REPUBLIC OF FIJI
WATER AUTHORITY OF FIJI (WAF)

REPUBLIC OF FIJI
PROJECT FOR FORMULATION OF WASTEWATER TREATMENT MASTER PLAN IN WESTERN DIVISION

FINAL REPORT
PART 3：MUNICIPAL SEWERAGE MASTER PLAN

OCTOBER 2024

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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Preface

The Final Report (F/R) of "the Project for formulation of Wastewater Treatment Master Plan in Western Division" is composed of the following four parts:

Part 1: Executive Summary

Part 2: Regional Wastewater Treatment Master Plan

Part 3: Municipal Sewerage Master Plan

Part 4: Pre-F/S of Priority Projects

This report is Part 3: Municipal Sewerage Master Plan of the F/R.

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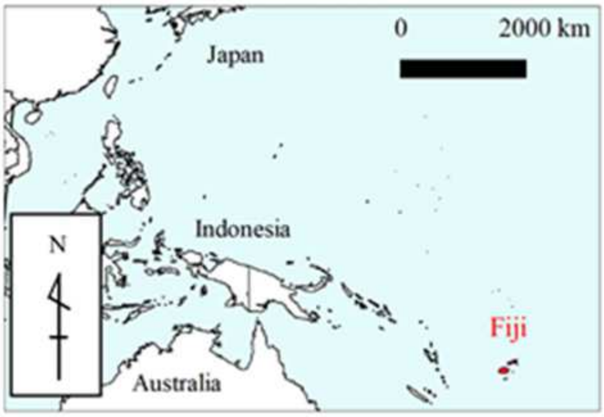
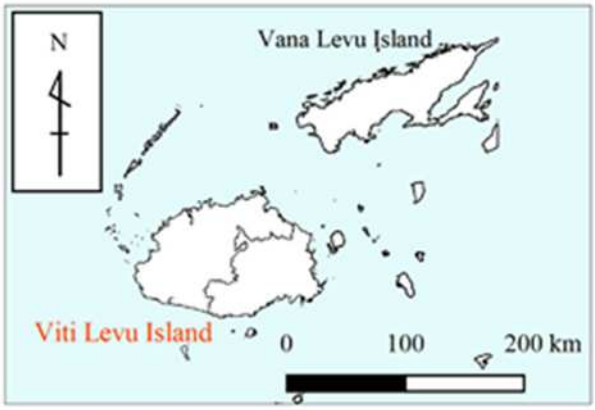
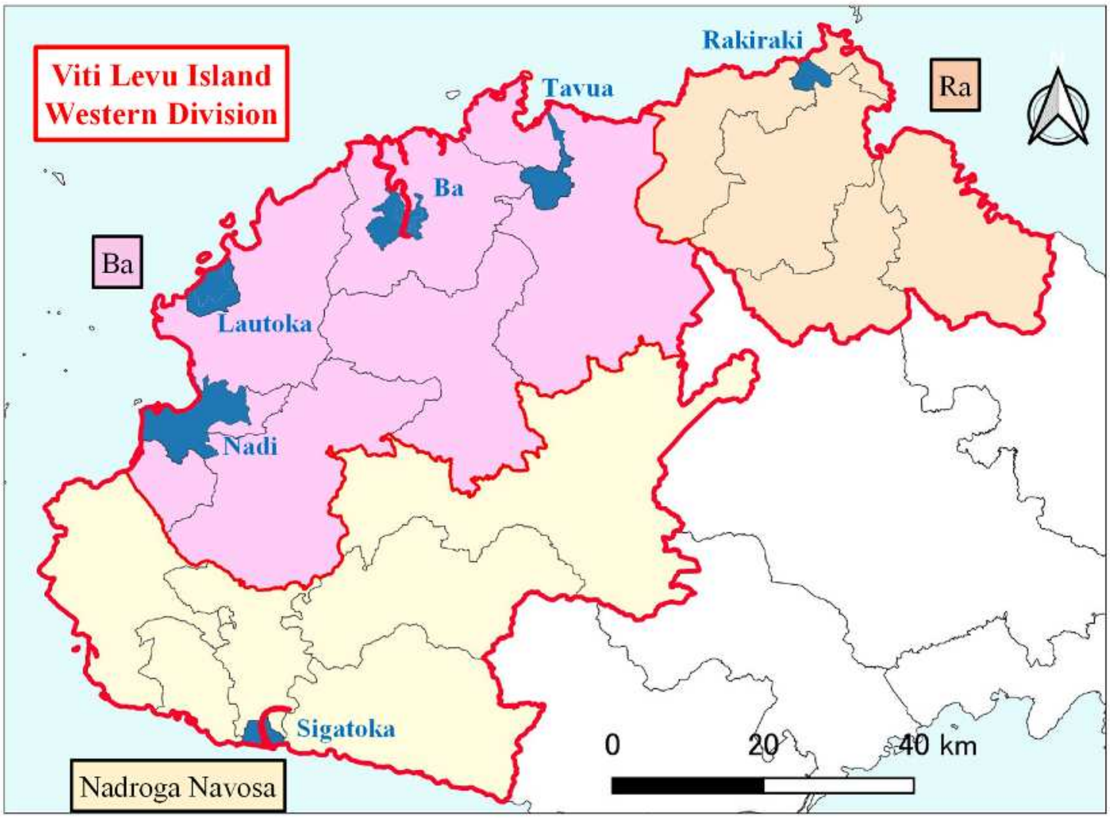






Province	Population		
	Urban	Rural	Total
Ba	165,411	82,297	247,708
Ra	5,987	24,445	30,432
Nadroga Navosa	10,293	48,638	58,931
Sub-total: Western Division	181,691	155,380	337,071
Entire Fiji	494,252	390,635	884,887

Source: Fiji Population & Housing Census 2017

Municipalty	Name of WWTP
Nadi	Navakai
Lautoka	Natabua
Ba	Votua
Sigatoka	Olosara

ABBREVIATIONS

ADB	Asian Development Bank
ADWF	Average Dry Weather Flow
AEC	Annual Equivalent Cost
AHP	Analytic Hierarch Process
AL	Aerated Lagoon
AS	Australian Standards
ATP	Affordable To Pay
BOD	Biochemical Oxygen Demand
CAPEX	Capital Expenditure
CD	Capacity Development
CBH	Central Bureau of Health
COD	Chemical Oxygen Demand
C/P	Counter Part
CWIS	Citywide Inclusive Sanitation
DBOM	Design Build Operation Maintain
DD	Detailed Design
DF/R	Draft Final Report
DOE	Department of Environment
DOF	Department of Fisheries
DOL	Department of Land
DTCP	Department of Town and Country Planning
DWS	Department of Water and Sewerage
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
ESC	Environmental and Social Considerations
FBS	Fiji Bureau of Statistic
FIRR	Financial Internal Rate of Return
FOG	Fats, Oil, Grease
FRA	Fiji Roads Authority
F/R	Final Report
F/S	Feasibility Study
GCF	Green Climate Fund
GHG	Greenhouse Gas
GIS	Geographic Information System
HQ	Headquarters
IC/R	Inception Report
IDEA	Intermittent Decant Extended Aeration
IEE	Initial Environmental Examination
JCC	Joint Coordination Committee
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
JPP	JICA Partnership Programs
KCCP	Knowledge Co-Creation Program (JICA)
LCC	Lautoka City Council

LEDS	Fiji Low Emission Development Strategy 2018-2050
L&D	Lecture & Discussions
LMMA	Locally Managed Marine Area
MBBR	Moving Bed Biofilm Reactor
ME	Mechanical/Electrical
MHCD	Ministry of Housing and Community Development
MHMS	Ministry of Health and Medical Services
MIMS	Ministry of Infrastructure and Meteorological Service (before organizational restructuring: current MPW)
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japanese)
MLMR	Ministry of Lands and Mineral Resources
MOA	Ministry of Agriculture
MOE	Ministry of Economy (before organizational restructuring: current MOF)
MOF	Ministry of Finance (after organizational restructuring: former MOE)
MoU	Memorandum of Understanding
MOWE	Ministry of Waterways and Environment
M/P	Master Plan
MPW	Ministry of Public Works, Meteorological Services and Transport (after organizational restructuring: former MIMS)
MRMD	Ministry of Rural and Maritime Development and Disaster Management
MWCPA	Ministry of Women, Children and Poverty Alleviation
NFA	National Fire Authority
NPO	Non-Profit Organization
NTC	Nadi Town Council
OD	Oxidation Ditch
ODA	Official Development Assistance
OJT	On the Job Training
O&M	Operation and Maintenance
PDWF	Peak Dry Weather Flow
PG/R	Progress Report
PI/R	Project Implementation Report
Pre-F/S	Pre-Feasibility Studies
R/D	Record of Discussion
SCF	Standard Conversion Factor
SDGs	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEZ	Significant Ecological Zone
SOP	Standard Operation Procedure
SP	Stabilization Pond
SPD	South Pacific Distilleries Ltd.
SS	Suspended Solids
TC	Technical Committee
TF	Trickling Filter
TLFC	iTaukei Land and Fisheries Commission
TLTB	iTaukei Land Trust Board
T-N	Total Nitrogen
TOR	Terms of Reference
T-P	Total phosphorus
TSS	Total Suspended Solids
UNDP	United Nation Development Program

WAF	Water Authority of Fiji
WWTP	Wastewater Treatment Plant

CHAPTER 1 INTRODUCTION

1-1 Background

The Western Division of the Republic of Fiji (hereinafter referred to as "Fiji"), which includes Lautoka and Nadi (the second and third largest cities of Fiji, respectively) as well as Nadi International Airport, is an important location for tourism and other major Fijian industries. Despite robust growth in recent years, wastewater treatment capacity has not kept up with increases in resident and tourist populations. Development of this essential infrastructure corresponding to the increasing demand is urgently needed.

"National Development Plan 2017-2036" formulated by Fijian Government in 2017 targets to provide access to centralized treatment systems for 70% of the Fijian population by 2036, thorough the construction and expansion of public wastewater treatment systems in all urban centers. The "Data Collection Survey of Water Supply and Wastewater Sector in the Republic of Fiji" conducted by JICA in 2019 confirmed that the treatment performance of the four existing wastewater treatment plants located in the Western Division is insufficient. The main reasons were found to be over-capacity operation and lack of proper operation and maintenance (hereinafter referred to as "O&M"). The cause of the over-capacity operation was determined to be due to the existing sewerage master plan (hereinafter referred to as "M/P") being outdated and not reflecting current conditions. The causes of inadequate O&M were found to be a) O&M not being performed according to operational/water quality data, and b) lack of standardized O&M manuals.

To strategically improve the sewerage infrastructure of the Western Division of Fiji, JICA implemented the "Detailed Planning Survey for the Project for Formulation of Sewerage Master Plan in the Western Area" to confirm roles of each agencies/department involved with sewerage works. The project contents were discussed and agreed to as the following:

- "Wastewater Treatment Master Plan in Western Division" (hereinafter referred to as the "Regional Wastewater M/P") which considered centralized and decentralized treatment systems for the Western Division
- "Sewerage M/P for Priority Cities in the Western Division" (hereinafter referred to as "Municipal Sewerage M/P")
- Pre-Feasibility Studies for the Priority Projects (hereinafter referred to as "Pre-F/S").
- Strengthen O&M of sewerage facilities

1-2 Objectives and Expected Outcomes

This project, entitled "Project for Formulation of Wastewater Treatment Master Plan in Western Division," will carry out various activities necessary to achieve the four outputs summarized below. By achieving these outputs, the Project aims to improve the performance of sewerage facilities in the Western Division, promote projects for the expansion of facilities, and contribute to the protection and improvement of urban and public health and the water environment of the Western Division.

Output-1	A Regional Wastewater M/P that includes centralized and decentralized wastewater treatment systems for the Western Division of Viti Levu Island of Fiji (Wastewater treatment Master Plan in Western Division) will be formulated.
Output-2	A Municipal Sewerage M/P in priority cities and/or towns identified in the Regional Wastewater M/P will be formulated.
Output-3	A Pre-F/S including sludge management for priority sewerage project(s) selected in the Municipal Sewerage M/P will be conducted.
Output-4	Capacity on sewerage management of WAF and relevant agencies will be strengthened.

Objective:	Encourage treatment capacity improvement, facility expansion. Contribute to improvement to sanitation of public spaces and water environment of the Western Division

Source: JET and R/D

Figure 1-2.1 Objectives and Expected Outcomes

This project, which will be implemented over a period of three years, is divided into Phase 1 (October 2021-September 2022) and Phase 2 (October 2022-September 2024), depending on their output. Phase 1 formulated the Regional Wastewater M/P (Output 1), which reached an agreed conclusion with the Fijian side that out of the six target municipalities of the Western Division, Lautoka and Nadi had the highest priorities. In Phase 2, the Municipal Sewerage M/P (Output 2) will be formulated for Lautoka and Nadi; and the priority projects selected from the Municipal Sewerage M/P will be further studied in the Pre-F/S (Output 3).

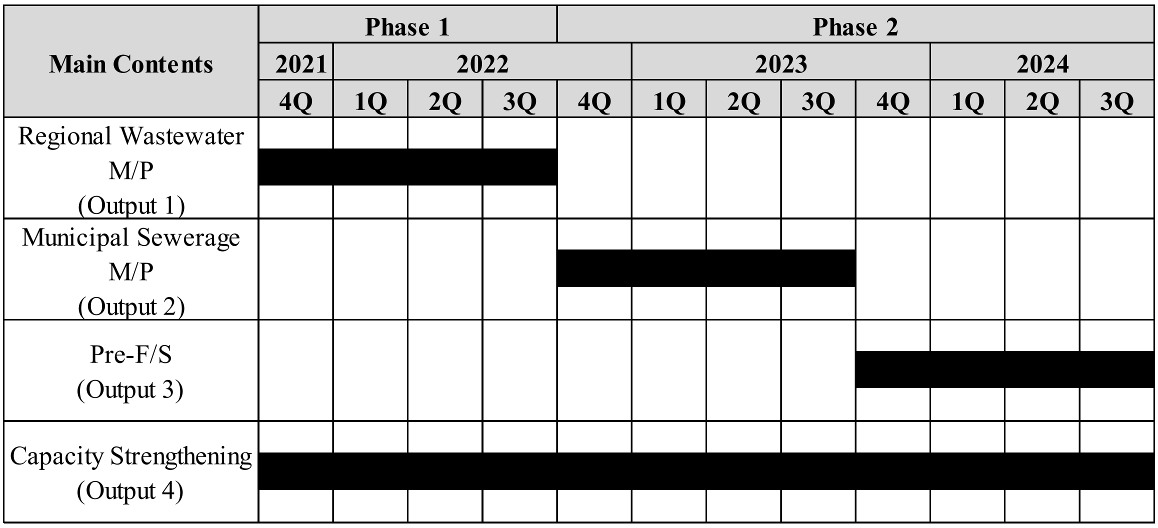
Capacity building of WAF and other organizations' sewerage management (Output 4) will be implemented throughout both Phase 1 and 2.The following activities were implemented in Phase 1.

(1) Assessment/evaluation on current capacity of WAF and related organizations, and surveys for requests on the training topics
(2) Formulation of Capacity Strengthening Plan based on above results
(3) Implementation of training sessions with support of Fukuoka City

Further training programs are scheduled to continue on in Phase 2.

1-3 Project Phasing

This project will be implemented in a total of three years. The formulation of the Regional Wastewater M/P from Output 1, and a part of Output 4 was carried out in the first year as Phase 1. Activities for Output 2 and 3 will be conducted in Phase 2 of this Project, to be carried out in the second and third years.



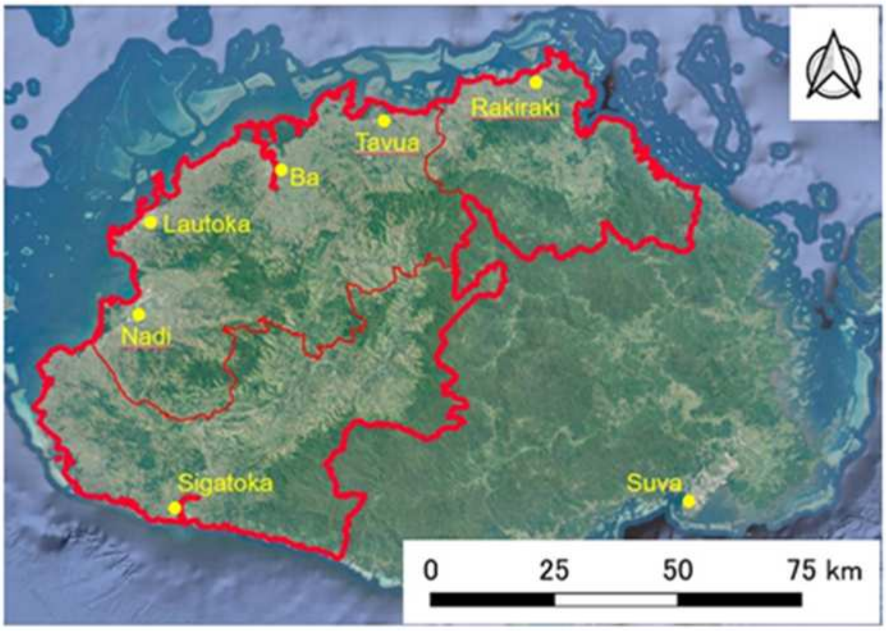
Source：JET and R/D

Figure 1-3.1 Project Phasing and Contents

1-4 Project Area

The Western Division of the Republic of Fiji is the target area for this Project. According to the 2017 National Census, the population of the Western Division is 337,000 people, with an urban population of 182,000 and a rural population of 155,000 (refer to the location map provided in the Introduction).

The target municipalities of the Municipal Sewerage M/P are Lautoka and Nadi. The priority project selected from the Municipal Sewerage M/P will then be studied in the Pre-F/S project to be implemented in the second half of Phase 2.



Source：JET

Figure 1-4.1 Project Area for Regional Wastewater M/P

1-5 C/P Agency

The counterpart (hereinafter referred to as "C/P") agencies for the project are as follows. Through the 1st field survey which started from mid-November, two C/Ps were added to the original list due to their important roles in Phase 1.

Implementing agency:	Water Authority of Fiji (WAF): Authority for centralized treatment systems
Related agencies:	Ministry of Infrastructure and Meteorological Service (MIMS[1]), Department of Water and Sewerage (DWS): Authority for decentralized treatment systems
	Ministry of Waterways and Environment, Ministry of Economy (MOE[2]), Ministry of Lands and Mineral Resources, Ministry of Housing and Community Development, Ministry of Health and Medical Services (Central Board of Health: CBH), Fiji Bureau of Statistics, iTaukei Land Trust Board, Ministry of Local Government, Municipal Councils, Provincial Councils, others

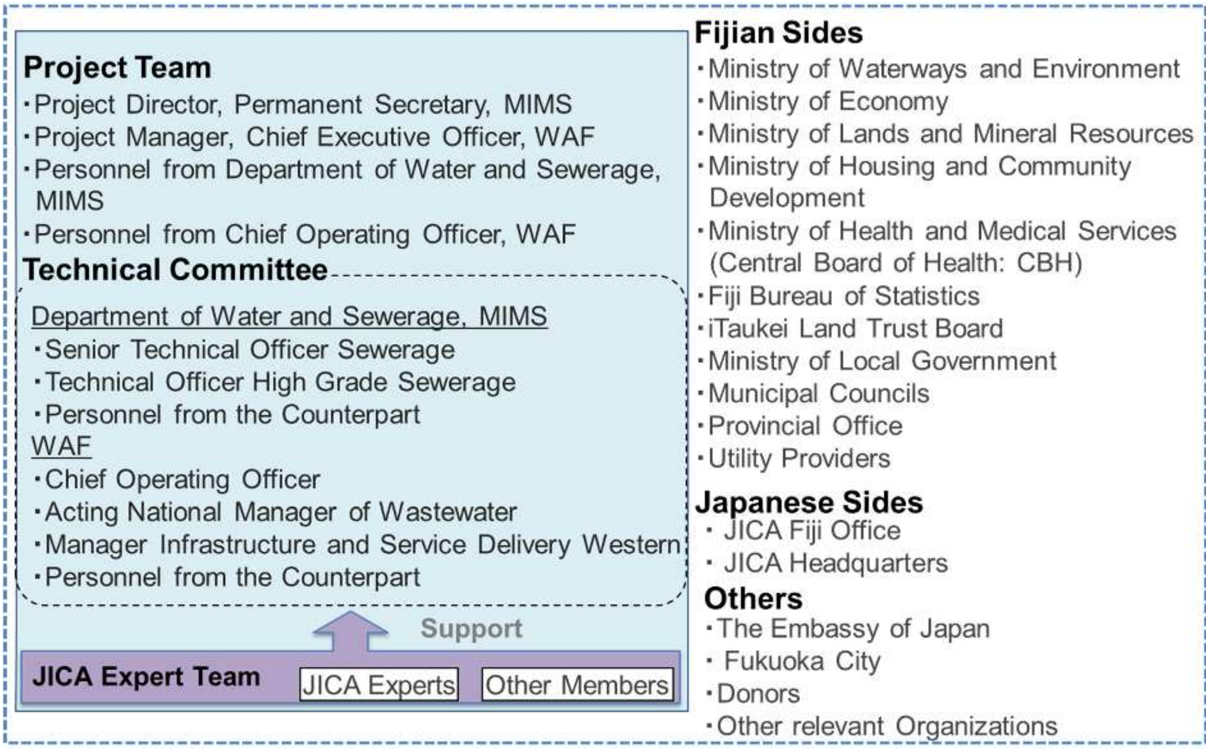
1-6 Project Implementation Structure

(1) Joint Coordination Committee

The project implementation structure is shown in **Figure 1-6.1**, with the Joint Coordination Committee (hereinafter referred to as "JCC") at its nucleus. This project will use the JCC to ensure mutual communication between parties throughout the planning process, and to ensure prompt approval of the formulated plans. The main role of the JCC is summarized as follows.

- Confirm and approve progress of Stage 1 Regional Wastewater M/P, Stage 2 Municipal Sewerage M/P and Pre-F/S
- Discuss overall direction of the project and build consensus between relevant authorities

1 MIMS: before organizational restructuring; current Ministry of Public Works, Meteorological Services and Transport (MPW)
2 MOE: before organizational restructuring; current Ministry of Finance (MOF)



Source：Created by JET based on R/D

Figure 1-6.1 Project Implementation Structure

(2) Advisor

Upon the formulation of the Master Plans and implementation of the Pre-F/S study in this project, the Road and Sewerage Bureau of Fukuoka City will be participating as an advisor to provide advice from a professional and technical standing point. In addition, Fukuoka City will also cooperate as the lecturer/instructor of the training program for WAF. Fukuoka City has a record over the years participating/cooperating with Fiji in its water and sewerage projects, holding connections with WAF and familiar with its institutional system; it is hoped that their knowledge will greatly support this project.

1-7 Members of the JICA Expert Team

JICA officials and JICA Expert Team (JET) consists of the following members (see **Table 1-7.1**). In addition, JICA has asked the Fukuoka City to participate as an advisor, and the bureau provides advice on project activities and plans as appropriate.

Table 1-7.1 Member of the JICA Expert Team

JICA	
NAME	**TITLE**
Kentaro YOSHIDA	Director, Environmental Management Group, Global Environment Department, JICA HQ
Shinichi WADA	Officer, Environmental Management Group, Global Environment Department, JICA HQ
Shigeki NAMBA	Project Formulation Advisor, JICA FIJI Office
Hideaki IWASE	Project Formulation Advisor (Regional Infrastructure), JICA FIJI Office
Advisor: Fukuoka City	
Hironori YASHIMA	Director, Policy Coordination Section, Road and Sewerage Bureau
Shingo MORIKAWA	Assistant Section Chief, Policy Coordination Section, Road and Sewerage Bureau
Shojiro HASHIZUME	Chief, Policy Coordination Section, Road and Sewerage Bureau
Mayumi ONO	Officer, Policy Coordination Section, Road and Sewerage Bureau

CONSULTANT TEAM		
NAME	TITLE	OCCUPATION
Yoshinobu NAKAJIMA	Team Leader/ Sewerage Works management	Nihon Suido Consultants Co., Ltd.
Kiyohiko HAYASHI	Deputy Team Leader/ Organization & Institutions	Nihon Suido Consultants Co., Ltd.
Tetsuo WADA	Sewerage planning	Nihon Suido Consultants Co., Ltd.
Hiroyuki KAWASHIMA	On-site wastewater treatment planning	Nihon Suido Consultants Co., Ltd.
Shinichi SASAKI / Yoko KOTEGAWA	WWTP planning and design	Nihon Suido Consultants Co., Ltd.
Hideyuki IGARASHI	Sewer network system and existing drainage survey	Yachiyo Engineering Co., Ltd.
Yasuaki MATSUMOTO	Mechanical engineering	Nihon Suido Consultants Co., Ltd.
Jyoji WAKAMOTO	Electrical engineering	Nihon Suido Consultants Co., Ltd.
Yuichiro KONNO	Implementation Plan and Cost estimation	Nihon Suido Consultants Co., Ltd.
Yoshiyuki CHOSO	Economic & Financial Analysis	Nihon Suido Consultants Co., Ltd.
Yuriko KUDO	Environmental & Social considerations/ Public Awareness	Yachiyo Engineering Co., Ltd.
Yasuo IIJIMA	Natural condition survey	Yachiyo Engineering Co., Ltd.
Koichi OKAZAKI	Water Supply Planning Advisor	Nihon Suido Consultants Co., Ltd.
Diana BOLA	Sewerage Planner	NRW Macallan (Fiji) Ltd
Aneshwar AMIT	Economic/Financial Analyst	NRW Macallan (Fiji) Ltd

Source：JET

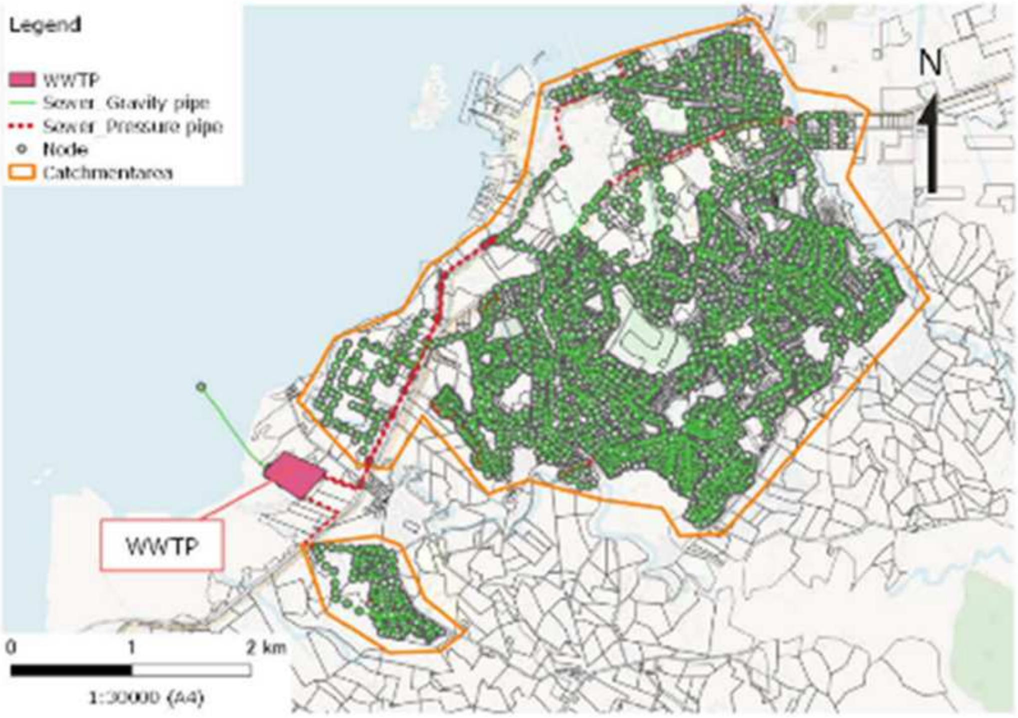
CHAPTER 2 CURRENT CONDITIONS AND PLANS IN THE TARGET AREA

2-1 Status of Centralized Treatment Systems

2-1-1 Natabua WWTP (Lautoka)

(1) Service Area

The service areas of the Natabua WWTP are shown in **Figure 2-1.1**. According to the 2017 census, the urban and peri-urban population of Lautoka is 71,573. WAF records show that there are 6,440 households connected to the centralized treatment system. Assuming 4.5 people per household (**APPENDIX 3-1**), the population connected to the sewer system is estimated to be 29,000.



Source :JET

Figure 2-1.1 Service Area of Natabua WWTP

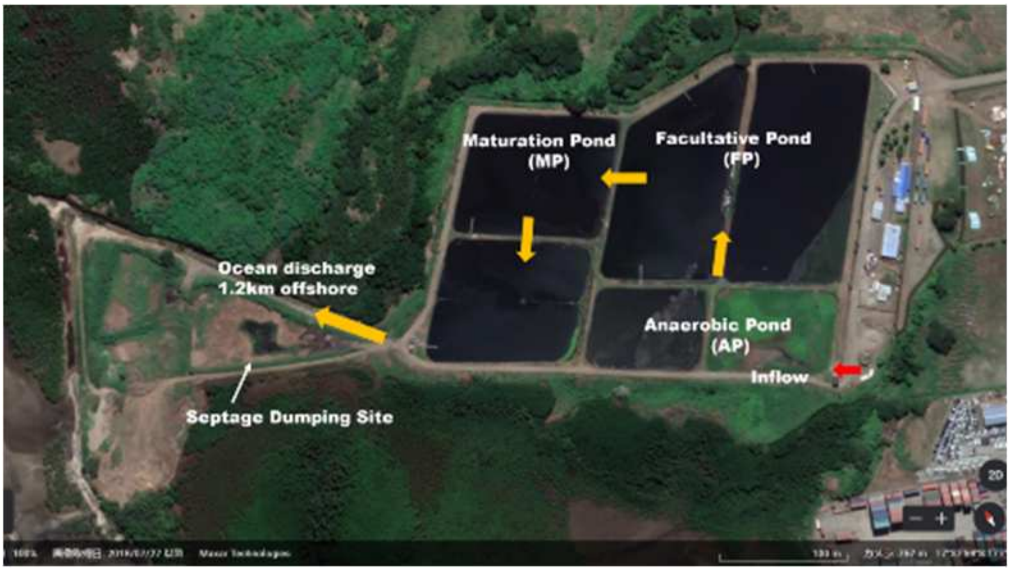
(2) Treatment Facilities

1) Outline of WWTP

Table 2-1.1 Outline of Natabua WWTP

Name	Natabua WWTP
Commencement of operation	1983
Treatment capacity	8,200 m^3/day
Inflow volume at present	Not measured
Wastewater treatment Process	Stabilization pond
Component of facility	Anaerobic pond: 2 Facultative pond: 2 Maturation pond: 2 Septage dump pit: 1
Wastewater treatment process	Inflow → Anaerobic pond → Facultative pond → Maturation pond → Pump facility → Ocean outfall
Sludge treatment process	Dredged sludge* → Mechanical dewatering → Disposal in WWTP site
Acceptance of septage	Accepted in an excavated pond
Discharging point	Ocean outfall (Pumped 1.2 km offshore)

*: Sludge in the ponds was dredged in 2021 for the first time since the commencement of operation.
Source: JST as per hearing survey at WAF



Source: JET

Figure 2-1.2 Layout of Facilities in Natabua WWTP

2) Influent and Effluent Quality

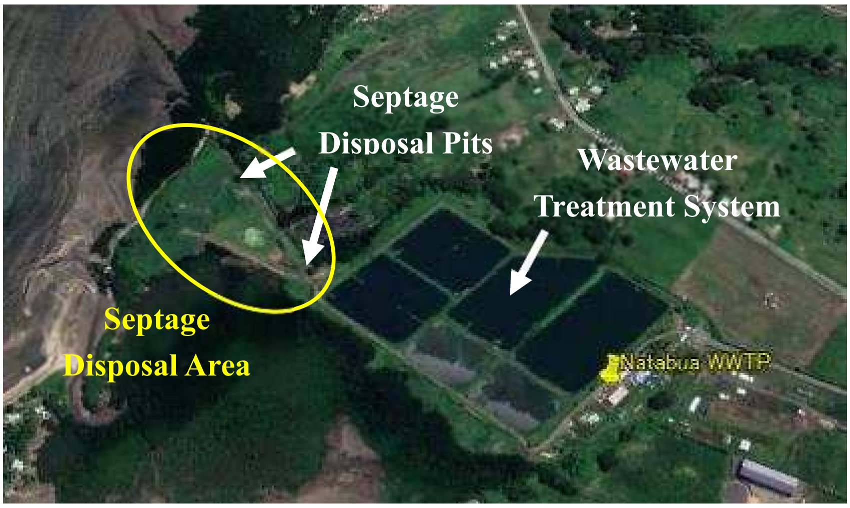
The central laboratory of WAF analyzes the water quality of each WWTP once a month. **Table 2-1.2** shows the annual average influent and effluent quality from 2014 to 2021. The influent quality in recent years has been affected by the drastic decrease in the number of tourist due to the closure of the border in Fiji as a response to COVID-19.

Natabua WWTP currently accepts bailed septage, but considering its negative effects on the wastewater treatment system, it is not inputted to the system; instead, septage is dumped in dug-out pits located in the natural wetland adjacent to the WWTP. Both pits are not equipped with discharge ports/rubber linings, and there is the possibility of septage flowing out to coastal waters.

