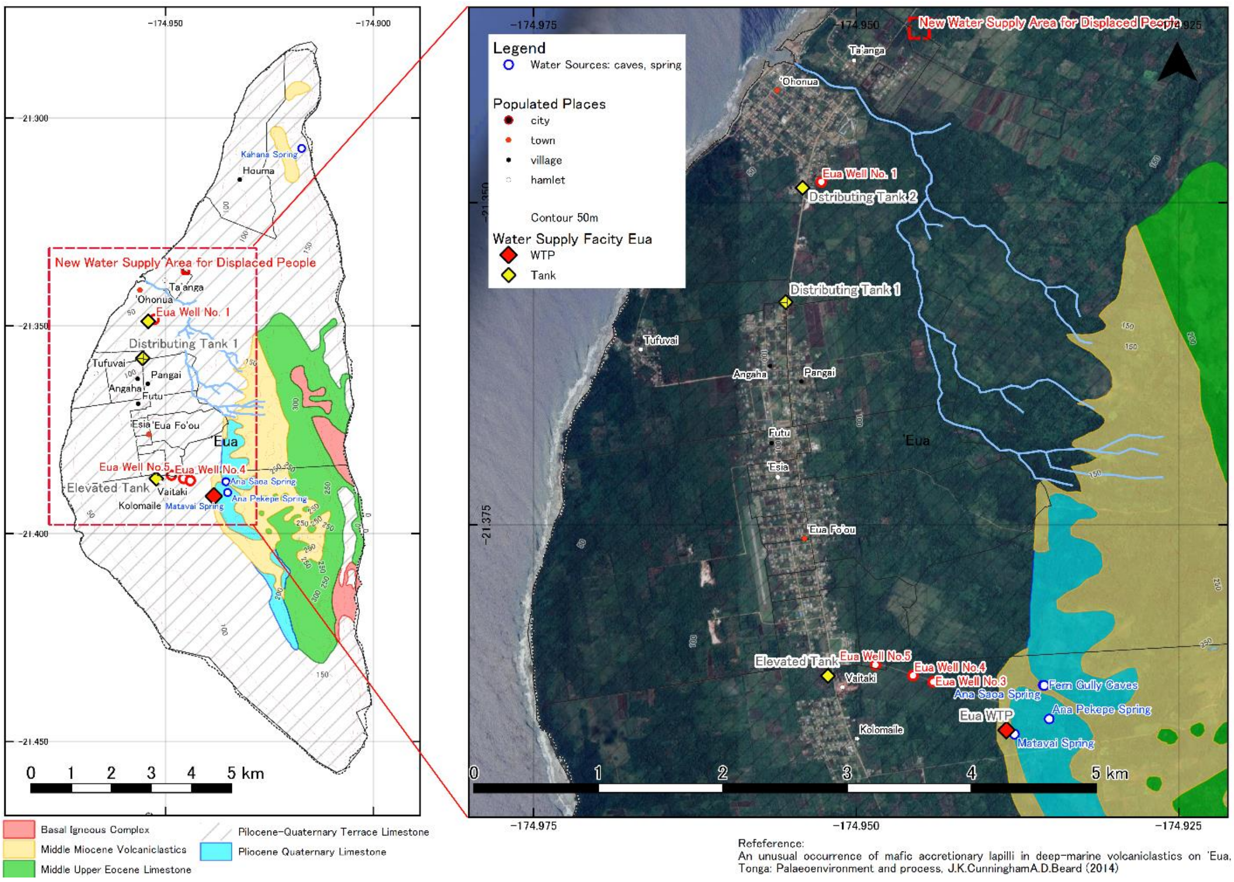
Year	Water Production (m^3/day)	Water Delivered (m^3/day)	Revenue Water (m^3/day)	Non-Revenue Water (m^3 /day)	NRW Rate
FY 15/16.	1,113	841	445	396	47.
FY 16/17.	1,227	900	480	420	46
FY17/18	1,237	844	488	356	42
FY18/19	1,155	789	473	317	40
FY19/20	1,241	944	572	371	39.
FY20/21	1,123	938	605	332	36
FY21/22	1,162	965	648	318	33

Source: Survey team based on data provided by TWB

2) Overview of water supply facilities

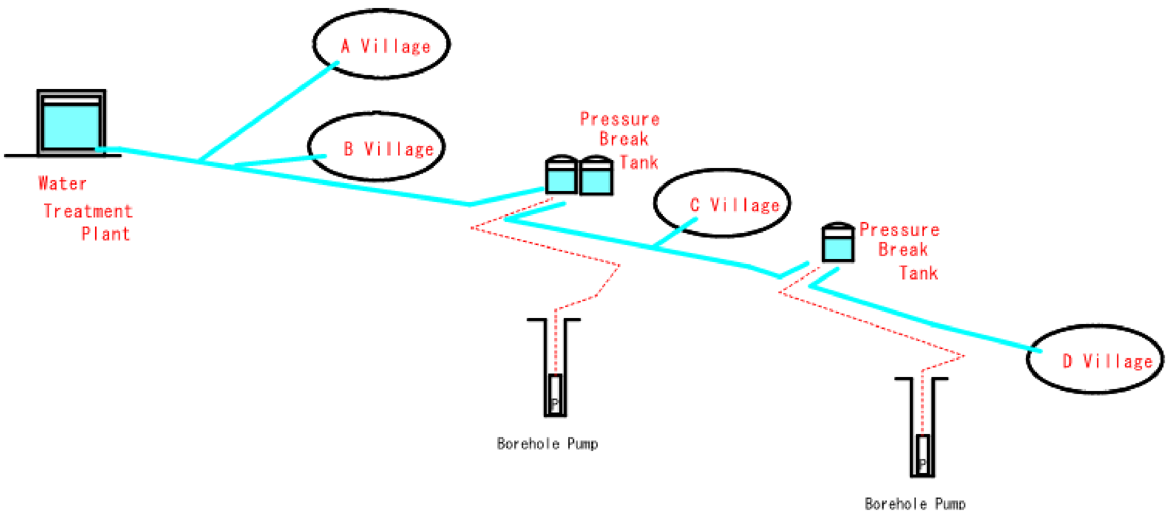
Figure 2.12 shows the location of existing water supply facilities on Eua Island. Eua Island's water supply consists of four (4) surface water sources (3 springs in Matavai, Pekepeka, Saoa cave and 1 Fern gully) and five (5) wells (three in Matavai and two in Ohonua). The surface water has a good quality as 5 NTU as turbidity in dry seasons, while it frequently exceeds 200 NTU at rainfall in the rainy season and TWB developed only one (1) water treatment plant on Eua Island out of the TWB's water supply facilities nationwide. The water treatment plant was developed with New Zealand funding under the Eua Water Supply Upgrade Project (EWSUP) from 2006 to 2008. The facility consists of a traditional sedimentation basin, membrane filtration, chlorine dosing system and a clear water reservoir (536 m^3 capacity). Piping from the water source and distribution pipes within the island were also developed by the fund. Water treatment process is carried out only during rainy season, while during dry season only chlorination is carried out via a bypass pipe. However, the water treatment system did not perform as the expected for the raw water of high turbidity that flowed into the water treatment plant after heavy rainfall during the rainy season immediately after the launching of the operation, and an additional rapid filtration equipment was installed around 2014. That rapid filtration equipment is currently also malfunction, and high turbidity water at the rainy season is distributed via a bypass pipe after the chlorination process.

As mentioned above, the surface water source becomes highly turbid during heavy rainfall in the rainy season, so three (3) intake wells in Matavai are also used combined with the surface water during the wet season. At the time of the field survey in August 2022, one of the well pumps failed and had been removed. The two (2) intake wells at Ohonua are operated supplementally only during the dry season when the water volume of the surface water sources is reduced, and once pumped to a pressure reducing tank, the water mixed with surface water is distributed by gravity.



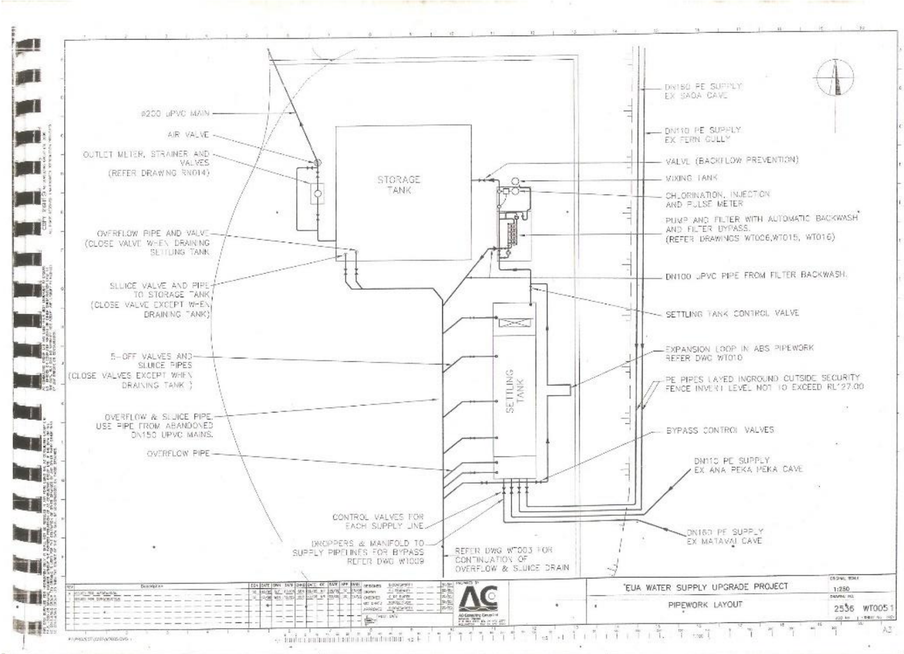
Source: Prepared by survey team

Figure 2.12 Location Map of Existing Water Supply Facilities on Eua Island



Source: Prepared by survey team

Figure 2.13 Schematic Diagram of Water Distribution System on Eua Island



Source: EWSUP drawings received from TWB

Figure 2.14 Plan of Existing Water Treatment Plant on Eua Island

2.2.5 Issues in water supply (target areas)

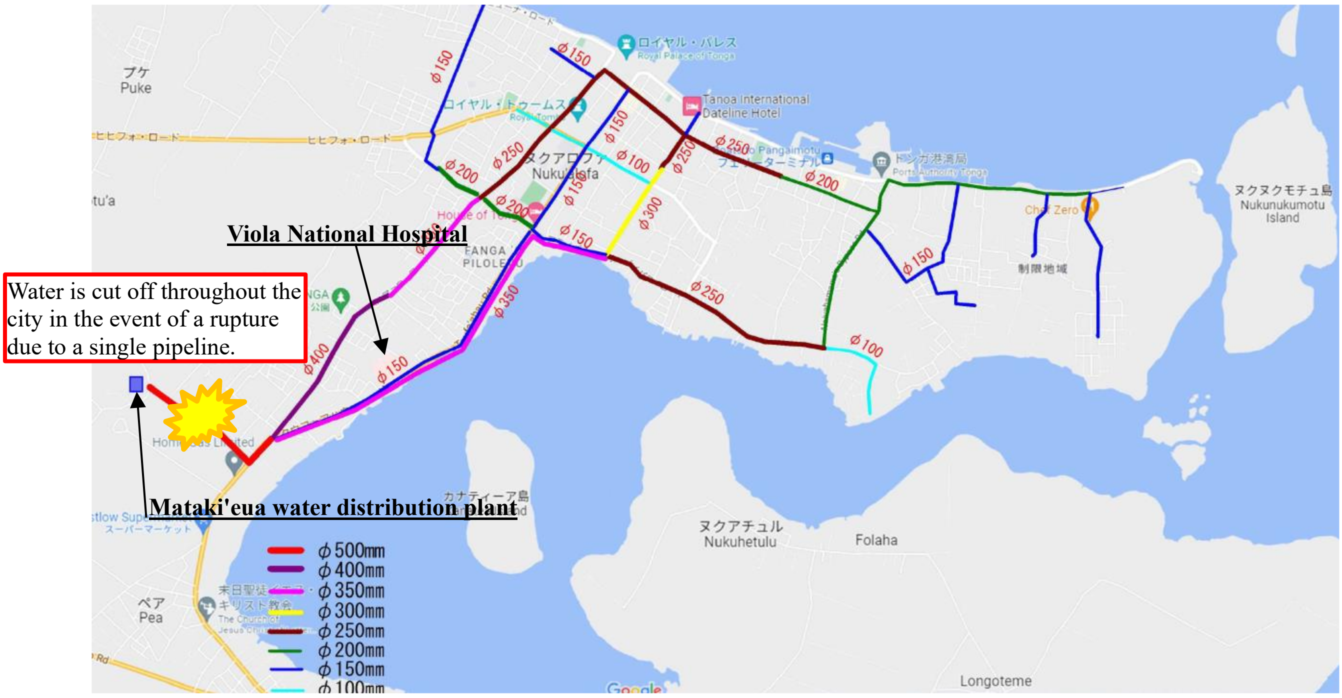
(1) Tongatapu Island

1) Vulnerability of water supply systems to natural disasters.

A submarine volcanic eruption on 15 January 2022 caused a power outage across entire Tongatapu Island. TWB's water supply service was not affected by the disaster because of their own installed emergency generator. In the surrounding village of VWC's water supply areas, however, the intake pumps stopped due to the power outage and the residents rushed to the TWB's Mataki'eua water distribution station for seeking the TWB's water. The residents living on the border between the TWB and VWC's water supply areas heard the complaints that water was available on the other side of the road (within TWB service area) but not on this side (inside the VWC supply area).

As shown in Figure 2.15, the water distribution main (500 mm diameter) from the Mataki'eua water distribution plant is partly a single line, and if this pipe were to break during a disaster, the entire city of Nukualofa would be potentially vulnerable to a water outage. If the water supply were to be cut off, it would be impossible to supply the water to the Vaiola National Hospital, the largest hospital on Tongatapu Island, which could bring an obstacle to the medical activities in an event of disasters. Furthermore, as an island country, Tonga has to import all pipe materials. Import of large-diameter pipes requires a long period of time for its procurement process from an order placement, fabrication to actual importation, and in the chaotic situation during a disaster, it is expected to take more time to transport materials, which may result in a long-term water supply outage.

As mentioned above, the area near Nuku'alofa on Tongatapu Island is highly dependent on TWB's water services, and from a crisis management perspective, the challenge to such risk is to make the entire water system redundant and resilient against large-scale natural disasters.



Source: Prepared by survey team

Figure 2.15 Potential Issues on Current Water Distribution Network

2) Vulnerability of water supply services in rural areas

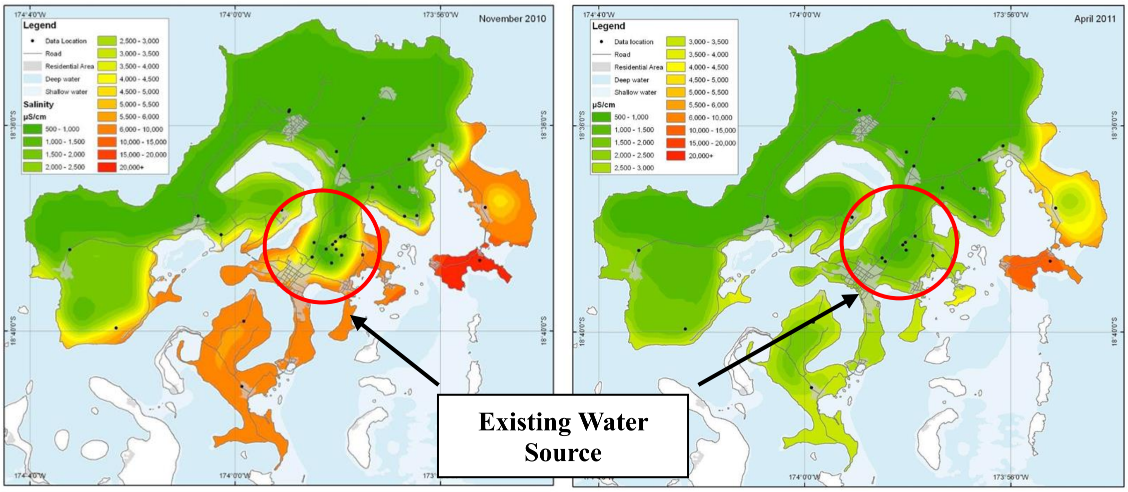
As mentioned above, the village water supply by VWCs has multiple problems such as vulnerability to natural disasters and climate change, lack of capacity to operate and maintain water supply facilities, and risks of water source contamination and waterborne diseases. In this sense, the VWC water supply is desirable to be integrated into TWB water services as much as possible from the viewpoint of stable supply of safe water. On the other hand, TWB has indicated its intention to gradually integrate the villages near its current TWB's water supply area, thus securing a fund and other resources for the expansion of TWB's pipe network is required. Implementation of activities to promote TWB's safe water to the village residents will need 1) the consideration of their potential awareness that tends to prefer lower water charge of the VWC's water supply and use of the rainwater compared to TWB's water and 2) their consensus building for the integration of TWB's water.

Photo 2.10 Water Supply Facilities in Peah Village

(2) Vava'u Island

1) Sea water intrusion to existing water sources

The existing groundwater sources of TWB on Vava'u Island have an urgent issue of taking a measure toward its heavy tendency toward sea water intrusion. Figure 2.16 indicates the significant difference of EC values on Vava'u Island between its dry and rainy seasons. Table 2.12 shows the relationship between the type of raw water and EC value (degree of salinity). In the rainy season on Vava'u Island, the EC ranges 500 to 3,000 µS/cm, which sometimes exceeds the WHO's threshold limit for 'potable raw water (1,500 µS/cm)', while in the dry season the EC exceeds its limit for 'non-potable raw water (2,500 µS/cm)' for by over 5,000 µS/cm.



Dry season (November 2010) **Rainy season (April 2011)**

Source: Survey team, based on 'Neiafu Groundwater Resources Assessment and Sustainable Management Report, Nicola Fry and Tony Falkland, December 2011'.

Note: Green color indicates low salinity (electrical conductivity) (500-3,000 µS/cm), orange to red color indicates high salinity (electrical conductivity) (>5,000 µS/cm).

Figure 2.16 Salinity Level of Existing Water Sources at Dry Season and after Wet Season

Table 2.12 Relationship between Raw Water type and Electrical Conductivity (Salinity)

Type of Raw Water	Electrical Conductivity: EC (µS/cm)	Remarks.
Rainwater	50 -100	
Groundwater with high desalination levels	250 - 500	
Normal groundwater	500 - 1,500	
Raw water for drinking (Threshold limit)	**1,500**	**Equivalent to WHO's threshold chloride concentration (250 mg/l)for drinking raw water**
Raw water for non-potable use (Threshold limit)	**2,500**	**Water quality limits for bathing and washing**
Brackish water with low salinity	2,500 - 5,000	
Brackish water with high salinity	10,000 - 50,000	
Sea water	50,000 - 55,000	

Source: Survey team, from Neiafu Groundwater Resources Assessment and Sustainable Management Report, Nicola Fry and Tony Falkland, December 2011.

In addition, as mentioned above, the increased risk of seawater intrusion into the existing freshwater lenses need to take a measure since it has been affected by the recent climate change, sea level rise due to global warming, the tsunami because of the country's geographical location in the Pacific Rim earthquake zone and the increased frequency of El Niño events.

2) Remaining asbestos pipes

The current NRW rate on Vava'u Island's water supply system is 40% to 50% that has been caused mainly by the leakage from ageing distribution pipes. In particular, replacement of the remaining deteriorated asbestos main of approximately 4 km extension in Neiafu is urgently required (Figure 2.17).

Asbestos pipes have been widely used as water pipes in the past due to their easy installation and low cost, while they are characterized by weak strength and a higher failure rate compared to other pipe types, and need to be renewed in terms of leakage prevention and durability

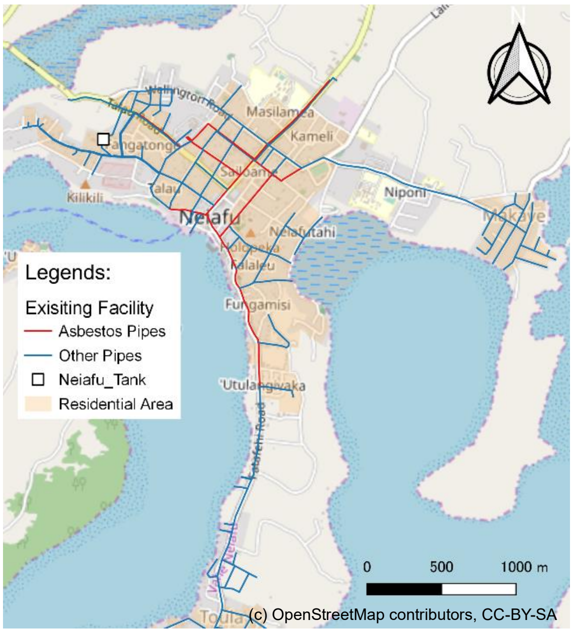


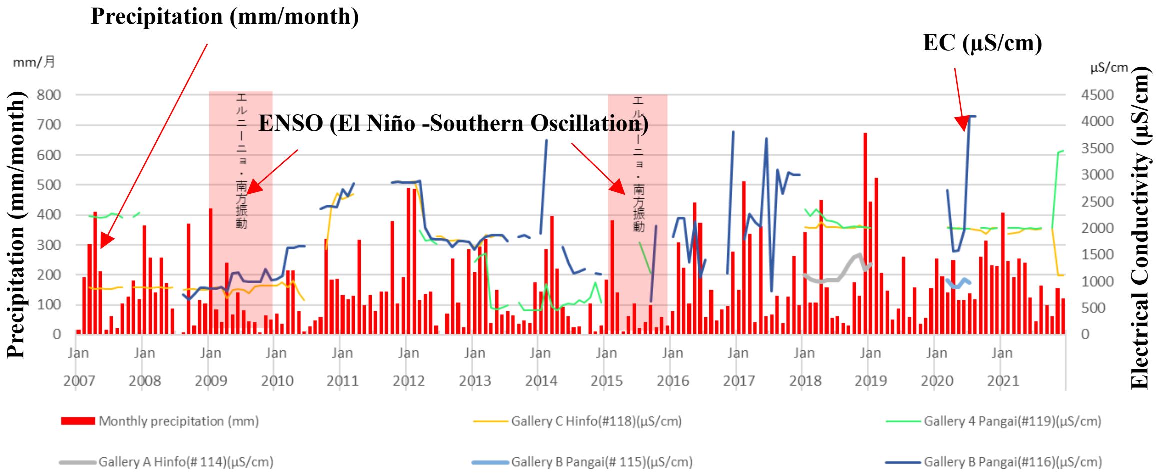
Figure 2.17 Location of Buried Asbestos Pipes

Source: Project for Improvement of Water Supply System in Vava'u, the Kingdom of Tonga, 2019

(3) Lifuka Island

1) Salination of existing water sources

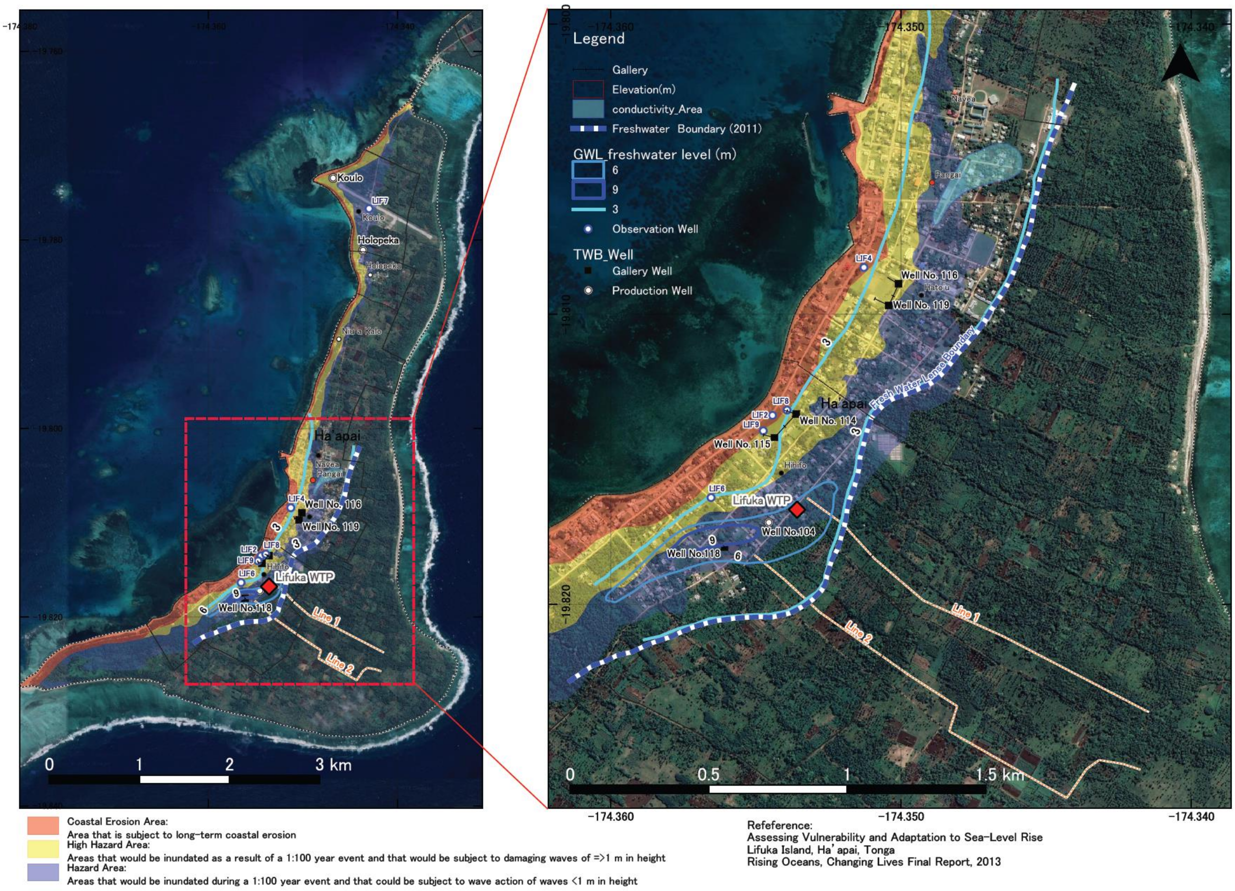
Figure 2.18 shows that the extreme decrease in precipitation reduced the groundwater recharge and increased EC values in the years when El Niño occurred during the period of the event and for several months afterwards from the meteorological data from 2007 to 2021, resulting in salination of the freshwater lens. Urgent measure is needed to be taken against the reduction of groundwater resources during such low precipitation events under the recent tendency that the risk of the weather events such as extremely low and high precipitation has increased potentially due to the effects of global climate change.
The survey team measured the actual EC values of the existing water source and found that the samples from the two of three infiltration galleries exceeded 1,500 µS/cm of WHO's threshold limit for drinking water and the water in the reservoirs had the same results.