Table 2-1.2 Water Quality of Natabua WWTP

Year	Influent (mg/L)						Effluent (mg/L)					
	T-SS	BOD	COD	T-N	T-P	FOG	T-SS	BOD	COD	T-N	T-P	FOG
Stand.							60	40	―	25	5	5
2014	533	318	594	8.4	4.6	236	81.6	64.3	170	4.4	3.4	38.2
2015	482	303	575	10.6	3.7	149	44.2	65.3	125	4.9	2.2	32.7
2016	439	394	828	-	0.6	22.4	52.3	43.6	117	-	0.8	4.2
2017	846	329	603	50.7	3.6	24.4	114.0	68.6	191	26.0	2.3	7.3
2018	295	207	517	41.3	2.3	71.4	54.8	51.1	140	21.6	1.2	32.3
2019	369	215.3	412.6	27.7	5.8	86.2	52.6	38.7	110.9	20.2	4.0	15.4
2020	874.5	217.6	526	19.8	8.1	168.8	58.1	35.7	124.1	14.7	5.7	40.1
2021	425.8	169.5	483.0	21.8	7.0	128.4	57.4	83.4	213.5	1.9	3.9	49.0
Avg. (~2018)	537	307	606	28.8	3.5	111	71.9	60.7	152	14.6	2.3	24.7
Avg.* (~2021)	534	274	572	26.2	4.4	110.9	65.3	56.9	149.3	13.6	2.9	27.1

Source: JET based on WAF data



Location of Natabua WWTP's Septage Disposal Area and Disposal Pits

Septage Disposal from Bailing Truck

Sludge Disposal Pit

Source：Google Maps, JET

Photo 2-1.1 Natabua WWTP (Lautoka)

(3) Sludge Treatment and Disposal

In general, sludge dredging of the anaerobic ponds are conducted once a few years to maintain its designed treatment capacity; however, in Fiji sludge dredging was not implemented for several decades due to the lack of budget. Dredging finally commenced in 2020 by a New Zealand company, and at the point of year 2023, the dredging at Natabua WWTP was completed. However, after mechanical dewatering the sludge was piled up in a nearby open lot, which do not have rubber linings, etc. (**Photo 2-1.2**, **Photo 2-1.3**). There is the possibility of sludge flowing back into the stabilization ponds or close-by coastal wasters along with rainwater.

Source：JET

Photo 2-1.2 Reference: Dewatering of Dredged Sludge by Private Company at Olosara WWTP

Source：JET

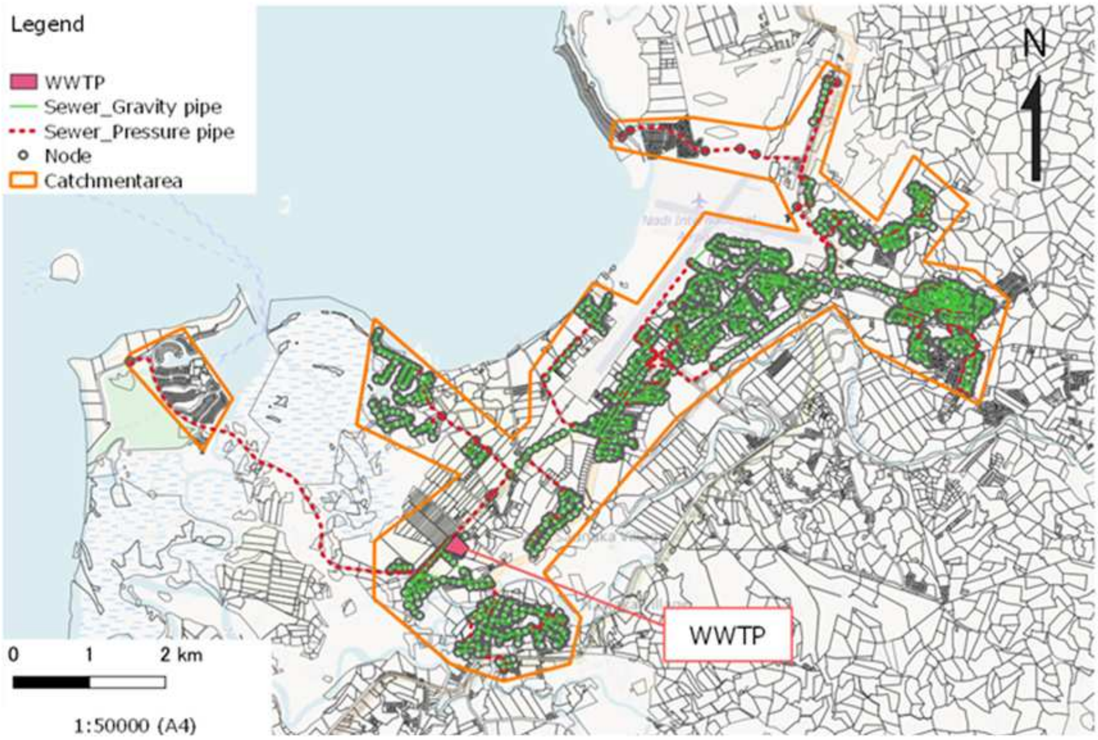
Photo 2-1.3 Disposal Site of Dewatered Dredged Sludge at Natabua WWTP

WAF is requesting landfill disposal of sewerage sludge at municipal waste disposal sites (such as Vunato disposal site in the case of Lautoka), but there are concerns about heavy metal contamination. Currently, there are no waste disposal sites that accept sludge. Additionally, WAF is coordinating with the environmental department to secure its own sludge storage site, but no progress has been made.

2-1-2 Navakai WWTP (Nadi)

(1) Service Area

The service areas of the Navakai WWTP are shown in **Figure 2-1.3**. According to the 2017 census, the urban and peri-urban population of Nadi is 71,048 and the population per household is assumed to be 4.5 people (**APPENDIX 3-1)**. WAF records show that there are 3,525 households connected to the centralized treatment system. The population connected to the sewer system is estimated to be 15,800.



Source: JET

Figure 2-1.3 Service Area of Nadi

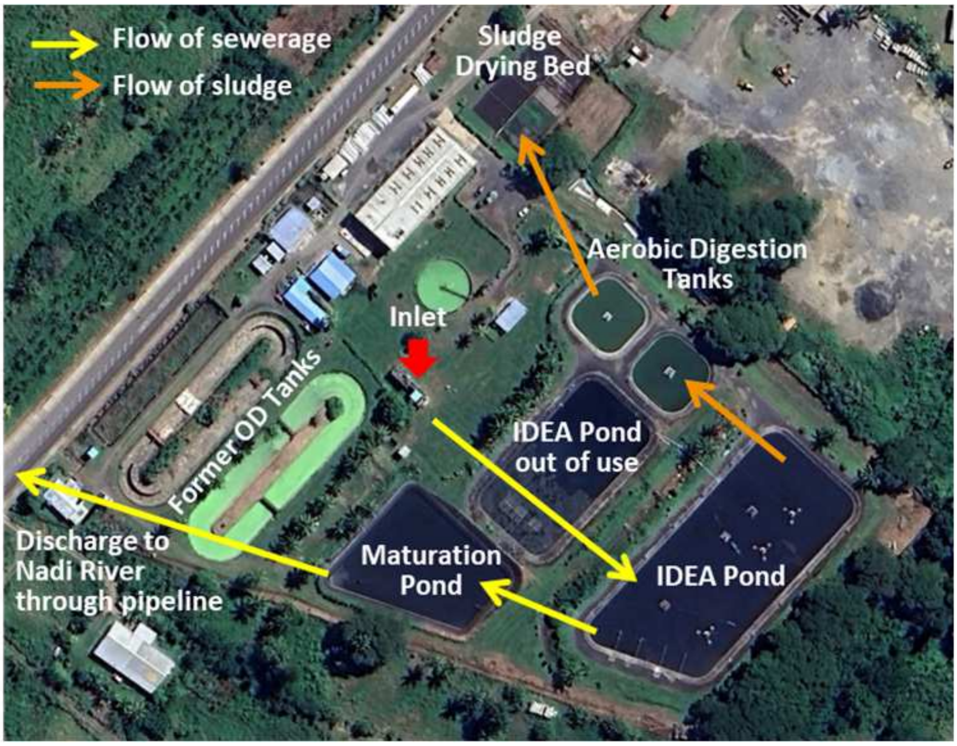
(2) Treatment Facilities

1) Outline of WWTP

Table 2-1.3 Outline of Navakai WWTP

Name	Navakai WWTP
Commencement of operation	1974
Treatment capacity	8,200 m^3/day
Inflow volume	Not measured
Wastewater treatment process	IDEA (Intermittent Decanted Extended Aeration)
Component of facilities	IDEA tank: 2 (1 is currently not operational) Maturation tank: 1 Aerobic digestion tank: 2 Sludge drying bed: 1
Wastewater treatment process	Inflow → Mechanical screen* → IDEA tank → Maturation tank → Discharge
Sludge treatment process	Excess sludge form IDEA tank → Aerobic digestion tank → Drying beds → Dumping site in WWTP
Acceptance of septage	No
Discharging point	Nadi River

*: Stop due to failure as of May 2022
Source: JST as per hearing survey at WAF



Source: JET

Figure 2-1.4 Layout of Facilities in Navakai WWTP

When it started operation, the WWTP used the oxidation ditch (hereinafter referred to as “OD”) process for wastewater treatment; however, treatment capacity became insufficient due to increase in influent volume and IDEA process (capacity 10,000 EP) was added in 1997. The operation of the OD treatment facility was discontinued at this time. In 2008, a larger IDEA facility (capacity 25,000 EP) was added due to further increase in influent volume. Operation of the smaller IDEA has now stopped due to age related deterioration and poor maintenance conditions of all four aerators of the IDEA tank.

Although eight aerators are required in the new larger IDEA tank, only six were installed (the reason is not known). Furthermore, five of them were down due to mechanical issues as of December 2021. Later, three units were newly installed, and the tank is currently operated with four aerators. It was found that several aerators became nonoperational due to damage from natural disasters such as tropical storms, but have now come back to operation.

The excess sludge drawn from the IDEA tank is supposed to be aerobically digested, dewatered by belt-press dewatering machine, solar dried, and disposed of in the disposal site in the treatment plant. However, as of December 2021, the dewatering machine has been out of order since 2011 and the sludge is directly solar dried after digestion.

2) Influent and Effluent Quality

Table 2-1.4 shows the annual average influent and effluent quality from 2014 to 2021. Navakai WWTP currently does not accept septage, and treats only sewerage flowing in from the sewer network.

Table 2-1.4 Water Quality of Navakai WWTP

Year	Influent(mg/L)						Effluent(mg/L)					
	T-SS	BOD	COD	T-N	T-P	FOG	T-SS	BOD	COD	T-N	T-P	FOG
Stand.							60	40	–	25	5	5
2014	965	503	934	9.2	3.5	257	80.3	54.9	138	5.4	2.8	51.6
2015	926	355	884	9.2	2.8	187	43.5	41.4	90.8	5.6	2.3	55.3
2016	589	451	1310	12.8	2.3	23.8	54.4	49.2	124	10.9	1.6	10.7
2017	513	317	648	57.9	3.3	16.5	155	84.7	233	32.0	1.5	10.3
2018	447	241	586	47.2	3.2	57.2	122	68.2	176	29.4	2.4	22.8
2019	253.4	188.3	441.3	32.7	6.5	142.9	42.6	28.6	77.0	26.5	5.9	60.1
2020	198.8	143.4	432.6	20.4	7.6	132.8	24.3	20	103.3	15	2.8	35.6
2021	201.5	131.6	287.5	20.6	9	153.9	29.2	31.3	54	20.3	4.3	53.7
Avg. (~2018)	688.0	373.4	872.4	27.3	3.0	108.3	91.0	59.7	152.4	16.7	2.1	30.1
Avg.* (~2021)	511.8	291.3	690.5	26.3	4.8	121.4	69.0	47.3	124.6	18.2	3.0	37.6

Source: JET based on WAF data

(3) Sludge Treatment and Disposal

The IDEA process adopted at Navakai WWTP produced excess sludge as a byproduct of its treatment. Design-wise, the withdrawn sludge is aerobically digested, mechanically dewatered, sun-dried, and finally disposed onsite at Navakai WWTP. During the site visit conducted on December 2021, it was found that the mechanical dewaterer was not in operation due to mechanical failures; after digestion, sludge was directly sun-dried and piled up in a corner of the WWTP boundaries. Since the area is not covered with rubber linings etc., there is a possibility of the sludge flowing into nearby waterbodies, etc.

2-2 Current Status of Sewerage Sludge Treatment

2-2-1 Sludge treatment at WWTPs

Currently, sludge treatment at Natabua and Navakai WWTP is not being properly carried out due to factors such as equipment failures.

As for reference, Suva's Kinoya WWTP is equipped with Fiji's one and only anaerobic digestion tank and balloon-type gas holder, but currently no sludge is being inputted. In addition, gas refinement facilities and flare stacks are not yet installed

2-2-2 Offsite Sludge Disposal Sites

(1) Incineration Facilities

In the Western Division, there are currently no large-scale incineration facilities for solid waste. Lautoka Hospital in Lautoka City has a medical waste incinerator, but it is not intended to receive other types/large amounts of waste. For this reason, incineration of sludge outside WWTPs is assumed to be an unrealistic option.

(2) Landfill Disposal Sites

WAF has made requests for municipal waste landfills (ex. Vunato Landfill) to accept dewatered/dried sewerage sludge in the past. However, due to concerns of possible heavy metal contamination in the sludge, these requests have not been met. WAF is also making attempts to coordinate with the DOE to secure its own sludge disposal sites, but no progress has been made.

2-2-3 Component Analysis Results of Sewerage Sludge

Fiji presently has not established standards for the disposal and utilization of sludge, including sewerage sludge. For this reason, the number of laboratories in Fiji that can conduct sludge component analysis is extremely limited. Laboratories at the University South Pacific, which is one of the few laboratories that is said to be capable of such analyses, are currently in the midst of procuring analytical equipment. Similarly, laboratories of the Ministry of Agriculture (hereinafter referred to as "MOA") is currently undergoing renovation. In this situation, sludge sample analysis is impossible to conduct.

As an alternative substitute, the sludge analysis results conducted by MOA in 2020 using Kinoya WWTP's sludge samples is referred to in this M/P (**Table 2-2.1**). These values are compared to standards for sewerage sludge landfill disposal and greenfield application (**Table 2-2.2**) established by organizations such as the EPA.

Table 2-2.1 Results of Kinoya WWTP Sewerage Sludge Analysis (2020)

Sample	Fe	Mn	Zn	Cu	As	Pb	Cr	Cd	Hg※	Ni※	Se※	Mo※
	(mg/kg-DS)											
Sample 1	17,030	131	260	112	<0.01	4	18	<0.01	—	—	—	—
Sample 2	20,225	134	978	211	<0.01	18	29	<0.01	—	—	—	—
Sample 3	18,916	95	990	216	<0.01	14	36	<0.01	—	—	—	—
Sample 4	16,672	20	847	211	<0.01	8	22	<0.01	—	—	—	—
Sample 5	19,104	73	913	199	<0.01	18	27	<0.01	—	—	—	—
Sample 6	19,350	73	877	194	<0.01	14	28	<0.01	—	—	—	—
Sample 7	19,175	131	260	112	<0.01	4	18	<0.01	—	—	—	—

※：Analysis Parameters not included in the 2020 Tests
Source: Created by JET based on WAF data

Table 2-2.2 Standards for Sewerage Sludge Landfill Disposal and Greenfield Application

Standard	Fe	Mn	Zn	Cu	As	Pb	Cr	Cd	Hg	Ni	Se	Mo
	(mg/kg-DS)											
EPA, Surface Disposal※1	—	—	—	—	30	—	200	—	—	210	—	—
EPA, Land Application※1	—	—	7,500	4,300	75	840	3,000	85	57	420	100	75
EU, Land Application※2	—	—	2,500 – 4,000	1,000 – 1,750	—	750 – 1,200		20 – 40	16 – 25	300 – 400	—	—

Source: Created by JET based on below literature
※1: "Code of Federal Regulations: : 40 CFR Part 503, Standards for the Use or Disposal of Sewerage Sludge," US Environment Protection Authority, Department of Environment and Natural Resources (2018)
※2: "Directive on the protection of the environment, and in particular of the soil, when sewerage sludge is used in agriculture," EU Council Directive (86/278/EEC), European Union (1986)

As shown in **Table 2-2.1**, seven samples were collected from the sludge sun-drying bed of Kinoya WWTP and analyzed to find the concentration of harmful substances such as arsenic and cadmium.

Comparison indicated that heavy metal concentrations of Kinoya's sewerage sludge were significantly lower compared to the sewerage sludge disposal/utilization standards shown in **Table 2-2.2**. For this reason, it is presumed that for the heavy metal parameters conducted in the 2020 analysis, sewerage sludge has the possibility of disposal and utilization outside of WWTPs.

However, it should be noted that among the standard parameters listed in **Table 2-2.2**, mercury, nickel, selenium, and molybdenum have not been analyzed, so with the available data the absolute safety of sewerage sludge cannot be guaranteed at this point.

2-3 O&M Status of Sewerage Facilities in WAF West

(1) Sewer Network Facilities

1) Maintenance System

Table 2-3.1 shows the current number of staff of the sewer network (sewer pipe) maintenance teams in the four municipalities in the western division.

Table 2-3.1 Maintenance System for Sewer Network

Municipality	Water Fitter	Technical Assistant	Service Technician	Trade Assistant
Nadi	3	3	1	1
Lautoka	2	3	-	-
Ba	4	2	-	-
Sigatoka	1	1	-	-

Source: WAF

2) Maintenance Status

Table 2-3.2 shows the current status, issues, causes of issues, and improvement methods for the maintenance of sewer networks in WAF.

Table 2-3.2 Maintenance of Sewer Networks

Current status	Causes	How to improve
*The main maintenance work is to clear the clogged pipes, and the status of pipe damage cannot be ascertained since patrols, inspections, and surveys are not conducted.	*Patrol cannot be carried out due to lack of personnel. *The pipe ledger of old pipes is inaccurate, and it is sometimes difficult to know where they are buried.	*Securing human resources to conduct regular patrols of pipes. *Maintaining pipeline ledger including old pipes.
*Clogged pipes are cleared using rotary pipe cleaners, and significant blockages are cleared by jet cleaning outsourced to private contractors.	*WAF does not have jet cleaning equipment or vacuum vehicles.	*It is also possible to procure and use jet cleaning equipment etc. at WAF. However, considering the maintenance of the equipment and securing human resources for its use, it is more economical and efficient to continue outsourcing to the private sector.

Source: JET

As shown in the table, WAF does not conduct patrols, inspections, or surveys of sewer networks, and also the pipe ledger is inaccurate, especially for old pipelines. In the present situation, it is difficult for WAF to plan systematic and efficient management by stock management. Preventive maintenance through planned patrols, inspections and surveys of pipes, as well as corrective maintenance for prompt repair of troubles such as pipe clogging is the basis of pipe maintenance and must be addressed first by WAF. WAF is better to secure human resources to conduct patrols and develop an accurate pipeline ledger.

WAF can procure jet cleaning equipment to repair clogged pipes; however in consideration of economy and efficiency for implementing maintenance of equipment and securing human resources who use it, continuing outsourcing to the private sector is considered to be effective.

(2) Pumping Stations

1) Maintenance System

The maintenance of the pumps is carried out by the mechanical and electrical equipment maintenance team (hereinafter referred to as "ME team"), and the clogging removal of the pumps is carried out by the sewer network maintenance team.

The ME team is in charge of the maintenance of all the mechanical and electrical equipment of the water supply and sewerage facilities in the western division, and its system is shown in **Table 2-3.3**.

Table 2-3.3 Maintenance System of ME Team

Site	Supervisor	Technical Officer	Technical Assistant	Mechanic	Electrician	Other
Natabua WWTP	1	2	1	2	2	1

Source: WAF

2) O&M Status

Table 2-3.4 shows the current status and issues in the O&M of pumping stations, the causes of the issues, and how to improve the issues.

Table 2-3.4 O&M of Pumping Stations

Current status and issues	Causes	Improvement methods
*The ME team regularly patrols the operational conditions of the pumps, the control panels, and the standby power generators, but since maintenance such as replacement of parts is not performed, deterioration is progressing.	*In addition to the shortage of personnel, preventive maintenance of facilities is not implemented due to shortages of materials, equipment, and consumables such as oil by O&M budget shortages.	>Secure sufficient personnel and budget for implementing preventive maintenance. +Prepare equipment ledger for planned equipment maintenance.
*The sewer network maintenance team is responsible for dealing with pump clogging, but it only cleans the pumps and does not check for ME troubles and deterioration.	*Since the members of sewer network maintenance team do not have sufficient knowledge of ME equipment, they cannot identify troubles of equipment during pump cleaning.	+Cleaning of pumps is a good opportunity to check the condition of the casing and impeller of pumps, so either (1) increase number of mechanics in the sewer network maintenance team to check the pump condition, or (2) increase cleaning staff to the ME team to perform the pump cleaning work, should be considered.
*The pipes and buildings of the pumping station are corroding.	*Due to lack of budget	*Secure budget for repairs. At least, it is necessary to record and report the state of corrosion, etc., at patrol by the ME team.

Source: JET

(3) WWTP

1) O&M system

Table 2-3.5 shows the O&M system of WWTPs in four municipalities in the western division. As shown in the table, the WWTPs is staffed with technical officers, operators, and technical assistants. The Votua WWTP in Ba and the Olosara WWTP in Sigatoka are managed by patrol monitoring, so only one or two technical staff are assigned.

Table 2-3.5 O&M System of WWTPs

WWTP	Municipality	Technical Officer	Operator	Technical Assistant
Navakai	Nadi	1	3	3
Natabua	Lautoka	2	2	1
Votua	Ba	1	-	-
Olosara	Sigatoka	2	-	-

Source: WAF

2) O&M status

Table 2-3.6 shows the current status, issues, causes of issues, and improvement methods for O&M of the existing WWTPs in the Western Division

Table 2-3.6 O&M of WWTPs

Current status and issues	Causes	Improvement methods
Navakai WWTP *Mechanical screen equipment and sludge dewaterer are out of order. *Measurement of the effluent quality is conducted only once a month by the WAF Central Water Quality Laboratory and it is difficult to use the data for considering operating conditions such as activated sludge concentration and ratio of aeration time/sedimentation time in the IDEA tank.	*The mechanical equipment has to be managed by the ME team, but since maintenance such as oiling and parts replacement has not been done at all, the deterioration is remarkable. *Although DO concentration if the reaction tank and the effluent transparency, etc. are the daily measurement items, are not implemented because measuring equipment are not on the site.	*Securing a budget and developing a system for regular maintenance of ME equipment. *Refer to Table xx to create a mid-term management plan for equipment, and perform regular maintenance according to it. *For the time being, the SV of activated sludge and the transparency of treated water, which are measured using simple and inexpensive equipment, will be measured daily if possible. *Estimate the range of appropriate operation conditions from the relationship between the measured SV and transparency. *Improve the organization so that various measurements and analysis of the measurement results can be done at the WWTP.
Natabua WWTP *Although it is the central city of the Western division, the sewerage is treated by the simplest stabilization pond method, and the effluent quality is poor. *Highly polluted sludge from the distillery is put into the WWTP and pumped directly into the ocean.	*It is difficult to treat highly polluted LTW and septage (septic tank sludge) by using the stabilization pond process in over lorded. *Since it is discharged directly, it does not affect sewerage treatment, but it is a source of pollution in the sea.	*Improve the effluent quality by introducing mechanical sewerage treatment system. Establish an appropriate O&M system. *Distillery sludge should be treated by putting it into the septage treatment facility to be constructed planned in this M/P. Establish an organizational structure for proper O&M of sludge treatment plants.
Votua WWTP **Olosara WWTP** *Accumulated sludge in anaerobic and facultative ponds is not dredged systematically, resulting in deterioration of the effluent quality.	*Accumulated sludge in the Olosara WWTP was dredged for the first time in 2022 since it started operation in 1986, but there are no plans to dredge regularly.	*Originally, in the stabilization pond method, the sludge in the anaerobic pond should be dredged once every few years. Implement planned sludge dredging including Natabua WWTP.

Source: JET

2-4 Current Condition of Decentralized Treatment Systems

(1) Installation of Sanitation Facilities (Toilets)

Table 2-4.1 show the types of sanitation facilities (toilets) and their connection types in the Ba province, based on data from the 2017 Census. In both urban and rural areas of Ba Province, the percentage of "flush to septic tank" is over 60% when compared by type of facility, with septic tanks being the most widely used.

Table 2-4.1 Installation (Connection) Conditions of Sanitation Facilities (Toilets)

Toilet Facility (Province Total)	Ba Province		Ba Province (Urban Area)		Ba Province (Rural Area)		Western Division	
	Number	%	Number	%	Number	%	Number	%
Flush to piped sewer system	13,712	24.4	13,283	35.4	429	2.3	14,292	18.7
Flush to septic tank	35,857	63.9	22,622	60.2	13,235	71.4	49,638	65.1
Flush to pit latrine	936	1.7	300	0.8	636	3.4	1,741	2.3
Pit latrine with slab	1,818	3.2	486	1.3	1,332	7.2	3,937	5.2
Pit latrine without slab (open pit)	986	1.8	184	0.5	802	4.3	2,051	2.7
Water sealed	2,365	4.2	487	1.3	1,878	10.1	3,843	5.0
Shared toiled	388	0.7	198	0.5	190	1.0	635	0.8
Other	50	0.1	15	0.0	35	0.2	98	0.1
Total	56,112	100	37,575	100	18,537	100	76,235	100

Source: Created by JET based on the 2017 Population & Housing Census

The site survey held in April 2022 revealed that the use of “drum systems” is common in Fiji and are counted as septic tanks. However, they often do not have the capacity required by the National Building Code and lack openings for inspection and sludge removal.

(2) O&M Situation of Septic Tank

The survey also investigated desludging frequency. When asked how often sludge was removed from their septic tanks, about half of respondents answered “never” followed by “uncertain” and “more than 10 years.” Less than 10% of those surveyed responded that they bail their septic tanks once every 10 years or less. Among them only one restaurant and one store indicated that they bail their septic tank once a year. Of those that responded “once every 10 years or more” most admitted they called the bailer only because of problems such as leaks or overflows. It is suspected that desludging is almost never done in general households.

Source ：Created by JET based on information gathered during the interview surveys

Figure 2-4.1 Results of the Interview Survey

(3) Collection of Septage/ Sludge

In Fiji, septage/sludge collection (desludging + transport = “bailing”) services are provided by private companies. These bailing companies offer services on an “on-call” basis, and there are currently nine companies (with 20 trucks in total) trucking in sludge to WWTPs in the Western Division, all registered with WAF. This includes companies that are based in areas outside the Western Division, as well as companies that specifically bail/transport sludge and liquid waste from private corporations. In Fiji, the Waste Business Permit was abolished in 2018, making it possible to operate anywhere in the country by obtaining an Environmental Permit under the jurisdiction of the DOE.

Table 2-4.2 Sludge Collection Companies with Bases in the Western Province

Company	Base	Number of Trucks
Waste Bailers	Nadi	1
Honey Dew	Lami	4
Paradise Beverages	Lautoka	1
Waste Clear Fiji Ltd.	Nausori	1
ZAH Environment Waste Solution	Ba	2
Waste Clear West	Lautoka	4
Vinits Transport	unknown	3
Sudesh Transport Ltd.	Sigatoka	1
Carpenters Carry Clean	Lautoka	3

Source: JET based on WAF data

The following information was obtained from conducting interviews with three of these sludge collection companies.

- Majority of the customers are commercial facilities and offices. Households rarely request bailing services.
- The capacity of concrete septic tanks installed in residences is 2 to 4 m^3. The drum system is often installed in rural areas. the former is bailed about once every 10 years and the latter once every five years.
- Most septic tanks treat only toilet wastewater. Grey water is discharged nearby without treatment.
- Hotels often have two septic tanks. one for toilet wastewater and another for grey water. Bailing is done once every six months to one year.
- Hotels and restaurants often have grease traps. they are cleaned once every three months. The collected oil and sludge are transported and disposed at the WWTP together along with septage.
- Bailing typically takes about one hour. However, if the sludge has solidified at the bottom, it has to be broken up and bailed, which can take about two hours.
- The cost is determined by the distance from the company’s truck base to the bailing location. The distance of the septic tank etc. from the nearest road, or where the truck is parked, does not affect the cost.
- Bailing removes the entire contents of the septic tank (sludge, scum, and sewerage, which are collectively referred to as “septage”)

(4) Disposal of Septage/ Sludge

The septage/sludge collected by these companies is transported to a WWTP operated by WAF for treatment.

Of the four WWTPs operated by WAF in the Western Division, the three shown in the table below accept septic tank sludge. These facilities use the stabilization pond method for treatment. At Votua and Olosara WWTPs, septage/sludge is introduced directly into the anerobic ponds. At Natabua WWTP, the sludge is discharged directly into wetlands adjacent to the WWTP. The sludge input point is a natural wetland with two dumping pits. However, there is no constructed discharge point. The sludge either soaks into the ground or flows out to the ocean.

Table 2-4.3 Condition of Treatment of Septage/Sludge

Facilities that accept septage	Treatment process
Natabua WWTP (Lautoka)	Sludge dumping pit
Votua WWTP (Ba)	Dump to treatment system (stabilization pond)
Olosara WWTP (Sigatoka)	Dump to treatment system (stabilization pond)

Source：JET

2-5 Sewerage Tariffs and Bailing Charges

2-5-1 Sewerage Tariffs Structure

Water and sewerage tariffs are shown in **Table 2-5.1**. The increasing block tariff system is used for household water tariff calculations in Fiji. Flat rates are applied to commercial and governmental water use. Unlike water, flat rates are applied to all users for sewerage tariff calculations. Sewerage rates are significantly lower than water rates.

Table 2-5.1 Water and Sewerage Tariffs

User	Type	Volume	Tariff (FJD/m^3)
Domestic	Water	0 - 50m^3	0.153
		51 - 100m^3	0.439
		100m^3 -	0.838
	Sewerage	Flat rate	0.200
Commercial	Water	Flat rate	1.060
	Sewerage	Flat rate	0.200
Government/ Schools	Water	Flat rate	0.529
	Sewerage	Flat rate	0.200

Source：WAF

2-5-2 Septic Tank Bailing Charges

(1) Bailing Costs

According to the interview survey with the sludge collection companies, bailing charges are determined by the distance from the truck base to the bailing location. The amount of septage collected is not considered in the billing. The customer pays the bailing company directly. **Table 2-5.2** shows the bailing costs reported by a company headquartered in Lautoka, during the interview survey for several areas of the Western Division. The costs shown are general estimates based on past data for collection at the centers of each area.

Table 2-5.2 Bailing Charges According to Interview with Company

Area	Charge for Septage Removal (FJD/Location)
Rakiraki	1,000 - 1,500
Tavua	500 - 600
Ba	300 - 330
Lautoka	200 - 250
Nadi	300 - 330
Sigatoka	500 - 600

Source：JET Interview Survey

A separate company, also headquartered in Lautoka, reported that bailing costs were 200 FJD in Lautoka, and 550 FJD in Rakiraki. These data were verified with customers using this company's services. They reported that although a single bailing request may cost over 1000 FJD, if multiple shops apply for services as a single request the costs are similar to those shown in **Table 2-5.2.** When a bailing company located in Sigatoka was surveyed, they reported that bailing in central Sigatoka would cost about 350 FJD. As can be seen, bailing costs differ greatly between regions. This large difference is a problem that must be overcome.

(2) Sludge Acceptance (Treatment) Tariffs

WAF charges 6 FJD/m^3 to accepted septage/sludge from bailing trucks. The total charge is calculated based on truck capacity and not the actual volume input into the treatment system. The weight of the trucks is not measured. If household septic tanks are 2 m^3, treatment cost would amount to 12 FJD, which is significantly less than what is charged by the sludge collection companies. This may be a factor contributing to the fact that the problem of sludge collection companies illegally dumping septage into waterways was not heard of in Fiji.

2-6 Issues on Sewerage Planning Confirmed through Formulation of M/P

As shown earlier in Section **2-1**, WAF has been already providing sewerage services to central areas of Lautoka and Nadi, especially inside of the Lautoka City Boundary and the Nadi Town Boundary. In order to achieve the NDP, it is necessary to expand the service area and the capacity of WWTPs in the future.

Major issues relating to expansion of WWTP and sewerage collection network are listed in **Table 2-6.1.**

Table 2-6.1 Issues on Sewerage Planning

No.	Item	Contents
Issues on WWTP		
1)	Effluent Standards	In Fiji, two types of effluent standards are established: (1) General standards, and (2) Significant Ecological Zone standards (hereinafter referred to as “SEZ standards.”) The SEZ standards are not pre-applied to certain waterbodies/coastal areas that have certain characteristics/conditions; instead, when a new effluent point is to be established, the DOE conducts site-specific examinations (studying the local geological and environmental characteristics) to determine its application. In meetings with the DOE, it was indicated that SEZ standards are applied to “Coastal areas and rivers with delicate environmental characteristics,” but no specific conditions for the standards’ application was given. The DOE also stated that by conducting environmental studies/assessments of effluent effects to the discharged water body, there is the possibility of applying General standards to effluents that are discharged offshore through ocean outfall pipes.
2)	Securing land for WWTP	Since the existing WWTPs in Natabua and Navakai are in the center of the municipalities, it is necessary to examine whether it is possible and appropriate to expand the site for the capacity expansion of WWTPs. If it is difficult to expand the site around the existing WWTPs, or if it is more efficient and economical to install multiple WWTPs, it is necessary to find another site.
3)	Securing land for final disposal of sludge	WAF requests landfill disposal at municipal solid waste disposal sites, but due to concerns on heavy metal contamination in sewerage treated sludge, there are currently no waste disposal sites accepting sludge. Moreover, the standards for acceptance of sludge for final disposal have not yet been set by the DOE. Securing external sludge disposal sites and utilizing method of sludge are important issues.
4)	GHG reduction and biogas power generation	The "Climate Change Act 2021" enacted in 2021 set net zero emissions of greenhouse gases (hereinafter referred to as “GHG”) by 2050 as a long-term goal for global warming countermeasures. Concrete measures for the Kinoya WWTP in the Suva have been mentioned, and in the sewerage sector, digestion biogas power generation is expected to contribute to net zero. The Municipal Sewerage M/P for the western division should also include the consideration of the digestion biogas power generation as in the case of the Kinoya WWTP.
Issues on Sewer Network		
5)	Construction of additional pipes in crowded area	In both Lautoka and Nadi, sewer pipes have already been installed in the city center. It is expected that it will be difficult to redevelop the sewers necessary for the expansion of the area in the city center because of traffic congestion and many other infrastructures buried under the existing roads.
6)	High initial cost for network	Of the total project cost estimated in the Regional Wastewater M/P, the proportion of the cost related to sewerage collection network development is high. For the Kinoya service area, a long-distance pumping system is applied for collection, but it is expected to consider a multiple WWTP system.

Source：JET

WAF has been concerned about 5) and 6) above since the Regional Wastewater M/P in the western division was formulated. Instead of treating sewerage in each municipality at one WWTP, the consideration of implementing multiple WWTP is requested by WAF.

Regarding 4), Fiji enacted the "Climate Change Act 2021" in 2021, and set net zero emissions of greenhouse gases by 2050 as a long-term goal for global warming countermeasures.