Source: Prepared by survey team

Figure 2.18 Annual Fluctuation of Precipitation and EC of Water Sources on Lifuka Island

In addition, the IPCC Sixth Assessment Report (2021) predicts that sea level in Tonga will rise by 0.28 to 1.01 m by 2100 due to long-term climate change effects. Furthermore, the risk of storm surge damage is increasing more than ever due to the intensification of cyclones and other factors. These sea level rise and storm surges are likely to lead to salination and shrinkage of the freshwater lens and damage to existing water supply facilities. The electromagnetic surveys (EM34) conducted in the 1990's provides the clear findings that the freshwater lens on Lifuka Island was unevenly distributed along the western coast with no promising freshwater groundwater on the eastern side, which indicates that development of new water sources can only be expected to a limited extent. As shown in Figure 2.19, the water source have potential risk of seawater intrusion into the freshwater lens and its shrinkage due to rising tides even in the galleries and observation wells close to the west coast, thus measures against such risk are required to be taken.



Source: Assessing Vulnerability and Adaptation to Sea-Level Rise, Lifuka Island, Ha'apai, Tonga (2013).

Figure 2.19 Areas at Risk of Coastal Erosion and Storm Surge in Medium to Long Term

(4) Eua Island

1) Treatment of high turbidity raw water during wet season.

Historical development of water treatment plant on Eua Island.

Eua island is the only area where TWB has a water supply system to intake the surface water as its source. The water quality is good during dry season with its turbidity less than 5 NTU, however, during rainy season it become high with its value exceeding 200 NTU. Therefore, only WTP (water treatment plant) in TWB was developed for treatment of the high turbidity, which was funded by New Zealand under the Eua Water Supply Upgrade Project (EWSUP) in 2006 to 2008. The WTP consists of ordinary sedimentation basin, membrane filtration unit, chlorine dosing unit and a clear water reservoir. Piping from the water source and distribution pipes within the island were also developed by the project. The water treatment by the whole process was carried out only at rainy seasons, while only chlorination was carried out during the dry seasons via a bypass pipe.

However, the treatment system did not perform as expected function just after the commencement of the operation for the raw water of high turbidity after the heavy rainfall during the rainy season that flowed into the plant, and an additional rapid filtration unit was introduced around 2014. The rapid filtration equipment that was installed is currently out of order, and high-turbidity water at the rainy season is distributed directly via a bypass pipe even after chlorination.

Survey by JICA senior volunteers.

JICA senior volunteers conducted a survey of the water supply facilities on Eua Island between 2012 and 2014 after the construction of the WTP on Eua Island. The report notes that the raw water entering the WTP after rainfall was cloudy and remained turbid even after the filtration through 5 µm filter paper. The turbidity of the raw water was considered to be a colloidal substance that could not sediment by gravity.

The report also notes that the membrane filtration unit used a 20 µm disc-type filter manufactured by Aqua Source, France, and that the filter is normally used as a pre-filter for membrane filtration units and does not completely remove turbidity. The membrane filtration unit could hardly produce purified water as cleaning was repeated every 10 minutes or less due to membrane blockages caused by turbidity, and the operation of the membrane filtration unit had to be shut down.

High turbid raw water after rainfall (sedimentation tank receiving chamber)

Membrane filtration system introduced.

Membrane units used.

Treated water with no change in turbidity (left: raw water before filtration; right: treated water after filtration)

Source: JICA Senior Volunteer Report Oct.2012.

Photo 2.11 Treatment of High Turbid Raw Water using Membrane Filtration System installed

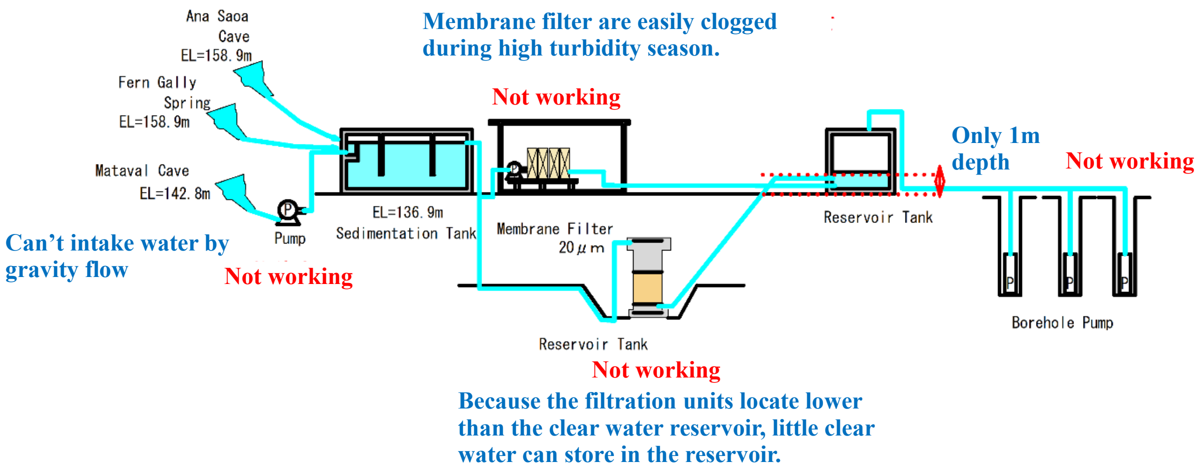
2) Facility design not taking advantage of effective head by elevation differences

The WTP on Eua Island takes in its raw water from four (4) surface water sources (Matavai, Pekapeka, Saoa Caves and Fern gully) and three (3) wells. The water from Pekapeka, Saoa caves and Fern gully can be conveyed by gravity flow to the sedimentation tank in the WTP, while the water from Matavai Cave is needed to be pumped up to the sedimentation tank. Currently, that pump is out of order, and the water is not taken from Matavai Cave. On the other hand, Matavai Cave has a largest potential capacity of the intake water out of the three (3) surface water sources, which becomes a big challenge for its facility design that the water from Matavai Cave cannot be flown by gravity.

In addition, the rapid filtration unit mentioned above is located at lower elevation than that of the sedimentation tank and water reservoir, and the water can be stored up to only 1m above the water level of the reservoir when the rapid filtration unit is in use, of which system is not enough to cover the peak water supply volume. The existing treatment system that the rapid filtration is installed at the lower elevation than that of the reservoir can be a possible design flaw.

Sedimentation basin and rapid sand filter shot from the top crest of the water clear reservoir.

Enlarged Photo
Rapid filtration units are located below the ground level of the WTP.

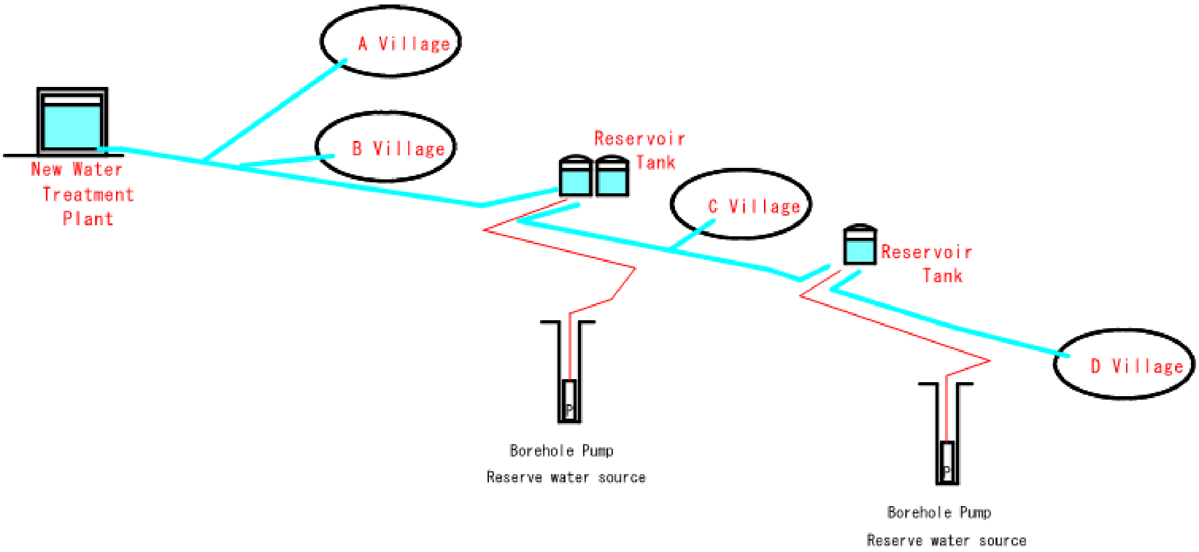


Source: Prepared by survey team

Figure 2.20 Schematic Diagram of Current Problems with WTP in Eua' Island

3) Energy inefficient water distribution systems

Figure 2.21 shoes the water distribution system by the elevation difference of each facility on Eua Island. The head of the elevation difference of approximately 120 m between the WTP in Matavai district and the downstream water supply area has to be decreased stepwise in two pressure reducing tanks on the way for distribution by gravity flow to the downstream supply areas. Two (2) intake wells in Ohonua are operated supplementally only during the dry seasons when the amount of the water intake from surface water sources is low, and the water is pumped up once into the pressure reducing tanks and mixed with surface water for gravity flow distribution, which is not energy efficient. A possible full use of the water of Matavai cave mentioned above will not need the pump-up of the groundwater at the two wells in Ohonua, which is recommended to be examined for change of the original design.



Source: Prepared by survey team

Figure 2.21 Schematic Diagram of Water Distribution System on Eua Island

4) Renewal of asbestos pipes

Approximately 1 km of asbestos pipe remains in the water pipe from the Ohonua intake well, which needs to be renewed in terms of prevention of water leakage and raising of durability.

2.2.6 Others

(1) Climate Change

Tonga has been hit by a variety of natural disasters such as earthquakes, volcanic eruptions and cyclones, and the country has faced a new threat of climate change in recent years.

The climate change has caused plenty of threats to the country, including intense winds and storm surges associated with cyclones, sea level rise, extremely heavuy rainfall and drought due to the change of precipitation patterns, and rising air and sea surface temperature.

The maximum temperature in Tonga has increased by 0.1° C per decade, consistent with the trend of the global warming. In addition, the data since 1950 provides a continuous descending trend in rainfall at the rainy season on Tongatapu Island.

The sea level of the country has risen by about 6 mm since 1993, which is larger than the increase rate compared to the global annual average of 2.8 mm to 3.6 mm. The sea level is expected to rise by 3 to 17 cm by 2030.

The Tongan Government has also focused on combating the climate change, as Prime Minister Akilisi Pohiva spoke it as a biggest threat to livelihoods, security and well-being and the need to maintain the temperature rise below 1.5° C at the World Meteorological Organization meeting held in Tonga in October

2018.

(2) Damages by Past Cyclones

In addition to the natural environment around Tonga, which is prone to the occurrence and development of cyclones due to its geographical conditions, cyclones of enormous size and strong force has increased due to the effects of climate change, and cyclone-induced storm surges and tsunamis has also been increasing.
In January 2014, Cyclone Ian caused significant damage to the Ha'apai Islands and in February 2016, another Cyclone Winston also caused a damage to the Vava'u Islands.
Furthermore, in February 2018, the largest cyclone in the history of Tonga, Gita, hit Tongatapu Island, causing devastating damage.
The cyclones classified as Category 5 that have hit Tonga in the past are shown in Table 2.13.

Table 2.13 Cyclones in Tonga (Category 5)

Name	Date / Year of Hit	Central Pressure (hPa)	Maximum Instantaneous Wind Speed	Areas Damaged
Cyclone Ron	1998 Jan.	900	270 km/h (75.0 m/s)	Tongatapu Island
Cyclone Heta	Dec 2003.	915	260 km/h (72.2 m/s)	Tongatapu Island
Cyclone Ian	2014 Jan.	930	285 km/h (79.2 m/s)	Ha'apai Island
Cyclone Winston	2016 Feb.	884	285 km/h (79.2 m/s)	Vava'u Island
Cyclone Gita	2018 Feb.	927	230 km/h (63.8 m/s)	Tongatapu Island, Eua Island.

Source: Survey team

2.3 Relevant Plans

2.3.1 Outline of National Development Plan

In its work on the Sustainable Development Goals (SDGs), Tonga reviewed their goals based on the "TONGA STRATEGIC DEVELOPMENT FRAMEWORK (TSDF I) 2011 - 2014 in 2015" and formulated the "TONGA STRATEGIC DEVELOPMENT FRAMEWORK (TSDF II) 2015-2025 ~A more progressive TONGA" as revised frameworks, setting Key Performance Indicators (KPIs) for short, medium and long-term targets and promoting comprehensive and inclusive sustainable development to promote comprehensive and inclusive sustainable development.
In order to realize the above development plan, a national infrastructure development plan, the National Infrastructure Investment Plan 2013 to 2023, was formulated and priority projects were proposed for each sector. Among these, two (2) development projects in the water sector were proposed, namely, the "Expand Nulu'alofa system to growth areas as an initiative to extend water supply to urbanized areas on Tongatapu Island", and another "Outer islands water supply improvement project as an initiative to improve water supply to the outlying islands."
In addition, the Pacific Islands Forum (PIF) has developed the Pacific Regionalism Framework toward formulation of development plan for pacific island countries with the regional goals of sustainable development, economic growth, enhanced governance and security as key objectives.

The government of Tonga updated the "Tonga Strategic Development Framework (TSDF I) 2011 - 2014" and established "Tonga Strategic Development Framework (TSDF II) 2015-2025 - a more progressive

TONGA", which tackles a development plan toward promoting comprehensive and sustainable development with setting Key Performance Indicators (KPIs) for short, mid and long-term targets.
To put the development plans into execution, "National Infrastructure Investment Plan 2013 to 2023" was also formulated, in which the priority projects were proposed by each sector. With regard to the water sector, in this investment plan, two development projects, "Expand Nulu'alofa system to growth areas" as an initiative to extend water supply to the urbanized areas on Tongatapu Island and "Outer Islands Water Supply Improvement Project Plan" as an initiative to improve water supply to the outer remote islands, were proposed.
Furthermore, a development plan named "Pacific Plan" toward sustainable development, economic growth, enhancement of governance and security was established as pacific regionalism framework in PIF (Pacific Islands Forum).

Above national development plan in Tonga is listed in Table 2.14.

Table 2.14 National Development Plans in Tonga

Year	Development plans, etc.
2011	TONGA STRATEGIC DEVELOPMENT FRAMEWORK (TSDF I) 2011 - 2014
2013	National Infrastructure Investment Plan 2013 to 2023
2015	TONGA STRATEGIC DEVELOPMENT FRAMEWORK (TSDF II) 2015-2025 ~A more progressive TONGA

Source: Survey team

2.3.2 Upper Level Plans and Relevant Plans for the Project

In 1992, the TWB formulated "Tonga Water Supply Master Plan" which set out the future direction of Tonga's water supply. However, the master plan has not been updated or revised since then. On the other hand, TWB also formulated "Outer Islands Water Supply Improvement Project Plan" in 2012 which outlines the direction for redevelopment of the water supply facilities on the remote islands to launch redevelopment of water supply facilities on the remote islands where the development of the water supply facility is behind compared to those of Tongatapu Island.
As for upper level plans, "Investment Proposals Tonga Water Board" that was formulated in 2016 with the support of PRIF (Pacific Region Infrastructure Facility), proposes the following two (2) investment plans in relation to the water supply sector .

a) Improvement of TWB's water supply operations, including asset management and groundwater source management toward improved water quality, reduced NRW (Non-Revenue Water), water tariff review and improved meter reading and billing method (Investment Proposal 1)
b) Expansion of TWB's water supply area to include parts of the rural areas of Tongatapu Island and remote islands areas (Investment proposal 2).

TWB also developed "Tonga Water Board Business Plan 2022-2027", which proposes the investment plans in the water supply facilities for the next five (5) years.
In addition to above plans related to the water supply sector, the Government of Tonga developed the "HungaHunga-Tonga-Hunga-Ha'apai Volcanic Eruption and Tonga Tsunami (HTHH Disaster) Recovery and Resilience Building Plan 2022 – 2025" with the support from development partners, which guides the

recovery and restoration plan for the damage caused by the HTHH volcano eruption and tsunami on January 15, 2022. The plan covers all sectors with total budget of at least USD 24 billion where recovery and rehabilitation efforts are required. The plan also identifies four (4) priority areas of housing rehabilitation, food security and livelihoods, tourism and public infrastructure, of which public infrastructure includes the expenditure on "Water supply including tanks, pipes, and water channels" in the water supply sector. However, the breakdown of the cost estimate of the investment proposal is not provided clearly.

2.3.3 Urgency and Priority of the Project

(1) Urgency of Recipient Counterparty for Implementation of Projects

The water supply facilities in Tonga, particularly the environment of the water source, are vulnerable to natural disasters such as sea level rise, cyclones and volcanic eruption which have been caused potentially by recent climate change, and the freshwater lens of the main water source is in danger of being salinated. In addition, existing water supply facilities, which were developed with financial and technical assistance from foreign donors, are deteriorating as identified in the broken pipes, pumps, chlorine dosing equipment and water meters. In addition, once in an event of giant-scale disaster as seen in the HTHH volcano eruption and subsequent tsunami, it is necessary to maintain the livelihood of the residents by providing emergency water supply. Furthermore, the recent global pandemic of COVID-19 has provided a lesson that clean water supplies are essential, e.g. for hand washing from the guidance of WHO/UNICEF of "Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19" in 2020. Based on this background, TWB needs to develop water supply facilities that are hygienically safe and provide a stable supply. In this sense, water supply facilities in Tonga need to be urgently developed.

(2) Priority to Development to Water Supply Sector

The "Tonga National Infrastructure Investment Plan 2021 to 2030" that was prepared by the Government of Tonga in 2021, places infrastructure projects investment in the country's water supply sector as a high priority as shown in Table 2.15 among the top ten projects through assessment from multiple perspectives - social, political, technical and natural environment - based on the country's development strategy.

Table 2.15 List of Infrastructure Projects with High Priority in Tonga

No.	Project.	sector	Score*1
1	Nuku'alofa Power Network Upgrade Project (NNUP) Area 3, 4 and 5	Energy	91.1
2	Centralized Tonga Water Board and Village Water Supply Tongatapu	Water Supply	91.1
3	Additional/Replacement Generators (Tongatapu, Vava'u, Ha'apai, 'Eua)	Energy	91.1
4	Multi-Hazard Early Warning/Emergency Operations Centre (Niuas)	Disaster Prevention	88.9
5	Convert dump sites to new structured landfill, Ha'apai & 'Eua	Solid Waste Management	88.9
6	Improved Water Supply System in Vava'u (Greater Neiafu)	Water Supply	88.9
7	New international secondary / redundancy internet cable	Information and Communication	84.4
8	Improved ʻEua Water Supply System	Water Supply	84.4
9	Upgrade and Expansion ʻEua Mobile and Fixed Networks	Information and Communication	84.4
10	Upgrade Touliki coastal protection structure	Coastal Protection	84.4

Source: Tonga National Infrastructure Investment Plan 2021 to 2030.

Note: 1*: Assessment based on Multi Criteria Assessment (MCA), http://www.ejolt.org/2015/02/multi-criteria-assessment-mca/

2.3.4 Comparison of Multiple Candidate Projects

(1) 1st Screening for Candidate Projects

The challenges with high need to be addressed by TWB is summarized as below based on Section 2.2 aforementioned above with regard to the issues in the water sector in Tonga.

Common issues to all islands

(i) Improvement of water quantity management
(ii) Improvement of water quality management
(iii) Reinforcement of emergency recovery in an event of disasters
(iv) Reinforcement of emergency water supply in an event of disasters

Tongatapu Island

(i) Resilience of water supply systems against natural disasters
(ii) Integration of village water supply areas into TWB water network

Vava'u Island

(i) Measures against the sea water intrusion into the water sources
(ii) Replacement of remaining asbestos pipes

Lifuka Island

(i) Measures against the sea water intrusion into the water sources

Eua Island

(i) Rebuilding energy-efficient water supply systems that take advantage of elevation differences
(ii) Replacement of remaining asbestos pipes

First (1st) screening was made on above challenges that are suitable to be implemented as Japan grant aid projects as described below. In the 1st screening, the candidate projects were selected from their suitability as the reconstruction assistance projects, either for 1) recovery / reconstruction, 2) disaster prevention and 3) measures against climate change. However, as mentioned above, two (2) perspectives on the challenges of the disaster prevention and the climate change were evaluated taking the minor impact identified by the survey on the existing water supply facilities by the volcanic eruption and tsunami into consideration.
The results of the 1st screening are summarized in Table 2.16.
The introduction of the expensive portable desalination unit as listed as a common issue to all islands may not bring a sustainable effect considering the current situation that most of the equipment donated by different donor are out of order and not used because of the difficulties of procurement of spare parts as a island country.
Therefore, above option is not adopted as priority project by putting high priority on implementation of the projects for development multiple water sources and bypass connection pipes.

Table 2.16 1st Screening of Candidate Projects

Island	Issue	Project Contents (draft).	Recovery / Reconstruction	Disaster Prevention	Climate Change	Priority Evaluation	Reason for Evaluation
Common to all four islands	Improvement of water quantity management	➢ Provision of flow measurement equipment (including OA equipment for recording)	Unsuitable	Unsuitable	Moderate	**Unsuitable**	Relatively less suitable due to indirect and small effects.
Common to all four islands	Improvement of water quality management	➢ Construction / improvement of water testing laboratory (including provision of water testing equipment and OA equipment)	Unsuitable	Suitable	Suitable	**Suitable**	High importance of precise evaluation of the impact by natural disasters and climate change through monitoring of water quality
Common to all four islands	Reinforcement of emergency recovery in event of disasters	➢ Construction / improvement of workshops (including provision of repairing equipment, spare parts, satellite telephone etc.)	Unsuitable	Suitable	Unsuitable	**Suitable**	Highly important for early assessment of damage situation and emergency recovery in the event of natural disasters
Common to all four islands	Reinforcement of emergency water supply in event of disasters	➢ Provision of portable desalination units and water trucks.	Unsuitable	Suitable	Unsuitable	**Suitable (*)**	High need for emergency water supply especially on remote islands that are vulnerable to natural disasters and climate change taking the difficulty of securing of drinking water once damaged
Tongatapu	Resilience of water supply systems against natural disasters	➢ Multiple water sources through the development of new water sources ➢ Installation of bypass connection pipes to secure emergency water distribution routes	Unsuitable	Suitable	Unsuitable	**Suitable**	High need for resilience of the water supply systems due to the. experience of concentrated demand for the TWB's water supply in Tongatapu by the volcano eruption and tsunami in January 2022.
Tongatapu	Integration of village water supply into TWB service network	➢ Extension of existing water distribution pipe network and construction of reservoirs (incl. connection to village water supply area)	Unsuitable	Moderate	Unsuitable	**Unsuitable**	Low cost effective of the integration of the village water supply to TWB's water supply except certain effect for disaster prevention
Vava'u	Measures against sea water intrusion to water sources	➢ Multiple water sources through the development of new water sources ➢ Strengthening water resources management capacity	Unsuitable	Unsuitable	Suitable	**Suitable**	High compatibility with the measures to be taken against climate change taking the current progressing of the sea water intrusion into the existing water source into account.
Vava'u	Replacement of remaining asbestos pipes	➢ Replacement of asbestos pipes	Unsuitable	Unsuitable	Moderate	**Unsuitable**	Relatively low suitability due to the indirect and small effect, while it's an issue that should be addressed immediately.
Vava'u	Integration of village water supply into TWB service network	➢ Extension of existing water distribution network and construction of reservoirs (including connection to village water supply)	Unsuitable	Moderate	Unsuitable	**Unsuitable**	Low cost effective of the integration of the village water supply to TWB's water supply except certain effect for disaster prevention
Eua	Rebuilding energy-efficient water supply systems to take advantage of elevation differences	➢ Reconstruction of gravity-flow water distribution system ➢ Construction of water treatment plant (WTP) which can conduit water by gravity flow ➢ Adoption of Slow Sand Filter for a new WTP that minimize mechanical and electrical equipment.	Unsuitable	Moderate	Unsuitable	**Unsuitable**	Low cost effective of the high construction cost combined with the need of long-term support to its O & M
Eua	Replacement of remaining asbestos pipes	➢ Replacement of asbestos pipes	Unsuitable	Unsuitable	Unsuitable	**Unsuitable**	Relatively low suitability due to the indirect and small effect, while it's an issue that should be addressed immediately.
Lifuka	Measures against sea water intrusion to water sources.	➢ Multiple water sources through the development of new water sources ➢ Strengthening water resources management capacity	Unsuitable	Unsuitable	Suitable	**Suitable**	High compatibility with the measures to be taken against climate change taking the current progressing of the sea water intrusion into the existing water source into account.

* However, **NOT** feasible due to difficulties of procurement of spare parts

(2) Outline of Priority Projects

A draft outline of the five (5) priority projects identified in the 1st screening is shown as below.

(i) Improvement of water quality management (common to all four islands)

Item	Outline
Name	Improvement of water quality management
Target beneficiary	TWB Tongatapu headquarters, TWB's branch offices on remote islands (Vava'u, Lifuka, and Eua Islands)
Background	TWB's head quarter in Tongatapu and its branch offices on remote islands do not have basic water quality testing equipment and do not conduct daily testing for the essential parameters such as turbidity, pH and residual chlorine. TWB has a water quality testing laboratory in Nukualofa, Tongatapu. However, only the parameters such as faecal coliform, EC (Electrical Conductivity) and residual chlorine can be measured, which is insufficient for the sole laboratory function. The branch offices transport the water samples by air to the laboratory in Nuku'alofa once a month and receives the results of water quality tests for the above three (3) parameters by email. However, daily management of water quality is not conducted. Groundwater sources (freshwater lenses), which are the main source of water supply in Tonga, are susceptible to environmental impacts such as natural disasters, climate change and external pollution, and once affected, it will take a long time to recover the condition to the original state. It is therefore extremely important to monitor and manage water source and water supply quality on a daily basis and to assess the impact of natural disasters and climate change on water quality. Water quality management will be fundamental to the water source management which importance has increased especially in Tonga, where the risk of sea water intrusion to the water source has increased. Based on the above background, this project proposes the development of a water quality testing laboratory and capacity building in water quality management as a small-scale grant aid, with the aim of "Strengthening of water quality management".
Project component	1) Facility construction: • Water quality testing laboratories 2) Equipment provision: • Water quality testing equipment (for daily testing) • Office automation (OA) equipment for recording and analysis 3) Soft component: • Guidance on water quality management (water quality testing, data analysis & development of manuals, etc.)
Estimated cost	Approx. 40 Million Japanese Yen
Expected outcome	1) Improvement of water supply quality 2) Improvement of daily water quality management 3) Rapid response to water quality abnormalities caused by natural disasters, climate change, etc.
Considerations for implementation	• Existing facilities can be updated with new equipment, and one room in the TWB office or workshop can be developed as a laboratory without construction of a new building. • Outsourcing will be carried out for the testing of periodical parameters are envisaged. However, the actual water quality testing equipment to be procured will be determined through further study on the capacity and offered price of the outsourced company. • A support to the soft component is envisaged through the use of a well-equipped water testing laboratory to ensure the acquisition of water quality analysis skills and the sustainability of their effectiveness.

(ii) Reinforcement of emergency recovery in an event of disasters (Common to all four islands)

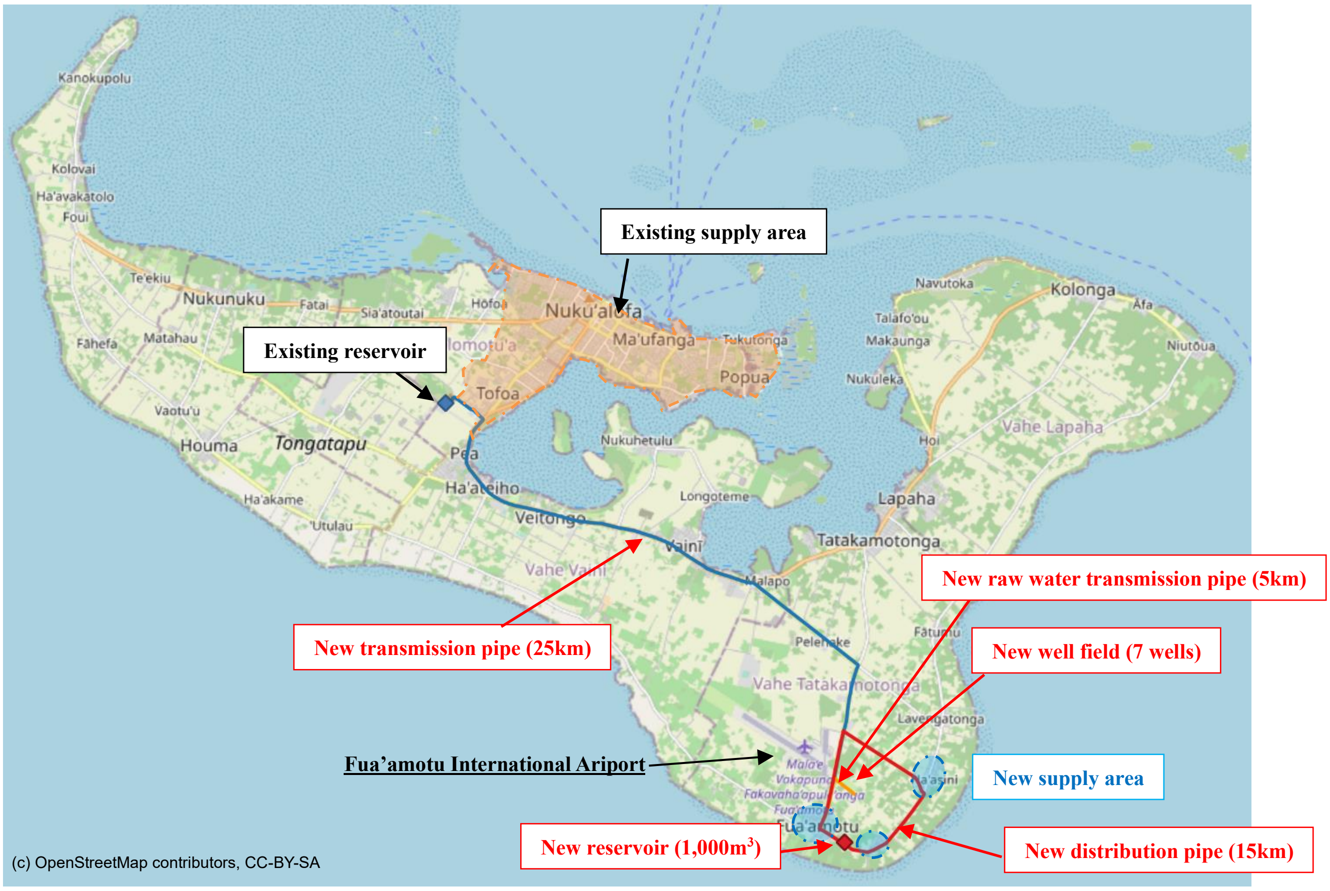
Item	Outline
Name	Support to enhance emergency recovery
Target beneficiary	TWB Tongatapu headquarters, TWB's branch offices on remote islands (Vava'u, Lifuka, and Eua Islands)
Background	The submarine volcanic eruption of HTHH and tsunami on 15 January 2022 brought serious damage to the water supply pipes of 265 houses on the coastal area of Nuku'alofa, 57 houses on Eua Island and 25 houses on Lifuka Island, and the accumulation of volcanic ash caused the failure of water intake pumps, electrical panels and generators. In addition, the blockage of submarine cables caused major disruptions to the communication network, which made it impossible to assess the damage to water supply facilities on the remote islands. As the result, it took approximately two (2) weeks for the water supply system to be recovered. Furthermore, Tonga has also experienced a number of large-scale earthquakes and cyclones in the past, and the country has a potential risk of long-term water supply interruptions due to the damage to the water distribution mains. Therefore, early acquisition of such damage to the water supply system and restoration of the system in the event of a large-scale disaster will be a major challenge. This project proposes the development of workshops, supply of necessary equipment and materials, and capacity building for emergency recovery as a small-scale grant aid, with the aim of "strengthening emergency recovery of water supply systems".
Project component	1) Facility construction: • Workshops 2) Equipment provision: • Repairing equipment • Spare parts and other water supply materials and equipment • Small-scaled generator • Satellite telephones (for communication in an event of disasters) • Office automation (OA) equipment for recording and analysis 3) Soft components: • Guidance on use of equipment and water quantity management
Estimated cost	Approx. 0.1 Billion. Japanese Yen
Expected outcome	1) Early acquisition of the state of damage to water supply facilities in the event of disasters in each island 2) Shortened period to be recovered from disaster 3) Improved water quantity management and early acquisition of the affected areas in the water supply in an event of disasters.
Considerations for implementation	• Survey on the existing workshops on Tongatapu and Vava'u Island for the renovation works, and survey on the land acquisition for development of the new workshops on Lifuka and 'Eua Island will be needed. • The purpose and effectiveness of the equipment to be provided should be scrutinized, and specifications and quantities should be considered. • Support to strengthen the capacity of operation of above workshops to be developed by the project in order to ensure sustainability of the effectiveness • Another scheme of technical support through dispatching JOCV[*1] or JICA experts on the aspect of emergency recovery will also be considered.

*1: Japan Overseas Cooperation Volunteers

(iii) Resilience of water supply systems against natural disasters (Tongatapu Island)

Item	Outline
Name	Resilience of water supply systems against natural disasters (Part 1) (Development of new water sources and related water supply facilities)
Target beneficiary	Tongatapu Island
Background	Tongatapu Island is home to approximately 74% (74,454) of the total population of Tonga, and TWB provides its water services to approximately 60% of the population, mainly in Nuku'alofa through pumping the groundwater (freshwater lens). The HTHH volcanic eruption on 15 January 2022 caused a power outage across the entire area of the island. TWB's water supply system was not affected by the disaster due to the operation of their own emergency generator that had already been equipped. However, the water supply of the surrounding villages was disrupted due to the power outage and the shutdown of the intake pumps, and forced the residents to rush to the TWB's Mataki'eua water distribution station to seek the water. At that time, TWB provided water directly to the local population, which resulted in a tight water supply to the city. The experience of the disaster made TWB realize the importance of ensuring redundancy of the water supply system in an event of natural disasters. The project proposes the development of multiple water supply sources through the development of a new water source and a connecting pipe to the existing reservoir, with an aim of "resilience of the water supply system against natural disasters". Fua'amotu area in the south-eastern part of the island where a freshwater lens with a thickness exceeding 10 m is expected as a potential candidate site.
Project component	1) Basic survey: • Water source surveys, installation of groundwater observation wells 2) Facility construction: • New production wells (7 wells x Approx. 400m^3/day, including electromagnetic flow meters) • Solar and emergency power generation systems (new water sources) • New reservoir (V = 1,000 m^3) • Raw water transmission pipe (L = 5 km, from new water source to reservoir) • Transmission pipe (L = 25 km, from new reservoir to Mataki'eua reservoir) • Distribution pipe (L = 15 km, extension of water supply to surrounding villages) • Electromagnetic flow meters (7 locations for reservoir, distribution and transmission pipelines, etc.) 3) Soft component: • Guidance on O & M of water supply facilities
Estimated cost	Approx. 2.82 Billion Japanese Yen (Basic survey: 0.08 + Facility construction: 2.44 + Equipment provision: 0.25 + Soft component: 0.15 + Consulting service: 0.26)
Expected outcome	1) Improved emergency response to increased water demand in the event of natural disasters 2) Improved water supply services toward long-term stability through developing water sources less susceptible to salination 3) Improved TWB's capacity to manage groundwater resources 4) Improved village water services through integrating into TWB water supply system 5) Improved TWB's revenues through expansion of water supply areas
Considerations for implementation	• Detailed site acquisition survey is required for the development of new water sources and the construction of reservoirs and pipelines. • The purpose and effectiveness of the equipment to be provided should be scrutinized, and specifications and quantities should be considered. • Technical assistance on "emergency water supply", including operation of new water sources in an event of disasters, and technical assistance on "water source management"" to strengthen the capacity of groundwater source management are considered, with support envisaged through JOCV or dispatch of experts.

Item	Outline
Name	Resilience of water supply systems against natural disasters (Part 2) (Development of bypass connection pipes).
Target beneficiary	Tongatapu Island
Background	Tongatapu Island is home to approximately 74% (74,454) of the total population of Tonga, and TWB provides its water services to approximately 60% of the population, mainly in Nuku'alofa through pumping the groundwater (freshwater lens). The current TWB's water supply system in Nukualofa is based on a network of distribution pipe that was developed in 2001 by the Japan grant aid project titled "Nuku'alofa Water Supply Development Project". On one hand, the 500 mm diameter water main from the reservoir is partly a single line, which will bring a potential risk of water suspension throughout Nukualofa when this pipeline was damaged in an event of natural disasters. Such water suspension will not enable TWB to supply the water to the Vaiola National Hospital, the largest hospital on Tongatapu Island, which will become an obstacle to the medical operations in an event of disasters. Tonga has also experienced many large-scale earthquakes and cyclones in the past, and if the water main is damaged, the water supply could be cut off for a long period of time. For the above reasons, development of the bypass connection pipe is proposed to "secure a water distribution route in case of emergency" in order to enable water supply in an event of a breakage in the water distribution main.
Project component	1) Facility construction: • Bypass connection pipes (L = 5.5 km, φ300 – φ500 mm) • Electromagnetic flow meter (1 place)
Estimated cost	Approx. 0.5 Billion Japanese Yen (Facility construction: 0.45 + Equipment provision: 0.005, Consulting service: 0.045).
Expected outcome	1) Secured water distribution routes in an event of natural disasters and emergencies. 2) Improved water pressure in existing water supply areas due to multiple water distribution routes.
Considerations for implementation	• High volume of road traffic, traffic disturbance and noise/vibration are expected at the construction and should be taken into account when implementing the project. • Technical support by dispatching JOCV or JICA expert on "Emergency water supply" including the operation of bypass communication pipes in an event of a disaster



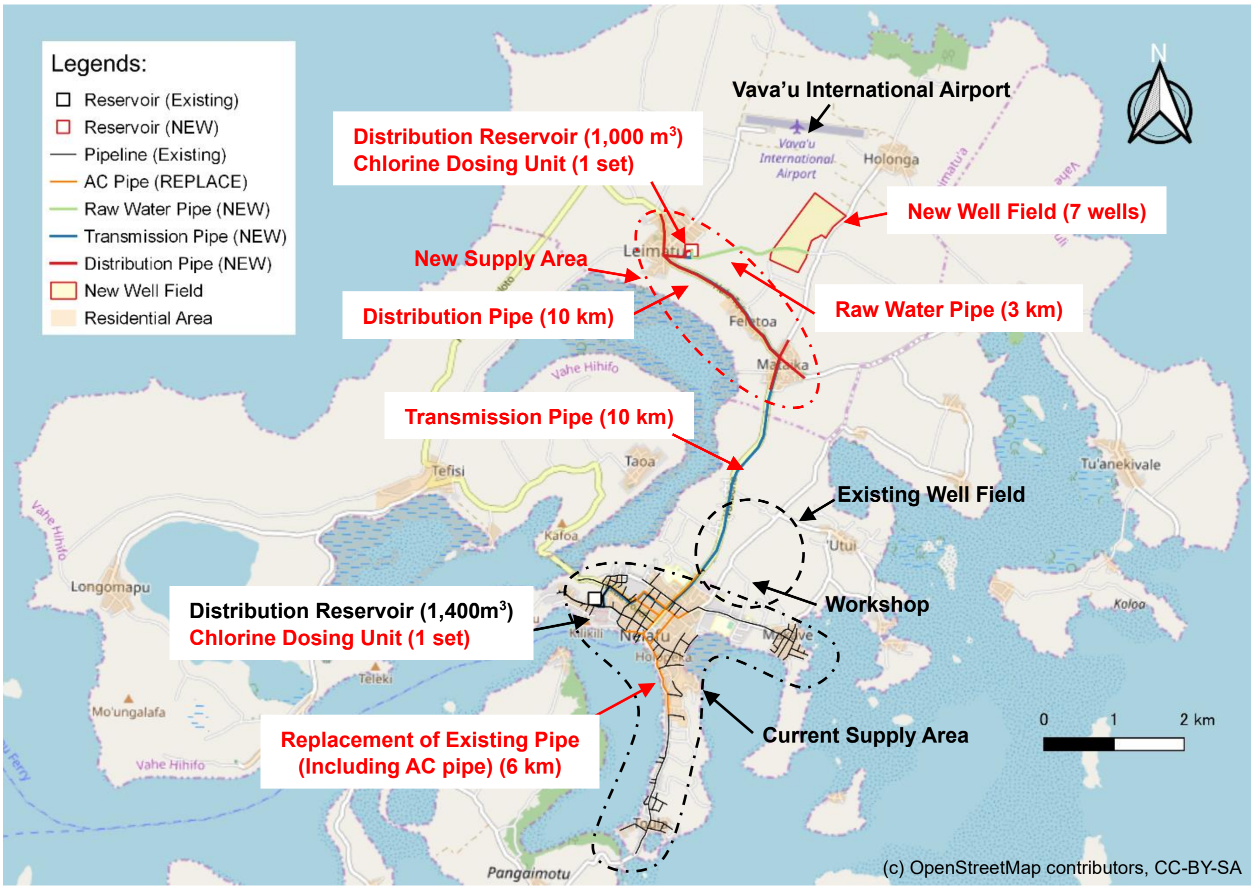
Source: Prepared by survey team

Figure 2.22 Proposed Project on Resilience of Water Supply Systems against Natural Disaster (Tongatapu Island)

(iv) Measures against salination of water sources (Vava'u Island)

Item	Outline
Name	Measures against sea water intrusion to water sources due to climate change (Part 1).
Target beneficiary	Vava'u Island
Background	TWB operates the water supply in Neiafu, the center of Vava'u Island which is expected to develop as a center of the tourism industry in the future in Tonga. Sea water intrusion has progressed to the existing TWB's production wells in the vicinity of Neiafu, where are the water source (freshwater lens) and the supplied water quality exceeds 1,500 µS/cm of the WHO's threshold limit of EC for drinking water. In addition, the increased frequency of El Niño occurrences due to climate change in recent years combined with significant decrease in precipitation and the sea level rise have become another factor of increasing the risk of the salination of the water source, which has become an urgent issue for taking measures against the risk (EC value exceeding 5,000 µS/cm was recorded at the existing water source at the past El Niño occurrence). In contrast, the groundwater in the northern part of the existing water source (near the Prison Area) has a thick freshwater lens with EC of around 500 µS/cm, and has high potential as a new water source. Thus, this project proposes the diversification of water sources and the strengthening of water source management through combining the operation of existing water sources with the development of new water sources, with the aim of "Addressing the salination of water sources due to climate change".
Project component	1) Basic survey: • Water source surveys, installation of groundwater observation wells 2) Facility construction: • New production wells (7 wells x Approx. 400m^3/day, including electromagnetic flow meters) • Solar and emergency power generation systems (new water sources) • New reservoir (V = 1,000 m^3) • Raw water transmission pipe (L = 3 km, new water source - new reservoir) • Transmission pipe (L = 10 km, new reservoir - existing reservoir) • Distribution pipes (L = 16 km, extension of water supply to surrounding villages, renewal of Asbestos Concrete pipes) • Electromagnetic flow meters (7 locations for reservoir, distribution and transmission pipelines, etc.) 3) Soft component:. • Guidance on O & M of facilities and water source management
Estimated cost	Approx. 1.42 Billion Japanese Yen (Basic survey: 0.05 + Facility construction: 1.21 + equipment provision: 0.02 + Soft component: 0.01 + Consulting service: 0.13)
Expected outcome	1) Prevention of salination of existing water sources through spreading the location of water intake 2) Ensured redundancy in the water supply system through multiple water sources 3) Developed water sources less susceptible to salination and improved water supply services toward long-term stability 4) Improved TWB's capacity of groundwater source management 5) Improved quality of supplied water 6) Improved water supply situation through integrating village water supplies into the TWB water supply system. 7) Improved TWB's revenues through expansion of water supply areas 8) Increased tourism demand through the stable provision of safe water services
Considerations for implementation	• Detailed site acquisition survey is required for the development of new water sources and the construction of reservoirs and pipelines. • The purpose and effectiveness of the equipment to be provided should be scrutinized, and specifications and quantities should be considered. • Separately, another technical support by dispatching JOCV or JICA on "Emergency water supply" including the operation of bypass communication pipes in an event of a disaster

	• Technical support on 'water source management' to strengthen the capacity of groundwater source management are to be considered, with support envisaged through dispatch of JOCV or experts.

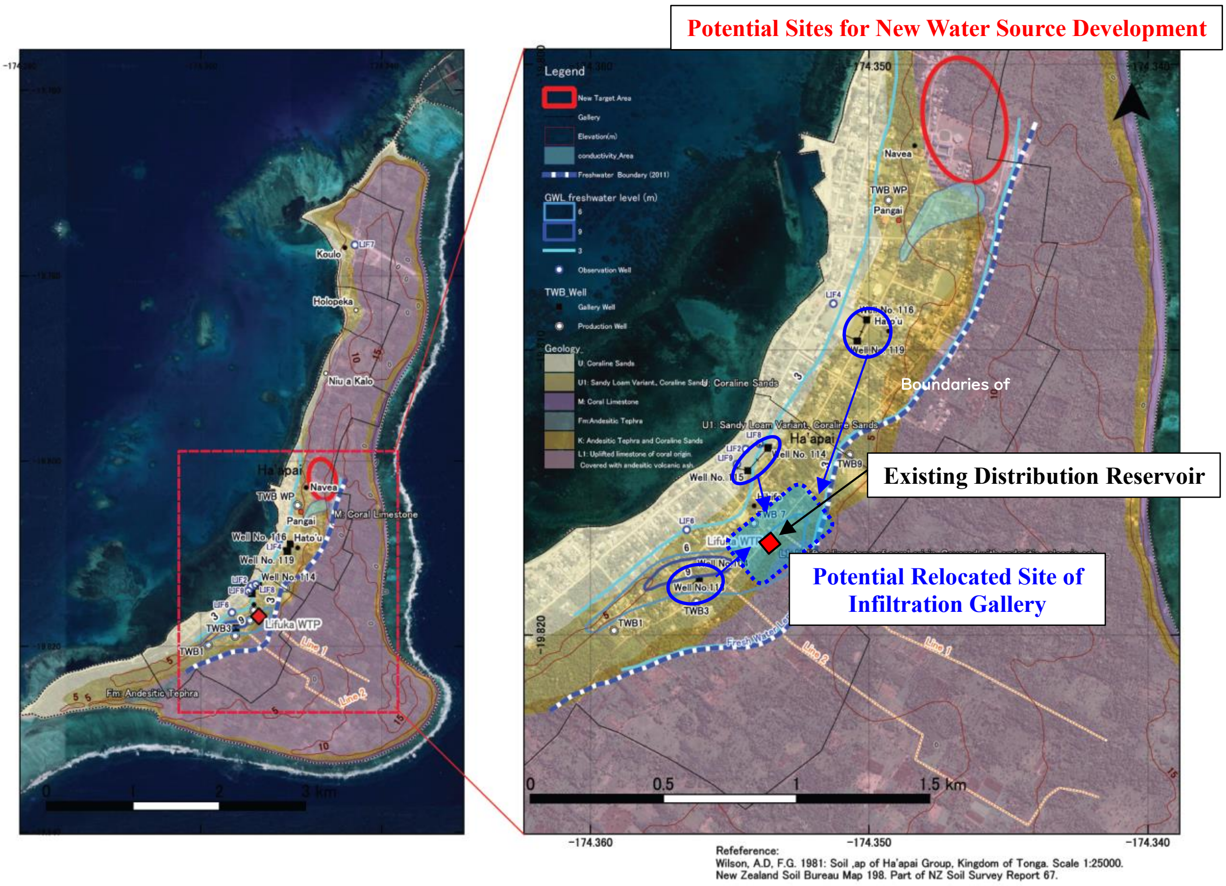


Source: The final report "Project for Improvement of Water Supply System in Vava'u, the Kingdom of Tonga", 2019

Figure 2.23 Proposed Project against Salination of Water Sources (Vava'u Island)

(v) Measures against salination of water sources (Lifuka Island)

Item	Outline
Name	Measures against sea water intrusion to water sources due to climate change (Part 2).
Target beneficiary	Lifuka Island
Background	Lifuka Island, part of the Ha'apai Islands, is the area where the salination of the groundwater has progressed in severest state in Tonga, and most of TWB's existing water sources are above the WHO's threshold limit for drinking water. Furthermore, the available underground freshwater layer (freshwater lens) is located at a distance of only 200-600 m from the west coast and is only about 9 m thickness at maximum, resulting in severe chronic water shortages during the dry season when groundwater recharge is reduced. According to the IPCC Sixth Assessment Report (2021) , in the medium to long term sea levels in Tonga will rise by 0.28 to 1.01 m by 2100. This, coupled with increased cyclone intensity and other factors on low-lying islands such as Lifuka, is increasing the risk of storm surge damage, etc., and there is increasing concern about the salination of freshwater lenses and the impact on existing water supply facilities. Based on the above, this proposal provides the development of a new water source and the strengthening of underground management to reduce the impact of salination, with the aim of "addressing the salination of water supply sources due to climate change". The most likely candidate sites for new water sources are near the current reservoir, away from the coast, or in the northern part of the Pangai district.
Project component	1) Basic survey: • Water source surveys, installation of groundwater observation wells 2) Facility construction: • New water sources in the vicinity of existing distribution station or in the Pangai area (3 sites) • Solar and emergency power generation systems (new water sources) • Raw water transmission pipe (L = 2 km, new water source to existing water distribution station) • Equipment supply: • Electromagnetic flow meter (1 location) 3) Soft components: • Guidance on facility O&M and water source management
Estimated cost	Approx. 0.31 Billion Japanese Yen (Basic survey: 0.03 + Facility construction: 0.24 + Equipment provision: 0.005 + Soft component: 0.05 + Consulting service: 0.03)
Expected outcome	1) Developed water sources less susceptible to salination and improving the long-term stability of water supply services 2) Mitigated damage to water supply facilities against climate change induced natural disasters 3) Improved capacity on groundwater source management of TWBs. 4) Improvement of water supply quality
Considerations for implementation	• Detailed studies on land acquisition and compensation are required for the development of new water sources and the construction of pipelines. • Groundwater contamination countermeasures are necessary for the construction of new water source facilities due to the shallow groundwater table. • The purpose and effectiveness of the equipment to be provided should be scrutinized, and specifications and quantities should be considered. • Technical support on "water source management" to strengthen the capacity of groundwater source management are to be considered, with support envisaged through dispatch of JOCV or experts.