＜The Laws of Fiji, Climate Change Act 2021 Part 9: Climate Change Mitigation＞

[CLI 38] Long term emissions reduction target

38 **(1)** The long term emissions reduction target for Fiji is net zero greenhouse gas emissions by 2050.

(2) The Minister must, with the assistance of the Committee, take all reasonable steps to promote the achievement of the long term emissions reduction target through the development and implementation of carbon budgets, the LEDS, NCCP and NDC.

(3) Every 5 years the Minister must, with the assistance of the Committee, publish a statement of—

(a) Fiji's greenhouse gas emissions over the 5-year period, and any preceding 5-year periods reported on under this section;

(b) an assessment of the progress made towards Fiji's NDC and the long term emissions reduction target at the national and sectoral levels, with reference to carbon budgets and mitigation measures, policies and programmes; and

(c) recommendations on measures needed to meet the emissions reduction target in Fiji's NDC and the long-term emissions reduction target.

"Fiji Low Emission Development Strategy 2018-2050" (hereinafter referred to as "LEDS") sets multiple scenarios that take into account strategic global warming countermeasures for future development plans in Fiji in order to achieve the above goals. This report summarizes simulation results for total GHG emissions in each scenario. Sectors targeted by LEDS include sewerage and waste disposal, and the following three policies are set as policies for global warming countermeasures.

- National 3R (Reduce-Reuse-Recycle) initiatives
- Waste energy utilization in wastewater treatment plants and landfills
- Waste Management Awareness Program

The target facility of the sewerage sector in the LEDS scenario is the Kinoya WWTP in Suva. In order to cover the increase in greenhouse gas emissions due to the expansion of the treatment plant (i.e., the increase in the amount of treated water), the rehabilitation of the digestion tank, installation of the flare stack for the recovered methane gas (detoxification by burning surplus gas), or use of heat and biogas power generation is assumed as target action.

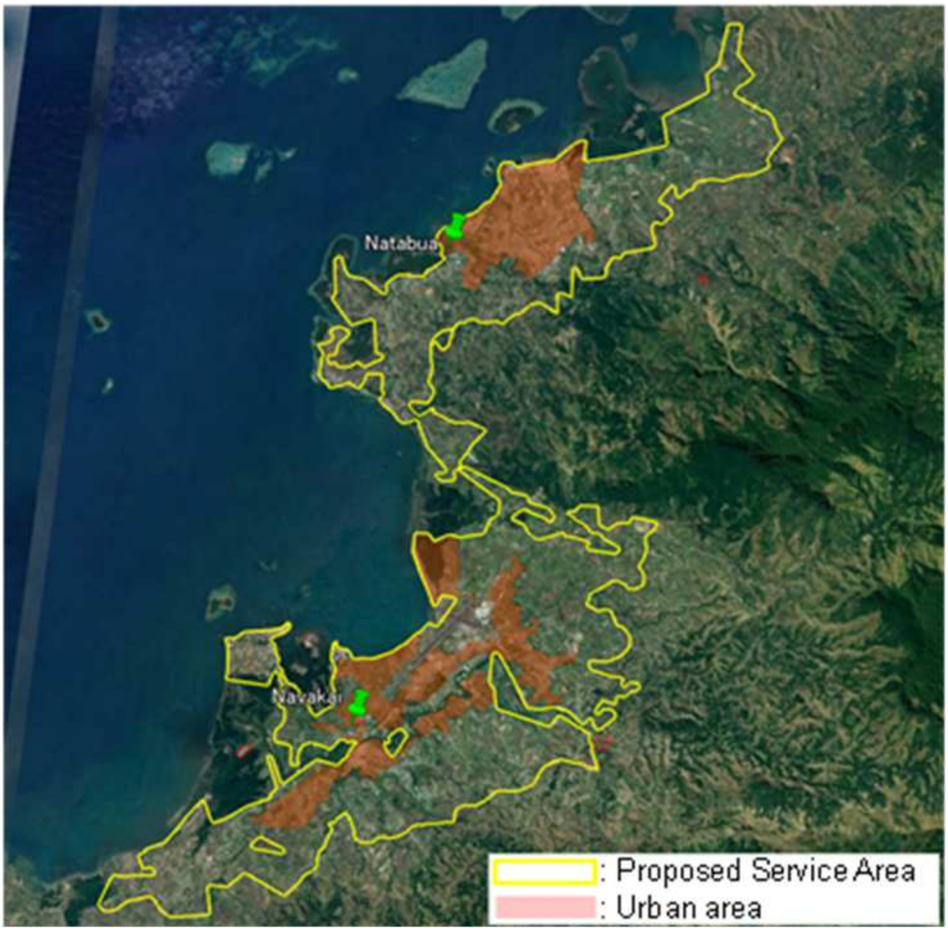
CHAPTER 3 SEWERAGE PLANNING AND DESIGN

3-1 Target Year

Although the target year for the Wastewater Treatment M/P for the Western Division was set to 2036 in accordance with the National Development Plan at the workshop held in February 2023, the DTCP commented that a 50-year plan was being formulated. In response to the need for a long-term plan for the sewerage sector, the target year was reset to 2043, which is 20 years after the plan formulation year (2023). Therefore, the future population and other social trends that determine the scale of the facility will be the scale in 2043.

3-2 Proposed Service Area

The service area, which indicates the area where the wastewater generated is treated by the sewerage system, is the same as in the Regional Wastewater M/P, as shown in **Figure 3-2.1**. There is no change in the planning area in general, because the area was set to achieve the national development goal of "70% population access to the centralized treatment systems."



Source: JET

Figure 3-2.1 Proposed Service Area (Lautoka, Nadi)

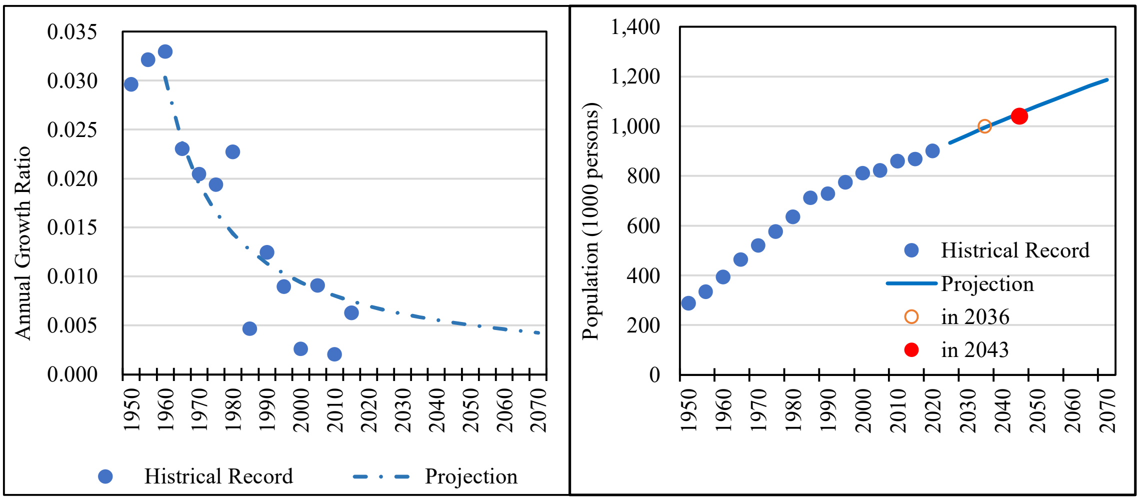
3-3 Planned Served Population

Due to the change in the planned target year, the planned served population is changed to the population projection in 2043.

The future population of the Regional Wastewater M/P was estimated based on past population trends, and that of the Municipal Sewerage M/P also is estimated using the same prediction method.

(1) Future Population of Fiji

By taking into account the declining trend of the population growth rate in the past years, the population in 2043 is estimated to be about 1.04 million, which is an increase of 40,000 comparing to the projection in 2036 of 1 million.



Source: Fiji Bureau of Statics, JET

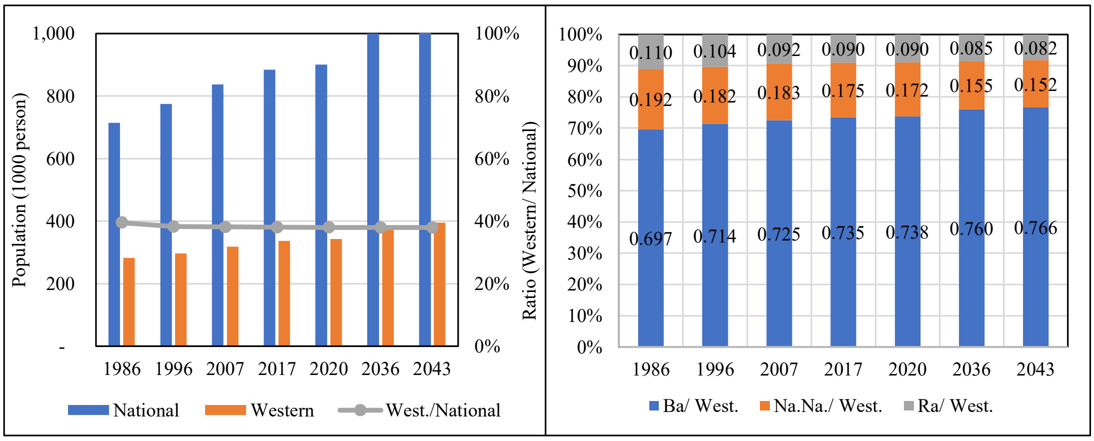
Figure 3-3.1 Population Forecast Based on Historical Data

(2) Populations of Divisions and Provinces

Figure 3-3.2 shows the changes in the population of the Western Division against the whole of Fiji, and the population ratios of the three provinces in the Western Division in the past in the left side.

Since the population ratio of the Western Division to the whole of Fiji has remained at 38% from the past, the population in 2043 in the Western Division is estimated 396,000 people that is 38% of the total population of 1,040,000 in Fiji.

Trends of provincial population ratios show a slight increase in Ba Province and slight decreases in Ra and Nadroga-Navosa Provinces. This trend is expected to continue in the future. Based on existing trends, the population ratios of Ba, Nadroga-Navosa, and Ra in 2043 are expected to be 76.6%, 15.2%, and 8.2%, respectively.



Source: Fiji Bureau of Statics, JET

Figure 3-3.2 Population Ratio of the Western Division to Fiji, and that of 3 Provinces

(3) Population of Urban, Peri-Urban, Rural Area

Table 3-3.1 shows the urban, peri-urban, and rural populations of the provinces of the Western Division in 2017. The urban area mostly coincides with the city and town boundaries established by each city/town[3]. As of 2017, roughly 25% of the entire population resided in urban areas. The peri-urban area, where development is yet to take place, accounts for about 30% of the population. The remaining 45% of the population is distributed throughout the rural areas.

The Fiji Bureau of Statistics expects the population distribution in urban, peri-urban, and rural areas to be 31%, 43%, and 26%, respectively, in 2036. This pattern denotes an expectation of population migration towards urban areas in the future.

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Based on the assumption that the population will continue to shift to urban centers, the populations in the urban, peri-urban, and rural populations by province in 2043 were set as shown lower part of **Table 3-3.1**.

[3] Current Town Boundary in Nadi is a part of the Urban area. Future town boundary is planned to expand up to Urban area.

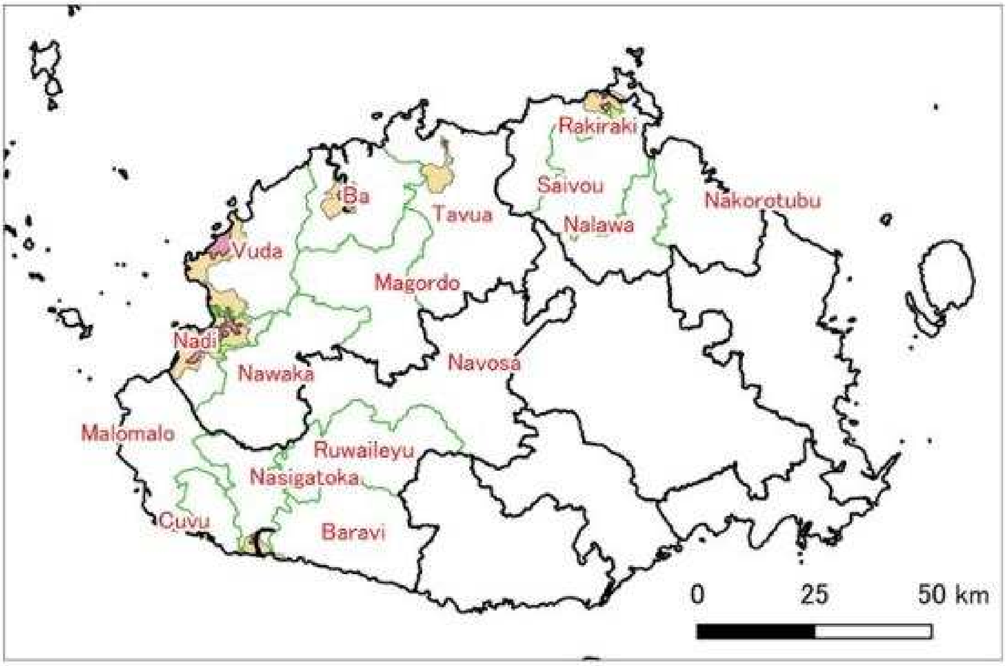
Table 3-3.1 Urban, Peri-Urban and Rural Populations by Province

Year	Province / Category	Ba	Nadroga-Navosa	Ra	Total	Distribution Ratio
2017	Urban	81,662	1,533	1,672	84,867	25.2%
	Peri-Urban	85,145	8,976	4,292	98,413	29.2%
	Rural	80,878	48,431	24,452	153,761	45.6%
	Sub-Total	247,685	58,940	30,416	337,041	100.0%
	Ratio	73.5%	17.5%	9.0%	100%	
2043	Urban	127,800	2,400	2,500	132,700	33.5%
	Peri-Urban	160,400	22,400	10,400	193,200	48.8%
	Rural	15,100	35,400	19,600	70,100	17.7%
	Sub Total	303,300	60,200	32,500	396,000	100.0%
	Ratio	76.6%	15.2%	8.2%	100%	

Source: Fiji Bureau of Statics, JET

(4) Population of Districts (Tikina)

The population of each district in 2043 is distributed according to the ratio of each district in 2017 as shown in **Figure 3-3.3**. As the population of Urban and Peri-Urban increases, the population of Districts consisting only of Rural will decrease slightly.



Source: Fiji Bureau of Statics, JET

Figure 3-3.3 Three Provinces of the Western Division and Its Districts

Table 3-3.2 Population Forecast by District

Province	District (Tikina)	Population 2017				Population 2043			
		Total	Urban	Peri-Urban	Rural	Total	Urban	Peri-Urban	Rural
Ba	Ba	39,372	6,405	9,441	23,526	35,730	10,030	22,260	3,440
	Magodro	4,806			4,806	2,300	-	-	2,300
	Nadi	59,717	29,016	29,422	1,279	96,560	45,420	50,950	190
	Naviti *	2,910			2,910	1,390	-	-	1,390
	Nawaka	16,121		8,406	7,715	16,960	-	15,840	1,120
	Tavua	23,269	1,194	7,616	14,459	18,320	1,860	14,350	2,110
	Vuda	99,264	45,047	30,259	23,958	130,970	70,490	57,000	3,480
	Yasawa *	2,226			2,226	1,070	-	-	1,070
	sub-total	247,685	81,662	85,145	80,878	303,300	127,800	160,400	15,100
Ra	Nakorotubu	4,392			4,392	3,530	-	-	3,530
	Nalawa	4,932			4,932	3,950	-	-	3,950
	Rakiraki	13,908	1,672	3,949	8,287	18,70 0	2,500	9,560	6,640
	Saivou	7,184		343	6,841	6,320	-	840	5,480
	sub-total	30,416	1,672	4,292	24,452	32,500	2,500	10,400	19,600
Nadroga-Navosa	Barava	8,332		628	7,704	7,200	-	1,570	5,630
	Cuvu	7,264			7,264	5,310	-	-	5,310
	Malolo *	3,211			3,211	2,350	-	-	2,350
	Malomalo	15,484			15,484	11,310	-	-	11,310
	Nasigatoka	14,338	1,533	8,348	4,457	26,490	2,400	20,830	3,260
	Navosa	5,106			5,106	3,730	-	-	3,730
	Ruwailevu	4,430			4,430	3,240	-	-	3,240
	Vatulele *	775			775	570	-	-	570
	sub-total	58,940	1,533	8,976	48,431	60,200	2,400	22,400	35,400
Western Division		337,041	84,867	98,413	153,761	396,000	132,700	193,200	70,100

*Italics**: Located on islands other than Viti Levu.
Source: Fiji Bureau of Statistics, JET

(5) Planned Served Population

The planned served population of Nadi and Lautoka is estimated from the service area and the District area in **Table 3-3.2**. As shown in **Table 3-3.3**, the planned served population is with 120,070 in Lautoka and 101,670 in Nadi.

Table 3-3.3 Planned Served Population in Lautoka and Nadi

Municipal	District	Urban	Peri-Urban	Rural	Total	Remark
Lautoka	Vuda	70,490	50,070	160	120,720	
Nadi	Nadi	45,420	45,020	90	90,530	
	Nawaka	-	11,140	-	11,140	
	Sub-total	45,420	54,68656,160	90	101,670	
Total		115,910	106,230	250	222,390	

Source: JET

3-4 Wastewater Flow

(1) Unit Domestic Wastewater Flow

The unit of domestic wastewater flow adopts the value set in the Regional Wastewater M/P and calculates the volume by multiplying the planned served population.

According to the amount of domestic revenue water in the first quarter of 2021 shown in **Table 3-4.1**, the average of the six cities/towns is 236 L/person/day. Currently, WAF has set domestic water consumption at 220 L/person/day and the sewerage recovery rate at 90%. This is not significantly different from the average of the six city/towns, hence the value specified by WAF will be adopted for the planning.

Table 3-4.1 Domestic Revenue Water Flow

Municiplaity	Domestic Revenue Water Flow		Number of Connections	Users per Connection	Consumption per User
	(m^3/3 months)	(m^3/day)	(Connection)	(Capita/Connection)	(L/day/capita)
Nadi	1,993,236	22,147	19,713	4.5	0.250
Lautoka	1,778,871	19,765	17,436	4.5	0.252
Ba	677,151	7,524	8,321	4.5	0.201
Tavua	237,936	2,644	2,841	4.5	0.207
Rakiraki	154,442	1,716	2,006	4.5	0.190
Sigatoka	399,114	4,435	4,564	4.5	0.216
Total	5,240,750	58,231	54,881	4.5	0.236

Source: WAF

(2) Non-Domestic Flow

Non-domestic wastewater volume is estimated by the business water consumption shown in the water supply M/P, plus the wastewater volume from new development areas.

The commercial water demand forecast is summarized in the appendix of the latest version of the water supply M/P, and the planned water volume by the development plan/scale in Lautoka and Nadi is calculated. In addition to this forecast, the district development information collected from DTCP and the Investment FIJI is taken into account to change the amount of non-domestic wastewater volume.

Non-domestic wastewater volume is calculated as the sum of the existing business revenue water volume and the future business demand. The wastewater recovery rate for the design flow is assumed based on the IWA that 80% of the generated wastewater will flow into the sewerage system; that is 80% of the demand is expected to be sewerage volume.

Table 3-4.2 Business Revenue Water Flow

(m^3/day)

Business Revenue Water	Lautoka	Nadi	Total	Notes
Current revenue water	10,300	11,200	21,500	WAF revenue water volume (latest value before COVID-19)
Expected volume in the future	12,700	21,200	33,900	Business demand in the service area in the latest version of the water supply M/P (Additions in this survey)
Total	23,000	32,400	55,400	
Non-domestic wastewater volume	18,400	25,920	44,320	80% of the generated volume

Source: WAF

(3) Infiltration Water Flow

The infiltration water is the water that infiltrates into the sewerage system through the joints of pipes, etc. in fine weather. The amount of infiltration water is estimated to 10% of the amount of generated wastewater by adopting the value set in the Regional Wastewater M/P. In the Guidelines for Planning & Design of Sewerage Facilities 2014 of Japan, it is assumed to be 10% to 20% of the amount of wastewater generated. In Fiji, 10% will be adopted because the depth of sewer pipes is generally shallow.

(4) Design Flow

Based on the above, the design flow for Lautoka and Nadi is summarized in **Table 3-4.3**. The increase of the planned population due to the extension of the target year and the adoption of the cumulative value of non-domestic demand will make the increase of the daily average wastewater volume. The volume for Lautoka and Nadi will be 1.5 times and 1.6 times more than the Regional Wastewater M/P, respectively. For the ratio of daily average to daily maximum, the value used in the water supply M/P demand forecast that is 1.1 will be adopted.

Table 3-4.3 Design Flow

No	Item	Unit	Lautoka	Nadi	Note
1	Population	capita	120,720	101,670	Modified and Increase
2	Water Consumption	m^3/capita/day	0.220	0.220	No change from the Regional Wastewater M/P
3	Return Ratio	%	90	90	No change from the Regional Wastewater M/P
4	Unit wastewater Flow	m^3/capita/day	0.200	0.200	No change from the Regional Wastewater M/P
5	Domestic Flow	m^3/day	24,144	20,334	Modified and Increase
6	Non-Domestic Flow	m^3/day	18,400	25,920	Modified and Increase
7	Generated Wastewater	m^3/day	42,544	46,254	Modified and Increase
8	Infiltration Ratio	%	10	10	No change from the Regional Wastewater M/P
9	Infiltration Water	m^3/day	4,254	4,625	Modified and Increase
10	Total Inflow ADWF	m^3/day	46,798	50,879	Modified and Increase
11	Total Inflow PDWF	m^3/day	51,478	55,967	Modified and Increase

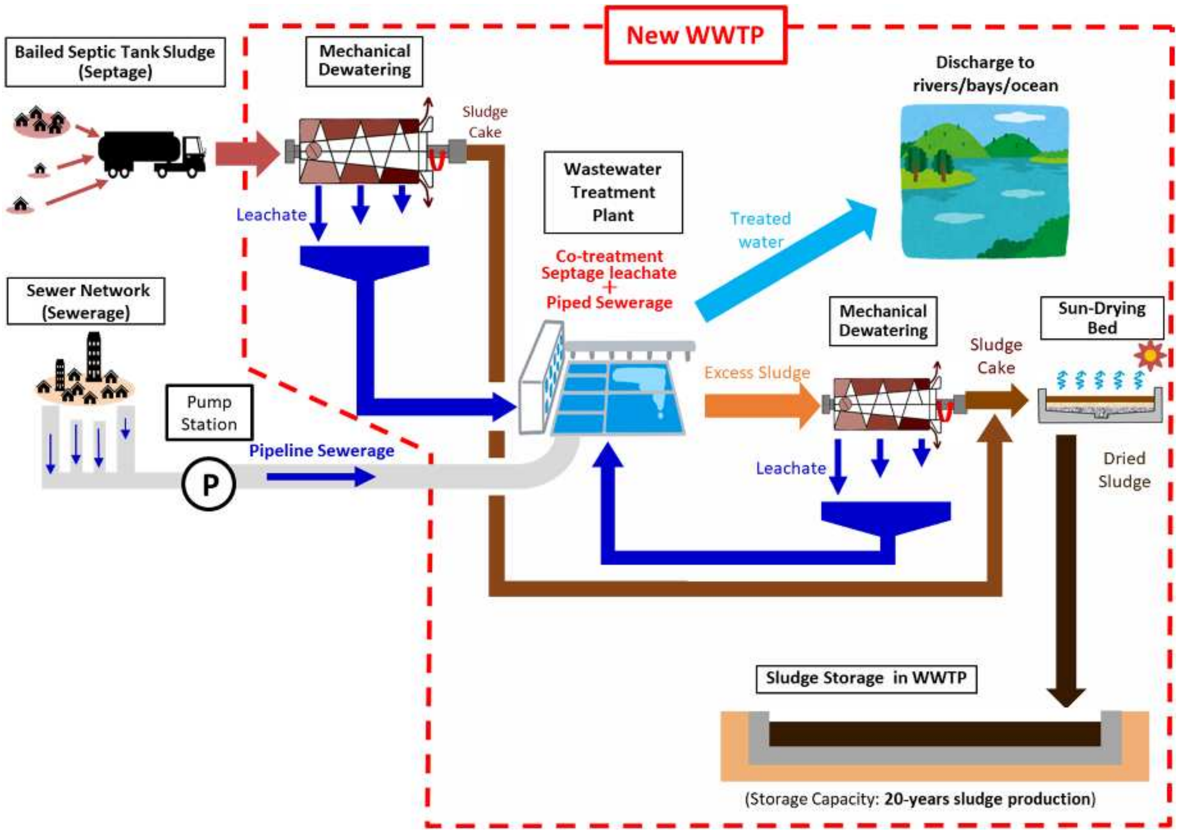
Source: JET

3-5 Planned Wastewater Quality

3-5-1 Setting of Treatment Object

In Lautoka and Nadi, Natabua WWTP currently accepts domestic septage; however, this septage is not treated at the plant, but instead dumped to an un-lined pit located in the wetland adjacent to the WWTP.

In this project, the WWTP treatment targets are set as the "pipeline sewerage (raw sewerage)" and "domestic septage collected by bailing trucks." Domestic septage is received by the receival tanks and mechanically dewatered; the leachate is treated together with the pipeline sewerage in the wastewater treatment process. Dewatered sludge is disposed to the sludge storage site (within the WWTP) after sun-drying. The treatment process flow is shown in **Figure 3-5.1**.



Source: JET

Figure 3-5.1 Treatment Flow in the Wastewater Treatment Plant (Receiving Septage)

3-5-2 Planned Influent Water Quality

The influent water quality was set based on the actual influent water quality data (2014-2021) of the four existing WWTPs in the West, as well as parameter values that were adopted in past Donor projects. In this project, the highest value from these records/reports were adopted for safekeeping (**Table 3-5.1**). For details, refer to **APPENDIX 3-3**.

Table 3-5.1 Influent Water Quality Values Used for WWTP Design

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)	COD (mg/L)	Temp. (℃)
360.0	485.0	70.0	9.0	792	20.0

Source: JET

In the Regional Wastewater M/P, the average daily wastewater inflow (pipeline sewerage) to Natabua WWTP was set at about 31,000 m^3/day, whereas the forecasted septage amount (daily average) was to be 76 m^3/day. As shown in **Table 3-5.2**, the flowrate and water quality of the pipeline sewerage and domestic septage leachate (produced from dewatering) was examined, coming to a conclusion that the septage leachate has almost no effect on the WWTP influent water quality

Table 3-5.2 Water Quality of Pipeline Sewerage and Domestic Septage Leachate Mixture

WWTP	Pipeline Sewerage			Domestic Septage Leachate			Total Influent	
	TSS (mg/L)	BOD (mg/L)	Flowrate (m^3/day)	TSS (mg/L)	BOD (mg/L)	Flowrate (m^3/day)	TSS (mg/L)	BOD (mg/L)
Natabua (Lautoka)	484.1	360	30,974.9	620	250	68.0	486	360

Source: JET

3-5-3 Effluent Quality

As shown in **Table 3-5.3**, two types of effluent quality standards are established in Fiji: General standards, and the Significant Ecological Zone (hereinafter referred to as “SEZ”) standards, which is more stringent.

Table 3-5.3 Effluent Quality Standards

Parameter	Units	Concentration	
		General	Significant EcologicalZone
pH	pH	7-9	7-9
BOD5	mg/L	40	20
SS	mg/L	60	30
Fecal coliforms	CFU/100mL	400	200
TN	mg/L	25	10
Ammonia	mg/L	10	5
TP	mg/L	5	2

Source: Schedule 3 of the Waste Disposal and Recycling Regulations of Fiji (Environment Management (Waste Disposal and Recycling) Regulations, 2007).

According to the DOE, SEZ standards are "applied to coastal areas and river areas with delicate environmental characteristics." However, there are no set conditions of applications/materials clearly showing areas of SEZ standards application. Meanwhile, WAF is currently working on the expansion/renovation project for Kinoya WWTP in Suva, in which General standards effluent is planned to be discharged 1 km offshore through an ocean outfall pipe. In discussions with the DOE, it was confirmed that the same concept as the Kinoya WWTP could be applied to the Municipal Sewerage M/P for Lautoka and Nadi, leaving the option of "General standards + ocean discharge pipe" in the project.

According to DOE, when adopting "General standards + ocean outfall pipe", it is necessary to submit an Environmental Impact Assessment to the DOE and hold discussions at the F/S stage.

- Effluent volume and water quality to be discharged from WWTPs
- Degree of effluent dilution and environmental carrying capacity of the planned discharging area
- Environmental/biological assessment of planned discharging areas, etc.

3-6 Facility Planning and Design Parameters

3-6-1 Sewer Network

The conditions necessary for the sewer network (sewer pipe) planning are summarized below.

Table 3-6.1 Conditions for Calculation of Flow Rate in Sewer Pipes

Type of Pipe	Item	Condition
Gravity pipes	Manning's formula	$V = 1/n\ R^{2/3}S^{1/2}$
	Roughness factor	RCC n = 0.013, PVC n = 0.010 for new pipes
	Minimum velocity	0.60 m/s average flow, 0.80 m/s ultimate flow Minimum gradient = 0.3%
	Maximum velocity	3.0 m/s
	Maximum depth	H < 1.5 m (Open Trench), H> 1.5m (Soil retaining Works) Max. 7m
Pressure pipes	Hazen William's formula	$V = 0.85\ CR^{0.63}\ S^{0.54}$
	Roughness factor	C = 100 for cast iron pipe, C = 110 for PVC pipe
	Minimum velocity	0.8 m/s
	Maximum velocity	3.0 m/s

Source: JET

Table 3-6.2 Design Conditions of Sewer Pipes and Manholes

No	Item	Design Criteria
1	Peaking factor (PF) (Typical Factors)	PF = 2.25
2	Minimum Pipe Diameter	150 mm
3	Minimum Cover Over Top of Pipe	1.2 m
4	Potential Gravity Flow Pipe Materials Diameter < 350 mm Diameter > 350 mm	 PVC RCC
5	Estimated Manhole Spacing (Span) for the Plan	50 m

Source: JET

3-6-2 WWTPs

In the Regional Wastewater M/P, four wastewater treatment processes were adopted as candidates; the Stabilization Pond method (hereinafter referred to as "SP process"), Aerated Lagoon method (hereinafter referred to as "AL process"), OD process, and IDEA process. In the Municipal Sewerage M/P stage, two more treatment processes were added in request from WAF and MPW[4]: the trickling filter method (hereinafter referred to as "TF process"), and the MBBR process. (Details will be described in **Chapter 4-1-2**).

The design parameterss for each treatment process are summarized as follows.

[4] MPW: after organizational restructuring; former Ministry of Infrastructure and Meteorological Service (MIMS)

(1) Stabilization Pond

Treatment Process	Parameter	Range	Noted Reference
Anaerobic Pond	Pond Depth	2~5 m	Duncan Mara※1 , p.108
	HRT	≦1 days	Duncan Mara, p.108
Facultative Pond	Pond Depth	1.5~2.5 m	Power Water※2, p.50
	HRT	For ＜ 20℃: Min. 5 days For ≧20℃ : Min. 4 days	Duncan Mara, p.120
Maturation Pond		Typical value: 1 m Recommended Value: 1.3 m	Duncan Mara, p.136 Power Water, p.50
	HRT	Min. 3 days	Duncan Mara, p.143
	Surface Loading	70% or less of Facultative Pond	Duncan Mara, p.143
	k1	0.05/d	Duncan Mara, p.149

※1 : "Domestic Wastewater Treatment in Developing Countries", Duncan Mara, 2003
※2 : "Waste Stabilization Pond Design Manual," Power and Water Corporation, 2011
Source: JET

(2) Aerated Lagoon

Treatment Process	Parameter	Range	Noted Reference
Anaerobic Pond	Pond Depth	2~5 m	Duncan Mara※1 , p.108
	HRT	≦1 days	Duncan Mara, p.108
	Reduced Removal Rate	50 %	Duncan Mara, p.108
Aerated Facultative Pond	Pond Depth	2~5m (Diffused aerators needed when depth>3.7m) 3~5 m	MetCalf & Eddy, p.840 Duncan Mara, p.219
	HRT	2~6 days	Duncan Mara, p.214
	Electricity consumption rate of aerator	8 kW/1000m^3 wastewater treated	MetCalf & Eddy※2 , p.841
	Yield Coefficient of microorganisms	0.6~0.7 mg X/mg BOD	Duncan Mara, p.215
	Death rate coefficient of microorganisms	0.07/d	Duncan Mara, p.215
Sedimentation Pond	Pond Depth	1.0m minimum (above sludge layer)	Duncan Mara, p.220
	HRT	0.25 ~ 2 days	Duncan Mara, p.220
	Surface Loading	70% or less of Facultative Pond	Duncan Mara, p.143
	k1	0.05/d	Duncan Mara, p.149

※1: "Domestic Wastewater Treatment in Developing Countries", Duncan Mara, 2003
※2:"Wastewater Engineering 4th Edition," MetCalf & Eddy, 2004
Source: JET

(3) Trickling Filter

Treatment Process	Parameter	Range	Noted Reference
Primary Clarifier	Surface Loading Rate	35~70 m^3/m^2・day	JSWA※1, Ed.2019, p.103
	Water Depth	2.5~4.0m	JSWA※1, Ed.2019, p.103
	Weir Loading Rate	250 m^3/m・day	JSWA※1, Ed.2019, p.103
Trickling Filter: Common Parameters	Filter Media Height	1.5~2.0 m	JSWA※2, Ed.1984, p.377
	Filter Media Diameter	Maximum 45 m	JSWA※2, Ed.1984, p.377
	Media Specific Surface Area	100 m^2/m^3	WEF & ASCE※3, p. 13-146
	IWEM Kinetic Coefficient	0.40 $m^{m-1}d^{n-1}$	WEF & ASCE, p. 13-169
	Temperature Coefficient	1.089 (-)	WEF & ASCE, p. 13-169
	Reduction Factor for Surface Loss with Increasing Area	0.732 (-)	WEF & ASCE, p. 13-169
	Hydraulic Rate Coefficient	1.396 (-)	WEF & ASCE, p. 13-169
	Minimum Sewerage/Air Temperature Difference Requirement for Natural Draft Ventilation	Δ2.8℃	WEF & ASCE, p.13-159
	Air Flow in Filter Media	1 $m^3/min/m^2$	CPHEEO※4, p.250
Stage 1 Trickling Filter	BOD loading (BOD Removal)	1.20 kg-BOD/(m^3・day)	JSWA, Ed.1984, p.379
Stage 2 Trickling Filter	BOD loading (Ammonia Nitrification ＋BOD Removal)	0.16 kg-BOD/(m^3・day)	WEF & ASCE, p.13-173
	Ammonia Nitrification	75 %	WEF & ASCE, p.13-173
Final Clarifier	Settling Time	6~12 hr	JSWA, Ed.2019, p.108
	Water Depth	3.0~4.0 m	JSWA, Ed.2019, p.108
	Surface loading rate	8~12 m^3/m^2・day	JSWA, Ed.2019, p.108
	Weir loading rate	25~30 m^3/m・day 125~250 m^3/m・day	JSWA, Ed.2019, p.108 Metcalf & Eddy※5, p.620
Disinfection Tank	Chlorine contact time	15 min	JSWA, Ed.2019, p.238

※1：“ Sewerage Facility Planning and Design Guideline and Commentary: 2019 Edition,” Japan Sewerage Works Association, 2019
※2：“ Sewerage Facility Planning and Design Guideline and Commentary: 1984 Edition,” Japan Sewerage Works Association, 1984
※3：“Design of Municipal Wastewater Treatment Plants: WEF Manual of Practice No.8 ASCE Manuals and Reports on Engineering Practice No.76: Fifth Edition,” Water Environment Federation & American Society of Civil Engineers, 2010
※4：“Manual on Sewerage and Wastewater treatment: Second Edition,” Central Public Health and Environmental Engineering Organization, 1993
※5：”Wastewater Engineering 4th Edition,” MetCalf & Eddy, 2004
Source：JET

(4) IDEA Process

Treatment Process	Parameter	Range	Noted Reference
BOD Loading and Biomass	F/M Ratio	0.07856 kg/kg・d	MetCalf & Eddy※1, p.793
	SVI	100 mL/g	MetCalf & Eddy, p.793
	* No description due to a patent-related material.		

※1："Wastewater Engineering 5th Edition," MetCalf & Eddy, 2009
Source: JET

(5) OD Process

Treatment Process	Parameter	Range	Noted Reference
OD Basin	HRT	24~36 hr	JSWA※1, Ed.2019, p.103
	Water Depth	1.0~5.0 m	JSWA, Ed.2019, p.103
	Basin Width	2.0~6.0 m	JSWA, Ed.2019, p.103
	MLSS	3,000~4,000 mg/L	JSWA, Ed.2019, p.103
	BOD-SS loading	0.03~0.05 mg-BOD/kg-SS・d	JSWA, Ed.2019, p.103
	Return Sludge Ratio	100~200 %	JSWA, Ed.2019, p.103
Final Clarifier	Settling Time	6~12 hr	JSWA, Ed.2019, p.108
	Water Depth	3.0~4.0 m	JSWA, Ed.2019, p.108
	Surface loading rate	8~12 m^3/m^2・d	JSWA, Ed.2019, p.108
	Weir loading rate	25~30 m^3/m・d 125~250 m^3/m・day	JSWA, Ed.2019, p.108 Metcalf & Eddy※2, p.620
Disinfection Tank	Chlorine contact time	15 min	JSWA, Ed.2019, p.238

※1: " Sewerage Facility Planning and Design Guideline and Commentary: 2019 Edition," Japan Sewerage Works Association, 2019
※2: "Wastewater Engineering 4th Edition," MetCalf & Eddy, 2004
Source: JET

(6) MBBR Process

Treatment Process	Parameter	Range	Noted Reference
Primary Sedimentation Tank	Surface Loading Rate	35~70 m^3/m^2・d	Nishihara Kankyo※, p.10
	Water Depth	2.5~4.0 m	Nishihara Kankyo, p.10
	Weir Loading Rate	250 m^3/m・d	Nishihara Kankyo, p.10
MBBR Reactor	* No description due to a patent-related material.		
Final Clarifier	Surface Loading Rate	20~30 m^3/m^2・d	Nishihara Kankyo, p.10
	Water Depth	2.5~4.0 m	Nishihara Kankyo, p.10
	Weir Loading Rate	150 m^3/m・d	Nishihara Kankyo, p.10

※"Linpo process design document (draft)," Nishihara Kankyo Co., Ltd., 2010
Source: JET

CHAPTER 4 EXAMINATION OF SEWERAGE SYSTEMS

4-1 Comparison of Sewerage Systems

The challenges facing the expansion of the planned service area to meet the National Development Plan are described in **2-6**. Some of the main points are listed below.

a. Laying additional sewer pipes for the expansion area in the central part of the city will be difficult, due to the high density of existing pipelines.
b. According to an examination of the estimated costs of the Regional Wastewater M/P, the ratio of the sewer network construction cost to the total project cost is high.
c. As for the effluent standards (General/SEZ) for each WWTP, DOE indicated that their general policy is to apply SEZ standards; however, depending on the results of the discharge area's environmental studies, there is still the possibility to apply General standards to effluent discharged offshore through ocean outfall pipes.

Regarding each of the above points:

a.: Considering WAF's request to create multiple service areas, the cost of laying an additional trunk line in the central part of the city will be included in the examination.

b.: The sewerage collection method will be reconfirmed, including the interceptor method, which has reduced cost of branch sewers.

c.: In examining the creation of multiple service areas, several treatment processes that comply with effluent standards will be studied and compared.

Comparison/Examination of the sewerage systems will be conducted in the following order:

1. Comparison of collection systems (separated sewer, combined sewer, interceptor sewers)
   ↓
2. Primar examination and comparison of treatment processes (compare six processes using 10,000 m^3/day model[5])
   ↓
3. Examination of Multiple Service Area Options
   ↓
4. Secondary examination of treatment processes to be adopted at each WWTP

[5] In the Regional Wastewater M/P, a uniform comparison of the six wastewater treatment processes was not conducted, so a quantitative comparison of 10,000 m^3/day-scale model will be implemented in this M/P. The model scale was set to 10,000 m^3/day, which is the average influent flow for the multiple service area option (Section **4-1-4**)
.

4-1-1 Sewerage Collection Method

Sewerage can be collected through a separated system, a combined system, or an interceptor system that utilizes existing drainage infrastructure. General advantages and disadvantages of each are summarized in **Table 4-1.1.**

Table 4-1.1 Comparison of Collection Methods

Item	Combined System	Separated System	Interceptor System
Construction	Only one pipe is required, resulting in less competition with other underground infrastructure. Pipe diameter is greater than for separated system.	Two lines are required, making installation especially difficult on narrow roads. Diameter of each pipe is less than for combined systems. However, smaller pipes require greater gradients to convey water and may result in increased burial depths.	Simplest of the three methods as only the combined interceptor is required.
Cost	Lower cost as only one pipeline is required.	Construction of sewer pipes and stormwater pipes increases costs. However, construction of sewer pipes only is less expensive.	Only the combined interceptor pipe is constructed, making this the least expensive method.
Accumulation in pipe	Deposits accumulate easily due to the large pipe diameter and shallow gradient. However, it can be washed out to some extent by stormwater.	Little accumulation in the sewer pipes. Accumulation in the stormwater pipes is similar to combined sewers. This is also washed out to some extent by stormwater.	Deposits accumulate easily due to the large pipe diameter and shallow gradient. However, it can be washed out to some extent by stormwater.
Risk of cross-connections	None	Sufficient training is required. Cross-connections can result in stormwater infiltration issues.	None
Stormwater infiltration	Sewerage and stormwater are conveyed by the same pipe.	Stormwater infiltration issues can occur was the sewer pipes age. Countermeasures against stormwater infiltration may become necessary.	Major issues can be avoided by setting the appropriate interception ratio.
Water quality protection	During large rain events, untreated or undertreated water can flow into the discharge basin and present a risk of water pollution and environmental issues. Countermeasures against overflows during rain events is required.	The sewerage load is properly treated, so there are no issues related to water quality protection. Stormwater, including non-point source loads are conveyed separately into water bodies.	During large rain events, untreated or undertreated water can flow into the discharge basin and present a risk of water pollution and environmental issues. Countermeasures against overflows during rain events is required.
Improvement of sanitation	Sanitation around each household will be improved because no gray water will be discharged into nearby drains.	Sanitation around each household will be improved because no gray water will be discharged into nearby drains.	The collection system uses the existing drains, etc. around each household. Public sanitation around households will not be improved.
Sewerage service	Quality of both public health and waterbodies will be improved and individual connections will be made. Therefore, the collection of sewerage charges can be explained.	Quality of both public health and waterbodies will be improved and individual connections will be made. Therefore, the collection of sewerage charges can be explained.	Public sanitation of the immediate surroundings will not be improved and individual connections will not be made. Therefore, explanation of sewerage charges is more difficult.

Source: Compiled by JET based on the Sewerage Facility Planning and Design Guidelines can Comments (Part 1), 2019 issue

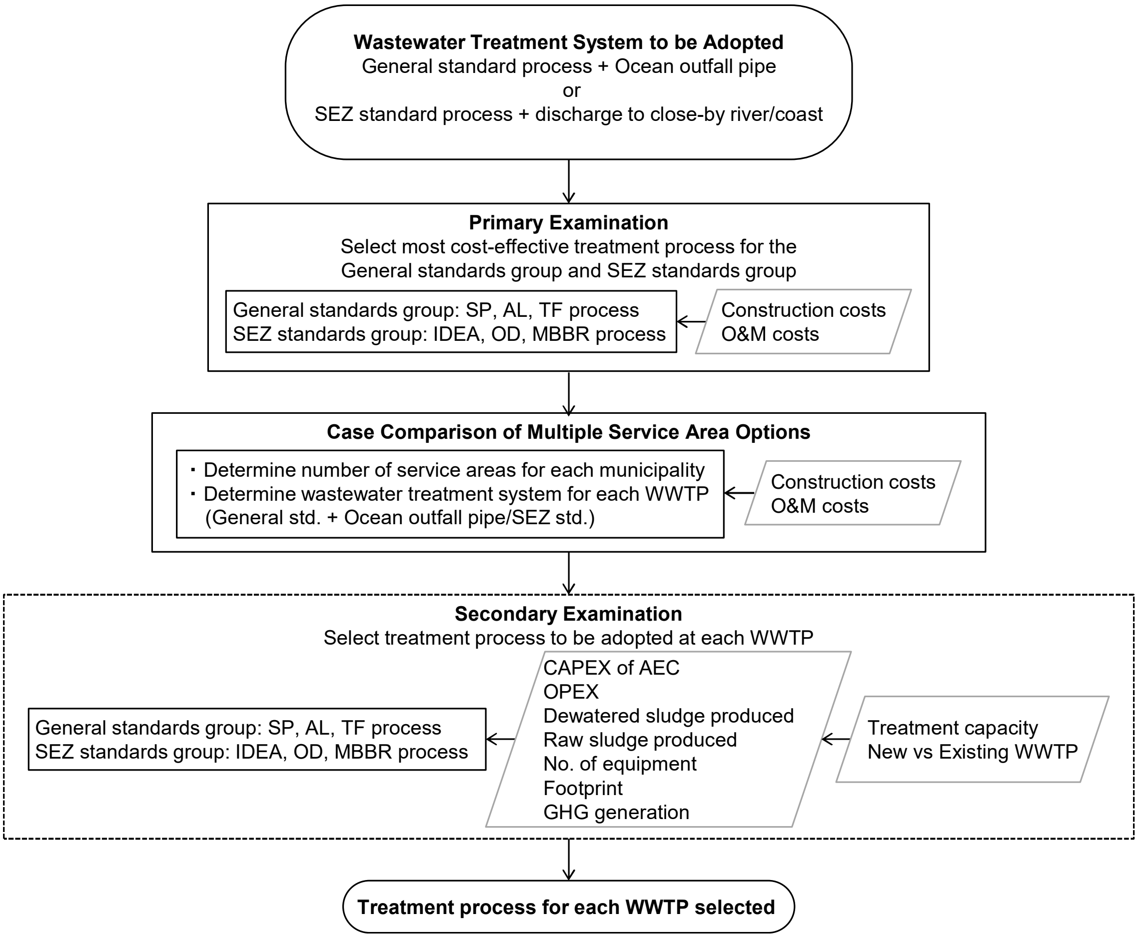
Fiji currently has 11 WWTPs in operation and the separated sewerage system has been adopted. Therefore, the Municipal Sewerage M/P will also adopt the separated collection system. Although the interceptor system has the advantage of being less expensive in terms of cost of branch sewers, it is not selected for the M/P due to environmental concerns and other issues listed below.

- The separated system can properly collect toilet wastewater as well as gray water. This will be the most effective in conserving the water quality for public health and protection of public water bodies and can contribute to achieving the main purpose of sewerage systems.
- There is no need to adopt a combined system as stormwater is already being drained using existing gutters and drainage channels.
- Since existing septic tanks receive toilet wastewater and permeate it into the ground, the interceptor will only be effective for collecting gray water.

4-1-2 Selecting a Treatment Process and Examination of a Multi-WWTP System

Regarding the effluent standards that are important conditions for selecting a treatment process, as shown in **3-5-3**. Discharge to the sea using ocean outfall pipes with a treatment process compatible with the General standard has a possibility of being approved, as well as the use of a treatment process compatible with the SEZ standard. WAF recognizes that SEZ treatment processes will increase the O&M costs, and Kinoya WWTP is also considering the application of the combination of general treatment process and ocean outfall pipe, so it is necessary to consider the combination method based on the case in Kinoya.

Figure 4-1.1 shows the workflow for selecting a treatment process and considering multiple WWTP systems. As a primary selection, a representative treatment process that can accommodate General standard and SEZ standard is selected by cost comparison. Based on the representative treatment process for each effluent standard selected in the primary selection, multiple WWTP systems are considered for each case, taking into account the cost of ocean outfall pipes, etc. Secondary selection of the treatment process to be applied to the WWTPs obtained from the multiple WWTP system study was performed. In the secondary selection, the design flow, location conditions of the treatment plant, and various evaluation criteria were set before the selection.



Source：JET

Figure 4-1.1 Workflow for Selection of Treatment Process and Multiple-WWTP System

4-1-3 Primary Selection of Treatment Process

(1) Treatment Processes to be Considered for Primary Selection

The treatment process in the primary selection includes the five candidate treatment processes considered in the Regional Wastewater M/P in the Western Division, as well as the trickling filter method, which was added at the request of the Fiji side. The 6 treatment processes are listed in **Table 4-1.2**.

Table 4-1.2 Wastewater Treatment Process Candidates

Treatment Process	Summary/ Past Cases of Adoption	Effluent Quality
Stabilization Pond (SP)	• Adopted at Natabua, Olosara, and Votua WWTP. • Selected when ample land is available and general effluent quality standards are required.	General
Aerated Lagoon (AL)	• Adopted when WWTP land area needs to be smaller than that of stabilization ponds. • Selected when ample land is available and general effluent quality standards are required.	General
Trickling Filter (TF)	• Included due to request from the Fiji side. • Single-stage TF process adopted at Kinoya WWTP. • Two-stage TF process will be examined due to high sewerage load of the influent.	General
IDEA	• Adopted at Kinoya and Navakai WWTP. Also proposed in the Detailed Design of the Navakai WWTP capacity expansion project. • Selected when the WWTP footprint needs to be especially small or when SEZ effluent quality is required.	General & SEZ
Oxidation Ditch (OD)	• One of the standard treatment process adopted in Japan and possibility of applicability in Fiji is high. • Selected when the WWTP footprint needs to be especially small or when SEZ effluent quality is required.	General & SEZ
Moving Bed Biofilm Reactor (MBBR)	• Included due to request from the Fiji side. • Less land area required compared to OD and IDEA processes. • Selected when the WWTP footprint needs to be especially small or when SEZ effluent quality is required.	General & SEZ

Source: JET

(2) Estimated Construction Cost

The estimated construction costs for each treatment process are shown in **Table 4-1.3**. As a result of the comparison, the AL process (total 90.7 million FJD) was the most economically advantageous treatment process for General standard in the total including the estimated construction cost and the estimated land acquisition cost. Among the treatment processs for SEZ-compatible, the OD process (total 118.0 million FJD) is the cheapest. The approximate construction cost was calculated using the same cost estimation conditions as in the Regional Wastewater M/P.

Table 4-1.3 Estimated Construction Costs for Each Treatment Process

Treatment Process	Required Footprint (ha)	Construction Cost (million FJD)	Land Acquisition Cost (million FJD)	Total (million FJD)
Stabilization Pond	36.0	93.4	23.4	116.9
Aerated Lagoon	14.2	81.4	9.3	90.7
Trickling Filter	11.6	111.6	7.6	119.2
Oxidation Ditch	9.0	114.9	5.9	120.8
IDEA	9.1	130.1	5.9	136.0
MBBR	9.4	118.3	6.1	124.3

Note: Land acquisition cost including sludge landfill area. Since the unit price of collected land costs varies from 20 to 110 FJD/m^2, an average of 65 FJD/m^2 is used for estimation.
Source：JET

(3) Estimated O&M Costs

The estimated annual O&M costs of the treatment plant are shown in **Table 4-1.4**. O&M costs include energy consumption costs for mechanical and electrical equipment, repair costs, and personnel costs for maintenance managers. Since there is currently no final disposal site for the sludge after sun drying, the sludge is currently planned to be stored (landfilled) within the WWTP site. If a sludge landfill outside the WWTP is secured in the future, the sludge removal and disposal costs will be added to the O&M costs below.

In terms of estimated annual O&M costs, the stabilization pond method, which does not require equipment such as aerators and is easy to manage on a daily basis, is the most economically advantageous. On the other hand, the MBBR process, which requires the operation of a large amount of equipment during treatment, was the most economically disadvantageous.

Table 4-1.4 Estimated Annual O&M Costs for Each Treatment Process

Treatment Process	Electricity Cost (million FJD/yr)	Repair Cost (million FJD/yr)	Labor Cost (million FJD/yr)	Annual O&M (million FJD/yr)
Stabilization Pond	0.10	0.37	0.04	0.51
Aerated Lagoon	0.38	0.48	0.05	0.92
Trickling Filter	0.45	0.843	0.14	1.43
Oxidation Ditch	0.51	1.21	0.18	1.89
IDEA	0.51	1.21	0.18	1.89
MBBR	0.64	1.43	0.18	2.25

Note*The number of personnel assigned to each treatment process will be adjusted as appropriate, taking into account Fiji's organizational capacity and other factors

Source: JET

(4) Comparison by Annual Equivalent Cost

An Annual Equivalent Cost (hereinafter referred to as “AEC”) is used to evaluate the estimated construction and O&M costs calculated above. The AEC of construction costs can be calculated by dividing the civil, mechanical, and electrical construction costs by their service lives (Civil part: 50 years, Mechanical part: 15 years, Electrical part: 10 years). **Table 4-1.5** compares the AEC for each treatment process. The stabilization pond process is cheaper according to the General standards, while the OD process is cheaper according to the SEZ standards.

Table 4-1.5 Annual Cost of Each Treatment Process

Treatment Process	Construction Cost (million FJD)				Annual Equivalent Construction Cost (million FJD/year)				O&M Cost	AEC
	Civil	Mecha.	Elec.	Total	Civil	Mecha.	Elec.	Total	(million FJD/year)	
Stabilization Pond	66.9	19.1	7.3	93.4	1.34	1.28	0.73	3.35	0.51	3.86
Aerated Lagoon	38.3	33.7	9.5	81.4	0.77	2.25	0.95	3.96	0.92	4.88
Trickling Filter	49.0	42.3	20.3	111.6	0.98	2.82	2.03	5.83	1.43	7.26
Oxidation Ditch	49.8	44.0	21.1	114.9	1.00	2.93	2.11	6.04	1.89	7.93
IDEA	53.1	50.1	26.9	130.1	1.06	3.34	2.69	7.09	1.89	8.98
MBBR	50.9	46.1	21.2	118.3	1.02	3.08	2.12	6.22	2.25	8.47

Note: The service life used for calculating the annual construction cost was 50 years, 15 years, and 10 years for civil engineering, machinery, and electricity, respectively.
Source: JET

The study of multiple WWTP system is an economical comparison based on the AEC shown in the table above, and also includes comparisons between "General treatment process + ocean outfall pipe" and "SEZ treatment process." It is judged that it would be safer selection to adopt an expensive treatment process as a representative process for General standard. Therefore, the TF process is selected as the representative process of General standard. The OD process is adopted as the representative process for SEZ standard.

4-1-4 Examination of Multiple Service Area Options

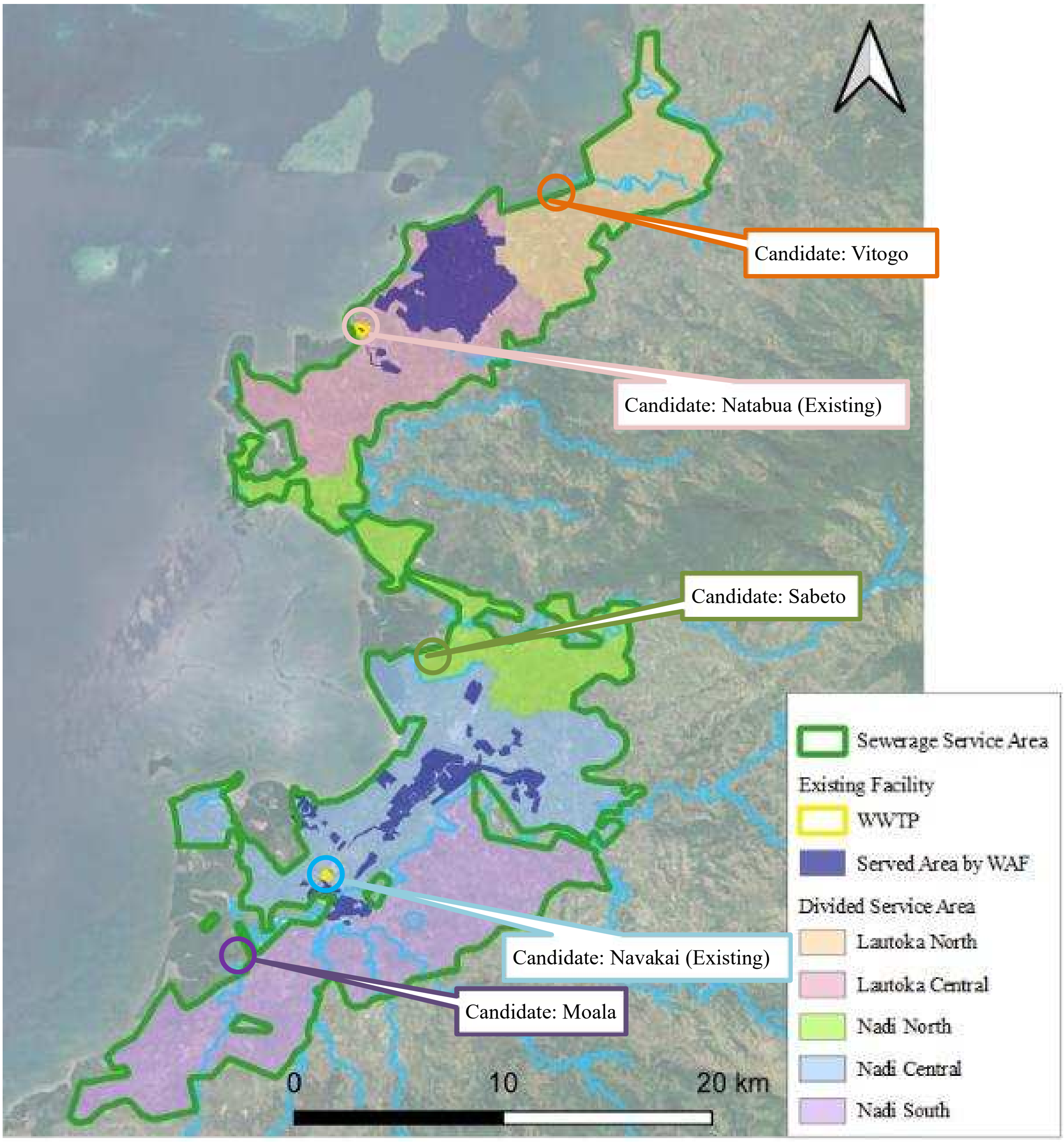
(1) Partitioning Service Areas

The following three points were considered when partitioning the project area into service areas shown in **Figure 4-1.2**. Lautoka was divided into two service areas and Nadi was divided into three service areas.

- Contour maps and spot elevation survey results were consulted, and service areas were created to maximize the use of gravity flow for sewerage conveyance.
- Whenever possible, inflow of sewerage into existing service areas was avoided.
- The new service area must have a candidate WWTP site.

Candidate WWTP sites were selected with the following considerations. In addition, the feasibility of land acquisition will be investigated and future studies that include environmental and social considerations will be implemented.

i. Located downstream (or a low point) of the service area.
ii. Located near receiving water bodies (rivers, oceans).
iii. Resettlement is not required or is especially low.
iv. As much as possible, not located in or near city centers (not applicable to existing WWTPs).
v. Cutting of mangrove forests is not required or is especially low.



Source: JET

Figure 4-1.2 Proposed Service Areas and Candidate WWTP Sites

(2) Design Flow of Each Service Area

Along with the creation of multiple service areas, the design flow of the two cities calculated in **3-4(4)** was distributed within each divided service areas. In addition, a southern part of the Lautoka service area was reassigned to the Sabeto service area (Nadi) in response to ground level survey results.

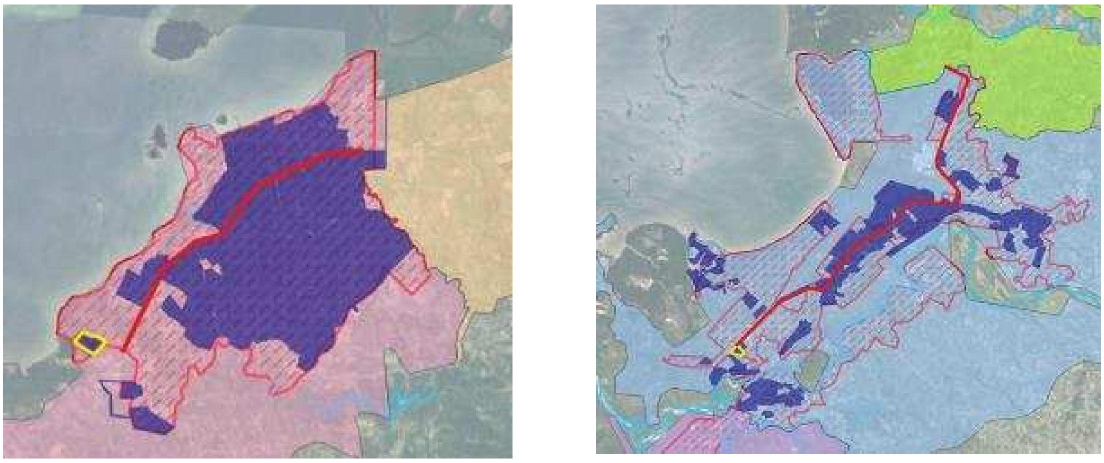
Table 4-1.6 Design Flow of Each Service area

No	Item	Unit	Lautoka		Nadi			Total
			Vitogo	Natabua	Sabeto	Navakai	South	
1	Population	capita	15,130	105,590	13,510	52,740	35,420	222,390
2	Water Consumption	m^3/capita/day	0.220	0.220	0.220	0.220	0.220	
3	Return Ratio	%	90	90	90	90	90	
4	Unit wastewater Flow	m^3/capita/day	0.200	0.200	0.200	0.200	0.200	
5	Domestic Flow	m^3/day	3,026	21,118	2,702	10,548	7,084	44,478
6	Non-Domestic Flow	m^3/day	2,760	15,640	3,110	14,000	8,810	44,320
7	Generated Wastewater	m^3/day	5,786	36,758	5,812	24,548	15,894	88,798
8	Infiltration Ratio	%	10	10	10	10	10	
9	Infiltration Rater	m^3/day	579	3,676	581	2,455	1,589	8,880
10	Total Inflow ADWF	m^3/day	6,365	40,434	6,393	27,003	17,483	97,678
11	Total Inflow PDWF	m^3/day	7,001	44,477	7,033	29,703	19,232	107,446

Source: JET

(3) Case Comparisons

- A mechanical treatment process was assumed for the Navakai WWTP expansion. Because it is located near the city center, discharge to the ocean is difficult. The nearby Nadi River will be the receiving body and SEZ effluent standards will apply.
- Since the other four WWTPs are located close to the sea, both the case of applying ocean outfall pipes with General and the case of corresponding to SEZ were examined.
- The TF process was adopted as the treatment process that complies with the General standards. The OD process was adopted as the mechanical treatment process that complies with the SEZ effluent standards.
- In the case of a centralized single-service area, an additional sewer line will be required to pass through the developed area, as shown in red line in **Figure 4-1.3**. The additional cost of this trunk line and pump station is included.
- For comparison of costs, the sum of the AEC of construction cost and O&M cost was used. This value is obtained by dividing civil, machinery, and electricity costs in the breakdown of construction costs by the service life of each (Civil part: 50years, Mechanical part: 15 years, Electrical part: 10 years).



Source: JET

Figure 4-1.3 Pipelines Crossing through Existing Service Area (Lautoka, Nadi)

The cases examined for Lautoka and Nadi are summarized in **Table 4-1.7** and **Table 4-1.8**. And **Figure 4-1.4** and **Figure 4-1.5** shows schematic summaries of each case.

Table 4-1.7 Description of Each Case (Lautoka)

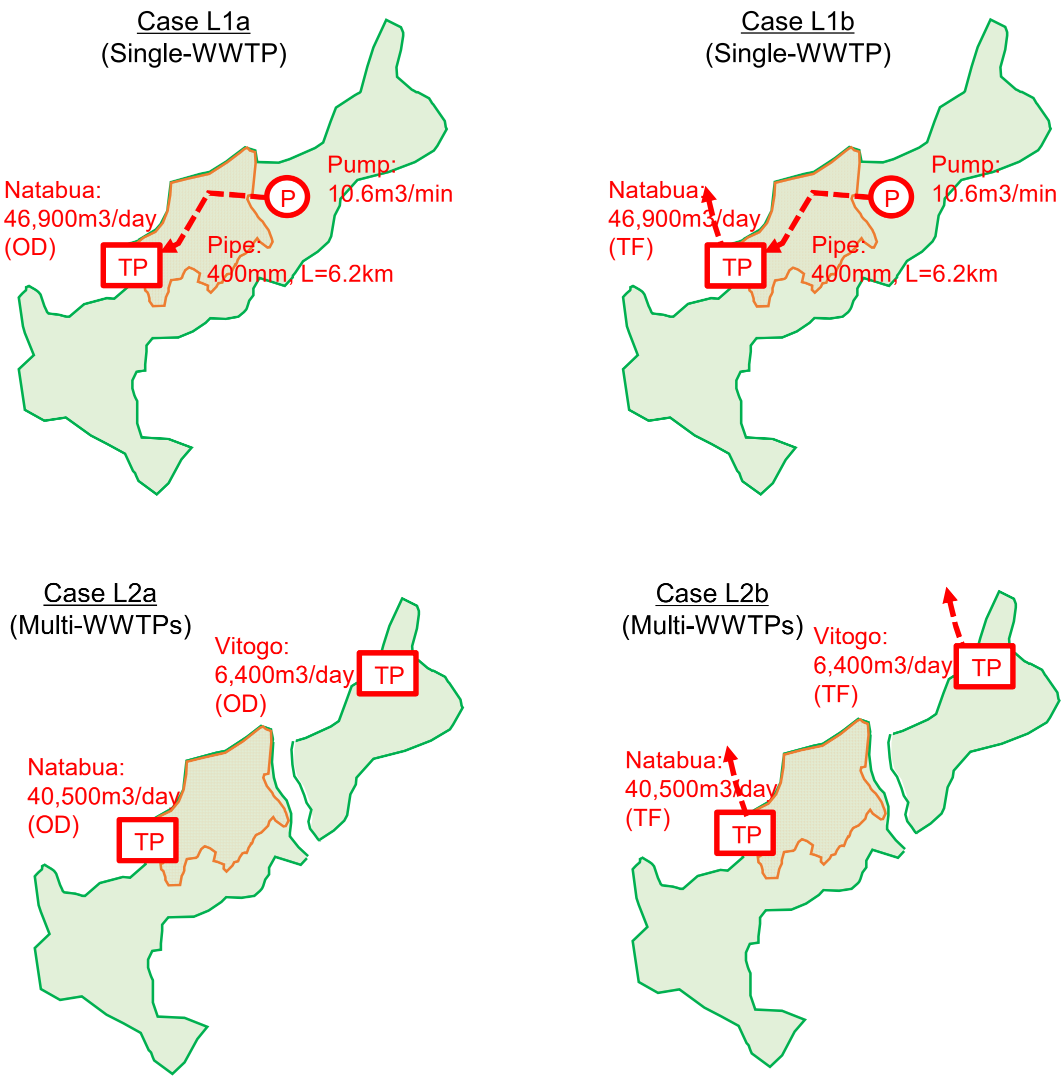
System	Case	Treatment Process	Summary/Characteristic
Single WWTP	L1a	Natabua: OD	・ O&M of only one WWTP is required, which is simpler than the other options. ・ Additional cost of transfer pipe and pumping stations from the existing service area is required.
	L1b	Natabua: TF	・ O&M of only one WWTP is required, which is simpler than the other options. ・ Additional cost of transfer pipe and pumping stations from the existing service area is required. ・ Ocean outfall pipe is required due to applying General standard process.
2 WWTPs	L2a	Natabua: OD Vitogo: OD	・ Highest WWTP cost. ・ Transfer pipe from existing service area is not required. ・ Greatest O&M staff requirements.
	L2b	Natabua: TF Vitogo: TF	・ Transfer pipe from existing service area is not required. ・ Although 2 WWTPs are installed, this case does not greatly increase the demands on O&M staff due to applying General standard process. ・ A ocean outfall pipe required to be constructed at both of WWTPs.