Source: Prepared by survey team

Figure 2.24 Proposed Project on Addressing Sea Water Intrusion to Water Sources (Lifuka Island)

(3) Prioritization of Candidate Projects

Taking the budgetary constraints as Japan grant aid projects into account, the priority for above five (5) projects was comprehensively assessed in terms of effectiveness, immediacy, economy, urgency, beneficiary and cost-effectiveness. Table 2.17 summarises the results of the project prioritization.

The project with highest priority is “Resilience of water supply systems against natural disasters (Tongatapu Island)”, followed by “Strengthening emergency rehabilitation (common to all four islands)”, then “Improvement of water quality management (common to all four islands)”.

Although the project on the Tongatapu Island water supply system resilience has a highest cost among the candidate projects, it is highly beneficial in terms of approximately 74% of the total population of Tonga and 78% of TWB's customers, and also its higher score in urgency and effectiveness as a support content following the recent submarine volcanic eruption and tsunami disaster. For this reason, the project “Resilience of the water supply system against natural disasters (Tongatapu Island)” was selected as the highest priority project and is described further in detail in Chapter 3 onwards.

Table 2.17 Prioritization of Candidate Projects

Project	Improvement of water quality management	Reinforcement of emergency recovery in an event of disasters	Resilience of water supply system against natural disasters	Addressing salination of water sources	Addressing salination of water sources
Target Island	Common to Four Islands		Tongatapu Island	Vava'u Island	Lifuka Island
Outline	Construction/ improvement of water testing laboratories (including provision of water quality testing equipment and OA equipment for recording)	Construction/ improvement of workshops (including provision of repairing equipment, spare parts, satellite telephones, etc.)	Multiplying water sources by developing a new water source and securing emergency water distribution routes by installing bypass connection pipes	Multiplying water sources by developing a new water source and strengthening water source management capacity	Securing water quality by developing a new water source
Effectiveness	- 1 – Improved water quality management	- 2 – Improved emergency recovery Improved incident response and equipment management	- 6 – Improved water supply coverage rate Improved water pressure Improved emergency water supply	- 4 - Improved water supply coverage rate Improved water source management	- 2 - Improved water source management
Immediate effectivity	- 3 - Equipment provision can produce an effectivity in a short term.	- 3 - Equipment provision can produce an effectivity in a short term.	- 2 - Water source and facility development can produce an effectivity in medium- to long-term.	- 2 - Water source and facility development can produce an effectivity in medium- to long-term.	- 2 - Water source and facility development can produce an effectivity in medium- to long-term.
Economy (Cost)	- 3 - Cost is lower compared to facility development	- 3 - Cost is lower compared to facility development	- 1 - Most costly.	- 2 - Moderate cost.	- 2 - Moderate cost.
Urgency	- 3 - High urgency for improvement because water quality management is a basis for water supply operation.	- 3 - Highest urgency for the measures for the disaster of HTHH eruption and tsunami.	- 3 - Highest urgency for the measures for the disaster of HTHH eruption and tsunami.	- 2- The degree of salination of existing water sources is lower than that of Lifuka Island.	- 3 - The progressing salination of the existing water sources is a matter of urgency.
Beneficiary	- 3 - The target beneficiary is the residents of all four islands.	- 3 - The target beneficiary is the residents of all four islands.	- 3 - Beneficiary is the largest among the four islands	-2 - The second largest beneficiary after Tongatapu Island.	- 1 - Lowest beneficiary among the four islands.
Total Score	- 13 -	- 14 -	- 15 -	- 12 -	- 11 -
Overall Evaluation*	3	2	**1**	4	5

Notes: "1" indicates that candidate project is evaluated as 1st rank for highest priority for implementation.

Only "Effectiveness" was scored on a 6-point scale; all other items were scored on a 3-point scale.

2.3.5 Information on Relevant Sectors

In response to the damage caused by the HTHH volcanic eruption and tsunami, the JICA Disaster Management Team has been conducting a survey from May 2022 to formulate a rehabilitation and reconstruction plan for infrastructure development, including harbors, housing and roads, which also includes the water supply sector. On the other hand, a detailed survey of the water supply sector was planned to be conducted under this project, an outline of this survey was explained at the joint meeting with JICA, and it was agreed that the survey results and the content of the reconstruction plan to be developed under this project would be shared with the JICA and reflected in the outcomes of the JICA Disaster Management Team. Based on the above, it is likely that the reconstruction plan will be implemented as part of JICA's reconstruction project, and it will be important to coordinate and consistent with the progress of the JICA team.

2.4 Responsible Authorities and Implementing Agencies

TWB, the executing agency for this project, was established in 1966 and operates water services in major urban areas in Tonga as one of the public enterprises under the jurisdiction of the Ministry of Public Enterprises (MPE) in accordance with the Public Enterprise Act 2002. TWB has its head office in Nuku'alofa (Tongatapu Island) and branch offices on the remote islands of Vava'u, Ha'apai and ‘Eua, and is responsible for all aspects of water services in urban areas from the O and M of the water supply facilities to collection of water charges.

Relevant authorities and institutions directly or indirectly involved in the implementation of the work is shown in Table 2.18. Water source management and protection in Tonga falls under the jurisdiction of the Ministry of Land and Natural Resources (MLNR). The Ministry of Meteorology, Energy, Disaster Management, Environment, Climate Change and Communications (MEIDECC) is involved in the disaster preparedness aspects of the HTHH eruption and tsunami on 15 January 2022. The Ministry of Infrastructure (MOI) which compiles estimated costs for the damage by the HTHH disaster on the entire infrastructure including the water sector is also involved.

Table 2.18 List of Relevant Authorities for Implementation of the Project

Responsibility	Name of Ministry or Agency
Implementing agency	Tonga Water Board (TWB)
Relevant ministry	Ministry of Public Enterprises (MPE)
	Ministry of Health (MOH)
	Ministry of Lands and Natural Resources (MLNR)
	Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC)
	Ministry of Social Infrastructure (MOI : Ministry of Infrastructure)

Source: prepared by the survey team

2.4.1 Relevant Government Agencies

(1) Ministry of Public Enterprises (MPE)

Water supply in Tonga is implemented by TWB, one of the public enterprises, and the Ministry of Public Enterprises is the government agency responsible for all public utilities including TWB. The Ministry is responsible for policy formulation, project planning, design, coordination and implementation of projects and operations related to public utilities, transport, telecommunications and public works within Tonga.

(2) Ministry of Health (MOH)

The Ministry of Health (MOH) provides preventive and curative health services in Tonga. The Ministry's work related to water services is as follows.

- Administering health ordinances, maintaining public health databases, providing education on environmental health
- Monitoring and necessary support for the activities of the Village Water Committees (VWCs) established under the Health Ordinance.
- Periodic inspection and guidance on water supply management in village areas (Once / month)

(3) Ministry of Land and Natural Resources (MLNR)

The role of the Ministry of Land and Natural Resources is to manage natural resources and energy, including land and water resources, and to contribute to the development or implementation of plans. The main activities of MNLR are the implementation and technical support of surveys, mapping, analysis and geological surveys. The Ministry's tasks related to the implementation of water supply projects are as follows.

- Water source management and decision of position of intake wells
- Implementation of water resources monitoring plans (including obtaining data on wells, such as chloride concentration, water temperature, pH, water levels, etc.)

(4) Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC)

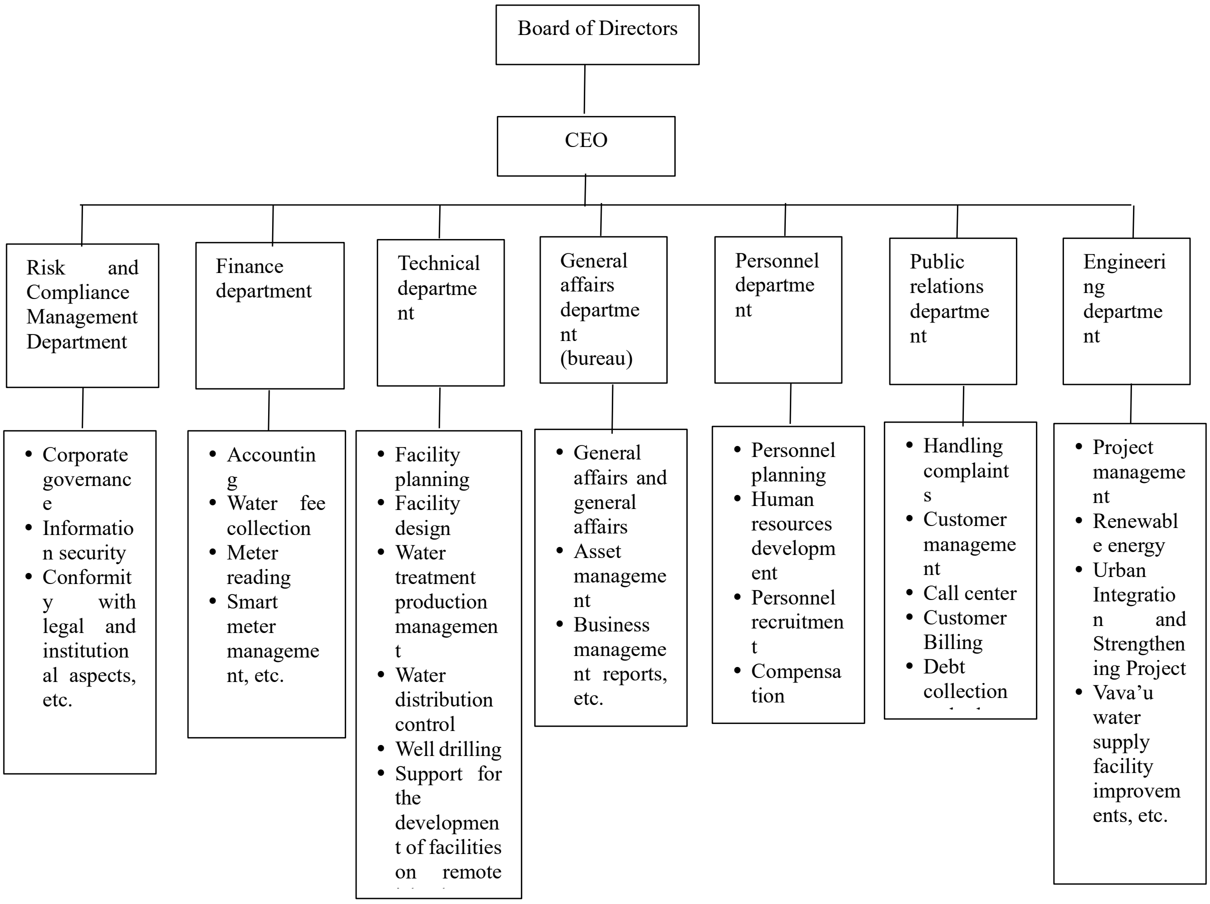
MEIDECC is developing warning and communication systems and formulating measures to be taken for disaster prevention aspects in Tonga, which has global vulnerabilities such as natural disasters and recent climate change, to address natural disaster risks and climate change risks.
MEIDECC is the country's coordinating agency for the actual damage and recovery measures by the 15 January HTHH volcanic eruption and tsunami, and is the country's counterpart agency to the JICA disaster prevention management team that was established in March 2022.

(5) Ministry of Social Infrastructure (MOI)

The Ministry of Social Infrastructure (MOH) is primarily responsible for the transport sector of ports, roads and airports in Tonga, as well as general infrastructure such as urban drainage and housing development. The Ministry provided data for the World Bank-supported recovery planning for the 15 January 2011 HTHH volcanic eruption and tsunami, including the estimate of the cost on the damage to all infrastructure, including housing and water supply systems, and the estimate of the cost of recovery.

2.4.2 Organization of Implementing Agency

Organizational chart of the TWB is shown in Figure 2.25, and the breakdown of the number of people in the organizational structure is shown in Table 2.19. The TWB is divided into three (3) departments - Finance Department, Engineering Department and Administration Department. As of 2022, TWB has total of 141 staffs (135 permanent and 6 daily staff), and constitutes 98 staffs at the Nuku'alofa Head Office and 43 at the remote island branches.



Source: prepared by the survey team based on TWB documents

Figure 2.25 Organizational Chart of Tonga Water Board (TWB)

Table 2.19 Staff Composition of TWB

(data) item	Number of staff		
	plan	full-time employee	contract employee
1. Nuku'alofa			
1.1 General administration, human resources and external relations	20	18	2
1.2 Financial matters	35	34	1
1.3 Technical relations	43	42	1
2. outlying branch offices			
2.1 Vava'u.	18	16	2
2.2 Ha'apai.	11	11	0
2.3 Eua.	14	14	0
total	141	135	6

Source: TWB

2.4.3 Vision / Mission of Implementation Agency

TWB has the following Vision and Mission.

Vision.
To be recognized by our customers and communities that we serve for supplying high quality water in an environmentally friendly and reliable manner at a reasonable price.

Mission.
To develop and expand the Tonga Water Board network and related services to provide customers with a reliable and high-quality water supply.

Source: TWB Annual Report 2019-2020.

2.5 Japan's Assistance to the Kingdom

2.5.1 History of Assistance of Japan

(1) History of Japan's ODA Assistance

Table 2.20 shows the performance of the cooperation by Japanese government to Tonga in the last five (5) years.

Table 2.20 Performance of Japan's Aid to Tonga

(Unit: million yen)

Year	Loan Project	Grant Aid Project	Technical Cooperation
2016.	-	1,594	352
2017	-	2,480	231
2018.		2,914	234
2019		62	173
2020		302	89
Total	-	7,352	1,079

Source: Ministry of Foreign Affairs' Official Development Assistance (ODA) Country Data Collection 2021.

The ODA in the water sector such as water resources / disaster management to the Kingdom has been executed through water supply projects by the scheme of grant assistance for grassroots human security projects and followed by several schemes of grant aid project, non-project grant aid and emergency grant aid. The following summarizes the results of the assistance in each scheme;

(2) Grant Assistance for Grassroots Human Security Projects

The Embassy of Japan in Tonga has implemented the Grassroots Human Security Grant Assistance Project to assist village areas, mainly those further away from city center to develop water intake wells and elevated tanks.

The projects that have been implemented since 2013 is listed in Table 2.21. The example of equipment provided to Feretoa village, which was the target of cooperation in 2015 and 2014 is shown below, while similar equipment has been provided to other villages.

- Intake pumps (2 units) with solar panel and diesel generator (each; 1 unit)
- Pump house

- Water tank (5,000 gallon)
- Ancillary equipment such as fence and pipes

Table 2.21 List of Grant Assistance for Grassroots Human Security Projects

Year	Name of Projects
January 2022	The Project for Upgrading of Water Supply System for Vaini Village
April 2021	The Project for Upgrading of Water Supply System for Nukunuku Village
March 2021	The Project for Upgrading of Water Supply System for Hihifo Village
December 2020	The Project for Upgrading of Water Supply System for Vaini Village
December 2018	The Project for Upgrading of Water Supply System for Pelehake Village, Tongatapu
December 2018	The Project for Upgrading of Water Supply System for Alakifonua District, Tongatapu
August 2018	The Project for Upgrading of Water Supply System for Lavengatonga Village, Tongatapu
August 2018	The Project for Upgrading of Water Supply System for Talafo'ou Village, Tongatapu
September 2017	The Project for Upgrading of Water Supply System for Folaha Village
September 2017	The Project for Upgrading of Water Supply System for Tatakamotonga Village
December 2016	The Project for Upgrading of Water Supply System for Nukuleka Village
November 2016	The Project for Upgrading of Water Supply System for Naptoka Village
June 2016	The Project for Upgrading of Water Supply System for Hihifo Village
June 2016	The Project for Upgrading of Water Supply System for Vaipoa Village
June 2016	The Project for Upgrading of Water Supply System for Falevai Village
May 2016	The Project for Upgrading of Water Supply System for Puke Village
August 2015	The Project for Upgrading of Water Supply System for Vaimalo Village
August 2015	The Project for Upgrading of Water Supply System for Ovaka Village
June 2015	The Project for Upgrading of Water Supply System for Fua‘amotu Village
September 2014	The Project for Upgrading of Water Supply System for Ha’alaufuli Village
September 2014	The Project for Upgrading of Water Supply System for Holonga Village
September 2014	The Project for Upgrading of Water Supply System for Feletoa Village
October 2013	The Project for Upgrading of Water Supply System for Mala'evakapuna Village

Source: Embassy of Japan in Tonga website.

(3) Grant Aid Projects

Grant aid project on replacement of AC pipes, construction of water treatment plant and equipment provision of flow meters and leakage detection equipment for Nukualofa, Tongatapu was executed as shown in Table 2.22.

Table 2.22 Grant Aid Projects

Year	Name of Project
August, 2001 (Completion)	The Project for Upgrading of Water Supply System for Nukualofa

Source: JICA website.

(4) Non-project Grant Aid

The following equipment was procured for NEMO (Tonga National Emergency Management Office) through non-project grant aid scheme.

Handover in August, 2017:

Crane truck (4 units), water truck (2 units), septic tank truck (1 unit), tent (15 sets), portable toilets (20 sets), lifeboat (2 ships), chainsaw (15 sets), emergency light with generator (10 sets), manual forklift (5 sets), and small excavator (1 unit)

Handover in June, 2015:

Tent (200 sets), desalination equipment (2 units), diesel pump (4 units), plastic tank (2,000 box)

E/N (Exchange of Note) on the following cooperation within the framework of the grant aid "Economic and Social Development Programme" was signed between Tonga and Japan in August 12, 2022 for the support to the recovery and reconstruction of the damage by the HTHH volcano eruption and tsunami in January 2022

Support for equipment related to the water supply on remote islands (Economic and Social Development Programme) (grant amount: 150 million Japanese Yen): Vehicles for recovery works, small excavators, generators, etc.

Source: Website of the Ministry of Foreign Affairs.

(5) Emergency Grant Aid

For the TOG's declaration of a state of emergency for the severe damage caused by the two (2) cyclones of Ian and Gita that landed the Kingdom in 2014 and 2018, respectively, GOJ procured tents, waterproof plastic sheets, generator, and plastic tanks.

In response to a request from the Government of Tonga for assistance for the damage caused by the HTHH volcanic eruption and tsunami that occurred in January 2022, JICA provided emergency relief supplies, including drinking water, canned food and tools for volcanic ash removal, which were transported to the area by the International Emergency Relief Team and Japan Self-Defense Force units.

Table 2.23 Emergency Grant Aid

Year	Name of Project
January-February 2022	Emergency grant aid for the damage by the HTHH volcanic eruptions and tsunami damage in Tonga.
February, 2018	Emergency grant aid for the damages by cyclone in the Kingdom of Tonga
January, 2014	Emergency grant aid for the damages by cyclone in the Kingdom of Tonga

Source: Survey team

(6) Other Assistance

A solar power electrification project was implemented in the rural and remote communities of Vava'u and Ha'apai Islands through Japan's Pacific Environment Community (PEC) Fund. 22 solar powered water pumps were installed at 17 villages on Vava'u Islands, and 36 solar powered deep freezers were installed on the remote islands of both islands by the project (the groundbreaking ceremony was held in July, 2017). In addition, technical cooperation has been implemented for the TWB's staffs through JICA's senior volunteer's training on water leakage detection and Knowledge Co-Creation Program.

2.5.2 History of Technical Cooperation

Technical cooperation training toward capacity building on water supply systems that are adaptable for remote islands has been implemented mainly by Okinawa prefecture for receiving the trainees in the pacific countries including the Kingdom.

The training on the following subjects were carried as shown in Table 2.24 for their details;

- Understanding on policies and legal framework on water supply facilities
- Understanding on biological treatment method (Slow filtration system)
- Understanding on water sources development targeting the countries with vulnerable water resources
- Understanding on way of water supply business
- Understanding on protection or reservation of water sources

In addition, transfer of technical knowledge and know-how that has been accumulated in Okinawa on the issues on the lack of water sources for stable secure of water supply, lack of water treatment system and water leakage was also carried out in this training.

Table 2.24 History of Technical Cooperation to Tongan Technical Staffs

Implementation Agency	Name	Contents of Training	Year
Okinawa Prefectural Enterprise Bureau	Water reservation management on remote islands	Lectures, practices and site inspection in Japan	2010
Okinawa Prefectural Enterprise Bureau	Water reservation management on remote islands (Total: 13 trainees including 2 Tongans)	Lectures, practices and site inspection in Japan	2011
Okinawa Prefectural Enterprise Bureau	Water reservation management on remote islands (Total: 13 trainees including 2 Tongans)	Lectures, practices and site inspection in Okinawa Prefecture	2012
Okinawa Prefectural Enterprise Bureau	Water reservation management and water utility operation on remote islands (Total: 9 trainees)	Lectures, practices and site inspection in water utilities related authorities and with partnerships with JICA Okinawa	2013
Okinawa Prefectural Enterprise Bureau	Water reservation management and water utility operation on remote islands (Total: 11 trainees)	Lectures, practices and site inspection in water utilities related authorities and with partnerships with JICA Okinawa	2014
Okinawa Prefectural Enterprise Bureau	Water reservation management and water utility operation on remote islands (Total: 12 trainees)	Lectures, practices and site inspection in water utilities related authorities and with partnerships with JICA Okinawa	2015
Okinawa Prefectural Enterprise Bureau	Water reservation management and water utility operation on remote islands (Total: 12 trainees	Lectures, practices and site inspection in water utilities related authorities and with partnerships with JICA Okinawa	2016

Source: Survey Team

2.5.3 Opinions by Recipient Country / Agency on Cooperation by Japan

Mr. Waterski Ma'afu of the branch manager of the TWB's branch office in Vava'u, one of the trainees in the training in Table 2.24 made the following comments on the training with his gratitude;

- The training with their excellent technical knowledges brought great benefits on the Kingdom's water supply sector,

- These knowledges cannot be fully utilized considering the current capacity of the TWB's O&M due to lack of necessary equipment

In addition, in the training in 2015, introduction on DMA (District Metered Area), watershed management, effective method for leakage repair and biological treatment method were given as useful subjects.