Source: JET

Table 4-1.8 Description of Each Case (Nadi)

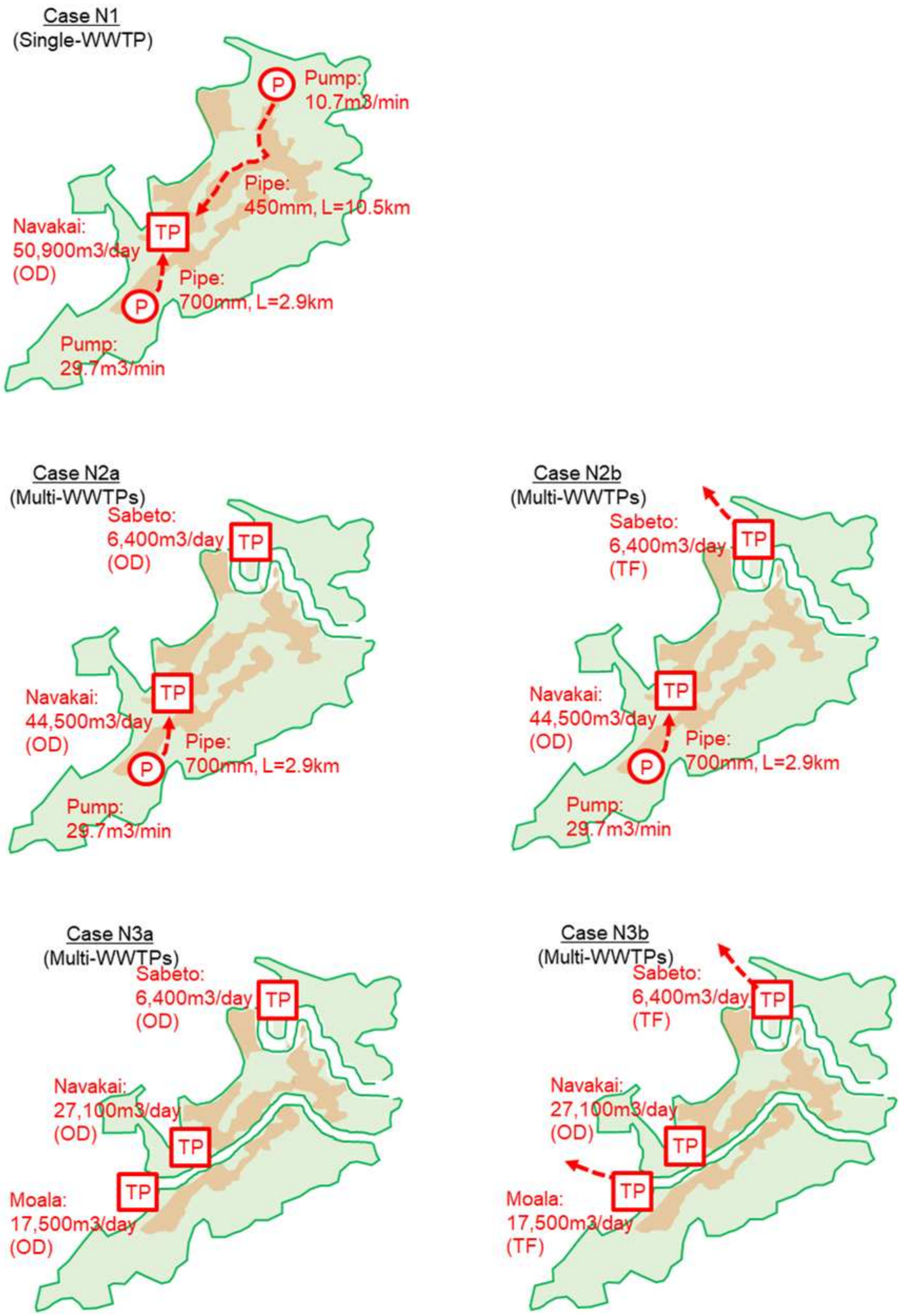
Zones	Case	Treatment Process	Summary/Characteristic
Single WWTP	N1	Navakai: OD	・O&M of only one WWTP is required, which is simpler than the other options. ・Additional cost of transfer pipe and pumping stations from the existing service area is required.
2 WWTPs	N2a	Navakai: OD Sabeto: OD	・Higher WWTP cost comparing with N1. ・Transfer pipe passing through central city from Sabeto area is not required. ・Greatest O&M structure and staff requirements.
	N2b	Navakai: OD Sabeto: TF	・Transfer pipe passing through central city from Sabeto area is not required. ・Although 2 WWTPs are installed, this case does not greatly increase the demands on O&M staff due to applying General standard process. ・Ocean outfall pipe is required for Sabeto due to applying General Gtandard process.
	N2c	Navakai: OD South: OD	・Transfer pump for the existing service area between Sabeto and Navakai is required. Since there are no merits to this case not already addressed in Case N1, this case will be removed from the analysis.
	N2d	Navakai: OD South: TF	・Transfer pump for the existing service area between Sabeto and Navakai is required. Since there are no merits to this case not already addressed in Case N1, this case will be removed from the analysis.
3 WWTPs	N3a	Navakai: OD Sabeto: OD South: OD	・Highest WWTP cost. ・Transfer pipe from existing service area is not required. ・Greatest O&M structure and number of staff are required.
	N3b	Navakai: OD Sabeto: TF South: TF	・Transfer pipe from existing service area is not required. ・The TF process is easy to operate and is adopted in two of the three WWTP. This case does not greatly increase the demands on O&M structure or the number of staff. ・Ocean outfall pipe is required for Sabeto and Moala due to applying General standard process.

Source: JET



Source : JET

Figure 4-1.4 Outlines of Facility in Each Case (Lautoka)



Source：JET

Figure 4-1.5 Outlines of Facility in Each Case (Nadi)

Constructions costs and O&M costs of each of the cases are summarized in **Table 4-1.9** and **Table 4-1.10**.

Lautoka
- ✓ Case L2b using the TF process for Natabua and Vitogo has the lowest total equivalent annual construction cost and O&M cost.
- ✓ L1a and L2a applying OD have high annual cost of WWTP.

Nadi
- ✓ The lowest total annual equivalent construction cost and O&M cost is case N3b, which applies the OD process to Navakai and the TF process to Sabeto and Moala.
- ✓ The case for two service areas in Navakai and Sabeto (Case N2a, N2b) is the next cheapest case, but there is a problem in securing land for the expansion of the WWTP area around Navakai.

Table 4-1.9 Annual Equivalent Costs of the Lautoka Cases

Case	Outline	Annual Equivalent Cost (million FJD/year)			
		WWTP	Transfer Pipe/Pump	Ocean Outfall Pipe	Total
L1a	1 WWTP (OD)	36.5	2.4		39.0
L1b	1 WWTP (TF)	30.9	2.4	0.53	33.9
L2a	WWTP (OD)+WWTP (OD)	38.1			38.1
L2b	WWTP (TF)+WWTP (TF)	32.2		1.4	33.6

Source: JET

Table 4-1.10 Annual Equivalent Costs of the Nadi Cases

Case	Outline	Annual Equivalent Cost (million FJD/year)			
		WWTP	Transfer Pipe/Pump	Ocean Outfall Pipe	Total
N1a	1 WWTP(OD)	39.9	4.8		44.8
N2a	WWTP(OD)+WWTP(OD)	41.6	1.7		43.2
N2b	WWTP(OD)+WWTP(TF)	40.5	1.7	1.0	43.2
N3a	WWTP(OD)+WWTP(OD)+ WWTP(OD)	43.9			43.9
N3b	WWTP(OD)+WWTP(TF)+ WWTP(TF)	40.4		2.5	42.9

Source: JET

Based on the above study results, the Municipal Sewerage M/P will formulate a sewerage plan that divides Lautoka into two service areas and Nadi into three service areas. In addition, even when comparing the expensive TF process as a representative treatment process compatible with the General standard, it was found that the application of the "treatment process compatible with the general & ocean outfall pipe" has an economic advantage.

Table 4-1.11 shows the results of the service area and treatment process as a primary selection. The treatment process to be applied at each WWTP will be selected secondarily in the next section.

Table 4-1.11 Service Area and Treatment Process (Primary Selection)

Municipal	Service Area	Standards/ Treatment Process	Remark
Lautoka	Vitogo	General/ Trickling Filter	Including ocean outfall pipe
	Natabua	General/ Trickling Filter	Including ocean outfall pipe
Nadi	Sabeto	General/ Trickling Filter	Including ocean outfall pipe
	Navakai	SEZ/ Oxidation ditch	Including ocean outfall pipe
	Moala	General/ Trickling Filter	Including ocean outfall pipe

Source: JET

4-1-5 Secondary Examination of Wastewater Treatment Processes

In this section, the treatment process to be applied for the five WWTPs determined in **4-1-4** are examined.

(1) Setting Evaluation Criteria and Criteria Weights

1) Selecting Evaluation Criteria

For the evaluation/comparison of treatment processes, a set of evaluation criteria was selected after discussions with WAF. Each criterion was given a certain scoring weight, scored, and totaled; the treatment process with the highest total score was adopted. **Table 4-1.12** summarizes the evaluation criteria for wastewater treatment processes.

As mentioned earlier in Section **2-6**, as a part of Fiji's national policy to achieve net zero GHG emissions by 2050, the utilization of sewerage sludge (bioenergy recovery) has been strongly requested for the sewerage sector. For this reason, the possible application of "sludge anaerobic digestion of + biogas-based power generation" was incorporated in the evaluation criteria. Details on sewerage sludge utilization can be found in **4-4-1(2)**.

Table 4-1.12 Evaluation Criteria for the Wastewater Treatment Process Selection

Criterion	Units	Notes
Cost (CAPEX of AEC)	million FJD/yr	Parameter for economic efficiency
Cost (OPEX)	million FJD/yr	Parameter for economic efficiency
Dewatered Sludge Produced	t/yr	Site footprint for sludge disposal (in the Municipal Sewerage M/P, assumed to be onsite of WWTPs) increases in proportion to the dewatered sludge produced Smaller the amount of sludge, higher the score in the evaluation
Raw Sludge Produced	m^3/yr	Based on the above-mentioned sludge utilization policy, bioenergy production increases in proportion wo the raw sludge produced. Smaller the amount of sludge, higher the score in the evaluation
No. of Equipment	Units	Parameter for easiness of O&M
Footprint	ha	Parameter for economic efficiency (land acquisition costs)
GHG Generation	kt-CO_2/yr	Parameter for impact on global warming

Source : JET

2) Setting Scoring Weights for Criterions

In setting the scoring weights for each criterion, two major points were considered based on WAF's requests.

The first point is the emphasis on O&M costs for economic evaluations. Scoring weights were set so the economic efficiency of the treatment process was placed at the utmost importance; within this criteria, further indications were made that WAF planes more emphasis on O&M costs, which continue during the facility's entire period of operation. For this reason, the scoring weight for O&M costs (Cost(OPEX))was set at 25%.

The second point is the different weighting for footprints between existing WWTPs and new WWTPs. Existing WWTPs (Navakai and Natabua) are located near city centers with active land development, with schools, residential areas, and commercial facilities in close proximity. Additional land acquisition in these areas is expected to be more difficult compared to new WWTPs (refer to **APPENDIX 4-1** for details). Due to this condition, the scoring weight for required footprints was set to 30% for existing WWTPs, whereas for new WWTPs was set to 20%.

Table 4-1.13 summarizes the scoring weight for each criterion.

Table 4-1.13 Scoring Weights for each Evaluation Criterion

Criterion	Weight (%)	
	Existing WWTP	New WWTP
Cost (CAPEX of AEC)	20	20
Cost (OPEX)	25	25
Dewatered Sludge Produced	5	5
Raw Sludge Produced	10	20
No. of Equipment	5	5
Footprint	30	20
GHG Generation	5	5
TOTAL	**100**	**100**

Source：JET

(2) Secondary Selection Result of Treatment Process

Table 4-1.14 to **Table 4-1.18** show the results of the treatment process comparison for each WWTP based on the above evaluation items and weighting. As a result of the comparison, the SP process had the highest score in Vitogo, Natabua, Sabeto, and Moala, which adopted the General standards. This was followed by the TF process and the AL process.

The OD process had the best evaluation in the SEZ criteria. However, regarding the criteria for the treatment process for the General Standard, the SP process has drawbacks such as the problem of odor generation as a factor that cannot be quantified, and the feasibility of securing a large site. Therefore, as a result of discussions, the TF process will be adopted for the General standards.

Table 4-1.14 Results of Treatment Process Comparison for Vitogo

Evaluation Criteria	Weight (%)	Unit / Score	General Standard SP	AL	TF
Cost (CAPEX of AEC)	20	million FJD/yr	2.8	3.0	4.0
		points	20.0	19.0	14.4
Cost (OPEX)	25	million FJD/yr	0.4	0.7	1.1
		points	25.0	14.0	8.0
Dewatered Sludge Produced	5	t/yr	655.4	2,195.2	4,672.0
		points	5.0	1.5	0.7
Raw Sludge Produced	20	m^3/yr	0.0	0.0	44,150.4
		points	0.0	0.0	20.0
No. of Equipment	5	Units	5.0	13.0	76.0
		points	5.0	1.9	0.4
Footprint	20	ha	26.5	10.6	8.7
		points	6.6	16.4	20.0
GHG Generation	5	kt-CO_2/yr	87.3	322.6	1,152.6
		points	5.0	1.4	0.4
TOTAL	100		66.6	54.2	63.9

Source：JET

Table 4-1.15 Results of Treatment Process Comparison for Natabua

Evaluation Criteria	Weight (%)	Unit / Score	General Standard SP	AL	TF
Cost (CAPEX of AEC)	20	million FJD/yr	17.1	18.0	23.8
		points	20.0	19.0	14.4
Cost (OPEX)	25	million FJD/yr	1.7	3.0	3.3
		points	25.0	13.8	12.8
Dewatered Sludge Produced	5	t/yr	4,147.2	13,891.5	29,565.0
		points	5.0	1.5	0.7
Raw Sludge Produced	10	m^3/yr	0.0	0.0	279,389.3
		points	0.0	0.0	10.0
No. of Equipment	5	Units	14.0	38.0	217.0
		points	5.0	1.9	0.3
Footprint	30	ha	131.9	50.2	41.1
		points	9.3	24.6	30.0
GHG Generation	5	kt-CO_2/yr	552.6	2,041.5	7,294.0
		points	5.0	1.4	0.4
TOTAL	100		69.3	62.2	68.6

Source：JET

Table 4-1.16 Results of Treatment Process Comparison for Sabeto

Evaluation Criteria	Weight (%)	Unit	General Standard		
		Score	SP	AL	TF
Cost (CAPEX of AEC)	20	million FJD/yr	2.9	3.0	4.0
		points	20.0	19.0	14.4
Cost (OPEX)	25	million FJD/yr	0.4	0.7	1.2
		points	25.0	14.0	8.0
Dewatered Sludge Produced	5	t/yr	655.4	2,195.2	4,672.0
		points	5.0	1.5	0.7
Raw Sludge Produced	20	m^3/yr	0.0	0.0	44,150.4
		points	0.0	0.0	20.0
No. of Equipment	5	Units	5.0	13.0	76.0
		points	5.0	1.9	0.4
Footprint	20	ha	26.8	10.7	8.8
		points	6.6	16.4	20.0
GHG Generation	5	kt-CO_2/yr	87.3	322.6	1,152.6
		points	5.0	1.4	0.4
TOTAL	100		66.6	54.2	63.9

Source：JET

Table 4-1.17 Results of Treatment Process Comparison for Navakai

Evaluation Criteria	Weight (%)	Unit	SEZ Standard		
		Score	OD	IDEA	MBBR
Cost (CAPEX of AEC)	20	million FJD/yr	18.9	20.7	18.3
		points	19.4	17.6	20.0
Cost (OPEX)	25	million FJD/yr	3.1	3.5	4.1
		points	25.0	22.5	19.0
Dewatered Sludge Produced	5	t/yr	14,837.3	14,837.3	20,772.2
		points	5.0	5.0	3.6
Raw Sludge Produced	10	m^3/yr	0.0	0.0	188,927.7
		points	0.0	0.0	10.0
No. of Equipment	5	Units	228.0	208.0	234.0
		points	4.6	5.0	4.4
Footprint	30	ha	22.6	20.7	28.3
		points	27.6	30.0	21.9
GHG Generation	5	kt-CO_2/yr	4,143.9	4,143.9	5,705.2
		points	5.0	5.0	3.6
TOTAL	100		86.6	85.1	82.5

Source：JET

Table 4-1.18 Results of Treatment Process Comparison for Moala

Evaluation Criteria	Weight (%)	Unit	General Standard		
		Score	SP	AL	TF
Cost (CAPEX of AEC)	20	million FJD/yr	7.8	8.2	10.8
		points	20.0	19.0	14.4
Cost (OPEX)	25	million FJD/yr	0.9	1.5	2.1
		points	25.0	13.8	10.3
Dewatered Sludge Produced	5	t/yr	1,792.0	6,002.5	12,775.0
		points	5.0	1.5	0.7
Raw Sludge Produced	20	m^3/yr	0.0	0.0	120,723.8
		points	0.0	0.0	20.0
No. of Equipment	5	Units	9.0	24.0	137.0
		points	5.0	1.9	0.4
Footprint	20	ha	62.2	24.0	19.7
		points	6.4	16.4	20.0
GHG Generation	5	kt-CO_2/yr	238.8	882.1	3,151.7
		points	5.0	1.4	0.4
TOTAL	100		66.4	54.0	66.2

Source：JET

Based on the above secondary selection, the treatment processes to be applied to each WWTPS are summarized in **Table 4-1.11**.

Table 4-1.19 Treatment Process to be Applied to Each WWTP

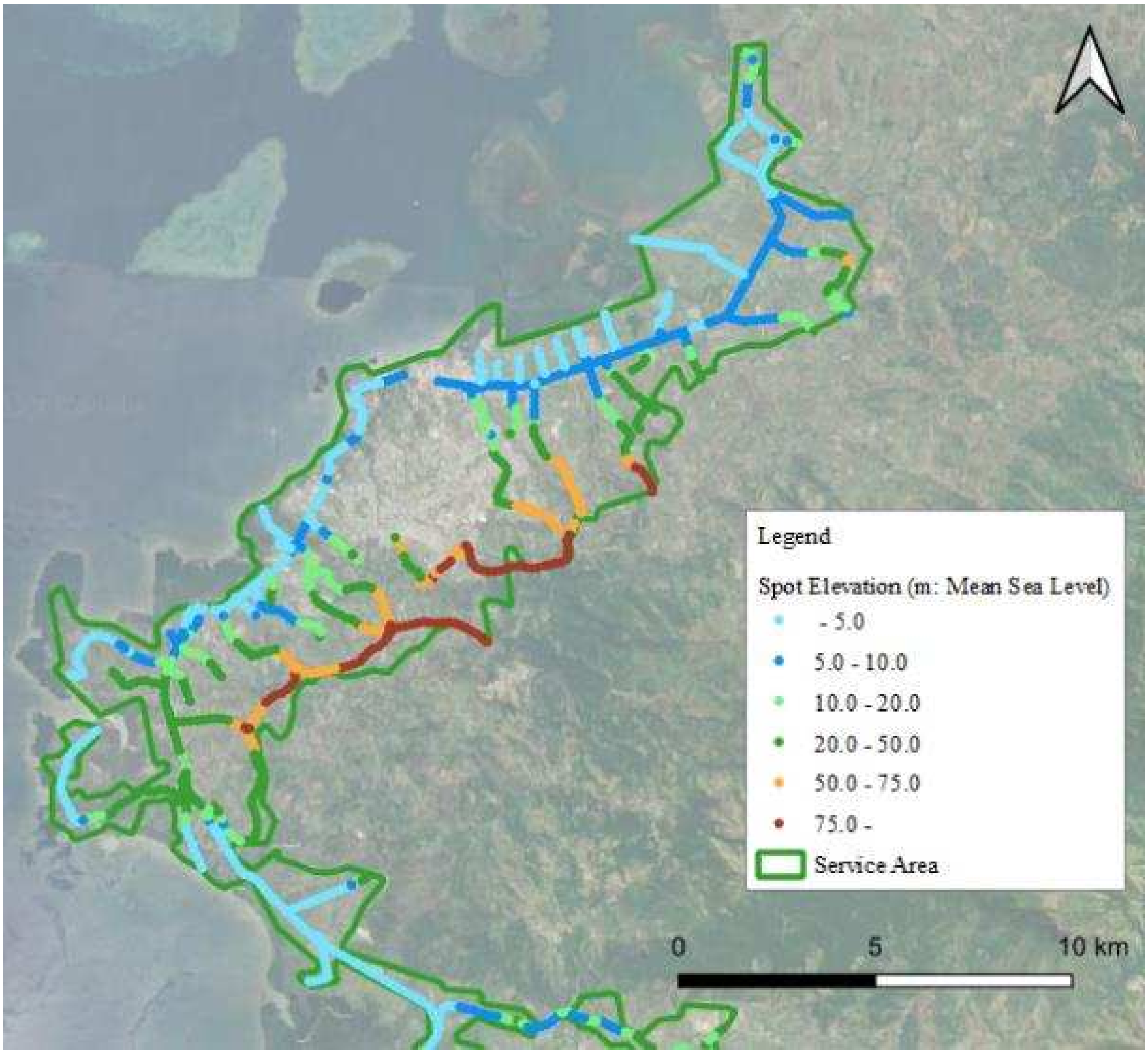
Municipal	Service Area	Standards/ Treatment Process	Remark
Lautoka	Vitogo	General/ Trickling Filter	Including ocean outfall pipe
	Natabua	General/ Trickling Filter	Including ocean outfall pipe
Nadi	Sabeto	General/ Trickling Filter	Including ocean outfall pipe
	Navakai	SEZ/ Oxidation ditch	
	Moala	General/ Trickling Filter	Including ocean outfall pipe

Source: JET

4-2 Planning of Sewer Pipelines and Pumping Stations

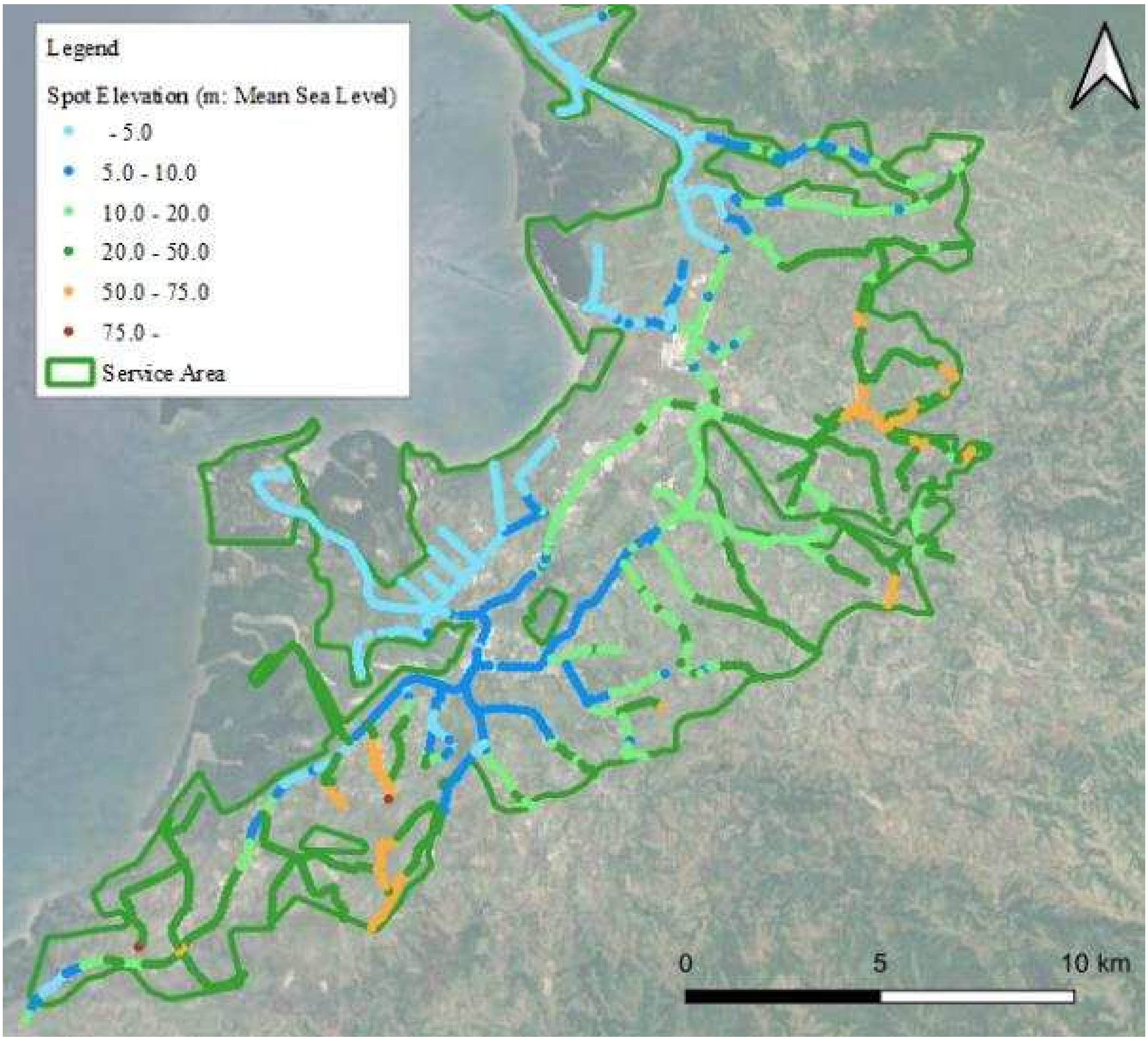
(1) Spot Elevation Survey

The results of the spot elevation survey for planning sewer pipelines are shown in **Figure 4-2.1** and **Figure 4-2.2**.



Source: JET

Figure 4-2.1 Result of Spot Elevation Survey (Lautoka)



Source: JET

Figure 4-2.2 Result of Spot Elevation Survey (Nadi)

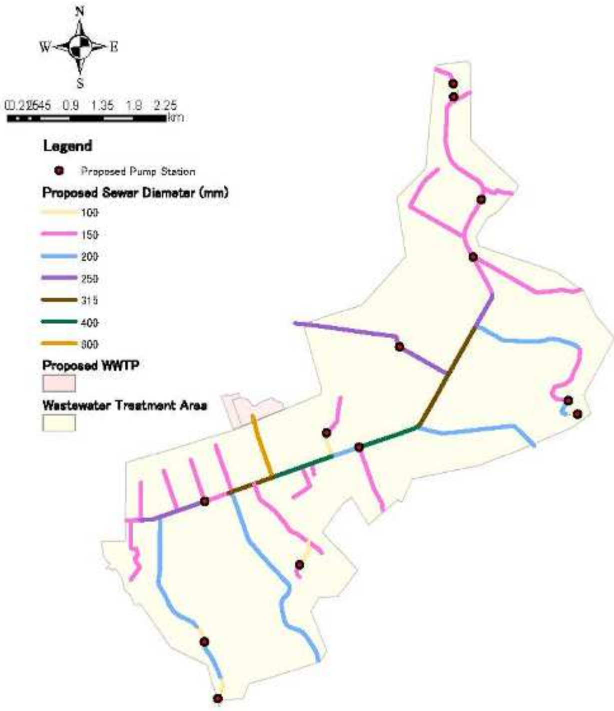
(2) Sewer Pipeline Plan

Based on the results of the survey and site investigations, sewer pipelines of each service area were planned. The outline of sewer pipeline facilities in each service area is shown in **Table 4-2.1**, and the sewer pipeline plans are shown in **Figure 4-2.5** to **.**

Table 4-2.1 Outline of Sewer Pipelines

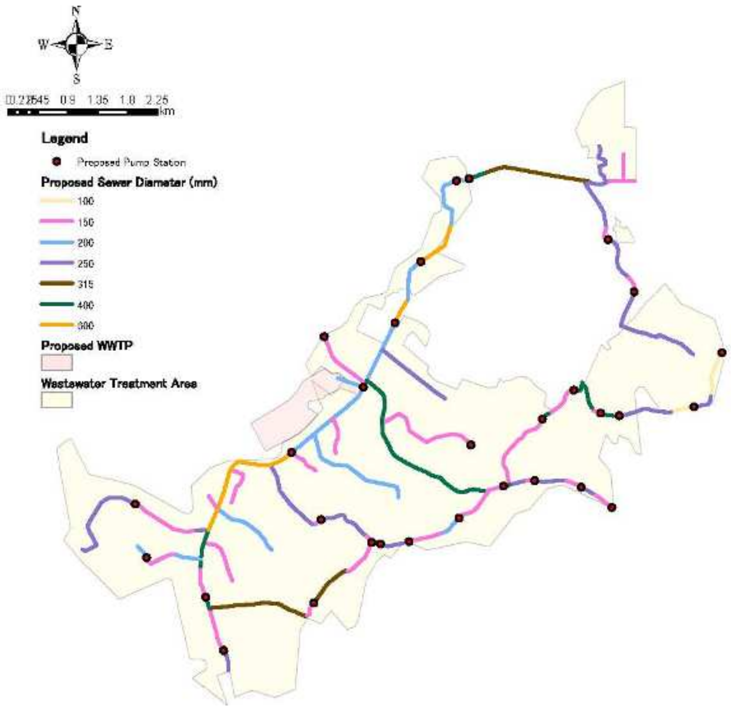
Municipality	Nadi			Lautoka		Total
WWTP Area	**Sabeto**	**Moala**	**Navakai**	**Natabua**	**Vitogo**	**-**
Length of Sewer (km) D100 mm	4.7	9.0	5.1	2.3	1.3	22.4
D150 mm	15.1	37.6	16.2	17.0	16.7	102.6
D200 mm	10.1	22.3	12.0	12.9	9.1	66.4
D250 mm	10.5	19.1	12.1	15.9	9.1	66.7
D315 mm	5.4	4.0	5.8	9.2	1.8	26.2
D400 mm	2.6	4.3	1.6	3.0	1.6	13.1
D600 mm	0.0	4.9	2.1	2.3	1.0	10.3
D750 mm	0.0	2.1	1.4	0.6	0.2	4.3
D900 mm	0.0	0.7	0.8	0.0	0.0	1.5
Total	48.4	104.0	57.1	63.2	40.8	313.5
Pumping Station (nos.)	35	54	37	30	12	168

Source: JET



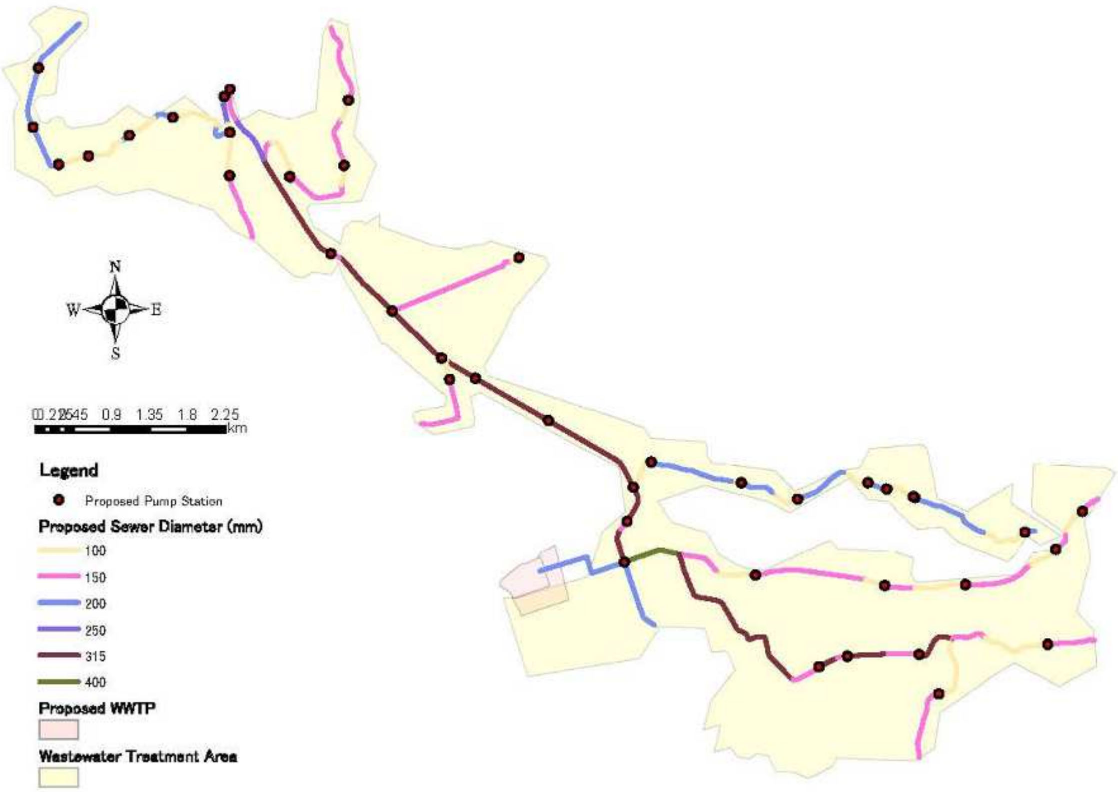
Source: JET

Figure 4-2.3 Plan of Sewer Pipelines (Vitogo Service Area (Lautoka))



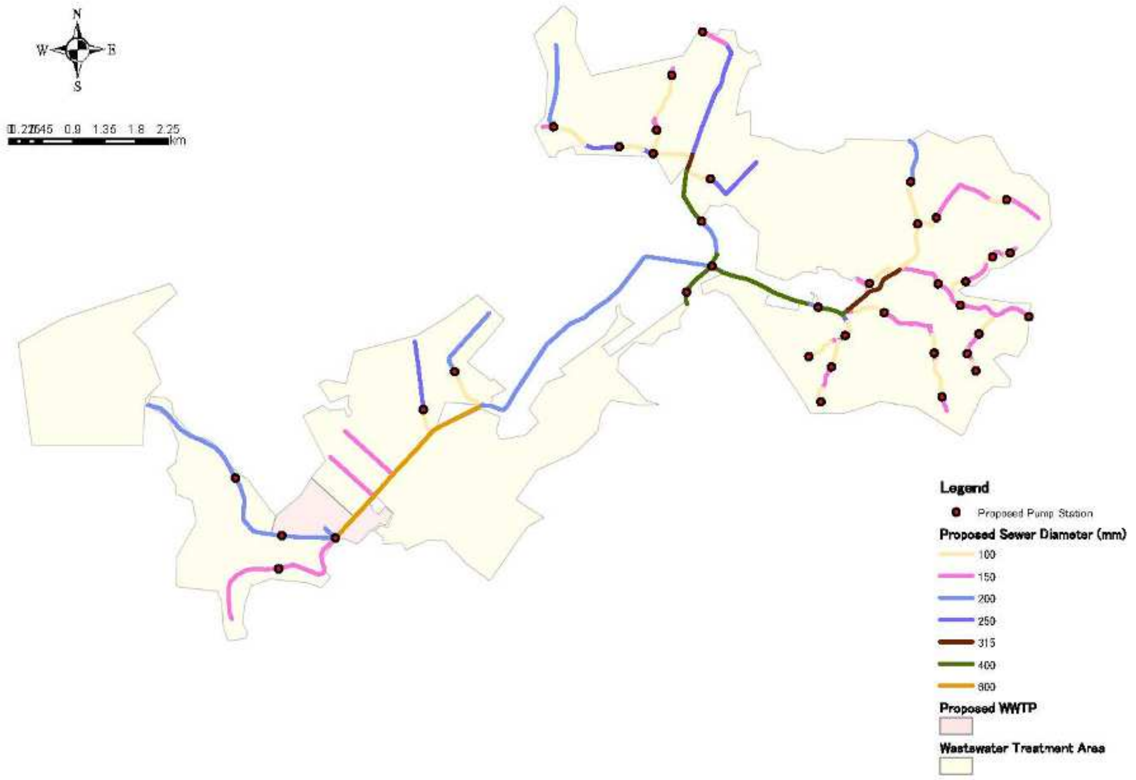
Source: JET

Figure 4-2.4 Plan of Sewer Pipelines (Natabua Service Area (Lautoka))



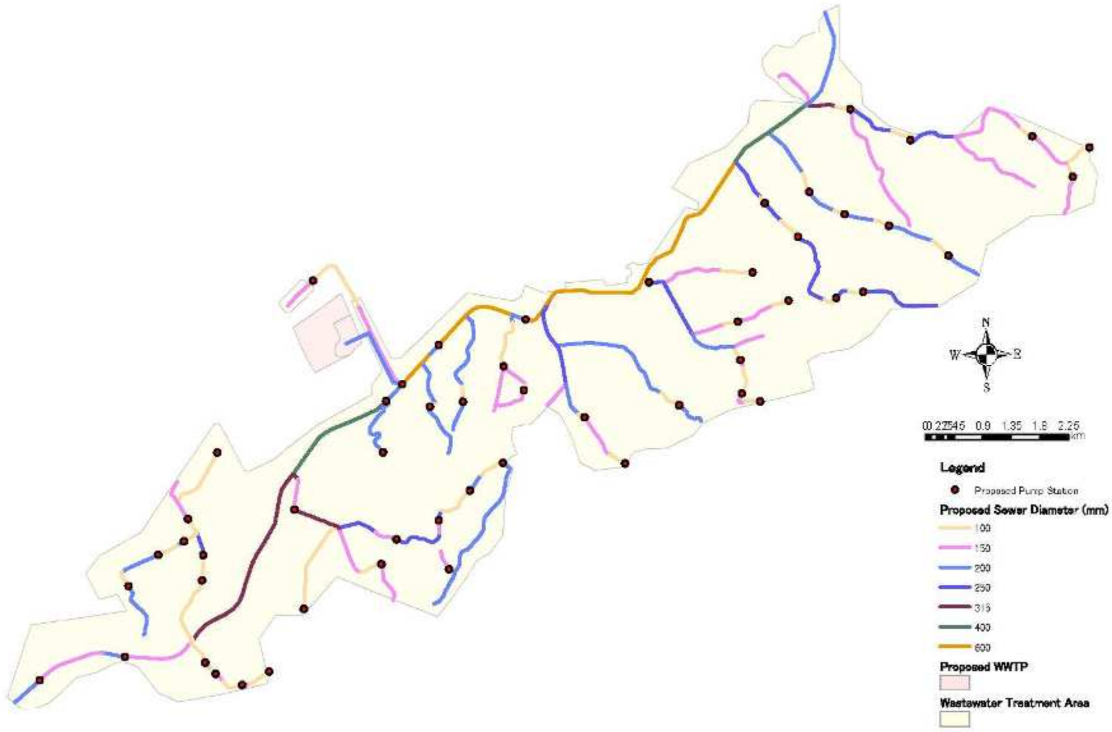
Source: JET

Figure 4-2.5 Plan of Sewer Pipelines (Sabeto Service Area (Nadi))



Source: JET

Figure 4-2.6 Plan of Sewer Pipelines (Navakai Service Area (Nadi))



Source: JET

Figure 4-2.7 Plan of Sewer Pipelines (Moala Service Area (Nadi))

4-3 Treatment of Septage (Sludge from septic tank)

In the Regional Wastewater M/P, it is proposed that the septage be treated jointly at a WWTP. First, this section describes the basic items related to septage treatment, and below describes treatment including sewerage sludge and septage in the proposed WWTP.

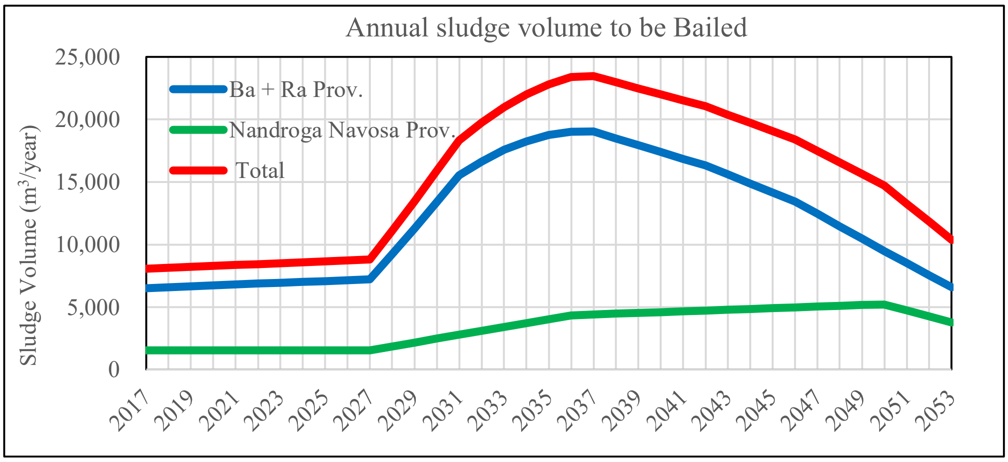
(1) Amount of Bailed Septage

The estimated amount of septage collected from the septic tank in Western division changes year by year due to the progress of sewerage development. At present, the service area is limited, and many residents have septic tanks inside and outside the service area, but the septage is mainly not removed from the septic tanks on a regular basis, so the amount of septage brought into the WWTP is not large. The amount of septage brought into the WWTP per year varies depending on the following factors.

- Population outside the service area (This factor will decrease year by year with the progress of expansion of sewerage development)
- The rate of regular desludging (This factor will increase gradually year by year due to increase the rate of regular desludging)

Regarding the rate of regular desludging, the Regional Wastewater M/P sets the withdrawal rate based on the target that the total of sewerage population rate and the rate of regular desludging is 70%. Based on the sewerage facility plan and staged development plan of the Municipal Sewerage M/P, the sewerage population coverage ratio is estimated to be 23% in 2036 (see Chapter 5 for details). Therefore, the rate of regular desludging from septic tanks in 2036 in the Municipal Sewerage M/P is set at 47%. **Figure 4-3 1** shows the estimated amount of septage to be bailed per year.

From this figure, the amount of septage to be brought to WWTP in 2036 will be estimated approximately 19,000 m^3/year in Ba and Ra province. Assuming that bailing works is performed 250 days a year on a weekday basis, the amount of sludge brought into the WWTP is estimated to be approximately 76 m^3/day.



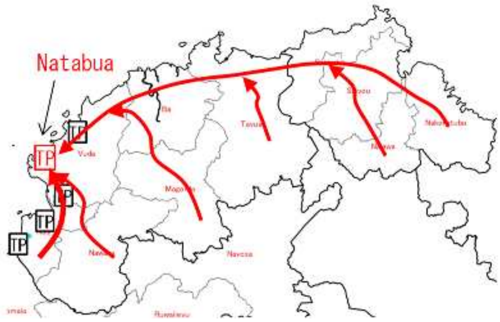
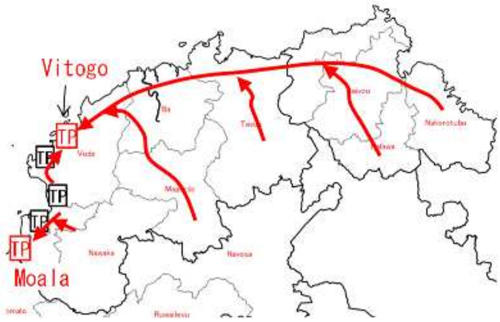
Source: JET

Figure 4-3.1 Estimated Annual Amount of Bailed Septage

(2) Septage Collection

A method of collecting and treating septic tank sludge (hereinafter referred to as "septage") in Lautoka was proposed in the Regional Wastewater M/P. In the Municipal Sewerage M/P, development of wastewater treatment with two service areas in Lautoka and three service areas in Nadi is planned. Cases studies for reception and treatment of septic tank sludge were analyzed and are compared in **Table 4-3.1** below.

Table 4-3.1 Case-Wise Examination of Spetage Treatment (Lautoka)

	Case1: Collect at one location in Natabua	**Case2: Collect at Vitogo and Moala**
Summary	Collect and treat all septage in one location at Natabua WWTP in Lautoka.  	Collect and treat septage at the two new WWTPs at Vitogo and Moala. 
O&M	・Dewatering of septage can be combined with that of sewerage, reducing initial investment costs and O&M costs. ・As with the above, treatment of water from the dewatering process can be combined with the wastewater treatment, reducing initial investment costs and O&M costs.	・There are more facilities and equipment that need to be operated and maintained. More labor will be required compared to Case 1. ・Water from the dewatering process will need to be treated in a separate process, increasing the facility and equipment O&M requirements.
Land Acquisition	Land will be acquired along with the land for the WWTP expansion, simplifying the process.	For the Vitogo and Moala WWTP sites, land for the septage treatment sites will need to be acquired first. This will complicate the land acquisition process.
Transport Distance	779,000 km/year (peak year)	587,000 km/year (peak year)
Environmental Impacts	・Many sludge vacuum trucks will need to pass through areas of Lautoka and Nadi that have high population density.	・The treatment plants will be located on the outskirts of the cities. Therefore, the number of vacuum trucks passing through densely populated areas will be reduced.

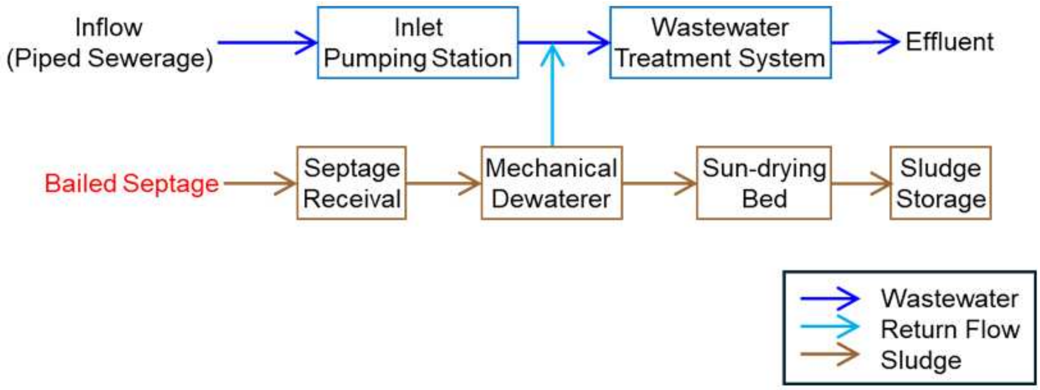
Source: JET

From the results of the comparison analysis and verifying with WAF their objectives, Case 1 (centralized septage treatment in Lautoka) was selected.

- Currently, a large amount of septage is brought to the Natabua WWTP in Lautoka. Since most of the private desludging company are in Lautoka, it would be effective to formulate a system based on the current situation.
- Although Nadi and Lautoka are prioritized for sewerage development, the relatively large population and number of houses in the area generate a large amount of septage, requiring a large number of vacuum truck trips. Therefore, even if Case 2 is selected, the impact on truck traffic between Nadi and Lautoka will be minor.

(3) Septage Treatment

Septage undergoes some degree of digestion whilst in the septic tank, and has properties similar to excess sludge and digested sludge. For this reason, septage will be directly dewatered using a screw-press dewaterer (the same type of dewaterer used for raw, excess, and digested sludge); the leachate will be treated with the pipeline sewerage at Natabua WWTP. After dewatering, septage will be sun-dried and stored in the onsite sludge storage area. (**Figure 4-3.2**)



Source: JET

Figure 4-3.2 Treatment Flow Diagram of Septage

4-4 Sludge Treatment Systems

4-4-1 Future Prospects in the Utilization of Sewerage Sludge

(1) Greenfield/Agricultural Application

1) Joint Research between WAF and MOA

As part of future utilization of sewerage sludge, WAF signed a Memorandum of Understanding (MoU) with the MOA in 2020, aiming for the application of sludge as fertilizer and/or soil conditioner. An agreement was made between the two parties to conduct joint research, and the MoU has been renewed every year since 2020 up to this day.

2) Current Status of the Research

In the MoU, WAF takes responsibility for sewerage sludge sampling, and the MOA takes responsibility for sludge analysis and studies to establish sludge application standards for greenfield/agricultural use.

Since MOA's laboratory is currently undergoing renovation work, the joint research program has been temporarily suspended after WAF collected/stored dried sludge samples from Kinoya WWTP. Resumption of the research has not yet been determined at this point.

According to WAF staff, due to this current situation, stakeholders such as local farmers show reluctance in the utilization of sewerage sludge, since the sludge analysis results and applicability for agricultural use is still unclear.

(2) Bioenergy Recovery (Anaerobic Digestion and Biogas Power Generation)

1) Fiji's National Policy (Climate Change Act 2021)

As mentioned in Section 2-6, Fiji has indicated global warming countermeasures for each sector in national policies such as the Climate Change Act 2021 and LEDS. For the sewerage sector, the utilization of recovered bioenergy from sludge (i.e. Power generation using biogas produced from anaerobic digestion of sewerage sludge)

It is a national policy to effectively use the energy of sludge, such as power generation.

2) Current Situation in Fiji

Currently the sewerage sludge produced in the Western Division's WWTPs are disposed onsite after sun-drying, and no measures of utilization/bioenergy recovery is taken.

Suva's Kinoya WWTP is equipped with an anaerobic digestion tank and balloon-type gas holder (both currently not in operation), but gas refinement facilities and flare stacks are yet to be installed, hampering effective utilization.

Biogas produced from anaerobic digestion contains both flammable methane gas and corrosive hydrogen sulfide, both which are harmful to human health. Since equipment corrosion and gas leaks can lead to serious accidents, so daily inspections, periodic maintenance, and troubleshooting are extremely important compared to other WWTP facilities.

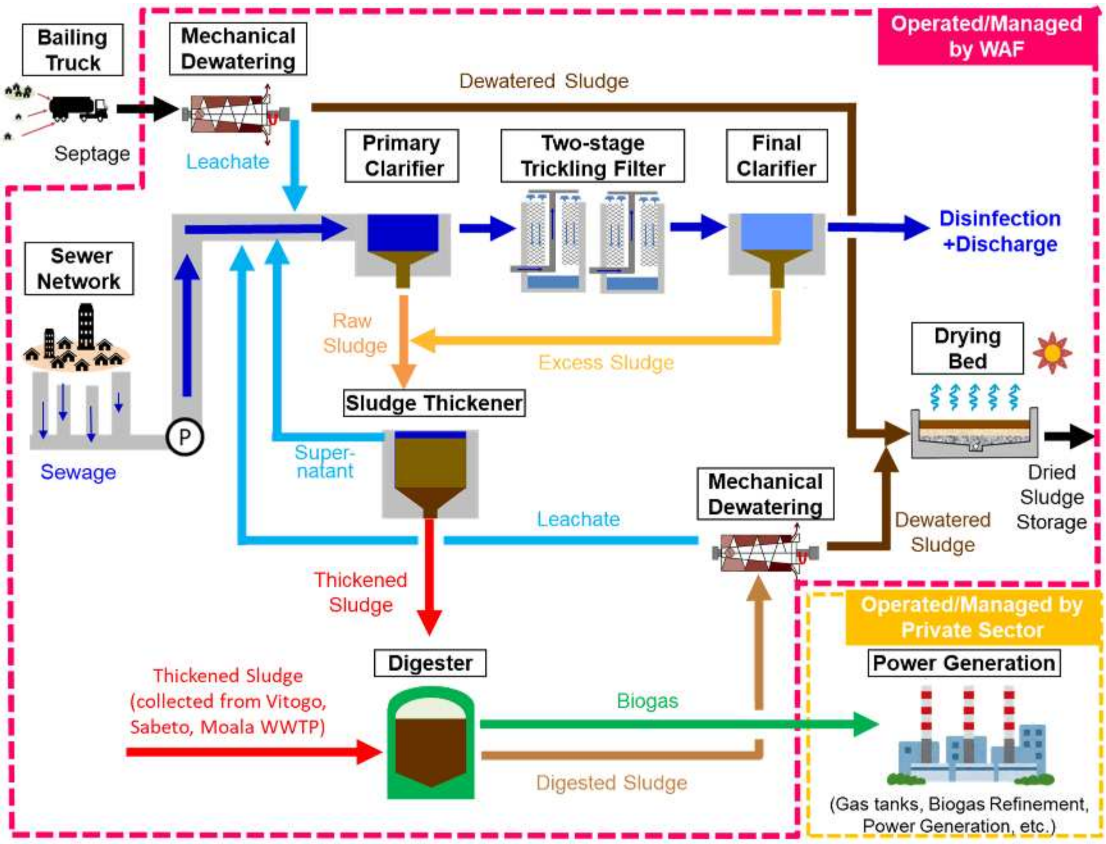
Therefore, highly specialized personnel are essential to maintain proper facility O&M, but considering the current O&M situation at WAF's WWTPs, direct management of facilities by WAF is extremely difficult to implement and maintain; WAF's management level has indicated its intention to outsource the operation of the facility. In Japan, O&M work of biogas power plants currently in operation is often outsourced to the plant manufacturers; similarly, it is essential to conduct the planning, design, construction and management of biogas power generation facilities to the public sector through PPP/PFI projects.

3) Preconditions for Biogas Power Generation Examination

In the examination for biogas power generation, in order to maximize the project efficiency/profitability, the following condition were set as a prerequisite.

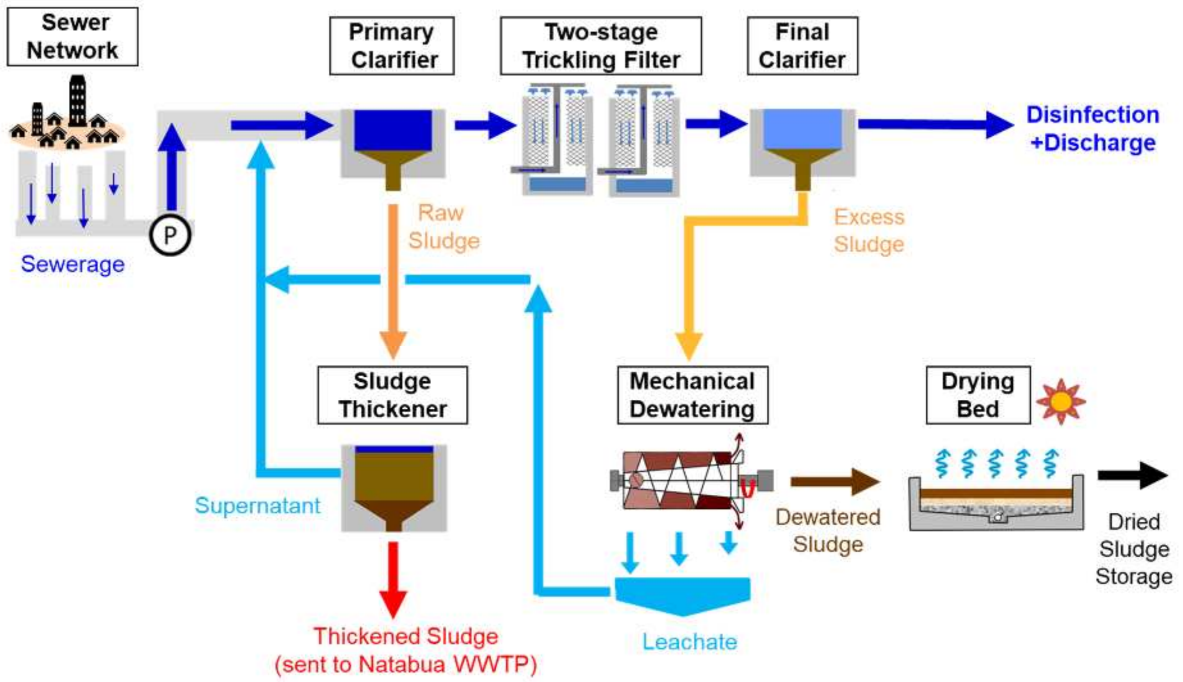
- All WWTPs in the Municipal Sewerage M/P are in full operation, receiving planned maximum sewerage inflow
- Sludge from all WWTPs will be collected to one site for centralized anaerobic digestion/biogas power generation to maximize efficiency.
- Sludge will be collected to Natabua WWTP which has the largest treatment capacity, and where land is presumed to be relatively easy to acquire. Regarding the sewerage sludge produced at Natabua WWTP, both raw sludge and excess sludge will be inputted to the anaerobic digester. ()

- For the other WWTPs, considering the cost of sludge transport, only raw sludge (with high calorific values) will be collected and bailed to Natabua WWTP for anaerobic digestion; excess sludge will be treated and stored onsite at each individual WWTP (**Figure 4-4.2**). In addition, to mitigate transportation costs, raw sludge will go through gravitational thickening before they are carried offsite. Navakai WWTP, which will adopt the OD process, generates no raw sludge; therefore, no sludge will be transported offsite(**Figure 4-4.3**)
- Electricity generated at the biogas power generation plant will be consumed by facilities of Natabua WWTP



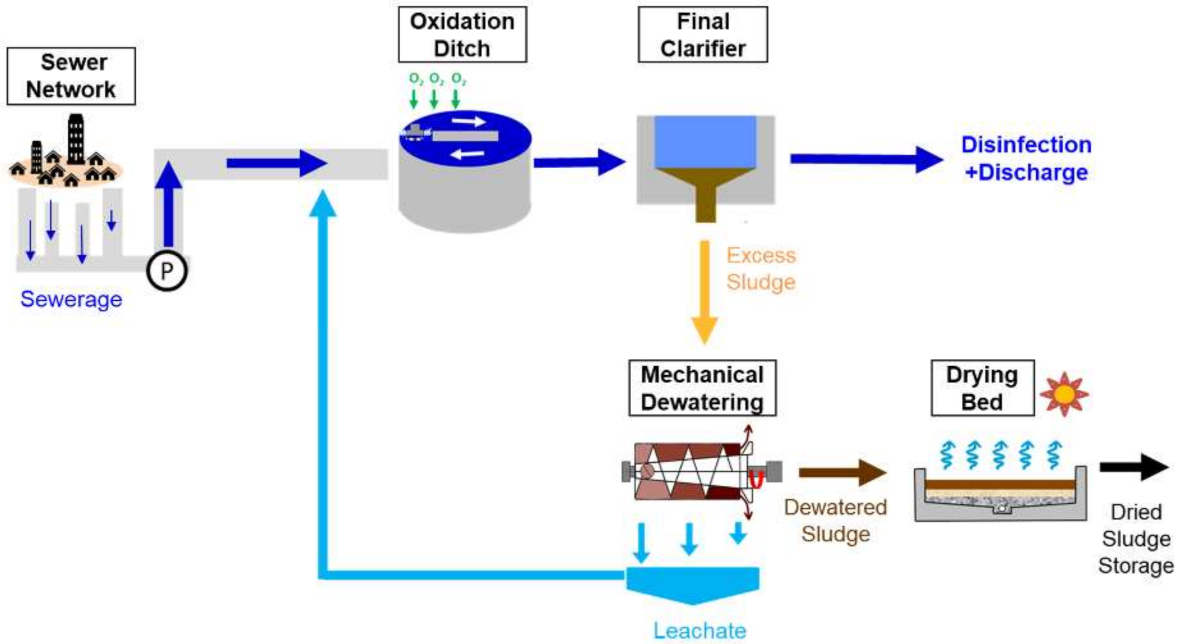
Source：JET

Figure 4-4.1 Sewerage and Sludge Flow Diagram for Natabua WWTP



Source: JET

Figure 4-4.2 Sewerage and Sludge Flow Diagram for Vitogo, Sabeto, and Moala WWTP



Source: : JET

Figure 4-4.3 Sewerage and Sludge Flow Diagram for Navakai WWTP

4) Examination Results

Under preconditions that all WWTPs treat the maximum inflow planned in the Municipal Sewerage M/P, the expected amount of sewerage sludge production, biogas production, methane gas production, and power generation was organized in the following table.

Table 4-4.1 Biogas Power Generation utilizing Sewerage Sludge

Parameter	Results
Biogas Production	4,607,240 m^3/yr
Methane Gas Production	2,764,344 m^3/yr
Generated Electricity	8,797 MWh/yr

Source: JET

Table 4-4.2 Construction/O&M Costs of Anaerobic Digester and Biogas Power Generation Plant

Parameter	Results
Footprint	2.3 ha
Land Acquisition Cost	1.5 million FJD
Construction Cost	57.2 million FJD
O&M Cost	1.9 million FJD/yr

Source: JET.

Calculations showed that theoretically the electricity produced by biogas power generation can recover energy equivalent to approximately 196% of the power consumption at Natabua WWTP (4,500 MWh/yr).

Upon construction of the anaerobic digesters, gas holders, biogas refinement facilities, biogas power generation and other related facilities, an additional 2.3 ha footprint is required aside from Natabua WWTP's footprint (**Table 4-4.2**). It should also be noted that the footprint requirement for sludge drying beds and onsite sludge storage of the digested sludge will be comparatively larger compared to other WWTPs, purely due to the difference in amount of sludge collected to Natabua WWTPs.

Lastly, as mentioned earlier in this section, sewerage sludge-based bioenergy production requires high levels of O&M, safety management, financial management, etc.; and outsourcing to private sectors such as PPP/PFF projects are essential. WAF hopes to outsource design, construction, maintenance, operational/financial management of the plant to private sectors specialized in the field, but at the current point, the project has been limited to abstract concepts, including funding sources.

4-4-2 Sewerage Sludge Treatment

Under the prerequisite of sewerage sludge-based bioenergy recovery, the treatment process of raw sludge and excess sludge was examined.

(1) Raw Sludge

Raw sludge is produced only in the trickling filter process.

1) Collection Method

As mentioned earlier in **4-4-1(2)** WWTPs that adopt the trickling filter process will have its raw sludge collected to Natabua WWTP for anaerobic digestion and biogas power generation.

Collection has two possible candidate methods: sludge pipes where sludge is sent through underground pipelines, and bailing trucks.

As for the sludge pipe option, these pipelines connecting Vitogo, Sabeto, and Moala WWTP to Natabua

WWTP will pass through Nadi and Lautoka's already-developed urban areas. WAF has requested to avoid large-scale excavation works in these areas as much as possible, so raw sludge collection will be conducted through bailing trucks.

2) Sludge Thickening Method

To efficiently collect sludge to Natabua WWTP, the raw sludge will be thickened at each WWTP before bailing. Sludge thickening has two possible candidate methods: gravitational thickening and mechanical thickening. Mechanical thickening is a method intended for the thickening of excess sludge, which properties make it difficult to thicken through gravitational thickening, so raw sludge will be gravitationally thickened at each WWTP.

3) Anaerobic Digestion

The thickened raw sludge collected from other WWTPs will be bailed to Natabua WWTP and inputted to its anaerobic digester. The biogas produced through digestion will be collected, refined, and utilized for power generation.

4) Sludge Dewatering Method and Sun-Drying

In general, there are three methods of sludge dewatering: centrifugal, belt-press, and screw-press dewatering. Centrifugal dewatering has advantages such as small space-requirements and high processing rates, but on the other hand has higher electricity consumption compared to other methods. In addition, its overhaul inspections (preferable to be performed once every few years) must be carried out at the manufacturer's factory. Since dewaterers will be most likely procured from countries outside of Fiji, such as Australia and New Zealand, transportation of the dewaterer to foreign manufacturers is not feasible; therefore, centrifugal dewatering will be emitted from the candidate list.

As for the remaining belt-press and screw-press dewatering, the largest difference between the two is the capability of direct sludge dewatering. Whilst sludge can be directly inputted to screw-press dewaterers, belt-press dewaterers need to have its sludge thickened before dewatering. The adoption of belt-press dewaterers automatically comes with the adoption of sludge thickening; however, anaerobic sludge has properties making its liquid-solids separation difficult, requiring mechanical thickening (centrifugal thickening, dissolved air floatation, belt-press thickening, etc.) and further increasing O&M costs.

From the above points, screw-press dewatering will be adopted for the dewatering of digested sludge. After dewatering, sludge will be placed in sun-drying beds to further reduce its volume before sludge storage.

(2) Excess Sludge

Similar to digested sludge, excess sludge has properties of difficult liquid-solid separation. For this reason the adoption of belt-press dewaterers required the adoption of mechanical thickening, adding on to construction and O&M costs. For this reason, screw-press dewaterers will be adopted for the dewatering of excess and dredged sludge. Afterwards, sludge will be sun-dried to reduce its volume before onsite sludge storage.

(3) Onsite Sludge Storage

In Japan, the final disposal of sewerage sludge is mostly done at landfills; however, as mentioned in **2-2-2**, Fiji`s municipal landfills currently do not accept sewerage sludge due to concerns about heavy metal contamination, and offsite sludge disposal is difficult in the current situation. In addition as reference, Kinoya WWTP’s sludge sample analysis did not include the concentrations of mercury, nickel, selenium, and molybdenum, which are parameters included in the EPA's sewerage sludge landfill disposal standards (**Table 2-2.1**, **Table 2-2.2**).

For this reason, in the Municipal Sewerage M/P, sewerage sludge will be stored onsite of the WWTPs, securing a 20-year worth footprint for sludge produced from each WWTP’s maximum planned influent.

It is expected that it will take a considerable number of years for the full capacity of the sludge storage area to be filled. During that period, the following activities are strongly recommended to secure the possible utilization and final disposal of sewerage sludge:

- Component analysis of sewerage sludge
- Establishment of sewerage sludge disposal standards (most likely conducted by WAF and DOE)
- Securing sewerage sludge final disposal sites
- Joint research and projects for sewerage sludge application to greenfield (fertilizer, soil conditioner)
- Sewerage sludge-based bioenergy recovery through PPP/PFF projects

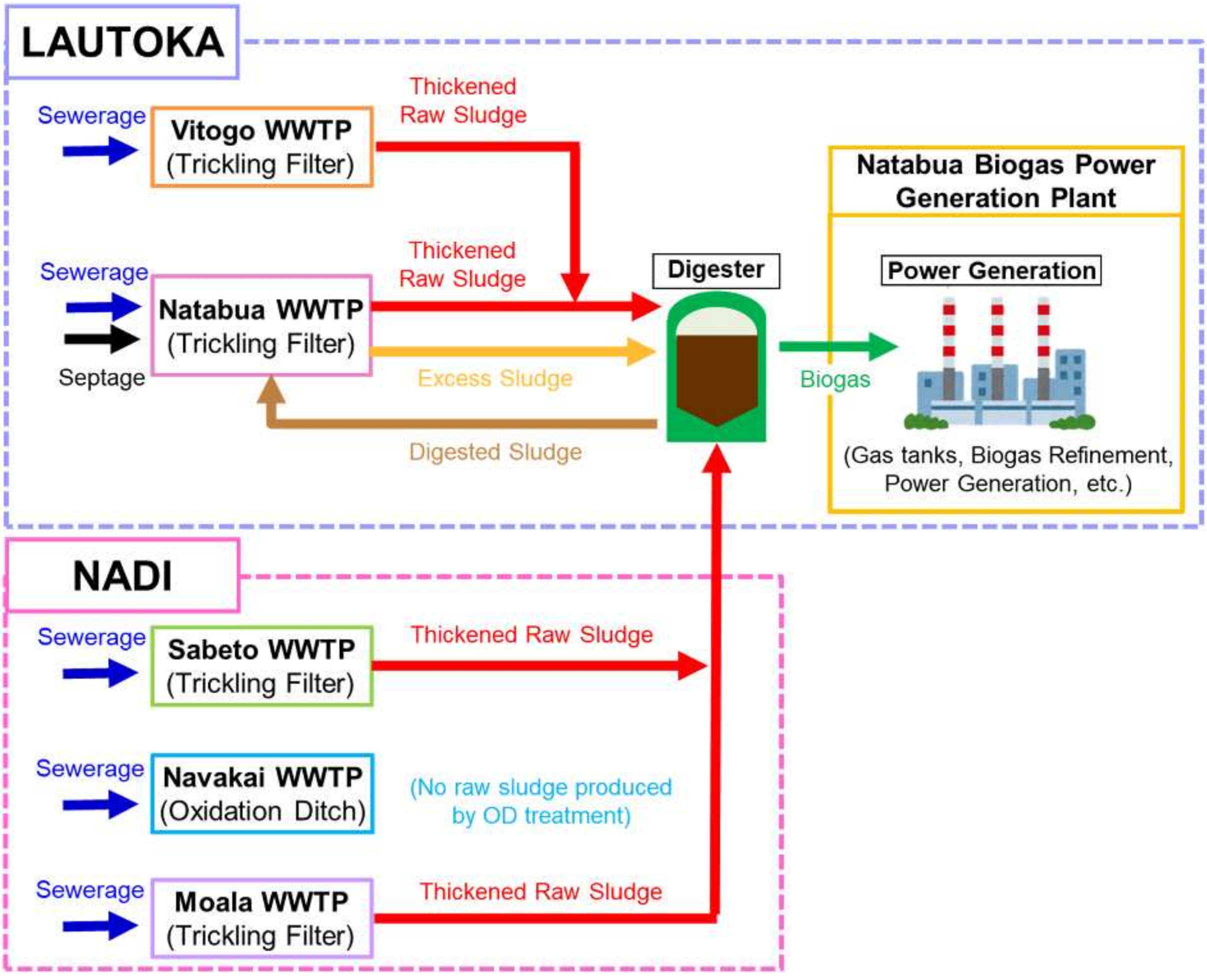
In order to ensure multiple sludge disposal options, it is anticipated that storage of dried sludge will become difficult in Natabua and Navakai, so in the long term, the consideration of small-scale incineration facilities (at least one in either area) will be essential.