2.6 Assistance by Third Party's Countries / International Donors

2.6.1 History of Assistance Related to the Project

Table 2.25 shows the list of the cooperations by international donors to the water supply sector in Tonga. The donors from Australian and New Zealand have implemented the projects in the water supply and also in other sectors. ADB has supported water supply project on Tongatapu Island, while EU has also provided their assistance to the Vava'u Island where the Neiafu city, the second largest city in the country, located.

Table 2.25 List of Past Cooperation for Water Supply Sector in Tonga

Name of Island	Project Name	Donor	Year	Content
Tongatapu Island	Nuku'alofa Water Supply Development Project	JICA	2001	• Intake facilities (Intake pumps: 3 units; crane truck for O&M: 1 unit) • Disinfection facilities • Renewal of asbestos pipes • Distribution pipes (total length: approx. 33 km) • Procurement of leakage control equipment • Rehabilitation of existing water supply pipes
	Nuku'alofa Water Supply Improvement Project	ADB/ AusAID	2019	• Production wells (16 wells) • Rehabilitation of existing wells (13 wells) • Reservoir (3,000 m^3) • Transmission pipe (9.5 km)
Vava'u Island	Neiafu Water Supply Facility Improvement Project	EU	1997-1999	• Production wells and intake pumps (15 wells) • Transmission pipes (200 mm diameter x 8.9 km) • Distribution main (8.9 km) • Rehabilitation of existing reservoir (1,000 m^3) • Office and workshop • Chlorine dosing unit • Water-level transmission system
Lifuka Island	Pangai-Hihifo, Lifuka Water Supply Improvement Project	AusAID	1998	• Construction of infiltration galleries (4 sites) • Intake pump (solar type: 2 units, electric type: 2 units) • Transmission pipe (1,300 m) • Elevated tank (12 m^3) • Transmission pump (1 unit) • Tools (1 set)
Eua Island	Eua Water Supply Upgrade Project	New Zealand Aid	2008	• New water treatment plant (1,000m^3/day) (sedimentation basin, membrane filtration system, chlorine dosing system, 536m^3 clear water reservoir) • Distribution pipes (3.6 km) • Production wells (2 wells)
	Matavai Water Treatment Plant Improvement Project	New Zealand Aid	2013	• Rapid filtration unit (2 units)

One of the projects that are planned to be implemented is a pipe network improvement project on Tongatapu Island, which will be financed by an ADB loan. The project includes the renewal of the water distribution network to reduce non-revenue water (NRW) and the installation of flow control valves in the existing DMAs, with a budget of USD 1.5 million., in which its design work was commenced in the summer 2022. SIONE private fund is planning to finance the rehabilitation of the sedimentation basin at the Matavai water treatment plant on Eua Island (adding a coagulation sedimentation process) and the construction of rapid sand filters, which is being designed by an Australian consultant and is scheduled to commence its construction in January 2023.

2.6.2 Existence of Request to the Project by International Donors

Currently, as mentioned above, two projects, the improvement of the pipe network on Tongatapu Island by ADB and the improvement of the water treatment plant on Eua Island by SIONE Private Find, are being implemented for TWB's water supply service. On the other hand, in terms of recovery assistance for the damages by the HTHH volcanic eruption and tsunami, a request from Tonga for non-project grant aid has been made to the Japanese Government and already been completed, while in terms of reconstruction assistance, neither project plan has been drafted nor specific project request has been made by TWB.

Chapter 3

Outline of the Project

Chapter 3 Outline of the Project

3.1 Approach to Solve Issues

3.1.1 Relation with Issues on Water Supply (National Level)

The issues faced in water supply sector in national level are summarized as below;

- Although multiple plans for water supply development have been formulated, they have not been implemented. The master plan for water facility development has not been updated since 1992.
- It's difficult to invest in facilities and equipment by the TWB's own funds due to the financial risks, such as reduced net income originating from increased depreciation cost associated with investment in facilities and equipment, and financial pressure due to the obligation to pay dividends to the government and their demands for lower water tariffs.
- The risk of salination of water sources (freshwater lens) has been increasing due to the reduced precipitation and sea level rise that has potentially been caused by the global warming and the effects of tsunamis.
- TWB's tap water is customarily not preferred for drinking purposes due to its high hardness originated from limestone and poor taste compared to the rainwater for their daily use for drinking. However, rainwater may potentially bring safety and stability risks for drinking purpose.
- TWB operators' capacity for O&M of water supply facilities is insufficient, and water quantity, quality management, chemical dosing control and equipment management are not properly practiced.
- Insufficient budget has been allocated to rehabilitate the water supply facilities and equipment that have been installed, resulting in increased malfunctions and water leakage due to ageing.
- Water supply in the village areas outside the TWB water supply area are facing problems in terms of finance and O&M capacity also with their vulnerability to natural disasters.
- Disaster response measures such as emergency water supply and recovery action are inadequate.

Above issues and their relationship to the proposed project are summarized in Table 3.1.

Table 3.1 Relationship between Issues in National Level and Proposed Projects

Issue	Improvement by Projects
Financial risks and insufficient funds for facility development	Increase of the tariff revenue through the development of new water source and expansion of water supply area
Salination of water source	Prevention of salination of water source through development of multiple water source systems and technical guidance on water source management.
Insufficient capacity to operate and maintain water supply facilities	Capacity building through technical guidance on the O&M of water supply facilities
Vulnerability of water supply services in rural areas	Overcoming vulnerability by integrating village water supply into the TWB distribution pipe network.
Inadequate response measures to disaster	Improved response to disasters through multiple water sources, construction of emergency bypass communication pipe, and technical guidance.

Source: prepared by the survey team

3.1.2 Current Status and Issues in Water Supply Sector and their Relationship to the Project

The issues in supplying drinking water faced by the current status of the water supply are (i) the vulnerability of the water supply system to massive natural disasters and (ii) the vulnerability of water supply services in village areas as described above. In response to (i), the proposed project will enable the system to overcome the increased water demand in urban centers in an event of disasters through developing new water sources to provide multiple water supply sources and connection pipe to the existing reservoir. In addition, the installation of the bypass connection pipe to the existing pipeline network will ensure an emergency route to enable water supply even in an event of a breakage in the water distribution main. In this way, the resilience of the water supply system against natural disasters will be enhanced. Regarding (ii), as a secondary effect, the distribution pipe network will be expanded to the village areas around the new water source and integrated into the TWB water distribution network with high safety and stability.

3.1.3 Scope of the Project

The scope of the cooperation by Japanese government is envisaged as (i) the development of new water sources and water supply facilities to form a resilient water supply system on Tongatapu Island and (ii) technical guidance through implementing soft component toward effective and efficient O&M of the newly developed water sources and water supply facilities to ensure that they are utilized in a sustainable manner.

3.1.4 Scheme of the Project

The project utilizes a Japan's ODA scheme of Grant Aid Project including a Soft Component. This is a type of ODA Grants in which the government of a partner country enters into contracts with consultants or contractors to construct facilities or to procure equipment and materials.

3.1.5 Implementation Schedule

The tentative implementation schedule of the proposed project is shown in Table 3.2 at this stage.

Table 3.2 Implementation schedule of proposed projects (Tentative)

Milestone for implementation	Year of implementation
Submission of Application form from the Kingdom of Tonga.	2023
Evaluation of the request by the GOJ (Government of Japan)	2023 to 2024
Preparatory survey (Basic design)	2024 to 2025
Detailed design	2026
Implementation (Construction, procurement, soft component)	2027 to 2028

Source: prepared by the survey team

3.2 Objective of the Project

3.2.1 Short-term Goals

The short-term goal of the project is to raise the resilience of the water supply system on Tongatapu Island by realizing multiple water sources through developing new water sources, improving emergency response to increased water demand in an event of natural disasters by installing a connection pipe to the Mataki'eua reservoir, and securing water distribution routes in an event of disasters by constructing a bypass connection pipe from the Mataki'eua reservoir.

3.2.2 Medium / long-term Goal

The medium- to long-term objectives are to develop new water sources that are less susceptible to salination, to realize the sustainable use of the groundwater source and improve the water supply service stability by strengthening water source management, and to optimize water supply by strengthening operation and maintenance capacity of water supply facilities and utilizing daily operation and maintenance data.

3.3 Description of the Project.

3.3.1 Outline of the Project

(1) Objectives of the Project

Based on the development policies and plans and the recovery and reconstruction plan from the damage caused by the HTHH submarine volcanic eruption and tsunami in January 2022, the proposed project will contribute to the resilience of the water supply system on Tongatapu Island by realizing multiple water sources through developing new water source development and a bypass connection pipe from the existing reservoir. The project will strengthen the system and contribute to improving the stability of the water supply system in Tonga which has been threatened by natural disasters and climate change.

(2) Outline of the Project

In order to achieve the above objectives, the project will develop new water sources and implement the necessary water supply facilities as well as the soft component.
The outline of the proposed project is summarized in Table 3.3.

Table 3.3 Outline of the Project

Component	Contents
Basic Survey	Water source development survey
	Installation of groundwater observation wells
Facility Construction	Production wells: 7 locations (including 1 magnetic flow meter per well)
	Solar power generation system: 100 kVA ,1 set
	Emergency power generation system: 100 kVA, 1 set
	Reservoir: 1,000m^3
	Raw water transmission pipe: 5km
	Transmission pipe: 25 km
	Distribution pipe: 15km
	Bypass connection pipe: 5.5km
	Electromagnetic flow meter: 8 locations
Soft Component	Technical guidance on water source management
	Technical guidance on operation and maintenance of water supply facilities

Source: Prepared by the survey team

3.3.2 Content, Scale and Quantity of the Projects

The detailed content, scale and quantity of the project described hereinunder.

(1) Development of New Water Sources

A study for the development of alternative water sources will be carried out to reduce the risk of salination of local water sources and to strengthen the water supply system to overcome the increasing intensity of natural disasters potentially caused by global climate change over the medium and long term. The candidate site for new water source is the Fua'amotu area in the south-east of the island (See Figure 3.1), where the thickness of the freshwater lens is expected over 10 m. The target development water volume is planned to be set as 9,341 m^3 /day × 30% = 2,800 m^3/day as back-up water for the actual water supply volume of Nuku'alofa's current water supply in 2021. Seven (7) new wells will be developed as production wells to limit the pumping rate per well to 5 L/sec = 432m^3/day as shown in the following calculation to avoid salination possibly caused by the upconing.

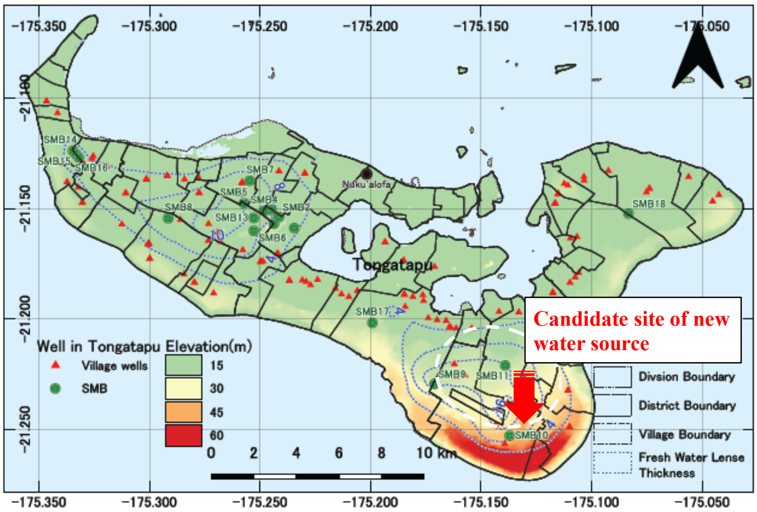


Figure 3.1 Location of Potential New Water Source Development on Tongatapu Island

- Pumping rate per well: 5 L/sec = 432 m^3/day (24-hours operation)
- Number of production wells required: 2,800 m^3/day ÷ 432 m^3/day ≈ 7 wells

1) Contents of the survey for the development of new water sources

The following section describes the content of the survey works related to the development of new water sources.

Estimation of groundwater recharge;

The following works will be carried out to estimate the groundwater recharge in the target area and assess the amount of groundwater that can be developed.

- Calculation of evapotranspiration by gathering existing meteorological data (e.g. rainfall, temperature, sunshine hours) and vegetation information
- Gathering existing soil conditions and hydrogeological information (e.g. hydraulic conductivity, storage coefficient, effective porosity)
- Developing a simplified groundwater recharge model
- Estimation of groundwater recharge at potential new water source development sites.
- Assessment of the amount of groundwater that can be developed

Geophysical exploration;

Geophysical exploration will be carried out to determine the actual drilling sites and estimate the shape of the freshwater lens (distribution area, depth and potential volume) of potential new water source development sites.

The geological structure of Tongatapu Island is not complexed as it basically consists of volcanic ash soils and limestone layers. Therefore, geophysical exploration methods for groundwater development will focus on electromagnetic prospecting (EM34) and electrical vertical electric survey (VES), taking into account their past experience and workability. The characteristicss of each exploration methods are listed below.

Table 3.4 Electromagnetic and Electrical Resistivity Exploration Method

Name of Survey	Method	Measurement Time per Point	Advantage	Disadvantage	Applicability
Electromagnetic Survey	Loop-loop method (EM34)	Approx. 20 mins.	Good workability.	When the layer structure exceeds three layers, the conductivity and layer thickness of each layer cannot be uniquely determined.	Suitable for overview. The electrical conductivity detected in the exploration is compared and verified with the actual conductivity of the observation borehole to establish it as the salt-fresh boundary.
Electrical resistivity survey	Vertical Electric Survey (VES)	Approx. 90 minutes.	Advantages to multi-layer analysis.	Few cases of application in freshwater lens surveys. Workability is not as good as with electromagnetic surveys.	It is suitable for close inspection as the apparent electrical conductivity can be estimated in multiple layers. However, for the establishment of the electrical resistivity (electrical conductivity) of the salt-fresh boundary, it is necessary to make corrections based on actual measurements in the observation borehole, as in electromagnetic surveys.

<u>Selection of well drilling sites;</u>

The drilling sites are selected based on the results of the geophysical exploration. In addition to the physical properties (e.g. electrical resistivity) obtained from the exploration, the spacing between each drilling point, the land use situation and the risk of groundwater contamination are also investigated in the selection process. Particular attention should be paid to the spacing of drilling points for production wells with a spacing of 0.75 to 1.0 km to avoid over-pumping or up-coning.

<u>Drilling of exploratory wells;</u>

Exploratory or test wells are drilled to estimate the appropriate pumping rate of production wells, EC values and aquifer hydraulic constants. The number of wells to be drilled shall be set as seven (7) taking its possibly converting the exploratory into observatory purpose.

Table 3.5 below shows the proposed specifications of the exploratory wells. The wells will be constructed to screen all the water below the unconfined water table and will be capable of measuring EC values at any groundwater depth.

Table 3.5 Specifications for Proposed Observation Wells (Draft)

	Specifications	Quantity	unit
1	Well drilling (drilling diameter: 9" and above)	100	m
2	Casing pipe (Bore diameter: 5 in, material: uPVC)	20	m
3	Casing screen pipe (bore: 5 in, material: uPVC)	80	m
4	Gravel packing (Depth: 15-100 m, including interception with bentonite, backfilling and cement filling)	85	m
5	Electrical logging (100 m)	1	set
6	Pumping test for water table drawdown (5 stages, 24 - 48 h continuous pumping including recovery test for water table)	1	set
7	Installation of wellheads and fencing.	1	set
8	Water-quality test	25	item

<u>Pumping Tests;</u>

In-situ pumping tests are carried out for the exploratory wells. As uplifted limestone of coral origin which forms the freshwater lenses is highly permeable, it is difficult to determine hydraulic constants such as hydraulic conductivity and storage coefficients using in-situ pumping tests such as the steady-state and transient methods. Therefore, it is recommended that the pumping tests in the basic survey should not be used to determine these hydraulic constants. Rather, it should be used to determine the appropriate pumping rate by measuring the change in EC values more in details.

<u>Water-quality test;</u>

As no national water quality standard is regulated in Tonga, the water quality testing is carried out using the WHO guideline for drinking water as a reference.

2) Installation of observation wells

<u>Drilling of observation wells;</u>

Total of ten (10) wells for observation of saltwater-freshwater boundary observation, will be developed together with the existing observation wells (3 wells). The additional seven (7) wells will be diverted from exploratory wells and will not be drilled again.

<u>Installation of groundwater monitoring instruments;</u>

Self-registering water level and EC meters in seven (7) wells will be installed to be converted to observation wells.

3) Installation of new production wells

<u>Conducting geophysical exploration;</u>

To compare and verify the results of geophysical exploration during water source development survey with the results of drilling exploratory wells and, if necessary, carry out additional geophysical surveys to improve the success rate of drilling production wells.

<u>Selection of well drilling sites;</u>

Based on the geophysical exploration results, location of drilling sites for seven (7) production wells will be selected. The drilling method will utilize the DTH (Down the Hole) method or the mud circulation method, both of which have a proven track record in Tonga.

<u>Well drilling and construction of ancillary facilities;</u>

Production wells will be drilled and ancillary facilities constructed. Due to the distribution and shape of the estimated freshwater lens and the limited pumping rate (approximately 5.0 L/sec), the facility can be designed on a small scale with a relatively small submersible pump. Therefore, the introduction of a hybrid system of solar and commercial power generation, which has advantages for small-scale facilities and is becoming increasingly popular in Tonga. As Tonga is prone to natural disasters, and power outages can be expected during emergencies, a power generator will also be introduced as part of the disaster prevention measures. The above hybrid power system will ensure redundancy in the water supply system at the source of electricity supply.

(2) Development of Water Supply Facilities

Figure 3.2 shows the general map of the improvement of facilities, while Figure 3.3 shows the flow of the water supply system after the facility improvement. A new water source will be developed in the Fua'amotu area in the south-east of Tongatapu Island, and a reservoir will be constructed on a hillside at a higher elevation in the village areas, from which a connection pipe will be installed for emergency back-up water supply to the existing Mataki'eua reservoir. The elevation difference between EL 60 to 70 m of the new water reservoir and EL. 20 to 30 m of the Mataki'eua reservoir will enable to convey the water by gravity flow. In addition, the water supply area will be expanded to the villages in the vicinity of the reservoirs, from where the water will be distributed by gravity flow at normal operation. The target villages are currently Fua'amotu, Nakolo and Ha'asini, although this will be finalized through further detailed surveys.

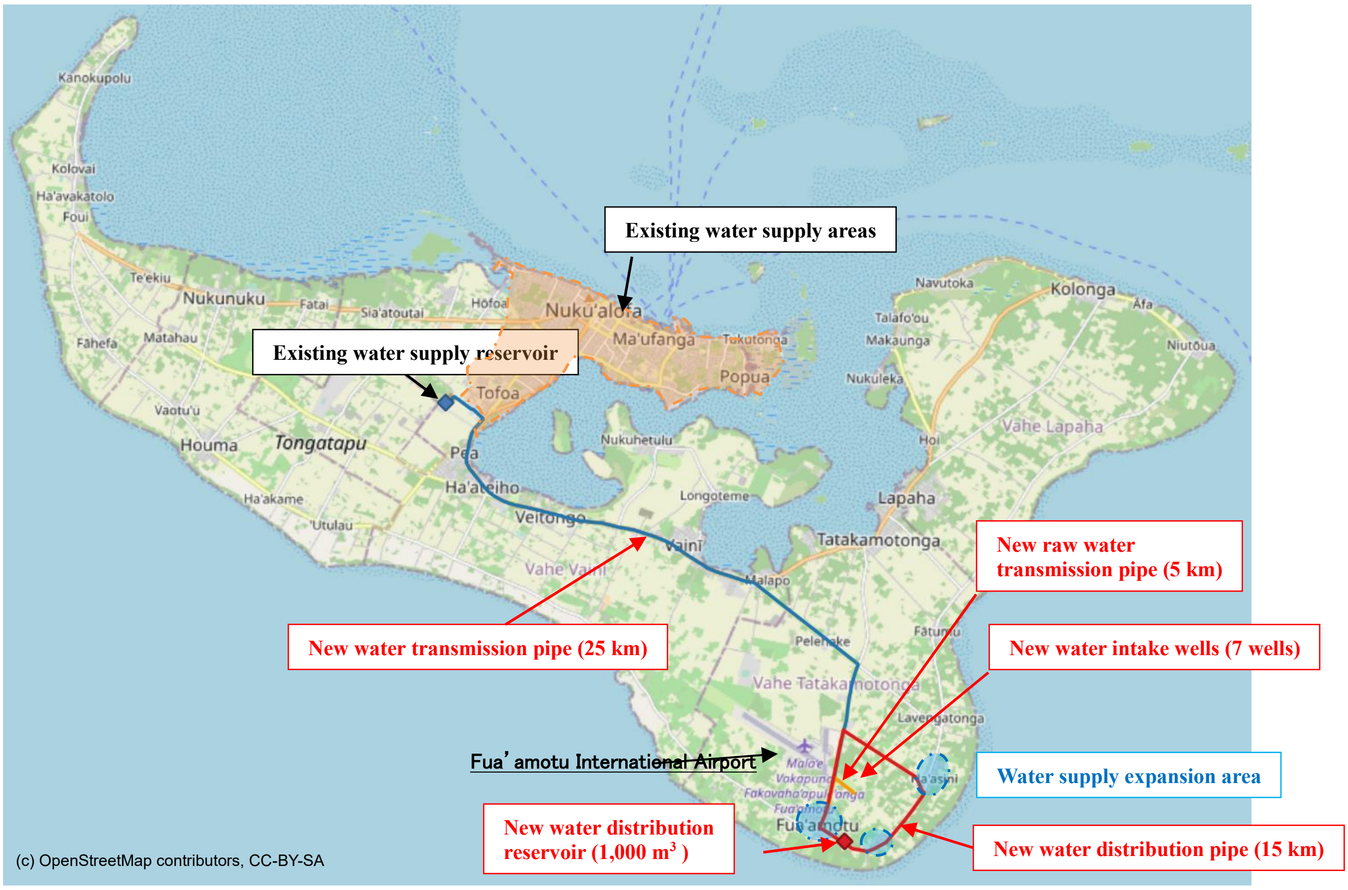


Figure 3.2 Proposed Improvement Plan of the Water Supply Facilities

Source: Survey team

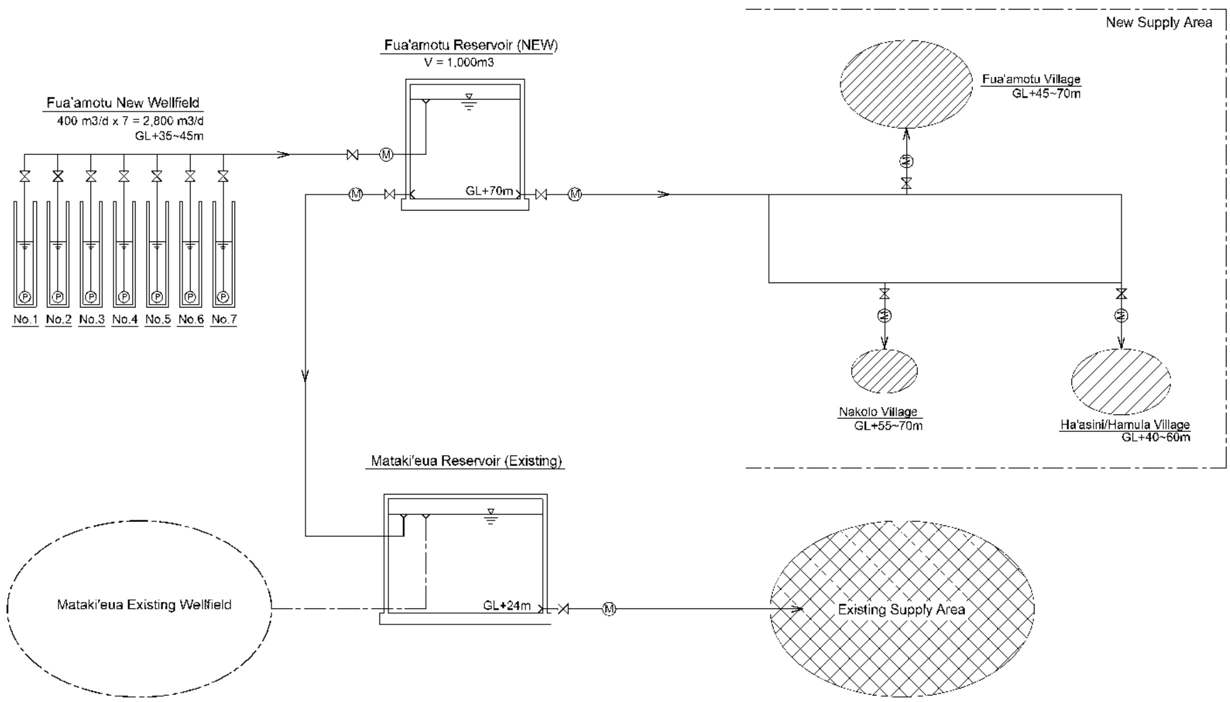


Figure 3.3 Schematic Flow Diagram of Proposed Water Supply System after Improvement

Source: Survey team

1) Construction of New Reservoir

The capacity of the new reservoir shall be 1,000 m^3 which is equivalent to a storage volume of 9 hours for approximately 2,800 m^3/day of the developed water volume from the new water source. The developed water volume for this project is set as a minimum volume as an emergency back-up water supply to the capital city of Nuku'alofa, then expanding the capacity of the reservoir needs to be taken into account in line with further water source development and water supply expansion in the future. The potential site of the reservoir is described later in details.