In addition, currently there are multiple chemical substances that the Fijian laboratories/research institutions cannot analyze due to the lack of analytical equipment/materials. Capacity development of these institutions is also necessary for the proper implementation and maintenance of sewerage projects in Fiji.

4-5 Overall Summary of Wastewater Treatment Plants

4-5-1 Overall Outline of Five WWTPs

The overall flow of sewerage, septage, and sludge is shown in **Figure 4-5.1**. Detailed treatment flow of each WWTP will be shown in following sections.



Source：JET

Figure 4-5.1 Overall Flow of Sewerage, Septage, and Sludge of WWTPs

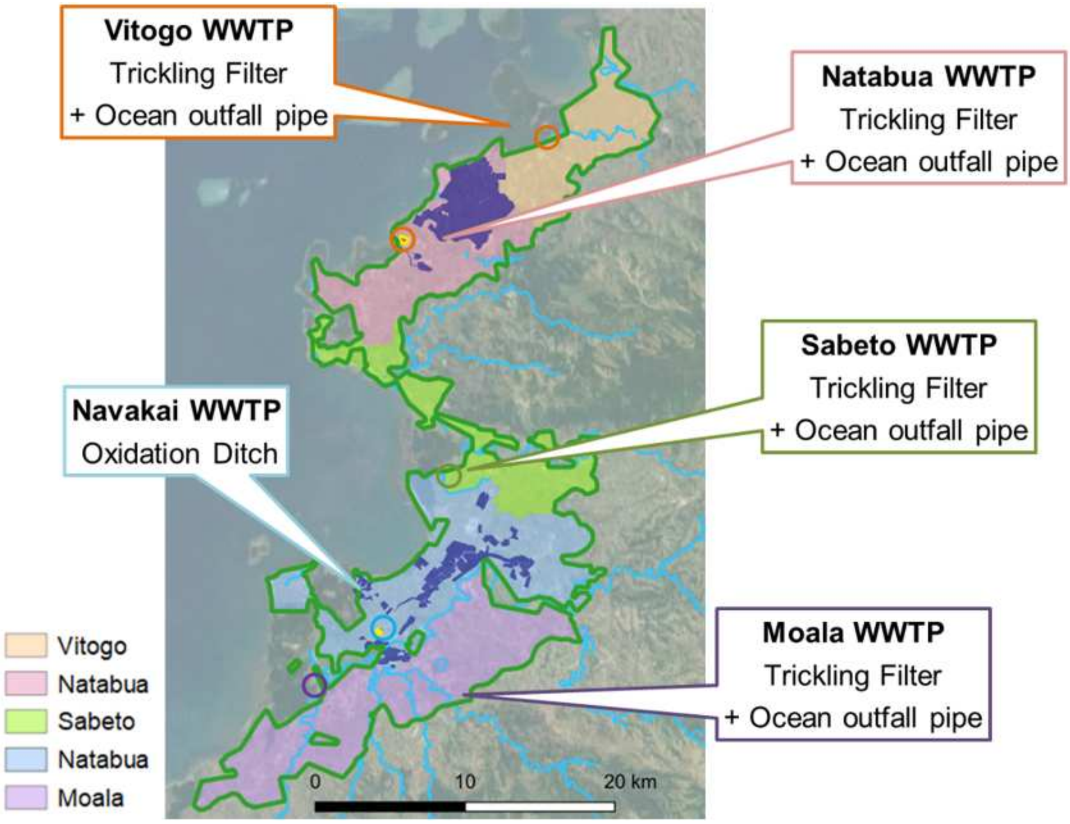
(1) Summary of WWTPs

Table 4-5.1 summarizes the basic information of WWTPs in Lautoka and Nadi. The location and service area of each WWTP are shown in **Figure 4-5.2**.

Table 4-5.1 Basic Information of WWTPs

Municipality	WWTP	Treatment Capacity (ADWF)	Effluent Standard	Treatment Target	Treatment Process
Lautoka	Vitogo	6,4000 m^3/day	General	Pipeline Sewerage + Return Flow	Trickling Filter
	Natabua	40,500 m^3/day	General	Pipeline Sewerage + Collected Septage + Return Flow	Trickling Filter
Nadi	Navakai	27,100 m^3/day	SEZ	Pipeline Sewerage + Return Flow	OD
	Sabeto	6,400 m^3/day	General	Pipeline Sewerage + Return Flow	Trickling Filter
	Moala	17,500 m^3/day	General	Pipeline Sewerage + Return Flow	Trickling Filter

Source: JET



Source: : JET

Figure 4-5.2 Location and Service Area of WWTPs

(2) Overall Flow of Septage and Sewerage Sludge

1) Septage

- All septage collected from septic tanks in Ba and Ra provinces will be bailed and treated at Natabua WWTP

2) Raw Sludge

- Raw sludge produced by the trickling filter process at Vitogo, Sabeto, and Moala WWTP will be gravitationally thickened at each WWTP, and bailed to Natabua WWTP for anaerobic digestion.
- Raw sludge produced at Natabua WWTP will also be gravitationally thickened and inputted to the anaerobic digester
- Navakai WWTP, which adopted the OD process, does not produce raw sludge; therefore there is no collection of sludge from Navakai WWTP.

3) Excess Sludge

- Excess sludge produced at Vitogo, Sabeto, Navakai, and Moala WWTP has low calorific value, and its transport to Natabua WWTP for anaerobic digestion/bioenergy recovery is inefficient. Therefore, excess sludge shall be treated and stored onsite at each WWTP

- Excess sludge produced at Natabua WWTP does not need to be bailed, and will be directly inputted to anaerobic digesters along with thickened raw sludge.

(3) Biogas Power Generation Plant

In line with the global warming countermeasure policies established in the Climate Change Act 2021 and LEDS, the anaerobic digestion of sewerage sludge, as well as the power generation plants utilizing the collected biogas will be incorporated in the Municipal Sewerage M/P. However, since specific project implementation schemes are yet to be determined, the digesters and power generation plant will not be included in the implementation schedule. The plant will include gasholders, biogas refinement facilities, and power generation facilities.

4-5-2 Lautoka

(1) Vitogo WWTP

The outline of Vitogo WWTP is summarized as follows.

Table 4-5.2 Outline of Vitogo WWTP

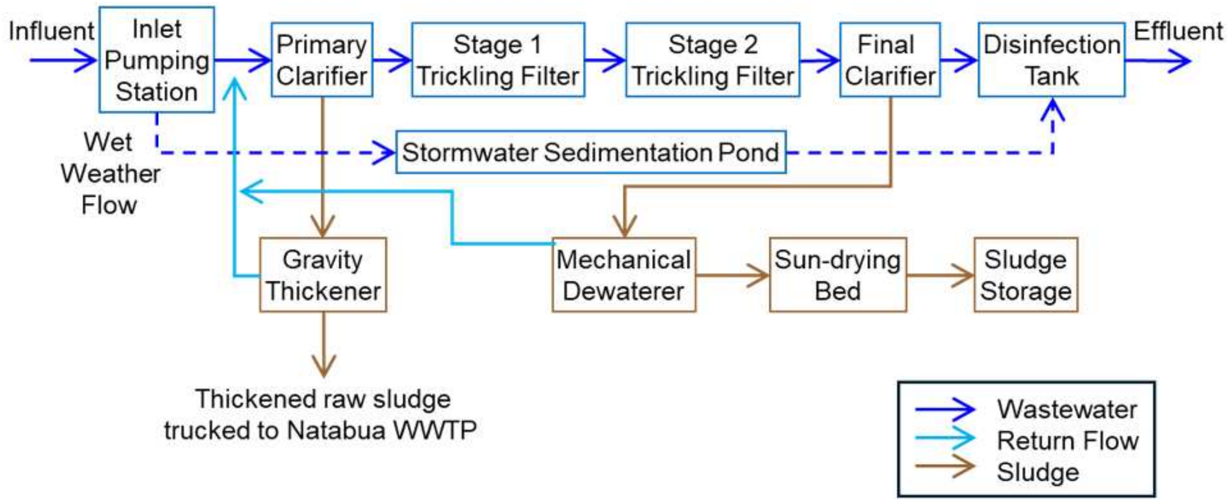
Parameter	Contents	
Treatment Capacity (ADWF)	6,400 m^3/d (32,000 EP)	
Target Effluent Standard	General standards	
Wastewater Treatment Process	Trickling Filter	
Treatment Targets	Wastewater	Pipeline Sewerage
		Return flow from sludge thickening/dewatering
	Sludge	Raw Sludge produced at Vitogo WWTP (Gravity thickening only)
		Excess Sludge produced at Vitogo WWTP
Footprint	Total	8.2 ha
	Wastewater Treatment	5.7 ha
	Sludge Drying Bed	0.5 ha
	Sludge Storage Area	2.0 ha

Source：JET

Characteristics of the WWTP:

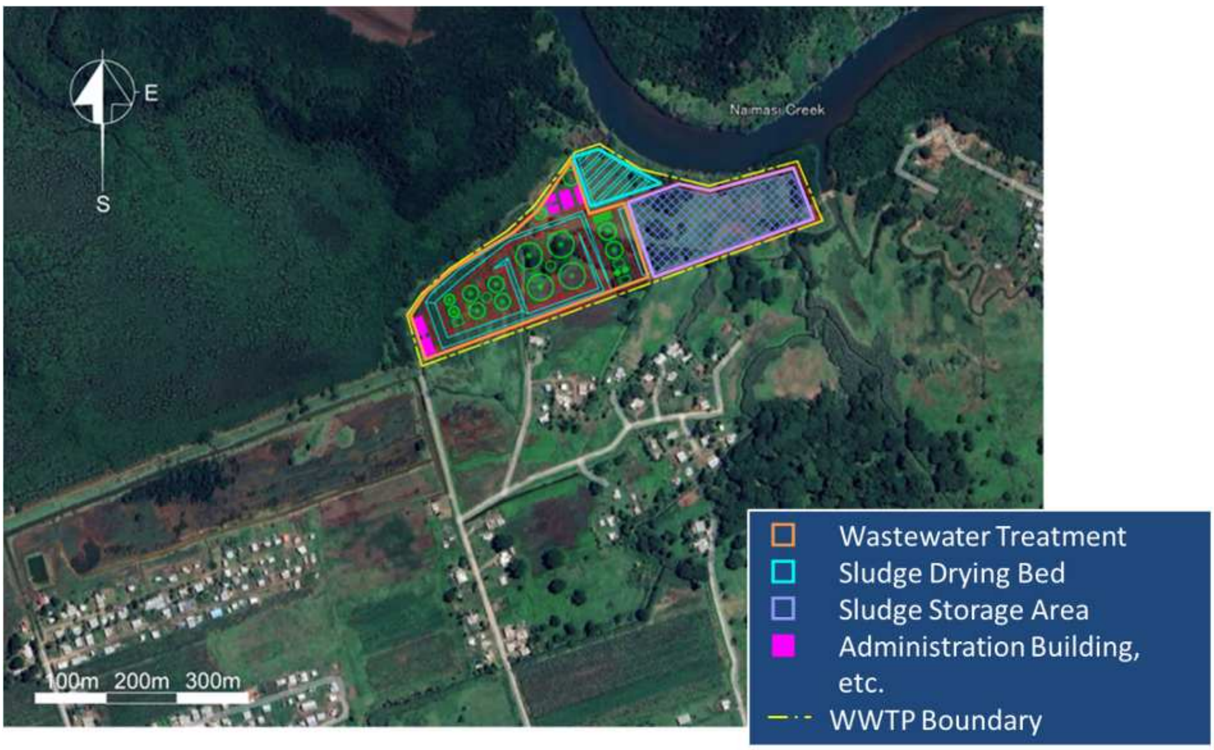
- Raw sludge produced from the Primary Clarifier will be gravitationally thickened, then bailed to Natabua WWTP.
- Excess sludge produced from the Final Clarifier will be mechanically dewatered, sun-dried, and stored onsite
- Treated effluent will be discharged to the ocean through ocean outfall pipes

Vitogo WWTP's treatment process flow and footprint image are shown as follows.



Source：JET

Figure 4-5.3 Vitogo WWTP's Treatment Flow Diagram



Source：JET

Figure 4-5.4 Vitogo WWTP's Footprint Image

(2) Natabua WWTP

The outline of Natabua WWTP is summarized as follows.

Table 4-5.3 Outline of Natabua WWTP

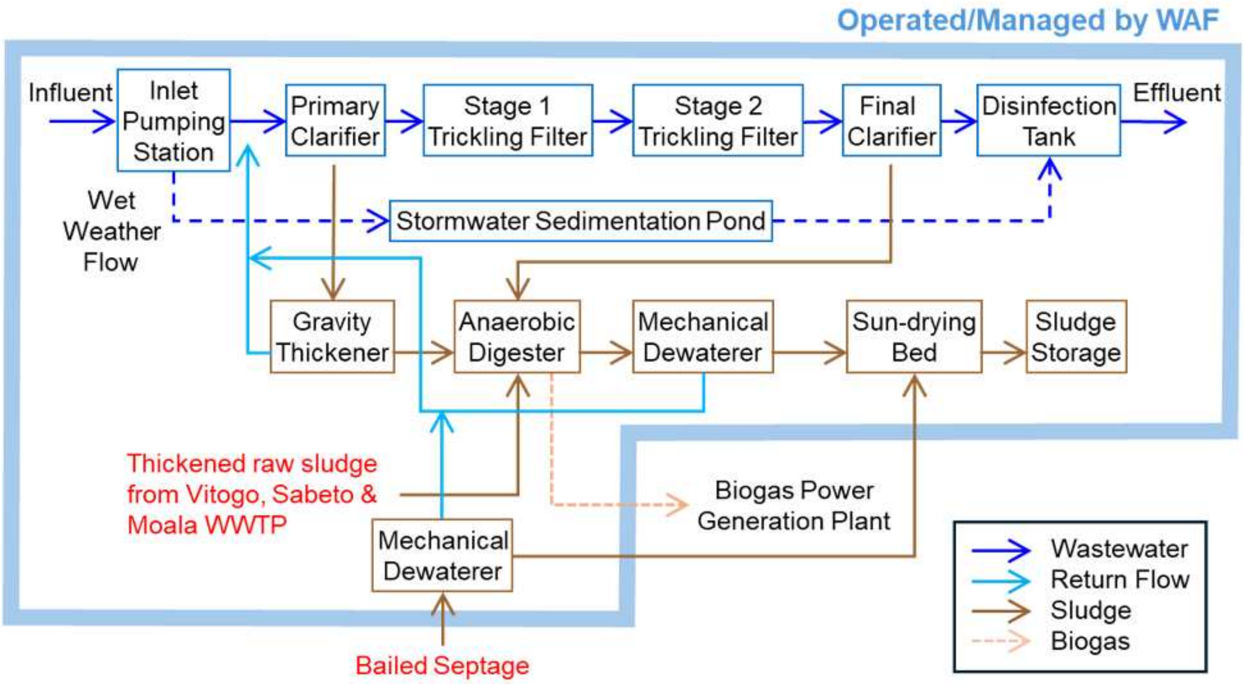
Parameter	Contents	
Treatment Capacity (ADWF)	40,500 m^3/d (202,500 EP)	
Target Effluent Standard	General standards	
Wastewater Treatment process	Trickling Filter	
Treatment Targets	Wastewater	Pipeline Sewerage
		Return flow from septage dewatering
		Return flow from sludge thickening/dewatering
	Sludge	Bailed septage
		Thickened raw sludge from Vitogo, Sabeto, Moala WWTP
		Digested sludge from biogas power generation plant
Footprint	Total	44.5 ha
	Wastewater Treatment	22.3 ha
	Sludge Drying Bed	3.4 ha
	Sludge Storage Area	16.4 ha
	Biogas Power Generation Plant	2.3 ha

Source: : JET

Characteristics of the WWTP:

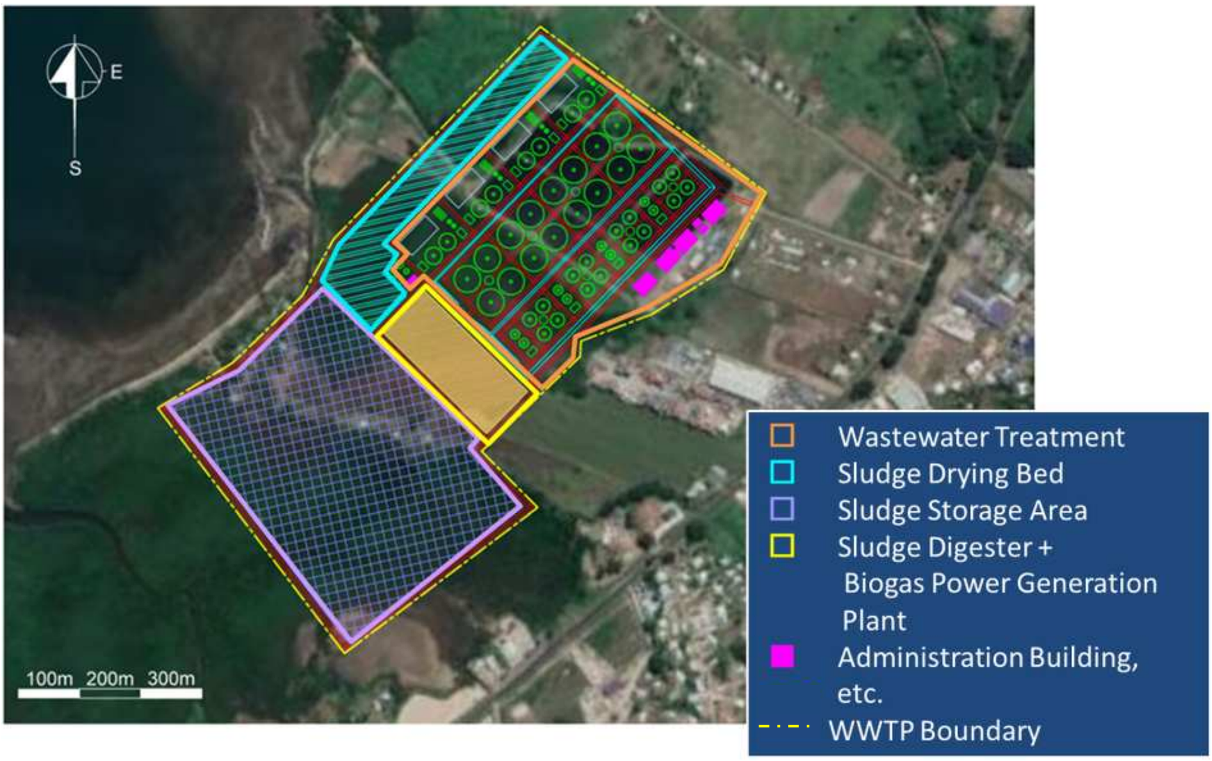
- All septage bailed from septic tanks in the Ba and Ra provinces will be collected to Natabua WWTP for treatment (maximum 76 m^3/day)
- Natabua WWTP will be equipped with an anerobic digester, and the below sewerage sludge will be inputted
  - Thickened raw sludge bailed from Vitogo, Sabeto, and Moala WWTP (250 m^3/day)
  - Thickened raw sludge produced at Natabua WWTP (508 m^3/day)
  - Excess sludge produced at Natabua WWTP (2827 m^3/day)
- Digested sludge produced from the anaerobic digesters will be mechanically dewatered, sundried, and stored onsite at Natabua WWTP
- The biogas produced by the anaerobic digester will be utilized at the adjoined biogas power generation plant (including gas holders, gas refinement facilities, biogas power generation facilities, etc.)
- Treated eluent will be discharged to the ocean through ocean outfall pipes

Natabua WWTP's treatment process flow and footprint image are shown as follows.



Source: : JET

Figure 4-5.5 Natabua WWTP's Treatment Flow Diagram



Source: : JET

Figure 4-5.6 Natabua WWTP's Footprint Image

4-5-3 Nadi

(1) Sabeto WWTP

The outline of Sabeto WWTP is summarized as follows.

Table 4-5.4 Outline of Sabeto WWTP

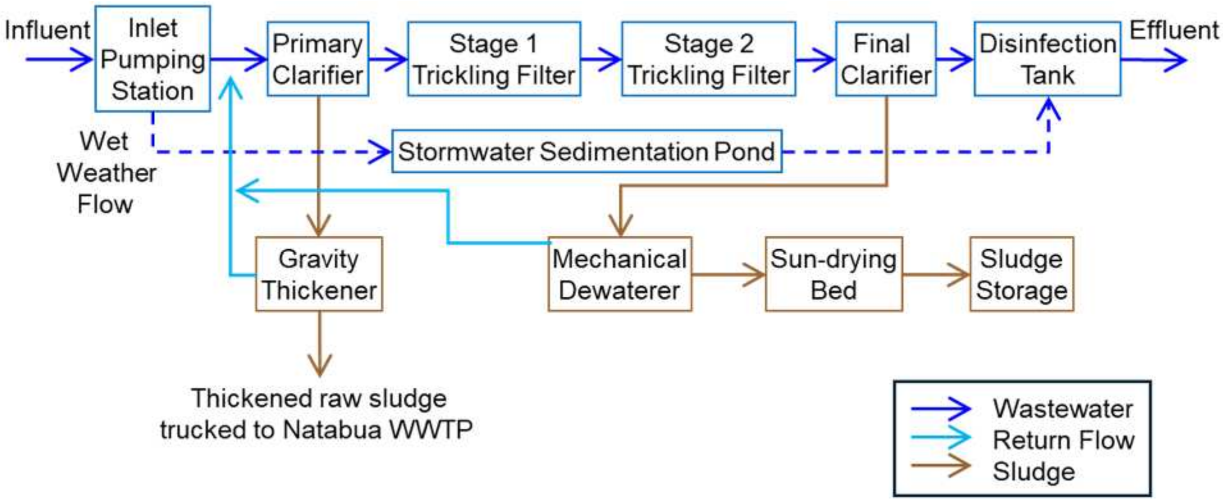
Parameter	Contents	
Treatment Capacity (ADWF)	6,400 m^3/d (32,000 EP)	
Target Effluent Standard	General standards	
Wastewater Treatment process	Trickling Filter	
Treatment Targets	Wastewater	Pipeline Sewerage
		Return flow from sludge thickening/dewatering
	Sludge	Raw Sludge produced at Sabeto WWTP (Gravity thickening only)
		Excess Sludge produced at Sabeto WWTP
Footprint	Total	9.5 ha
	Wastewater Treatment	7.0 ha
	Sludge Drying Bed	0.5 ha
	Sludge Storage Area	2.0 ha

Source: : JET

Characteristics of the WWTP:

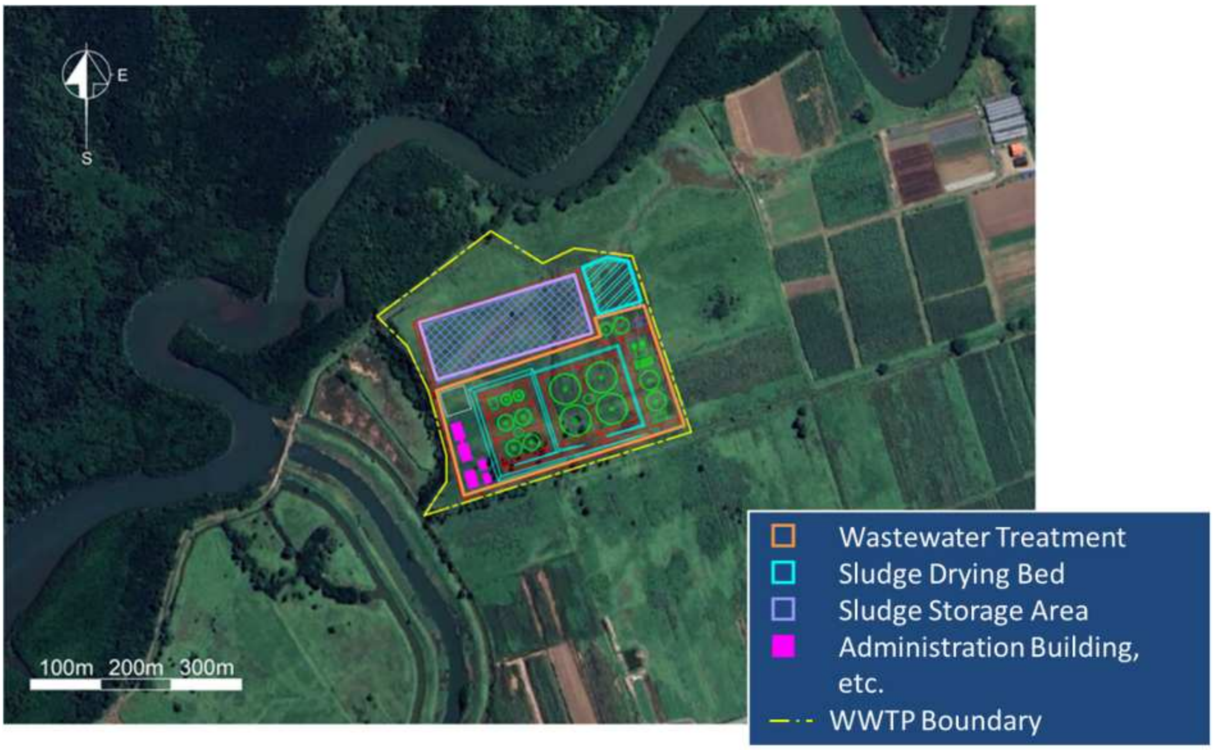
- Raw sludge produced from the Primary Clarifier will be gravitationally thickened, then bailed to Natabua WWTP.
- Excess sludge produced from the Final Clarifier will be mechanically dewatered, sun-dried, and stored onsite
- Treated effluent will be discharged to the ocean through ocean outfall pipes

Sabeto WWTP’s treatment process flow and footprint image are shown as follows.



Source: : JET

Figure 4-5.7 Sabeto WWTP's Treatment Flow Diagram



Source: : JET

Figure 4-5.8 Sabeto WWTP's Footprint Image

(2) Navakai WWTP

The outline of Navakai WWTP is summarized as follows.

Table 4-5.5 Outline of Navakai WWTP

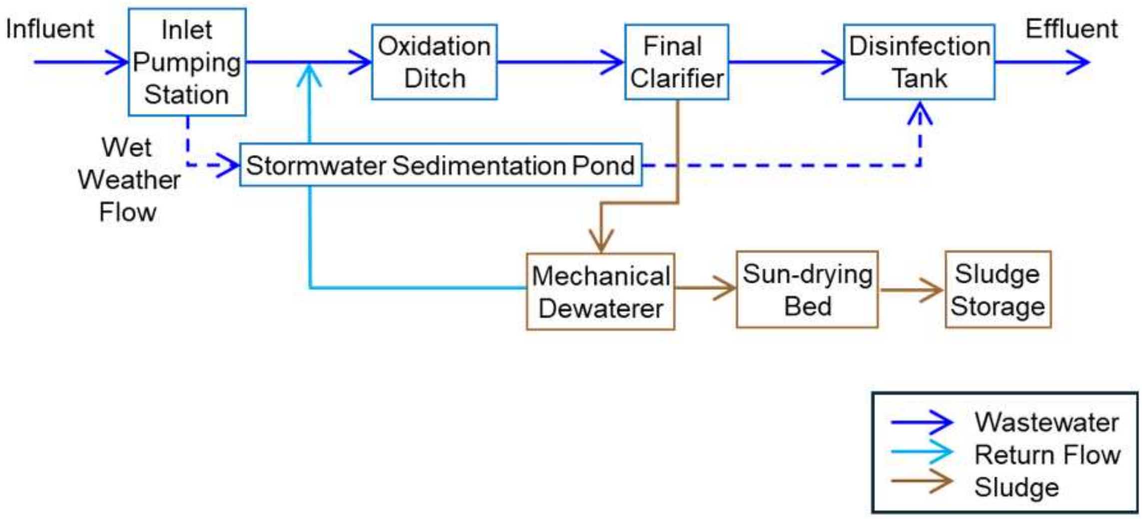
Parameter	Contents	
Treatment Capacity (ADWF)	27,100 m^3/d (135,500 EP)	
Target Effluent Standard	Significant Ecological Zone Standards	
Wastewater Treatment process	Oxidation Ditch	
Treatment Targets	Wastewater	Pipeline Sewerage
		Return flow from sludge dewatering
	Sludge	Excess Sludge produced at Navakai WWTP
Footprint	Total	22.8 ha
	Wastewater Treatment	10.5 ha
	Sludge Drying Bed	2.1 ha
	Sludge Storage Area	10.2 ha

Source: : JET

Characteristics of the WWTP:

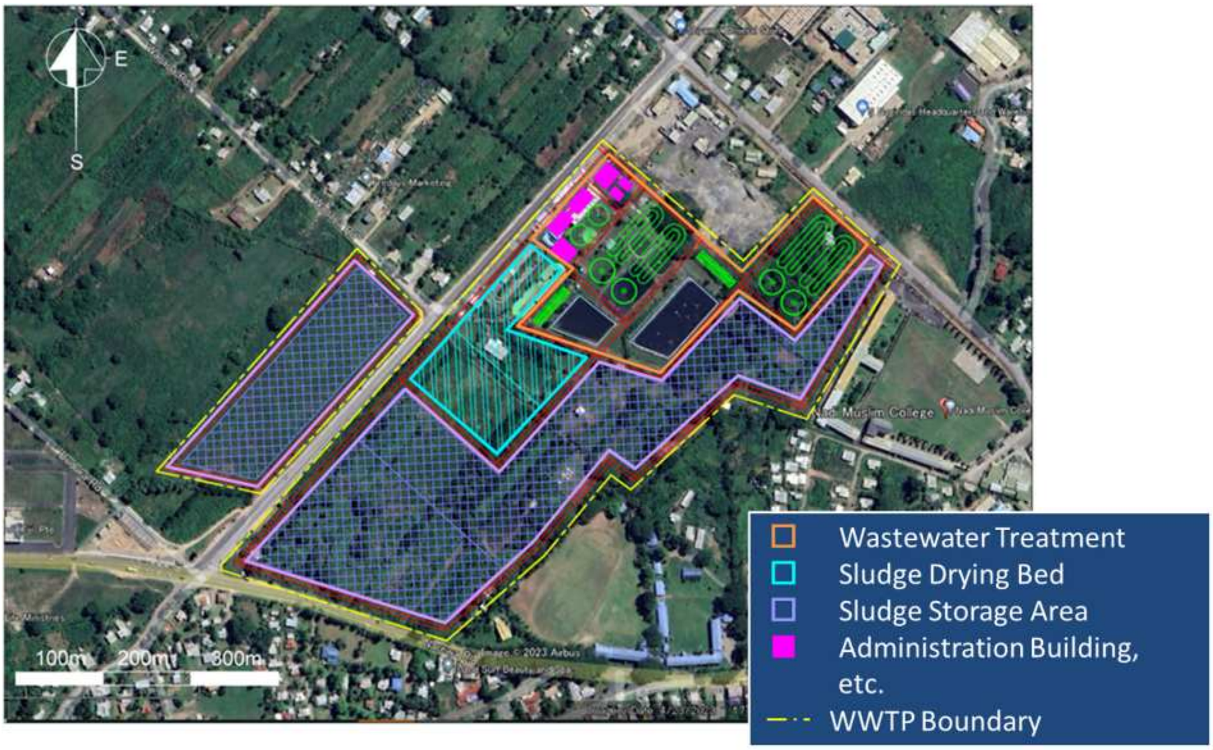
- Excess sludge produced from the Final Clarifier will be mechanically dewatered, sun-dried, and stored onsite

Navakai WWTP's treatment process flow and footprint image is shown as follows.



Source: : JET

Figure 4-5.9 Navakai WWTP's Treatment Flow Diagram



Source: : JET

Figure 4-5.10 Navakai WWTP's Footprint Image

1) Consideration of the Existing Navakai WWTP Detailed Design

Navakai WWTP has had plans/designs formulated in the past for its treatment capacity expansion; in 2021 a detailed design (hereinafter referred to as the "existing DD") was formulated to upgrade/increase the number of IDEA basins, expanding its treatment capacity to 15,000 m^3/day. However, multiple differences were found in the design conditions when compared to the Municipal Sewerage M/P, and direct incorporation of the existing DD was determined to be difficult.

The existing DD's IDEA process treatment capacity was estimated in accordance with the Municipal Sewerage M/P design conditions; when compared to the OD process, results showed that the OD treatment capacity per area of WWTP footprint was larger compared to the IDEA process. Discussions were held with WAF, and it was agreed that in the Municipal Sewerage M/P, Navakai WWTP's existing DD will not be incorporated, and the OD process was to be adopted. (Refer to **APPENDIX 4-6** for details)

(3) Moala WWTP

Moala WWTP is summarized as follows.