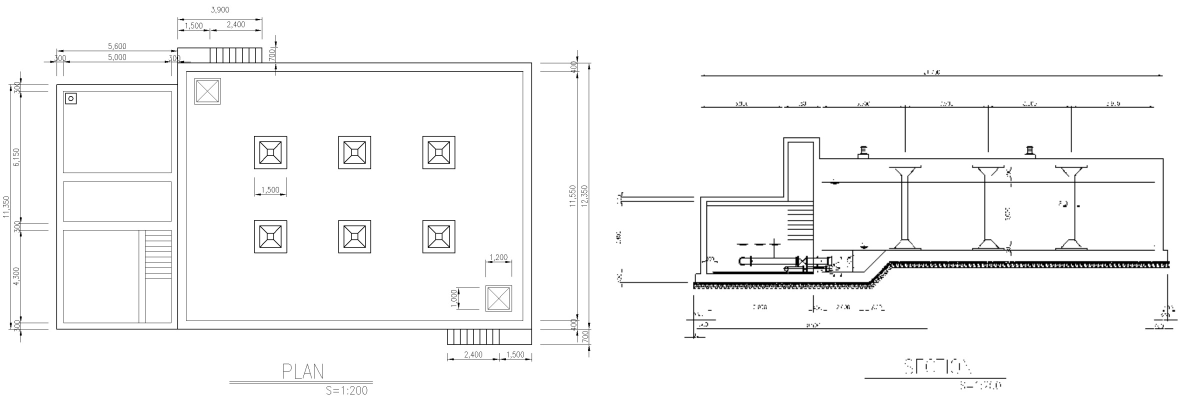


Figure 3.4 Plan and Section of New Reservoir (1,000 m^3)

Source: Survey team

2) Development of New Water Pipelines

A total of 45 km of pipelines will be constructed, which consists of the raw water transmission pipe from the new production well fields to the new reservoir (approx. 5 km), water transmission pipe from the new reservoir to the existing Mataki'eua reservoir (approx. 25 km) and the water distribution main and branches to the village areas around the new reservoir to be included in the water supply area (approx. 15 km). A construction of District Metered Areas (DMAs) will be considered to improve the flow management for the village areas where the water supply will be extended.

3) Development of Emergency Bypass Connection Pipe

The ø500 mm distribution main from the Mataki'eua water reservoir is currently a single line. The proposed bypass connection pipe as shown in Figure 3.5 will secure the water distribution route as dual lines in case of emergency, thereby improving the redundancy in the water supply system. The bypass connection pipe is estimated to be 5.5 km long with a diameter of 300 - 500 mm. Pipe network calculations show that the use of this bypass pipe at normal operation can be expected to improve the water supply pressure for the existing water supply area.

Water is essential for vital and social activities. If water supply is cut off at a disaster, a priority action of securing water will delay restoration activities. The bypass connection pipe will be possible to concentrate on other restoration works in an event of disasters.

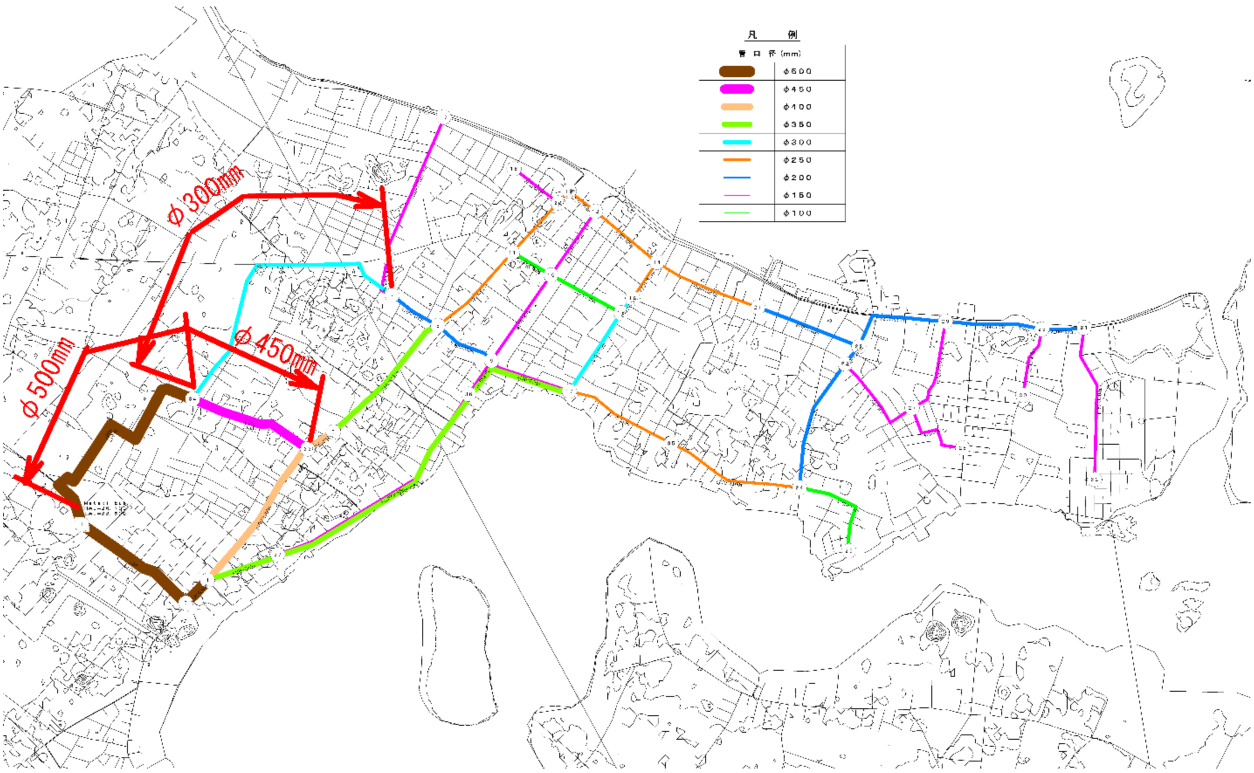


Figure 3.5　Proposed Development of Bypass Connection Pipe

4) Electromagnetic Flowmeter

In addition to the seven (7) flow meters in the new well field, new electromagnetic flow meters will be installed at total of eight (8) locations: one (1) for inflow pipe in the new distribution basin, one (1) for the distribution main, two (2) for the clear water transmission pipe, three (3) for the inflow section of each DMA in the village areas where water supply is being extended, and one (1) for the bypass connection pipe in the Mataki'eua reservoir.

(3) Implementation of Soft Component

1) Background of propose for soft component

The proposed project plans the implementation of facility construction with the aim of strengthening the water supply system against natural disasters. However, TWB, as the main body responsible for the maintenance of the water supply facilities, does not have sufficient knowledge and experience in operation and maintenance of the facilities.

Technical guidance should be provided to support the operation of the facility and streamlining of emergency response to maximize the outcome of the cooperation of the development of the proposed facilities. TWB has formulated their BCP (Business Continuity Plan) for emergency events which also covers emergency response measures in its annex. Specifying the operation of the proposed facility to be developed will enable to make a smooth response to an event of disasters.

In addition, as mentioned above, the progression of salination of groundwater source is a major issue for water supply services in Tonga, and technical guidance on the management of new water sources to be developed under the proposed project will be important. Technical guidance will be provided not only to TWB but also to MLNR which has a jurisdiction over water source management focusing on sustainable utilization of groundwater sources covering acquisition of skills on the methods for gathering and analyzing observation data and groundwater pumping restrictions based on observation results.

Table 3.6 lists the target subject of the soft component.

Table 3.6　Subjects of Soft Component (Draft)

Subject	Objective
Technical guidance on the O & M of water supply facilities	Efficient operation of the water supply system using the facilities and equipment to be developed and strengthening of capacities related to emergency response.
Technical guidance on water source management.	Strengthening O & M capacity of water sources for sustainable utilization of new and existing water sources

Source: Survey team

2) Objective of Soft Components

The objectives of the soft component are:

- "A system is established to properly operate and maintain the facilities developed by TWB and to smoothly implement emergency response, and to implement systematic water source management throughout Tonga utilizing the know-how acquired on water source management
- To "ensure that the know-how acquired on water source management is used to implement systematic water source management throughout Tonga".

3) Outcome of Soft Components

The expected outcomes of the implementation of the soft component are summarized below.

(i) <u>Technical guidance on operation and maintenance of water supply facilities;</u>

TWB staffs in charge of the facility operation will acquire the capacity to understand the composition and purpose of the entire water supply system, including water intake, transmission and distribution facilities to be developed by the grant aid project as well as the capacity to operate, maintain and manage the system appropriately and smoothly respond to emergency situations.

(ii) <u>Technical guidance on water source management;</u>

The outcome is that the TWB staffs will acquire the knowledge and skills related to water source management necessary for the continuous long-term utilization of the new water sources to be developed by the grant aid project, which will be shared with the staff of the remote island branches other than Tongatapu Island, and will also be used for the management of existing water sources in each branch offices.

3.3.3 Dispatch of Experts, Contents, Scale and Quantity of Materials and Equipment

The implementation schedule for the proposed project as project-based grant aid projects including dispatch of experts and soft components is shown in Table 3.7.

Table 3.7 Dispatch Schedule of Experts (Tentative)

Works \ Year	1st Year: Basic Design (months 1–12)	2nd Year: Detailed Design (months 1–12)	3rd Year: Construction Supervision (months 1–12)	4th Year: Coonstruction Supervision & Soft Componenet (months 1–6)	Required M/M
【Basic Design】					
Study on basic conditions (Planned Served Population)					2
Study on new water source development					3
Study on water supply system					3
Study on intake and conveyance facilities					6
Study on transmission and distribution facilities					5
Study on cost estimate, procurement and construction supervision					3
Study on environmental & social consideration					2
【Detailed Design / Construction Supervision】					
Intake Wells					15
Solar and emergency generator systems					7
Reservoir					11
Pipelines (Conveyance, Transmission & Distribution) and Distribution Networks					20
Cost Esitmate / Bidding					5
【Soft Component】					
Training on O & M of water supply facility					2
Training on water source management					2
【Dispatch of Experts】					
1.Water supply plan expert					11
2.Water source expert					18
3.Water distribution and its O & M expert					11
4.Pipe design and its O & M expert					18
5.Environmental & social consideration expert					2
6.Mechanical expert					9
7.Electrical expert					9
8.Cost Estimate / Contract Expert					8

Source: Prepared by survey team

(1) Tentative Allocation of Experts

Field of Expertise	Task
(i) Team leader and water supply planning	1. Project organization 2. Planning for the development of facilities 3. Planning of soft component 4. Technical guidance on the operation and maintenance of facilities
(ii) Water sources planning / Hydrogeology	1. Planning for the development of facilities 2. Basic survey on the development of new water sources 3. Installation of new observation wells 4. Assessment of new and existing water sources. 5. Reassessment of recharge rates 6. Technical guidance on water sources management.
(iii) Water distribution facility planning and maintenance	1. Planning for the development of facilities 2. Consideration of new water distribution facilities 3. Guidance on O & M for water distribution facilities 4. Guidance on emergency response including facility operations
(iv) Pipeline planning and maintenance	1. Planning for the development of facilities 2. Water pipeline planning (raw, clear water transmission and distribution pipes) 3. Guidance on O & M of pipeline 4. Guidance on safety measures
(v) Environmental and social consideration	1. Planning for the development of facilities 2. Land acquisition surveys for proposed sites for new water sources and reservoirs. 3. Water rights status survey for new water sources. 4. EIA support to TWB for implementation of water supply projects 5. Support for stakeholder consultations on new water supply projects
(vi) Mechanical equipment and O & M	1. Planning for the development of facilities 2. Examination of mechanical equipment for new water intake wells. 3. Examination of mechanical equipment for new water distribution facilities.
(vii) (Electrical equipment and O & M	1. Planning for redevelopment. 2. Examination of electrical equipment for new water intake wells. 3. Examination of electrical installations for new water distribution facilities. 4. Examination of development of solar and emergency power generation systems
(viii) Cost Estimate / tendering	1. Planning for the development of facilities 2. Cost estimation in basic and detailed design 3. Development of construction / procurement plans 4. Preparation of tender documents

Source: prepared by the survey team

(2) Procurement of Equipment

No provision of equipment is planned in the proposed project.

3.3.4 Rough Estimate of the Project Cost

The estimated project cost including basic survey, facility construction, soft component and design / supervisions is about 3.3 Billion Japanese Yen as shown in Table 3.8. Two (2) packages are indicated for its implementation in light of the constraints of the budget of the Japan grant aid scheme.

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Table 3.8 Breakdown of Estimated Project Cost

Unit: 1,000 yen

Component	Breakdown	Amount
1. Direct construction cost		
1.1 Basic survey	Water source survey: Geophysical exploration x 7 locations, installation of observation wells x 7 locations	61,000
1.2 Facility construction (Package 1) (Multiple water sources)	• Production well: 7 places (including pumps, flow meters, electrical panels, etc.) • Solar power generation equipment: 100 kVA 1 set • Emergency power generation equipment: 100 kVA 1 set • Reservoir: 1,000 m^3 • Transmission and distribution pipelines: 45 km. • Electromagnetic flow meter: 7 units	1,898,000
1.3 Facility construction (Package 2) (Bypass connection pipe)	• Bypass connection pipe: 5.5 km. • Electromagnetic flow meters: 1 unit.	353,000
1.4 Direct construction cost		2,312,000
2. Overheads (1.4 x 30%)		694,000
3. Total of construction costs		3,006,000
4. Soft component	• O & M of water supply facilities • Water source management	15,000
5. Engineering	Detailed design / construction supervision	301,000
6. 4. + 5.		316,000
Grand Total		**3,322,000**

Source: prepared by the survey team

3.4 Condition of the Project Site

3.4.1 Location (Land Acquisition, Land Use, Pollution Sources, etc.)

(1) Resilience of water supply systems against natural disasters (Development of new water sources and related water supply facilities)

1) Land availability for the project

The project site consisting of the new water source and reservoir as shown in Figure 3.6 is located in the vicinity of the current airport in Fua'amotu and is under the jurisdiction of the aviation authority. The land is currently owned by a Noble, thus TWB has to issue an official letter to justify the plan for implementation the project, followed by the land acquisition process. The pipeline route leading to the Mataki'eua reservoir is located on an existing road right of way and has no need to acquire a new right of way.

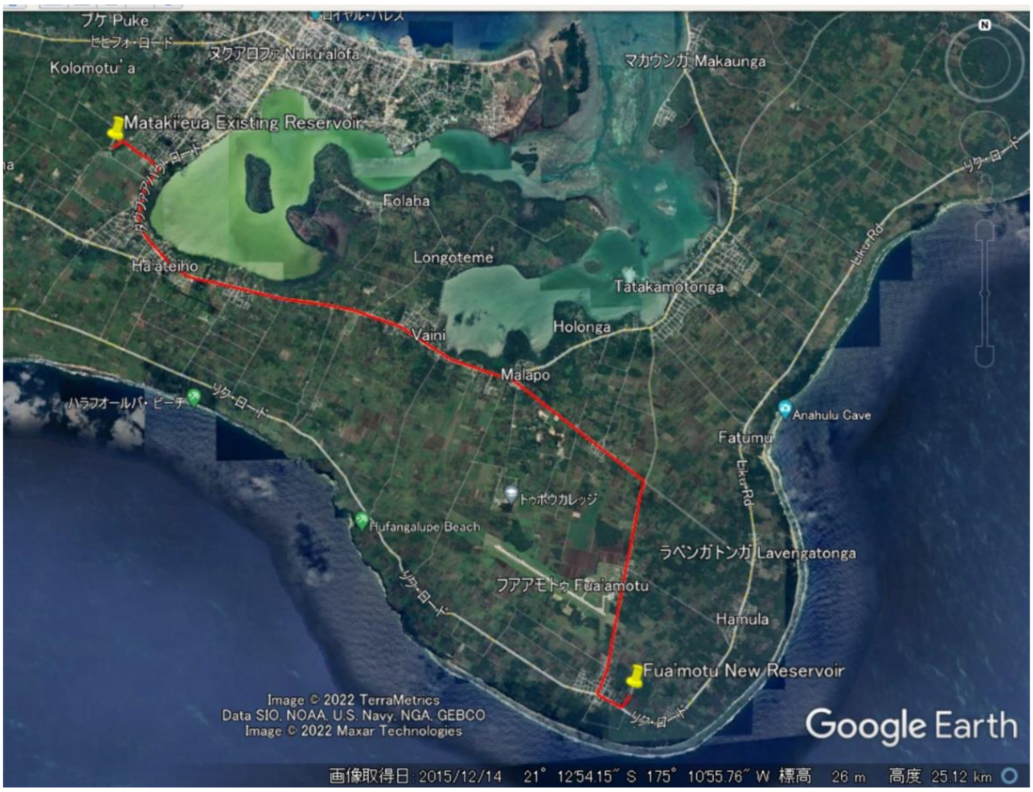

Figure 3.6 Location of Proposed Project Site

Source: Survey team

2) Land use

a) New water source and reservoir

The new water source area and the surrounding area of the reservoirs are mostly covered with grass and coconut forests partly cultivated with cassava and taro. However, the impact on the raw water to be withdrawn is assumed to be minimal. The area is also several hundred meters away from dwellings where sewage is discharged, and the impact of water pollution from the sewage is assumed to be minor.

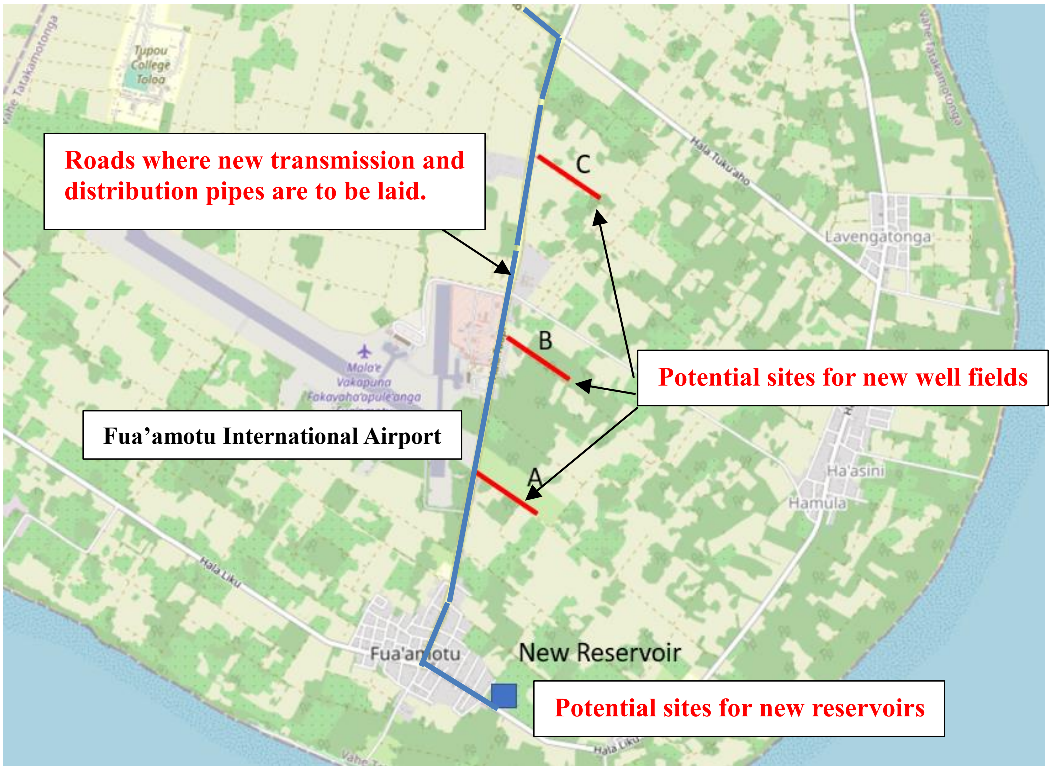

Figure 3.7 Potential Locations of New Water Sources and Reservoirs

Site situation of potential new well fields (1)

Site situation of potential new well fields (2)

Site situation in the vicinity of proposed new reservoir (3)

Site situation in the vicinity of proposed new reservoir (4)

b) Roads for proposed pipelines

Proposed pipes will basically be laid under the road. Most of the roads in Tonga are under jurisdiction of the Ministry of Transport (MOI), while the permit for the construction works of the pipelines can be easily obtained from the ministry according to interviews with TWB.

Photo. 3.1 shows the road conditions for the area from the new reservoir to the existing Mataki'eua reservoir. In the vicinity of the new reservoir, the village road is unpaved with the width less than 4 m, while the main road is paved and more than 4 m wide. The main road is paved with concrete pavement using coral limestone aggregate. The traffic volumes in the proposed project area are low and the impact of the construction works on the traffic is estimated to be relatively small.

Roads where pipes are to be laid and surrounding conditions (1)

Scheduled pipeline laying road (Tuku'aho road) (2)

Photo 3.1 Road Conditions from New reservoir to Existing Reservoir

3) Facilities potentially causing pollution

The new water source area and the surrounding area of the reservoir are mostly covered with grassland and coconut forests with some cultivation of cassava and taro, although the impact on the raw water to be withdrawn is assumed to be minimal. The area is also several hundred meters away from dwellings that discharge sewage, and the impact of water pollution from sewage is assumed to be negligible.

(2) Resilience of water supply systems against natural disasters (Part 2) (Development of bypass connection pipes)

1) Land availability for the project

The proposed bypass connection pipe, as shown in Figure 3.8, passes through the village road in Tofoa district from the existing Mataki'eua reservoir as a starting point, and branches into two (2) routes, namely, 1) the route passing through the existing village road up to the junction at the crossing point connecting with Vaha'Akolo Road with existing distribution network, and 2) another route passing through village road in Tu'atakilangi district and Hihifo Road up to the junction at the crossing point connecting with Alai'vahamama'o Bypass Road with existing distribution network.

The proposed route is planned to be developed in existing road right of way that belong to the government land, in which the land acquisition process is estimated to be easy as mentioned above.

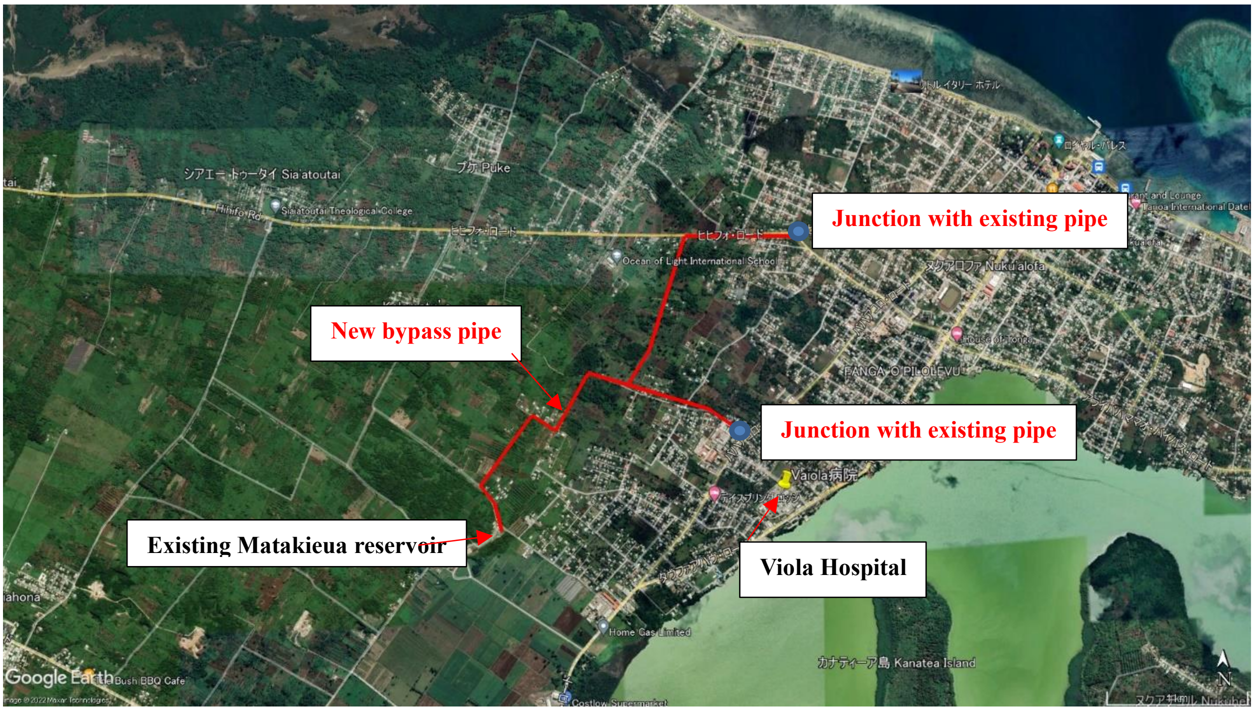

Figure 3.8 Planned Route of Proposed Bypass Connection Pipe

2) Land use

Photo 3.2 shows the roads where the new water distribution pipes are to be laid. The road width is approximately 4 m in the suburban area and 7 m on the main road in the urban area, respectively, which is a mixed paved/unpaved area. The main roads are paved with concrete and aggregates made of coral limestone. Traffic volumes in the proposed project area are low in the suburban areas for the high volume in the urban areas.

Roads for proposed pipeline and surrounding situation (1)

Roads for proposed pipeline and surrounding situation (2)

Proposed road junction for pipe laying (3) **Proposed road junction for pipe laying (4)**

Photo 3.2 Road for Proposed Pipeline Route

3.4.2 Natural Condition

(1) Topography and Geology

Tonga is located on the easternmost margin of the Indo-Australian Plate and is an arc-shaped archipelago formed by the uplift of the Indo-Australian Plate margin triggered by the subduction pressure from the Pacific Plate. Tongatapu Island extends 31.5 km in a northwest to southeast direction and approximately 18.5 km in a northeast to southwest direction, which has an overall northward inclined topography. In the vicinity of Fua'amotu in the south-eastern part of the island which is a potential site for a new water source, hilly areas with a maximum elevation of approximately EL. 65 m are distributed, sloping down towards the lowlands on the northern coast. A series of sheer sea cliffs are formed continuously on the southern coast, while a shallow lagoon separated from the open sea spreads in the central part of the island. In the eastern part of the island, karst landforms formed by chemical erosion of limestone are distributed, where limestone caves and sinkholes are often found.

Tongatapu Island is thought to have initially been a small reef that was formed in the south-eastern part of the current island. The island is believed to have gradually risen and a new reef was formed on the north-west side, resulting in the island's current topography.

The geology is composed of Miocene volcanic rocks as the basement with no outcrop on the island. The geology of the island which unconformably overlies the volcanic rocks, is mainly Pliocene to Pleistocene uplifted limestone of coral origin, reaching a thickness of about 134 m in Nuku'alofa and about 247 m in Fua'amotu, respectively. The surface layer is covered with a fine-grained andesitic volcanic ash layer about 5 m thick, which is used as fertile and productive agricultural land.

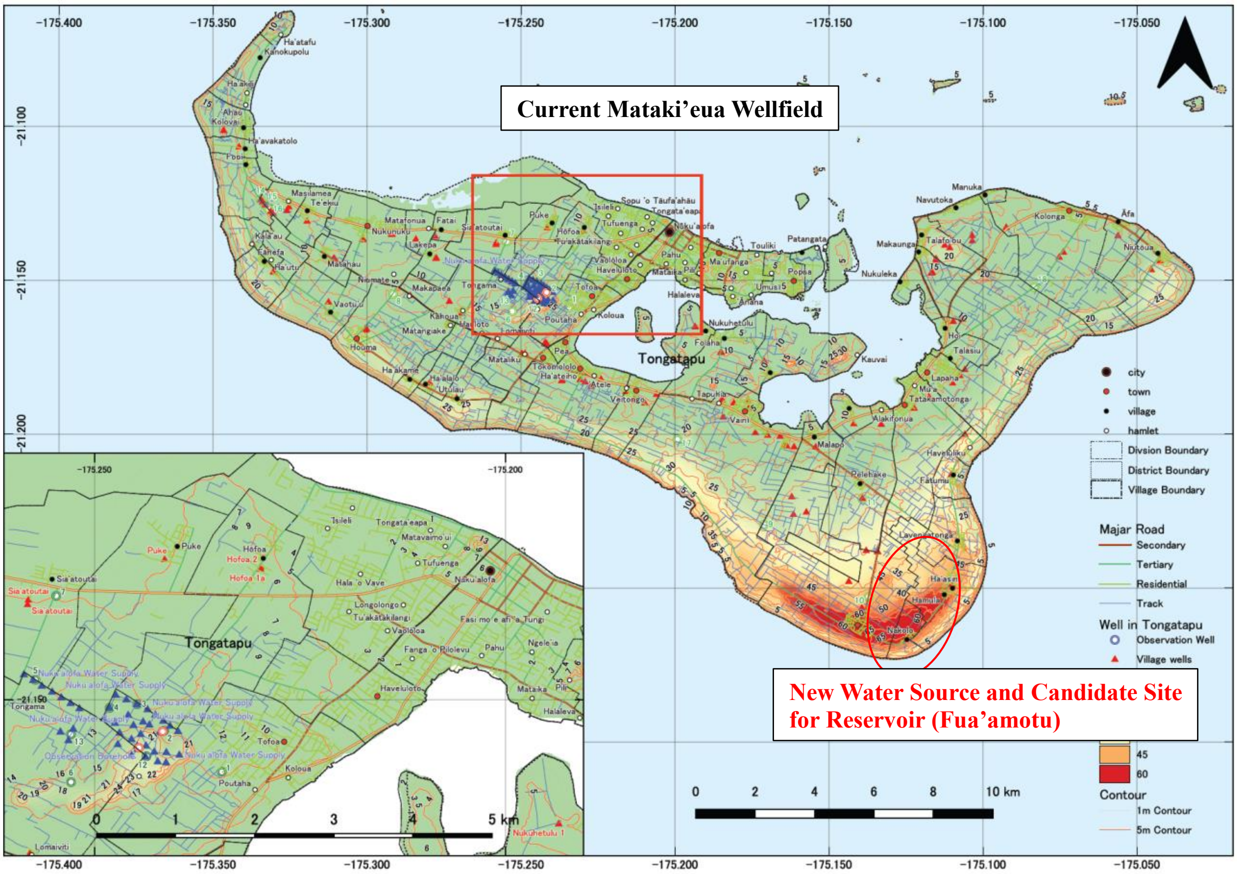

Figure 3.9 Topography of Tongatapu Island and location of project sites

Source: Survey team, based on information provided by TWB

(2) Meteorology

Temperatures in the capital city of Nukualofa have around 30° C (86° F) maximum and 20° C (68° F) minimum, with the highest temperatures in February and the lowest in July and August. Rainfall is divided into a wet season from November to April and a dry season from May to October, with around 60% of the annual rainfall concentrated in the wet season. Analysis of 30 years of data collected by the survey team from the Tonga Meteorological Service (TMS) for the period 1990 to 2020 shows that the Fua'amotu region in the south-east of Tongatapu Island had an average of about 1,900 mm/year of rainfall. The precipitation is strongly influenced by the cyclone intensity and frequency as well as by the El Niño Southern Oscillation. In particular, it is shown that Tongatapu Island has experienced extremely low rainfall during periods of the El Niño Southern Oscillation. For example, during the 1991 El Niño event, severely low rainfall was recorded with an annual rainfall of approximately 1,060 mm/year. In Nuku'alofa, the average rainfall between 1945 and 2006 was 1,727 mm/year, about 10% less than that of Fua'amotu, where the proposed new water source site is located at a higher altitude.

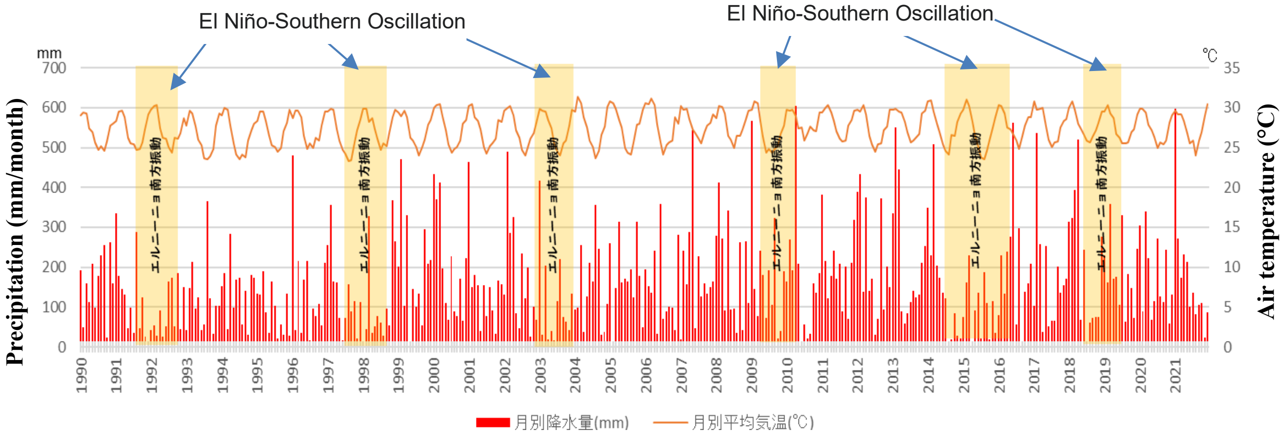

Figure 3.10 Past Trends in monthly precipitation on Tongatapu Island (1990-2020)

Source: Survey team based on information provided by TMS.

Table 3.9 Annual temperature change of temperature in Nuku'alofa

Month	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug..	Sep.	Oct.	Nov.	Dec.	Average
Min (°C)	23.3	23.6	23.4	22.5	21.1	20.2	18.9	18.9	19.2	20.1	21.3	22.4	21.2
Max (°C)	29.8	29.9	29.8	28.6	27.2	25.9	25	25	25.6	26.6	28	29	27.5
Mean (°C)	26.6	26.8	26.6	25.6	24.2	23	22	22	22.4	23.4	24.6	25.7	24.4

Source: https://www.climatestotravel.com/climate/tonga

(3) Water Source

1) Regional disparities in water sources

Similar to other islands, Tongatapu Island is largely covered by the formation of highly permeable limestone of coral origin, which has little or no surface water. The main source of water is the groundwater that is formed in freshwater lenses. Freshwater groundwater is estimated to be distributed throughout the island except for coastal areas and some localities. The average head of groundwater on Tongatapu Island is 0.4 m above sea level and the thickness of the freshwater lens with an upper limit of 2500 μS/cm conductivity for domestic use is estimated to be up to 14 m.

A total of 52 existing production wells, which provide the water source for the capital city of Nuku'alofa and other urban water supply areas, are located in the area of about 0.57 km^2 in the Mataki'eua region, about 5 km south-east of Nuku'alofa. However, only 39 wells were in operation as of August 2022 with the average pumped volume of 10,410 m^3/day of the groundwater. On the other hand, it is reported that around 200 wells for village water supply are operating under VWC control across Tongatapu Island, of which MLNR is aware of only 136 wells with no recorded pumping. In addition, a total of 18 observation wells (SMB 1-18) have been installed to observe the salt-fresh water boundary and investigate freshwater lens salination, with data collected several times a year for each.

Figure 3.11 shows the results of groundwater flow simulations based on the monitoring of the saltwater boundary by the observation wells. It is estimated that freshwater lenses thicker than 10 m are distributed in the hills around Fua'amotu in the south-east area of the island, which is expected to be a potential site for new water source development.

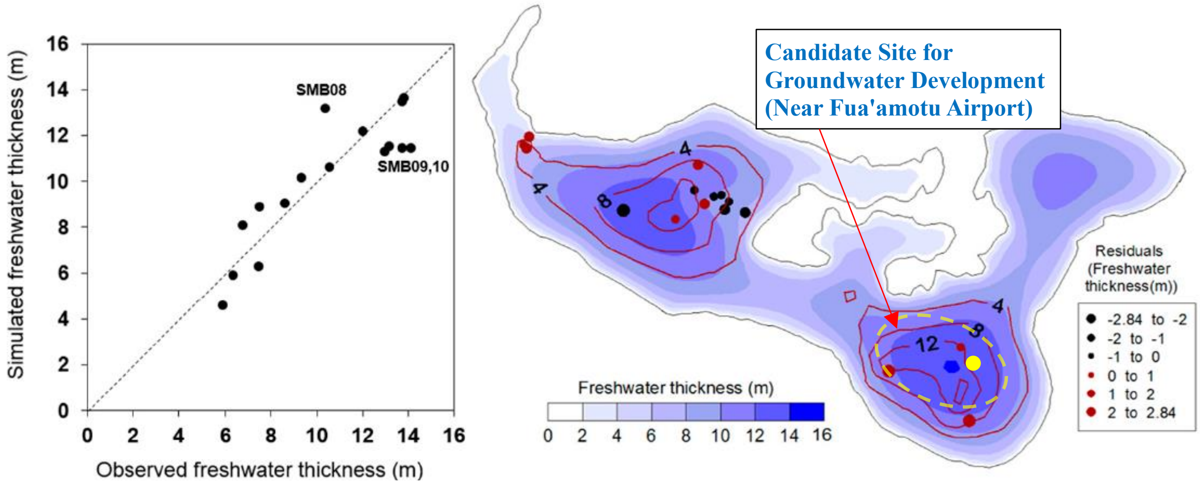

Figure 3.11 Estimation of Freshwater Lens Thickness at Observation wells in Tongatapu

Source: Roshina Babu 2018, Sharp Interface Approach for Regional and Well Scale Modelling of Small Island Freshwater Lens Tongatapu Island.

2) Salination of water sources

In 2007, MLNR made a measurement the EC (electrical conductivity) of 55 production wells to prepare a groundwater salinity distribution map for Tongatapu Island (see Figure 3.12). According to this distribution map, the salinity level is below the WHO's threshold limit of 1,500 µS/cm at the current well field for production in Mataki'eua and around Fua'amotu area as a potential new water source site. Two (2) wells measured by the survey team in August 2022 (see Table 3.10) also indicated the values of around 1,000 µS/cm. However, a serious value of 5,000 µS/cm for its salinity (EC) exceeding the WHO threshold limit was detected at the well in the Hihifo area in the north-west.

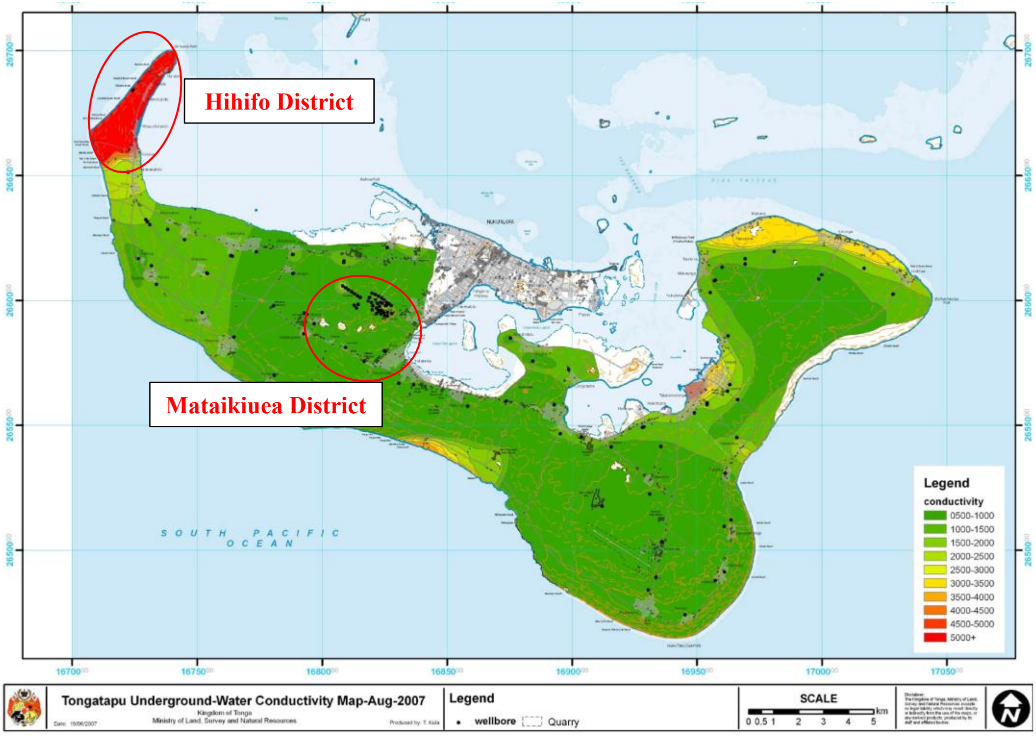

Figure 3.12 Distribution of Groundwater Salinity (EC) on Tongatapu Island.

Source: prepared by MLNR using measurements from 55 production wells in August 2007.

Table 3.10 Groundwater Salinity (EC) Measurements of Existing Water Sources in Tongatapu

Well Name .	classification	Electrical conductivity*. (μS/cm)	Pumped water quantity*. (L/S)	Remarks.
Well No. 214.	TWB production well	1090 μS/cm	3.9	Facilities within the Mataki'eua well cluster.
Well PW-6.	TWB production well	980 μS/cm	5.0	same as above
Pair-1.	VWC production wells	791 μS/cm	-	Located about 1 km south of the Mataki'eua well cluster.

*: measured during the field survey on 26 August 2022

3) Groundwater Balance and Recharge Volume

The groundwater recharge was analyzed using the WatBal (Water Balance) model in "Tongatapu Groundwater Vulnerability, June 2009", under several scenarios with changeable parameters such as intercepted storage and soil moisture storage to compare groundwater recharge under different vegetation and soil conditions. As a result, it was estimated that approximately 25 to 30 % of the annual precipitation is recharged on Tongatapu Island. For Nuku'alofa, which has an average rainfall of 1,724 mm/year, the average groundwater recharge was estimated approximately at 430 to 520 mm/year.

Figure 3.13 shows the annual rainfall and groundwater recharge rates for Nukualofa under the scenario in case of average recharge. The maximum groundwater recharge rate was estimated to be about 47% in 1971 as the year of highest rainfall compared to that of 0% in 1981, 1983, and 1992 as the years of recording lower rainfall.

UNESCO established approximately 20 to 50 % of average recharge as the amount of groundwater that can be sustainably used in pacific island countries including Tonga ("UNESCO (1991)"). Furthermore, 20 to 30 % of the average recharge was adopted as the sustainably usable groundwater volume for the islands with moderate rainfall such as Tongatapu Island as more secure figure ("Tongatapu Groundwater Vulnerability, June 2009"). Thus, in case using the above-mentioned average recharge rate of 430 to 520 mm/year, Tongatapu Island will have a sustainable available groundwater volume of about 86 to 156 mm/year. On a per unit area basis, 236 to 427 m^3/km^2/day or 2.7 to 4.9 $L/km^2/s$ can be estimated as the pumping potential.

On Tongatapu Island, the effective freshwater groundwater recharge area is set at 70% of the total area of the island excluding the areas within 500 m of the tidally influenced shoreline and 100 m of the lagoon, and the urban area of Nukualofa. The total area of the island is 257 to 260 km^2, namely, the groundwater recharge area for Tongatapu Island is estimated as approximately 180 km^2. Therefore, when 236 to 427 m^3/km^2/day is adopted as the sustainable available groundwater volume, approximately 42,000-77,000 m^3/day is estimated as the available freshwater groundwater volume for the entire Tongatapu Island.

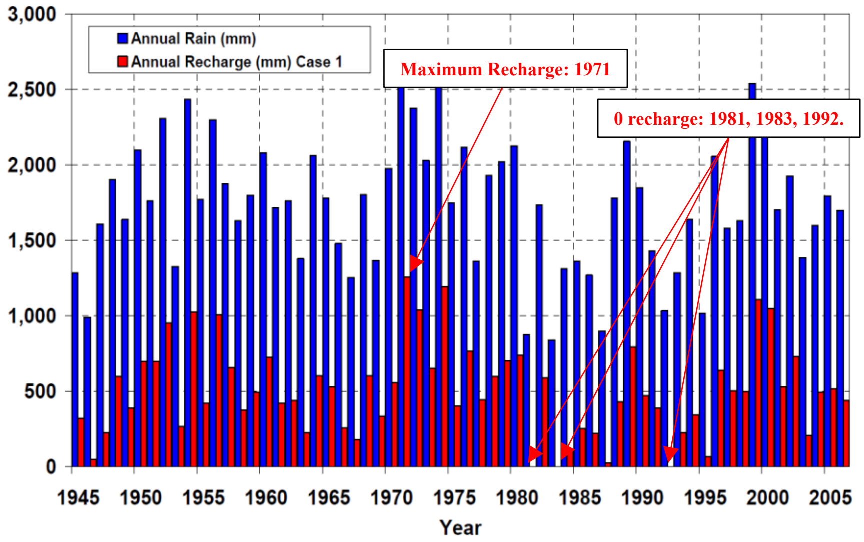

Figure 3.13 Annual rainfall and groundwater recharge in Nukualofa
Source: Tongatapu Groundwater Vulnerability, June 2009

4) Impact of Volcanic Eruptions and Tsunamis on water sources

The current Mataki'eua wells, which are the source of the urban water supply operated by TWB, are located more than 2 km from the coast and were reportedly not affected by the tsunami caused by the HTHH volcanic eruption. No evidence of contamination of groundwater by volcanic ash nor abnormalities in EC or pH values that exceeded standard values were measured at the site.

Meanwhile, in the Hihifo district in the north-west which is operated by VWC, the water source was not directly affected. However, the tsunami and ashfall generated by the volcanic eruption caused power generators and other power supply equipment to fail and water supply from the wells to be suspended for a long period.

3.4.3 Transportation

The transport network in t Tonga consists of land, sea and air routes. The total length of main roads is 680 km with 184 km of paved roads. Tonga has three (3) major ports: Nei'afu in Vava'u, Nuku'alofa in Tongatapu and Pangai in Ha'apai Islands. The transport between the country's islands is mainly by ferry and other vessels.

Tonga also has six (6) airports within the country. Two of these are international airports with paved runways, Fua'amotu International Airport on Tongatapu Island and Vava'u International Airport on Vava'u Island, which are served by different national and international airlines, including Fiji Airways, Air New Zealand, Air Tonga and Virgin Australia and Air Pacific.

In particular, Fiji Airways has been operating direct flights from Fiji (Nadi) to Tonga (Vava'u Island) twice a week (Wednesday and Saturday) since 2 April 2016. The reason is that the Vava'u Island offers attractive marine sports experiences, including whale watching, snorkeling, kayaking, kite surfing, sailing, diving and fishing.

In December 2019, JICA conducted a data collection survey on the two main airports (Fua'amotu International Airport and Vava'u International Airport) regarding the extension of runways and the expansion of terminals, etc., which will play an important role in Tonga in social, educational, medical services as well as a means of tourism, inter-island, international trade movement and transport.. The study was commenced to gather information on the extension of runways and terminals at the two main airports. In addition, the Fua'amotu International Airport served as a base for receiving emergency relief supplies from Japan and other countries when the HTHH volcano erupted in January 2022. However, the airport functions had to be temporarily suspended due to ash fall damage, and some damage to buildings due to ash fall removal work was confirmed in June 2022. JICA launched a study aimed at rehabilitation and reconstruction, assisting remote islands through improving connectivity between the main island and remote islands, and expanding and renovating the existing international passenger terminal building (PTB). The road leading to the potential new water source (Tuku'aho road) and the road in the proposed bypass connection pipe are mostly paved and will cause minor impact on the implementation of the project works.

3.4.4 Power Supply and Telecommunication

(1) Electricity

Electricity supply in Tonga is provided by the Tonga Electricity Authority. Tonga is poor in energy resources and has been dependent on imported oil resources for its electricity supply. In recent years, reflecting the transition to an energy-intensive economy, oil demand has further increased, and the country is vulnerable to energy security, as it is greatly affected by external factors such as fluctuations in international market prices of fossil fuels.

In view of this situation, the government of Tonga is introducing a target of 50% of electricity supply from renewable energy sources by 2020 in "The Tonga Energy Roadmap (TERM) 2010-2020" in order to secure diverse sources of electricity supply and ensure a stable electricity supply. However, the target has not been achieved.

At the 9th Pacific and Island Summit (PALM 9) in 2021, the Government of Japan made a statement that

Japan would provide high-quality infrastructure support to pacific island countries for the development of infrastructure including electricity, with an emphasis on openness, transparency, economic efficiency and debt sustainability.

In Tonga, the support is also being provided for the stable supply of energy through promoting the introduction of renewable energy and diversifying sources of electricity supply, as shown in the support such as the Grant aid of "Wind Power Generation System Development Programme".

Regarding the damage to power facilities caused by the HTHH volcanic eruption, the power grid was initially affected by the adhesion of volcanic ash to power lines and caused a damage on the power supply, resulting in flashovers in transformers, which damaged the submersible pump motors for wells and electrical control panels. Water supply by TWBs and VWCs was disrupted at the power outage from the grid. However, TWB was able to provide emergency water supply services as they had their own power generation facilities, while VWCs in the village areas could not provide water as the community did not have their own power generation facilities, thus they had to rush to TWBs for water supply services.

(2) Telecommunication

The telecommunications market in Tonga was 14 % with 11,000 fixed telephone lines and 70 % with 80,000 mobile phone lines as of July 2016. Internet penetration rate was estimated to be around 40 % as of July 2016. The two main telecom operators are Tonga Communications Corporation (TCC), a government-owned company established in 1984, and Digicel, a private company.

The large-scale HTHH eruption on 15 January 2022 caused major damage to the telecommunications network system through disrupting telephones, internet and other communication networks due to the severing of submarine cables, in which TWB took plenty of time to grasp a detailed assessment of the damage to the facilities.

At present (As of December 2022), all communication networks have been restored and no disruptions have been identified.

3.4.5 Security

Tonga is considered a relatively safe country among the pacific island countries, and as of July 2022, the Japanese Ministry of Foreign Affairs' "Overseas Travel Safety Information" have not issued an official warning of danger for the nationwide of Tonga.

3.4.6 Others

(1) Population

Tonga has conducted its national census every 10 years since 1956 and every five years since 2011, with 2021 being the latest census. Tonga has a population of 100,179, 18,559 households and 248 institutions. Population growth has been gradually declining from 1.1% in 1986 and declining since 2016. The ratio of urban to rural population has remained almost unchanged since 2006, in which the ratio accounts for approximately 21% for the urban area and 79% for the rural areas at the latest.

Table 3.11 Population Trend in Tonga

Item/ year	1986	1996	2006	2011	2016	2021
Total population	94,649	97,784	101,991	103,252	100,651	100,179
Average annual increase (%)	1.1	0.5	0.4	0.2	-0.5	-0.1
Average age (years)	19	20	-	21	22	22
Urban population	-	-	23,658	24,229	23,221	21,185
Urban population (%)	-	-	23.2	23.5	23.1	21.1
Rural population	-	-	78,333	79,023	77,430	78,994
Rural population (%)	-	-	76.8	76.5	76.9	78.9

Source: Tonga Census of Population and Housing 1996, 2006, 2011, 2016 and 2021

The five (5) administrative divisions of Tonga are, Ongo Niua, Vava'u, Ha'apai, 'Eua and Tongatapu from north to south. The division is divided into 23 districts, each of which further comprises several villages. Table 3.12 indicates the population by district in 2016 and 2021. The most populous district is Tongatapu Administrative District with 74,320 people, representing approximately 74% of the total population of Tonga. It is followed by Vava'u Administrative District with 14,182 inhabitants, or approximately 14% of the total population of Tonga. Apart from Vava'u, the population has been declining in recent years, particularly in Ha'apai, which was severely affected by the HTHH eruption and tsunami in January 2021, with an average annual decline of approximately 1.6%, and in Niuas, with a decline of approximately 1.4%.

Table 3.12 Population Trends by Administrative Division / District in Tonga

Name of Island	2021 Census (persons)	2016 Census (persons)	Population change 2016-2021 (persons)	Population change rate 2016-2021 (%)	Average Annual Growth 2016-2021 (%)
Tongatapu	74,320	74,611	-291	-0.4	-0.1
Vava'u	14,182	13,738	444	3.2	0.6
Ha'apai	5,665	6,125	-460	-7.5	-1.6
'Eua	4,864	4,945	-84	-1.6	-0.3
Ongo Niua.	1,148	1,232	-84	-6.8	-1.4
National Total	100,179	100,651	-472	-0.5	-0.1

Source: Tonga Census of Population and Housing 2021

Table 3.13 indicates the population trends in the Tongatapu administrative district. Currently, TWB provides water supply mainly to the capital city of Nuku'alofa, with the water supply areas of Kolofo'ou and Kolomotu'a districts accounting for approximately 46% of the total population of Tongatapu Island. On the other hand, Fua'amotu, a potential water source area for the proposed project, is located in Takakamotonga and has a population of 7,192 people or about 10% of the total population.

Table 3.13 Population trends in Tongatapu administrative district

District/ year	2011	2016	2021
Kolofo'ou.	18,957	18,064	17,274
Kolomotu'a.	17,088	17,120	16,868
Vaini.	12,949	12,999	13,199
Tatakamotonga.	7,233	7,043	7,192
Lapaha.	7,380	7,117	7,309
Nukunuku.	7,733	8,001	8,177
Kolovai.	4,046	4,267	4,301
total	75,416	74,611	74,320

Source: Tonga Census of Population and Housing 2021

Chapter 4

Conclusion

Chapter 4 Conclusion

4.1 Special Notes

Due to its geographical location, Tonga is exposed to different natural disaster risks such as cyclones, floods, droughts, earthquakes, volcanic eruptions, tsunamis, and sea level rise due to recent global warming. "The Global Risk Report 2020" ranks Tonga as second after Vanuatu among 181 countries in terms of "disaster risk". The H THH submarine volcanic eruption and tsunami that occurred in January 2022 caused extensive damage to the country's infrastructure and lifelines, which exposed the country's vulnerability to natural disasters .

In response to this situation, with the support of the Japanese government, a survey is currently underway by the JICA disaster prevention team to formulate a recovery and reconstruction plan for infrastructure such as ports, housing, and roads, and a support project is planned to be implemented in the future. The initiative of the aim of the JICA survey is based on " Build Back Better " concept which is to prepare for the next disaster in the reconstruction stage and create a more resilient community against disasters. The purpose of the project is to "strengthen the water supply system. Tongatapu Island has the largest area and population in Tonga, and the capital of Nuku'alofa is located as the political and economic center of the country. Nuku'alofa also has Vaiola Hospital, the country's only core hospital for preserving the lives and health of the people, which has to maintain its ability to supply clean water even in an emergency such as disasters without its outage. In addition, Nuku'alofa has to respond to supply water to the disaster-affected residents of remote islands. Furthermore, in order to overcome medium- to long-term salination of the freshwater lens as the water source, multiple water sources will be established in the target area. Securing it will ensure its stability as a tap water source.

The proposed project will improve these issues, bring safety and security to the lives of the people of Tonga, and contribute to strengthening the foundation for economic development .

4.2 Points of Concern

A comprehensive survey was conducted in a short period of time on all the islands where TWB operates the water supply business, and high priority projects were selected based on the survey results. Therefore, in the preparatory survey for cooperation, it is necessary to conduct a more detailed survey of the capacity of the executing agency and the external environment related to project implementation, and to evaluate the feasibility of the project. In particular, in this project, the development of a new water source in the Fua'amotu area was proposed. It is necessary to examine further in details the potential and sustainable pumping volume. In addition, since the management of production wells falls under the jurisdiction of the MLNR not the TWB, it should be noted that when planning technical guidance on water resource management, the target C/P should be determined in consideration of its effectiveness.

In Tonga, different procedures are required depending on the land ownership of royal, aristocratic, and government land. It is necessary to confirm the detailed procedures in line with the national regulations.

4.3 Conclusion

Tonga has various vulnerabilities to the external environment, such as sea level rise due to natural disasters and climate change. Therefore, overcoming this problem is an essential challenge for the social and economic development of the country. In particular, Tongatapu Island is the political and economic center of Tonga, which has the capital, Nuku'alofa. Maintaining the function of the lifeline is an essential issue for the future. Among these, water supply is directly linked to the life support of people in an event of disasters, and is an indispensable element for ensuring hygiene, implementing necessary medical treatment, and social activities in the recovery stage.

The proposed project aims to "resilience of the water supply system" for Tongatapu Island through implementing 1) development of multiple water sources, 2) development the bypass connection pipe and 3) technical guidance of the operation and maintenance of the water supply facilities and water sources. The goal is to overcome the vulnerability of the Tongatapu water supply system to the external risk environment and improve the stability of the water supply over the medium to long term.

Securing the stable supply of tap water, which is one of the most important lifelines in an event of disasters, the implementation of this project will bring safety and security to the lives of the people of Tonga and contribute to strengthening the foundation for economic development. Considering the past relationship between Japan and Tonga as well as the Japan's aid policy for the country, the implementation of the project is considered to have great significance.

4.4 Closing Remarks

The relationship between this survey team and TWB, the implementing agency of the other country, commenced since the team formulated the plan on the "2019 Water Supply Project Planning Guidance Project (Phase 2) Kingdom of Tonga Vava'u Island Water Supply Facility Improvement Plan" commissioned by the Japanese Ministry of Health, Labor and Welfare (MoHLW) in 2019. As each side continued to communicate with each other toward the realization of the project, the giant eruption occurred at the HTHH submarine volcano at around 13:00 on January 15, 2022 (Japan time). After that, the team received information from Mr. Quddus Fielea, Deputy CEO of TWB about the damage situation in the area, and the team launched the preparation of the proposal and was awarded the successful undertaking of the survey work from above MoHLW toward formulating the support plan for recovery plan in the water supply sector in Tonga.

Mr. Tevita Suka Mangisi, Ambassador Extraordinary and Plenipotentiary of Tonga to Japan , visited NJS head quarter, a representative company of the survey team, and expressed a high interest in the proposed assistance for the recovery in the water sector. In addition, the survey team conducted field surveys from mid- August 2022, all of which were accompanied by the Deputy CEO of TWB. The survey team had to carry out the fact findings on the damage situation in four (4) islands in a short period of less than two weeks. Without TWB's hospital support including local logistics such as accommodation in the islands, means of transportation, and arrangements for COVID-19 tests, it was difficult to complete the survey. Even after returning to Japan, they actively responded to the provision of information, which made the team realize their strong expectations for the future Japan's reconstruction assistance.

According to TWB, no third country/international organization has provided recovery / reconstruction assistance to the water sector. On the other hand, both the water supply and disaster prevention fields are the strengths of the support by the Japanese government, and the implementation of the proposed project will further strengthen the ties between the Japanese government and Tonga, which enhance Japan's presence in international contributions to the Pacific island nations. In addition, since more than one year has already passed since the disaster, it is hoped that the proposed project should be implemented without delay.

Appendix

Appendix -1 Survey Schedule

Itinerary		Destination	Investigation Contents
21-Aug	AM	Leave Narita to Hongkong, China	
Sunday	PM	Leave Hongkong to Auckland, New Zealand	
22-Aug	AM	Leave Auckland to Tongatapu, Tonga	
Monday	PM	Tonga Water Board（HQ)	Courtesy call, explanation of the project, exchange of the information
23-Aug	AM	Moving（Tongatapu to Eua) ⇒ Field Survey	Confirmation on damage situation by volcanic eruption and current situation of water supply, summarization of problems and issues
Tuesday	PM	Moving（Eua to Tongatapu)	
24-Aug	AM	Moving（Tongatapu to Lifuka)	Confirmation on damage situation by volcanic eruption and current situation of water supply, summarization of problems and issues
Wednesday	PM	Field Survey (Lifuka)	
25-Aug	AM	Field Survey (Lifuka)	
Thursday	PM	Moving（Lifuka to Vava'u)	
26-Aug	AM	Field Survey (Vava'u)	Confirmation on damage situation by volcanic eruption and current situation of water supply, summarization of problems and issues
Friday	PM	Moving（Vava'u to Tongatapu)	
27-Aug	AM	Internal Meeting	Analyzation of current and future issues Study on the improvement measures
Saturday	PM		
28-Aug	AM	Internal Meeting	Analyzation of current and future issues Basic planning on improvement of water supply facility
Sunday	PM		
29-Aug	AM	Tonga Water Board（HQ)	Sharing of the field survey result, Confirmation on the problems and issues, Information gathering on the existing facility plans
Monday	PM	Field Survey (Tongatapu)	Confirmation on damage situation by volcanic eruption and current situation of water supply, summarization of problems and issues
30-Aug	AM	MEIDECC, MLNR, MOH	Courtesy call, explanation of the project, exchange of the information
Tuesday	PM	Japanese Embassy in Tonga, JICA Tonga	
31-Aug	AM	Tonga Water Board（HQ)	Wrap Up Meeting、Proposal of the draft facility improvement plan, instruction of planning, opinion exchange, additional field survey
Wednesday	PM	Additional Field Survey (Tongatapu)	
1-Sep	AM	Tonga Water Board（HQ)	Instruction of Planning, opinion exchange
Thursday	PM	Leave Tongatapu to Auckland, New Zealand	
2-Sep	AM	Leave Tongatapu to Singapole	
Friday	PM	Leave Singapole to Narita	

Appendix-2 Visited Institution

Institution	Name	Post	Post/Title
Embassy of Japan in Tonga	Kazunari Fujiwara		Chief of Political and Economic Section, Second Secretary
Japan International Cooperation Agency (JICA) Tonga Office	Hiroaki Takashima		Resident Representative
	Tetsuji Nakasone	Planning investigator (project creation/implementation supervision)	Project Formulation Advisor (Project Formulation and Management)
Tonga Water Board (TWB)	Mr Sione Finau	Chief executive officer	Chief Executive Officer
	Mr. Quddus Fielea	Deputy Chief Executive Officer (Technical Division)	Deputy Chief Executive Officer – Engineer
Ministry of Land and Natural Resources (MLNR)	Ms. Rosamond C. Bing	Chief executive officer	Chief Executive Officer
	Mr. Taaniela Kula	deputy secretary Director, Geological Survey of Tonga	Deputy Secretary Head of the Tonga Geological Services
Ministry of Health (MOH)	Dr. Siale Akauola	Chief executive officer	Chief Executive Officer
Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Communications and Climate Change (MEIDECC) National Emergency Management Office (NEMO)	Ms. Moana Kioa	Chief executive officer	Principal Assistant Secretary of NEMO

Appendix-3 Notification Letter on Dispatch of the Survey Team

Ministry of Health, Labour and Welfare
Japanese Government
1-2-2, Kasumigaseki,
Chiyoda-ku, Tokyo 100-8916
Tel ＋ 81-3-5253-1111

日本国厚生労働省
〒100-8916
東京都千代田区
霞が関1－2－2
電話 03-5253-1111

July 26th, 2022

Attention: Mr. Sione Tutulu Finau, Chief Executive Officer, Tonga Water Board

Subject: Request for acceptance of a study group of "the Project for Water Supply Recovery Assistance Plan in the Kingdom of Tonga from HTHH Volcanic Eruption," organized by the Ministry of Health, Labour and Welfare of Japan

Dear Sir,

I am writing to you to seek a possibility of your arrangements for the study in Tonga.

The Ministry of Health, Labour and Welfare of Japan (MHLW) has a program called "the Water Supply Project Formation Program" to encourage international cooperation in the field of water supply. This program technically reviews a potential plan with support from the local water supply authority so that the Government of Japan will provide appropriate guidance and support and transfers the technical expertise of Japan.

This year the MHLW will work together with the NJS Co., Ltd (NJS). NJS awarded their proposal on "the Project for Water Supply Recovery Assistance Plan in the Kingdom of Tonga." We heard that the water supply facilities over there in Tonga were seriously damaged by the submarine volcanic eruption of Hunga Tonga–Hunga Ha'apai (HTHH) and its subsequent tsunami and they would be in need to be recovered. Our team would like to assess the damages on the water supply facilities in the main four islands in late August, 2022 and to discuss what could be the best replacement.

It is sincerely appreciated if you could kindly accept our study team and coordinate visits and consultations with the related institutions.

Sincerely yours,

井谷 哲也

ITANI Tetsuya
Director, Office of Global Health Cooperation,
International Affairs Division, Minister's Secretariat,
Ministry of Health, Labour and Welfare,
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RESUME

1. SUMMARY OF THE PROGRAM

Japanese ODA is implemented by the Ministry of Foreign Affair (MOFA) and Japan International Cooperation Agency (JICA). The Ministry of Health, Labour and Welfare (MHLW) is ordinary indirectly associated with ODA on water supply sector through consultation with MOFA and JICA as the ministry holding jurisdiction over water supply sector in Japan. The Water Supply Project Formation Program is provided by the MHLW to promote improvement projects in the countries having a wide range of challenges on the sector.

This year the MHLW will work together with NJS Co., Ltd., proposing “the Project for Water Supply Recovery Assistance Plan in the Kingdom of Tonga.”

2. PURPOSE OF THE STUDY

The study team conducts a fact-finding investigation from professional and technical points of view, aiming to support formulating a recovery plan for improvement in the water supply sector for the main four islands in Tonga where their water supply facilities have been seriously damaged by the submarine volcano eruption of HTHH and its subsequent tsunami.

3. STUDY ITEMS

Here are the major study items:

(1) To examine the current situations of water supply system in Tongatapu, Eua, Lifuka and Vava’u islands such as water resources, water supply facilities, operation and maintenance;

(2) To determine the current situation of water supply materials and equipment funded by the Government of Japan and the other donors;

(3) To interview the local water authorities; and

(4) To confirm water recovery plan.

4. EXPECTED INTERVIEWEE

(1) Mr.Taniela Kula, Deputy Director, Ministry of Land Survey and Natural Resources;

(2) Dr. Renold 'Ofanoa, Chief Medical Officer, Ministry of Health;

(3) Mr. Sione Tutulu Finau, Chief Executive Officer Tonga Water Board; and

(4) Mr. Quddus Fielea, Deputy CEO, Manager - Engineer, Tonga Water Board.

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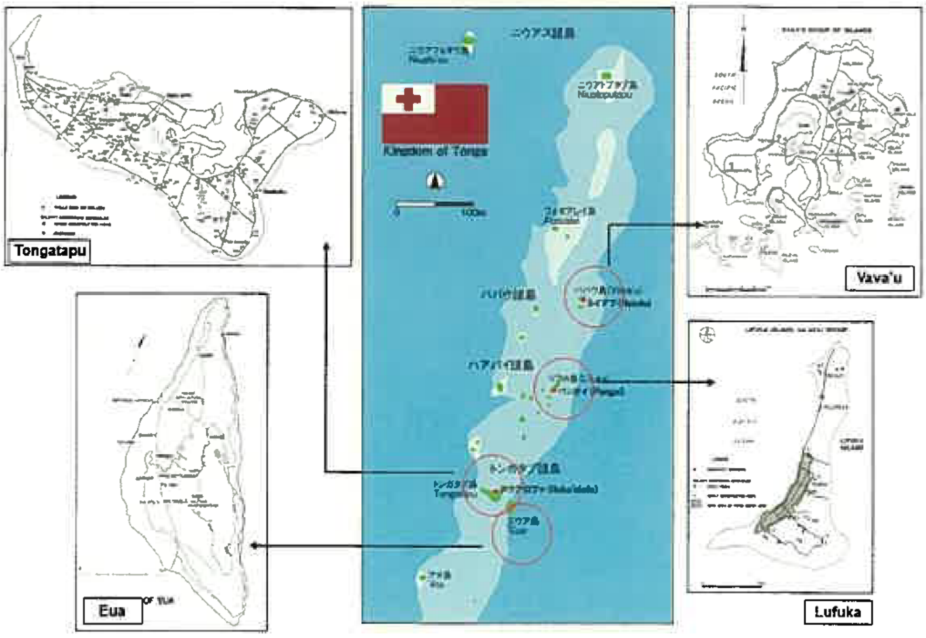
5. MEMBERS OF OUT TEAM

Our team consists of the following members:

Name	Responsibility	Occupation
Mr. ITANI Tetsuya	Project Manager	Ministry of Health, Labour and Welfare of Japan (MHLW)
Dr. YOSHITOMI Moeko	Project Coordinator	Ministry of Health, Labour and Welfare of Japan (MHLW)
Mr. YASHIRO Daisuke	Chief Consultant	NJS Co., Ltd.
Mr. NAKANISHI Sampei	Procurement of water supply material and equipment	NJS Co., Ltd.
Mr. HAYASHI Kenta	Water supply planning and design (Facilities)	NJS Co., Ltd.
Mr. SATO Tadashi	Water supply planning and design (Water Sources)	Earth System Science Co., Ltd.
Mr. SHINJO Keita	Water supply planning and design (Pipeline)	Ryusei Consultant Co., Ltd.
Mr. TAKARA Motomu	Water supply facility operation and maintenance	Ryusei Consultant Co., Ltd.

6. SURVEY AREAS

The survey area is the water supply areas of Tongatapu, Eua, Lifuka and Vava'u islands.



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7. STUDY SCHEDULE

Item \ Year	2022						2023		
	July	August	September	Ocober	November	December	January	February	March
1.Preparation in Japan	←—	—→							
(1) Submission of Planning Documents	▼								
(2) Submission of Questionnair	▼								
(3) Analisys of Problem after Disaster		▼							
2.Survey in Tonga		←→	←→						
(1) Survey of current issue and future plan		▼							
(2) Explanation of water supply development plan			▼						
3.Reporting in Japan			←—	———	———	———	———	———	—→
(1) Discussion of the report						▼			
(2) Explanation of Draft request letter							▼		
(3) Submission of Draft Report								▼	
(4) Submission of Final Report with request letter									▼

Appendix-4 Results of On-site Water Quality Test

1. Eua Island (August 23, 2022)

(1) Fern Valley

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s	1 0.0		
Electrical Conductivity (EC)	μS/cm	2 89	1,500 (WHO)	OK
pH	-	7.2	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^{-}	mg/L	less than 200	2 50 (WHO)	OK

(2) Saoa Spring

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	4 27	1,500 (WHO)	OK
pH	-	7.2	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^{-}	mg/L	less than 200	250 (WHO)	OK

(3) Matavai Water Treatment Plant

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	3 05	1,500 (WHO)	OK
pH	-	7.6	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	-	1.5 (WHO)	OK
Cl^{-}	mg/L	-	250 (WHO)	OK
Residual Chlorine	Mg/L	2.0	0.1 or more	OK

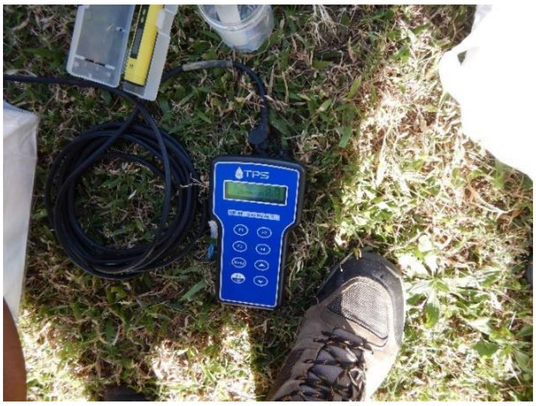
(4) Production Well (No.2)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	6 64	1,500 (WHO)	OK
pH	-	7.3	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	-	1.5 (WHO)	OK
Cl^{-}	mg/L	-	250 (WHO)	OK

2. Ha'apai Island (August 24, 2022)

(1) Production Well No.116 (Diesel Pump)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	5,200	1,500 (WHO)	**NG**
pH	-	7.6	6.5 – 8.5 (USEPA)	OK
$NH4^+$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^-	mg/L	300 or more	250 (WHO)	**NG**



(2) Production Well No.115 (Solar Driven Pump)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	1,380	1,500 (WHO)	OK
pH	-	7.4	6.5 – 8.5 (USEPA)	OK
$NH4^+$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^-	mg/L	300 or more	250 (WHO)	**NG**

(3) Production Well No. 104 (Dug Well)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	3,200	1,500 (WHO)	**NG**
pH	-	7.7	6.5 – 8.5 (USEPA)	OK
$NH4^+$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^-	mg/L	200 - 250	250 (WHO)	OK

(4) Reservoir

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	2,800	1,500 (WHO)	**NG**
pH	-	7.7	6.5 – 8.5 (USEPA)	OK
$NH4^+$	mg/L	-	1.5 (WHO)	OK
Cl^-	mg/L	200 - 250	250 (WHO)	OK
Residual Chlorine	mg/L	0.4 - 1.0	0.1 or more	OK

3. Vava'u Island (August 24, 2022)

(1) Production Well No.119 (Newly Constructed in 2020)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s	3.5		
Electrical Conductivity (EC)	μS/cm	2,167	1,500 (WHO)	**NG**
pH	-	7.5	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^{-}	mg/L	200 - 250	250 (WHO)	OK

(2) Production Well No.120 (Newly Constructed in 2020)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s	3.4		
Electrical Conductivity (EC)	μS/cm	1,385	1,500 (WHO)	OK
pH	-	7.3	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	-	1.5 (WHO)	
Cl^{-}	mg/L	-	250 (WHO)	

(3) Reservoir

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s	3.4		
Electrical Conductivity (EC)	μS/cm	1,620	1,500 (WHO)	**NG**
pH	-	7.0	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^{-}	mg/L	less than 200	250 (WHO)	OK
Residual Chlorine	mg/L	0.1	0.1 or more	OK

(4) Prison Area (Diesel Pump)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	6 17	1,500 (WHO)	OK
pH	-	7.4 _	6.5 – 8.5 (USEPA)	OK
$NH4^{+}$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^{-}	mg/L	less than 200	250 (WHO)	OK

(5) Leimatua Village Well (Solar-powered Pump)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	8 74	1,500 (WHO)	OK
pH	-	7.3	6.5 – 8.5 (USEPA)	OK
$NH4^+$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^-	mg/L	less than 200	250 (WHO)	OK

(6) Reimatua Village Reservoir (near the Community Center)

Item	Unit	Result	Standard Value	Evaluation
Flow Rate	L/s			
Electrical Conductivity (EC)	μS/cm	6 65	1,500 (WHO)	OK
pH	-	7.0	6.5 – 8.5 (USEPA)	OK
$NH4^+$	mg/L	less than 0.2	1.5 (WHO)	OK
Cl^-	mg/L	less than 200	250 (WHO)	OK
Residual Chlorine	mg/L	0.2	0.1 or more	OK