Table 4-5.6 Summary of Moala WWTP

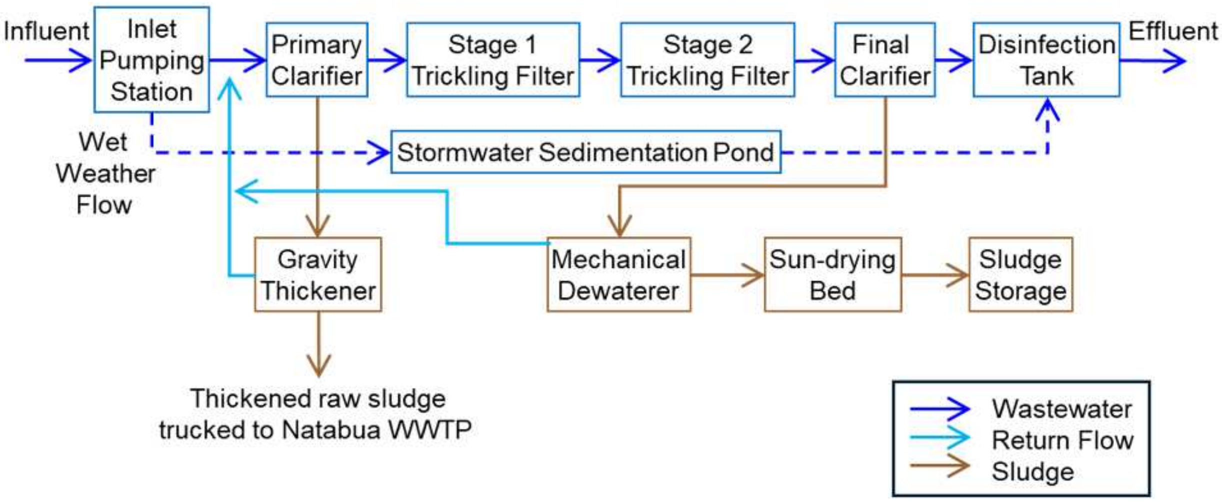
Parameter	Contents	
Treatment Capacity (ADWF)	17,500 m^3/d (87,500 EP)	
Target Effluent Standard	General standards	
Wastewater Treatment process	Trickling Filter	
Treatment Targets	Wastewater	Pipeline Sewerage
		Return flow from sludge thickening/dewatering
	Sludge	Raw Sludge produced at Moala WWTP (Gravity thickening only)
		Excess Sludge produced at Moala WWTP
Footprint	Total	18.4 ha
	Wastewater Treatment	12.5 ha
	Sludge Drying Bed	1.2 ha
	Sludge Storage Area	4.7 ha

Source: : JET

Characteristics of the WWTP:

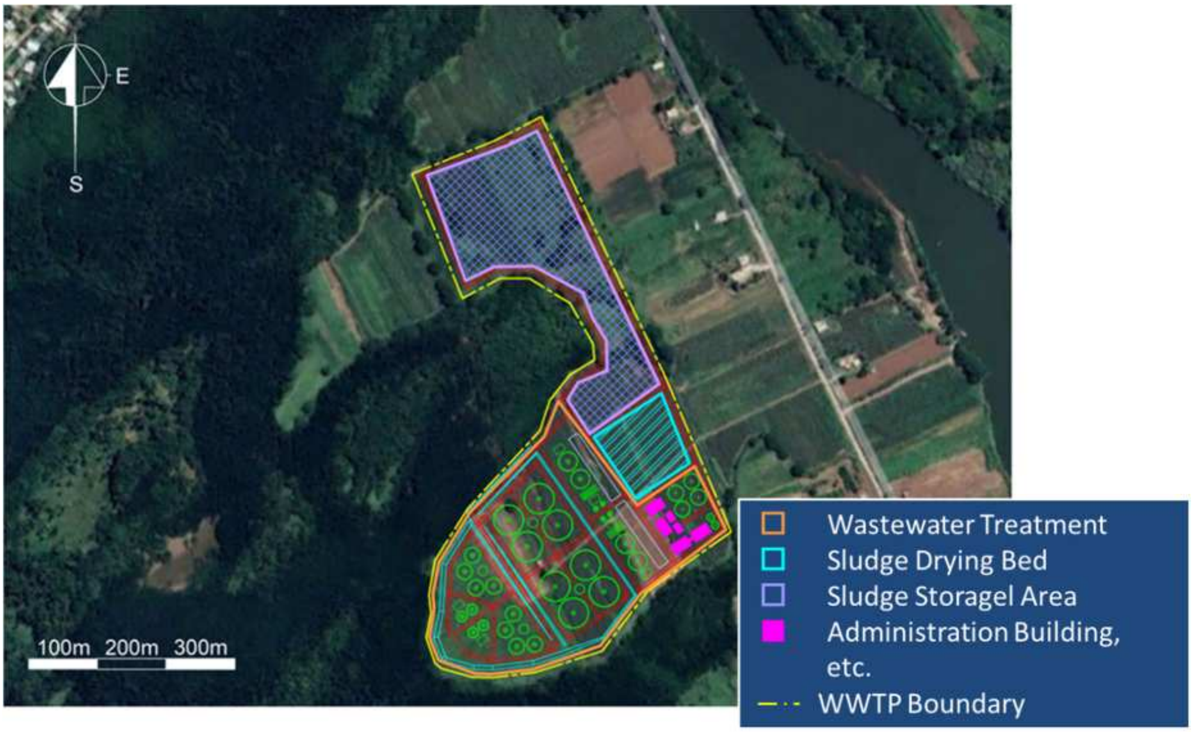
- Raw sludge produced from the Primary Clarifier will be gravitationally thickened, then bailed to Natabua WWTP.
- Excess sludge produced from the Final Clarifier will be mechanically dewatered, sun-dried, and stored onsite
- Treated effluent will be discharged to the ocean through ocean outfall pipes

Moala WWTP's treatment process flow and footprint image are shown as follows.



Source: : JET

Figure 4-5.11 Moala WWTP's Treatment Flow Diagram



Source: : JET

Figure 4-5.12 Moala WWTP's Footprint Image

4-6 Proposals for Future WWTP Design

The following are points are proposed to take into consideration for future designs of WWTPs.

(1) WWTP Buffer Zones

Information was collected from sources such as the Fiji Building Code, Public Health Act, Environment Management Act, National Liquids Strategy, Town and Country Planning Act, etc., regarding the regulation/requirement of buffer zones between WWTPs and adjacent public facilities, etc. As a result, in the construction of new WWTPs and/or expansion of existing WWTPs, the only clearly stated requirement was the EIA to be conducted by the DOE; as for buffer zones, which are often set up to mitigate noise and vibrations, was not clearly stated, limiting expressions to “Activity must not be a nuisance.”

From the above results, in the Municipal Sewerage M/P a minimum 5 meter-width buffer zone was set up along the WWTP site boundary, in reference to Japan’s Order for Enforcement of the City Planning Act. If further detailed conditions must be considered due to factors such as the type of lots/facilities adjacent to the WWTPs, these will also be considered in the Pre-F/S stage.

Table 4-6.1 Buffer Zone Requirements in Japan’s Order for Enforcement of the City Planning Act

第二十八条の三　騒音、振動等による環境の悪化をもたらすおそれがある予定建築物等の建築又は建設の用に供する目的で行う開発行為にあつては、四メートルから二十メートルまでの範囲内で開発区域の規模に応じて国土交通省令で定める幅員以上の緑地帯その他の緩衝帯が開発区域の境界にそつてその内側に配置されていなければならない。ただし、開発区域の土地が開発区域外にある公園、緑地、河川等に隣接する部分については、その規模に応じ、緩衝帯の幅員を減少し、又は緩衝帯を配置しないことができる。

Translation: Article 28-3

Upon the construction of facilities that have the possibility of producing environmentally negative effects (such as loud noise, vibration) must install buffer zones (Minimum width: 4 meters. Maximum with: 20 meters) within and along its site boundary. However, for boundaries that are adjacent to public parks, green fields, rivers etc., the buffer zone width can be reduced or eliminated.

Source: ”City Planning Law Enforcement Ordinance (1969, Ordinance No. 158),” 1969

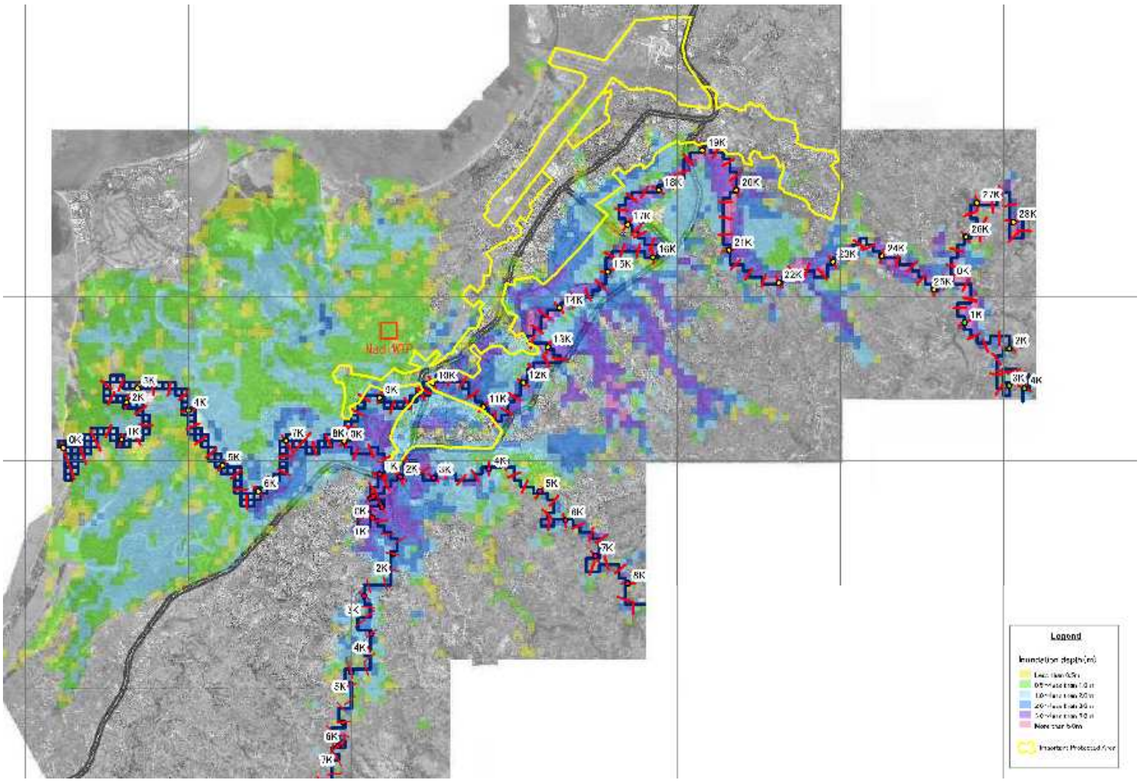
(2) Foundation of WWTP Facilities

No in-depth boring surveys have been conducted at the existing Navakai/Natabua WWTPs in the past, and detailed soil data is currently unavailable. The foundation type for WWTP facilities will depend on factors such as soil layer characteristics and groundwater level, so the foundation type will be reexamined after conduction of boring surveys scheduled in the Pre-F/S stage. It should be noted that estimated construction costs for facilities in the Regional Wastewater M/P and Municipal Sewerage M/P may vary depending on the foundation type.

(3) Flooding Countermeasures

WWTPs carry the risks of flooding due to their nature of being built in coastal or near-river areas. Therefore, along with the collection of past flooding records in Lautoka and Nadi, countermeasures should be taken into consideration for the WWTP planning and design.

As a result of data collection in Fiji, Lautoka did not have past flooding record data; however, for Nadi "The Project for the Planning of the Nadi River Flood Control" was formulated by JICA in 2016, simulating floods caused by the overflow of Nadi River. Simulation results are show in the following figure. According to the report, the depth of floodwater in the Navakai WWTP area is expected to range between 0.5 m to 1.0 m. From these results, the design floodwater depth for all WWTPs will be set to 1.0 m for this project.



Source：Created by JET based on "The Project for the Planning of the Nadi River Flood Control Structures," JICA, Yachiyo Engineering Co., Ltd.、CTI Engineering Co., Ltd. (2016)

Figure 4-6.1 Nadi Area Flooding Simulation Results

1) Design Ground Levels and Floor Levels

The design ground level and facility floor levels shall be determined considering the design floodwater depth of 1.0 m.

2) Flooding Countermeasures of Mechanical Equipment

The major components of mechanical equipment include grit chamber equipment, sewerage pump equipment, bioreactor equipment, blower equipment, clarifier equipment, chlorination tank equipment, and sludge dewatering equipment. Flooding countermeasures for these facilities are briefly covered in the following sections.

i) Grit Chamber Equipment

Flooding countermeasures for grit chamber equipment are listed as below.

Table 4-6.2 Flooding Countermeasures for Grit Chamber Equipment

Equipment	Flooding Countermeasure	Notes
Inflow Gate	Install the electric gate actuator at a height above the design floodwater depth.	
Automatic Screen	Install a submersible power supply box .	
Grit Removal Pump	Pump is a submersible sand pump. Install the connection terminal at a height above the design floodwater depth	

Source: : JET

ii) Sewerage Pump Equipment

Flooding countermeasures for sewerage pump equipment are listed as below.

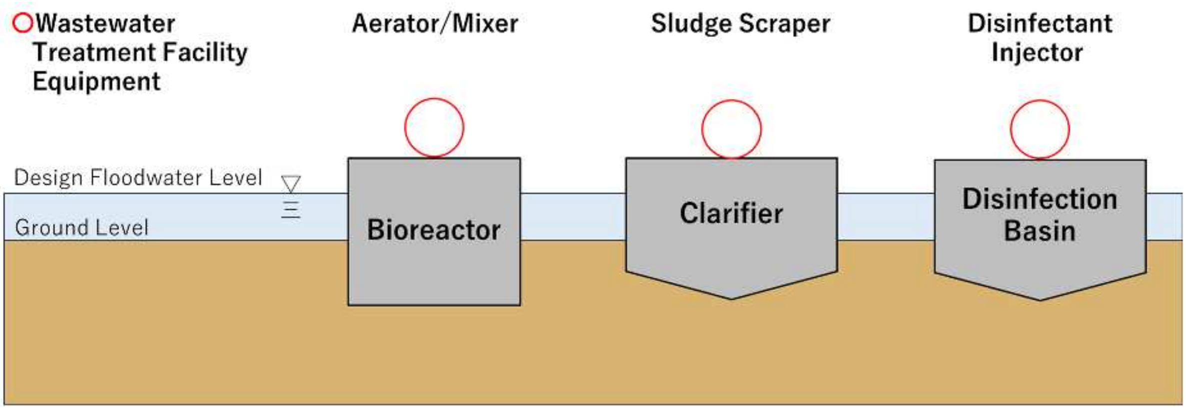
Table 4-6.3 Flooding Countermeasures for Sewerage Pump Equipment

Equipment	Flooding Countermeasure	Notes
Sewerage Pump	Pump is a submersible pump. Install the connection terminal at a height above the design floodwater depth	
Pump discharge valve	Adopt manual valve.	

Source: : JET

iii) Wastewater Treatment Equipment (Bioreactor, Clarifier, Disinfection Tank)

The depth of the tanks and basins will range between 2-3.5 m, so structures shall be placed so the top of concrete structures are at least 1 m above the floodwater level. Mechanical equipment of each tanks/basins shall be installed on top of the concrete structures to avoid submersing (**Figure 4-6.2**).



Source: JET

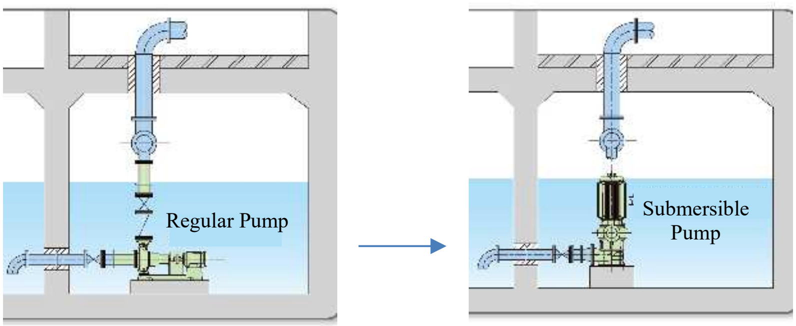
Figure 4-6.2 Image of the Floodwater Level, Concrete Structures, and Equipment

iv) Return Pumps and Excess Sludge Pumps

Return pumps and excess sludge pumps will be installed within the pumping station building. There are two methods for flooding countermeasures: (1) using a submersible pump and (2) installing a water-tight door at the building entrance. A schematic diagram of each method is shown below.

(Adopting Submersible Pumps)

Pumps are usually installed in underground levels, so if flooding occurs, the pump itself will be submerged under water, leading to pump failures. Instead, a submersible pump will be installed, which can continue to function even when underground floors go under water. It should be taken note to install the power supply connection terminal at levels above the floodwater level.



Source: "ShinMaywa Company Submersible Pump Catalogue," ShinMaywa Industries, Ltd. (2019)

Figure 4-6.3 Installment of Submersible Pumps in place of Regular Pumps

(Installment of Water-tight Doors)

Normal Status　　　　Flooding

Source: "General Waterguard Catalogue," Miwa Shutter Industries, Ltd. (2021)

Figure 4-6.4 Example of a Swing-type Water-tight Door

Water-tight doors are installed in the pumping building to prevent the intrusion of water. When determining the design ground level and floor levels of buildings, the floodwater level should be taken into account.

Examination/comparison of the two methods shall be conducted in the detailed design of the WWTP.

v) Sludge Dewatering Equipment

Flooding countermeasures of sludge dewatering equipment shall be done generally by placing the equipment at heights above the design floodwater level. The sludge dewatering building will be a two-story building. Level 2 will be composed of the dewatering room and sludge hopper room; Level 1 will be composed of chemical storage tanks, pump room, sludge storage tank, and truck loading/unloading room.

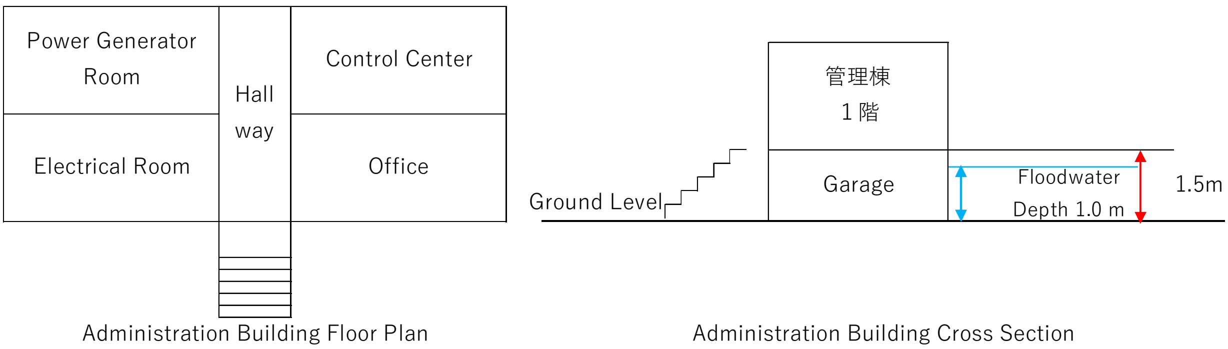
Considering the height requirement for the truck loading/unloading room, the height for Level 1 is estimated to be about 5 m. On the first floor, tanks and pumps will be placed on frame bases at least 1 meter in height. As for the dewatering machine, this will be placed on Level 2 to completely avoid submersion.

3) Flooding Countermeasures of Electrical Equipment

Similar to mechanical equipment, flooding countermeasures shall be determined based on the 1.0 m design floodwater depth determined from the past Nadi flooding simulation project. Major components of electrical equipment include substation equipment, emergency power generator equipment, supervisory equipment, and power equipment.

i) Substation, Emergency Power Generator, and Supervisory Equipment (Electrical Room, Power Generator Room, and Control Center)

Substation, power generator, and supervisory equipment will be installed in the main administration building of each WWTP. Since the design floodwater depth is set to be 1.0 m, the floor level of the administration building Level 1 shall be set at design GL+1.5m, equipped with a staircase at its entrance (**Figure 4-6.5**).



Source: JET

Figure 4-6.5 Image of the Administration Building

ii) Power Control Panel of Wastewater Treatment Facilities

An electrical equipment room shall be established on top of the wastewater treatment tank/basin concrete structures at levels higher than the floodwater level, where the power control panel of the wastewater treatment facilities will be placed to prevent submersion.

iii) Power Control Panel of Sludge Dewatering Equipment

The power control panel of sludge dewatering machine shall be placed on Level 2 of the sludge dewatering building to avoid submersion.

(4) Countermeasures for Seawater/Sea Breeze Exposure

Natabua WWTP is expected to require countermeasures for exposure to seawater/sea breeze due to its coastal location. Data on Fijian building restrictions/countermeasure requirements were collected.

Concrete structures in Fiji are constructed in accordance with Australian Standards (hereinafter referred to as “AS”). In AS, the exposure level of structures within 1 km from the coastline are classified as "Coastal (B1)", and structures within a range of 1-50 km from the coastline are classified as "Near Coastal (B2)." It should be noted that concrete structures in these categories have requirement for compressive strength (f'c), curing periods, etc., in addition to the covering thickness of reinforcing bars.

(5) Odor Control

Many of the complaints from residents nearby WWTPs are related to foul odors, and proper odor control is desired. Odor control methods can be categorized into two types: odor mitigation and deodorization. Odor mitigation is where considerations are made in facility design and O&M to reduce the generation/spread of odors. Deodorization is where odorous gases are collected and treated to remove odor substances.

1) Odor Mitigation

Odor substances (hydrogen sulfide, etc.) emitted from sewerage and sludge are generated as a result of microbial activity taking place in anaerobic conditions; these gases are released into the atmosphere at pipe outlets, etc., where sewerage/sludge is churned up and makes contact with air. For the WWTP systems planned in this M/P, facilities such as the WWTP inlet (onsite pumping stations and grit chambers), septage receival facilities, and sludge dewatering facilities fall under these conditions (anaerobic digesters are expected to be sealed in order to collect its gas for power generation). In future F/S and design stages, odor mitigation methods such as the below should be taken into consideration.

- Incorporate structural measures into the design to mitigate odor dispersion (ex. submerged inlets, minimize freefall turbulence by controlling water levels)
- Contain odors by installing odor-source facilities indoors and/or placing covers on tanks
- Position odor-source facilities away from surrounding residential areas, facilities etc.
- Frequently carry out cleaning and other O&M activities such as grit/screen residue disposal

In addition to the above measures, another method of odor mitigation is to disperse and dilute odor substances to acceptable levels. A typical method is to place vegetation around odor-source facilities and buffer zones around the WWTP. Not only do the branches/leaves of the vegetation induce turbulence in the atmosphere to disperse odor substances, but respirometric activities of trees are expected to help purification of the air to some extent.

2) Deodorization

Regarding deodorization treatment (which collects and treats odors generated from contained odor-source facilities), future detailed examinations will be based on design conditions such as the expected gas volume, types of odor substances, treatment targets values, O&M requirements, costs, etc. The following four methods are listed as typical deodorization treatment processes; however, it should be noted that application of chemical scrubbing and gas incineration are expected to be difficult considering the current procurement and O&M conditions in Fiji.

Table 4-6.4 Deodorization Processes

Method	Chemical Scrubbing	Gas Incineration	Activated Carbon Filters	Biological Treatment
Overview	・Odor gas is brought into contact with scrubbing solution, which absorbs and removes substances. ・Methods/chemicals vary depending on the target odor substance	・Odor gas is blown into an incinerator, where odor substances are burned and broken down at high temperatures (700 – 800℃)	・Odor gas is vented through adsorption towers packed with activated carbon filters to adsorb/ remove odor substances. ・In Japan, chemically treated coconut-shell activated carbon is typically used	・Odor substances are decomposed by microorganisms, such as soil-bed filters and media-packed towers
Advantages	・Small footprint ・High removal rate for low to medium concentration odor gases	・Capable of deodorizing high-concentration odor gases ・If sludge incinerators are installed, they can also be used to incinerate odor gases	・Relatively low O&M costs ・Relatively low O&M requirements	・Relatively low O&M costs ・Relatively low O&M requirements
Disadvantages	・Large number of sub-devices (recirculation pumps, chemical storage tanks, etc.) needed compared to other methods ・Relatively high O&M costs (procurement of chemicals, electricity) ・Relatively high O&M requirements	・High construction costs and O&M costs (fuel, etc.) ・Relatively high O&M requirements	・More frequent media replacement may be needed for high-concentration odor gases, increasing O&M costs	・Appropriate O&M is essential, since the deodorizing performance is dependent on soil bed conditions/microbial activity ・Soil-bed filters will require larger footprints compared to other methods

Source: JET

(6) Procurement Situation

1) Chemicals

As for disinfectants, sodium hypochlorite is currently used by WAF in its WWTPs. Hypochlorite is supplied by a Fijian private company, and is expected that no major issues will occur in its procurement.

As for the coagulants used in sludge dewatering, it was found from WAF staff interviews and photo records that coagulants were procured in the past for the belt-press sludge dewaterer at Navakai WWTP. Since the dewaterer has not been in operation since its breakdown, purchases by WAF are currently suspended. However, resumption of coagulant procurement can be expected in the future.

2) Mechanical/Electrical Equipment

Information on the procurement situation for mechanical and electrical equipment shall be collected/considered at planning stages to support the sustainable operation of WWTPs.

Most of the major mechanical equipment needed by the wastewater treatment processes adopted in the Municipal Sewerage M/P have a history of procurement in the past. For the trickling filter process, Kinoya WWTP has distributors, filter bed media, and final clarifier sludge scrapers that are currently in operation. For the oxidation ditch process, Navakai WWTP has surface aerators that could be applicable for the process' bioreactor

As for sludge dewatering, the procurement of a belt-press dewaterer at Navakai WWTP has been confirmed. As for other types of dewaterers (screw-press types), procurement records have not been found in WAF's sewerage division, but multiple manufacturers were confirmed in Australia, which will be a highly possible procurement source for Fiji. In addition, a Japanese international sludge dewaterer manufacturer provided information of their agent company in Australia, as well as a past dewaterer installment project that took place in Australia. The above data shall be referred to in future design stages of the WWTP.

Another issue addressed by WAF was the prolonged repair/procurement time for replacement parts when equipment failures occur (usually few months in length). As possible countermeasures, the securing/storage of spare parts for major machinery components at the time on primary procurement (equipment installment) is proposed, as well as including aftercare support services in the contract with the procurer company.

(7) Power Outage Countermeasures

Past records of power outage incidents in Fiji were collected and analyzed to examine the necessity of emergency generator installment, etc. Power outage countermeasures shall be taken into consideration for planning and design.

1) Power Outage Records

Past power outage records for years 2018-2023 in Lautoka and Nadi were collected and organized in **Table 4-6.5**.

Table 4-6.5 Number of Occurrences and Length of Power Outages in Lautoka and Nadi

Item		Nadi		Lautoka	
		Unplanned Outages	Planned Outages	Unplanned Outages	Planned Outages
Number of Occurrence (2018-2023)	(cases)	354	0	192	1
Maximum Duration Time	(hrs)	24	—	12	8
Average Duration Time	(hrs)	3.4	—	3	—
Minimum Duration Time	(hrs)	0.1	—	0.02	—
Annual Average	(cases)	59	—	32	1
Monthly Average	(cases)	5	—	2.7	—
Number of Power Outages exceeding 12 hours	(cases)	6	—	—	—
Average Duration Time of Power Outages exceeding 12 hours	(hrs)	15.8	—	—	—

Source：Created by JET based on EFL data

2) Necessity of Emergency Generators

Based on the past power outage records, the average number of power outage incidents in Lautoka and Nadi was found to be about 3 to 5 times a month, and the average duration time was about 4 hours or less. Maximum duration time was 24 hours in Nadi, and 12 hours in Lautoka.

Long-term power outages lead to negative impacts in both the service area and waterbodies where WWTP effluent is discharged to; shutdown of pumping stations cause sewerage overflow from manholes, and the deterioration of WWTP effluent quality due to death of microorganisms (activated sludge) in the bioreactors. Due to these effects, the installment of emergency power generators is essential for facilities.

3) Target Load of Emergency Power Generator

The target load for the emergency power generator will be determined based on the equipment installed for each treatment process. A general list of possible equipment is shown in **Table 4-6.6**.

Table 4-6.6 Target Load Equipment for the Emergency Power Generator

Facility	Target Load Equipment	Notes
Grit Chamber	Diversion well gate Grit chamber influent gate Grit scraper Automated screen Screen waste removal conveyer Grit removal conveyer	
Pumps	Sewerage pump Stormwater pump Auxiliary equipment of the above equipment	
Aerators/Blower	Blowers Auxiliary equipment of the above equipment Aerators	※1
Clarifiers	Sludge scrapers Return sludge pump Return sludge withdrawal valve	
Disinfection Tank	Disinfectant injector Auxiliary equipment of the above equipment	
Treated Water Recycling Facility	Treated water pump Sand filter pump Automatic strainer	※2
Power Generator	Fuel pump Cooling water pump Ventilation equipment Other auxiliary equipment of power generator	
Sludge Treatment Facility	Equipment that handles heat and would cause thermal related problems if stopped, such as the equipment in incinerator facility	
Other Facilities	Lighting equipment for maintenance Instrumentation power supply Disaster response equipment power supply Operational power supply DC power supply Fire hydrant pump Lift pump Floor drainage pump Electrical/ control room air conditioning power supply Other necessary power for maintenance	

※1：Load worth of securing the minimum required wastewater treatment capacity of the WWTP (approximately equal to the daily maximum influent flow)
※2：Only in cases it is used as sealing water for pumps: take note to keep to a minimum
Source：JET

(8) Data Collection on the Capacity of Power Transmission and Receiving Line

Depending on the treatment process to be adopted at each WWTP, there is a possibility that the current capacity of the power transmission/receiving lines may be insufficient. While collecting data/information on the power lines around the existing/new WWTPs, countermeasures (such as increasing transmission line) shall be examined.

1) Checking Current Equipment Load Capacity at Navakai WWTP

Navakai WWTP is currently operated by the IDEA process. Originally eight aerators were planned for installment, in which only six were actually installed. Currently, due to equipment breakdowns, four aerators are in operation. As for sludge treatment, one belt-press dewaterer is installed, but also not in operation due to breakdown. The current equipment electrical load capacity is estimated as follows.

Table 4-6.7 Navakai WWTP's Current Load Capacity※

Facility/ Equipment	Load (kW)	No. of Units	Three-phase Load Total (kW)	Building Footprint (m^2)	Capacity per unit area (KVA/m^2)	Buildings Facilities (KVA=kW)	Total Load (kW)
IDEA Basin Aerators	37	8	296	—	—	—	344
Sludge Dewaterer	15	1	15	—	—	—	
Buildings Power	—	—	—	300	0.07	21	
Buildings Lighting	—	—	—	300	0.04	12	

※Current load values are assumed values
Source: JET

2) Electrical Capacity for each Wastewater Treatment Process

The following table lists the electrical capacities of each wastewater treatment process candidate. The total load capacity is assumed to range between 500 kW～800 kW depending on the treatment process.

Table 4-6.8 Total Load*1and Transformer Capacity

Treatment Process	Waste-water Treatment (kW)	Sludge Treatment (kW)	Three-phase Load Total (kW)	Buildings Equipment Power *2 (kW)	Buildings Lighting *3 (kW)	Total Load (kW)	Calculated Transformer Capacity Requirement (KVA)	Rated Transformer Capacity (KVA)
Current Equipment at Navakai WWTP	296	15	311.00	21	12	344.0	303	500
OD Process Equipment	548.05	48.9	596.95	120	60	777.0	684	750
IDEA Process Equipment	434.35	39.1	473.45	95	48	616.5	543	750
MBBR Process Equipment	412.85	83	495.85	100	50	645.9	569	750
AL Process Equipment	649.05	—	649.05	65	52	766.1	675	750
TF Process Equipment	369.95	51.5	421.45	85	43	549.5	484	500

*1: Total load for the 10,000 m^3/day model of each treatment process
*2: Let Buildings Equipment Power = Three-phase Load Total×20%
*3: Let Buildings Lighting = Three-phase Load Total×10%
Source: : JET

3) Checking the Transmission Line Capacity

The transmission/receiving line capacities for new WWTPs are expected to significantly surpass the current capacities at Navakai WWTP. Therefore, the EFL substations' transformer capacity and existing transmission line capacity must be checked.

CHAPTER 5 STAGED DEVELOPMENT OF THE SEWERAGE SYSTEM

5-1 Staged Development and Components

5-1-1 Necessity of Staged Development

The overall sewerage development plan was described in **Chapter 4**. However, for the reasons outlined below, the overall project should be divided into several components and be implemented in stage-wises.

- Due to the high construction costs, development of all components at the same time will be difficult.
- In terms of O&M and budget, feasible expansion is recommended.
- Sewerage facilities should be developed as the city itself grows and develops.
- The development of decentralized treatment facilities, such as septic tanks, alongside the sewerage facilities is desirable.

5-1-2 Proposed Projects

(1) Lautoka

Table 5-1.1 shows the proposed projects in Lautoka and outlines of their facilities. Based on the current level of wastewater inflow to the Natabua WWTP (approximately 11,000 m^3/day on a revenue water basis) and the ultimate inflow of 27,000 m^3/day, a two-phase expansion of the WWTP is proposed. It is also proposed to develop the wastewater treatment plant (Ln-w3) as an independent component. Sewer network development has been divided into the trunk line/sub trunk line and branch.

Table 5-1.1 Proposed Development Components for Vitogo, Natabua (Lautoka)

Area	Type	Outline of Facilities	
Vitogo	WWTP (Lv-w1)	TF process: Total Capacity	Q=7,100 m^3/day (PDWF)
	Sewer Network (Lv-s1)	Trunk/Sub-trunk line	Dia.100-600mm L=41 km
	Sewer Network (Lv-s2)	Branch sewer	Dia.100- 250mm L=71 km
Natabua	WWTP (Ln-w1)	TF process: Half of total capacity (1/2)	Q=23,000 m^3/day (PDWF)
	WWTP (Ln-w2)	TF process: Half of total capacity (2/2)	Q=22,000 m^3/day (PDWF)
	Septage Treatment Plant (Ln-w3)	Receiving facility, Mechanical dewatering	Q=76 m^3/day
	Sewer Network (Ln-s1)	Trunk/Sub-trunk line Half of total length (1/2)	Dia.100-750mm L=32 km
	Sewer Network (Ln-s2)	Trunk/Sub-trunk line (2/2) Branch sewer (1/2)	Dia.100-750mm L=32 km Dia.100- 600mm L=72 km
	Sewer Network (Ln-s3)	Branch sewer (2/2)	Dia.100- 600mm L=72 km

Source: JET

(2) Nadi

Table 5-1.2 shows the proposed project components for the three service areas in Nadi. The expansion of the Navakai WWTP will be divided into two phases, taking into account the current amount of wastewater flowing into the Navakai WWTP (approximately 9,000 m^3/day based on the amount of revenue water) and the ultimate design flow into the WWTP. The expansion of the sewer collection network has been divided into trunk, sub-trunk and branch lines.

Table 5-1.2 Proposed Development Components for Sabeto, Navakai, Moala (Nadi)

Area	Type	Outline of Facilities	
Sabeto	WWTP (Ns-w1)	TF process: Total Capacity	Q=7,100 m^3/day (PDWF)
	Sewer Network (Ns-s1)	Trunk/Sub-trunk line	Dia.100-400mm L=49 km
	Sewer Network (Ns-s2)	Branch sewer	Dia.100-400mm L=78 km
Navakai	WWTP (Nn-w1)	OD process: Half of total capacity (1/2)	Q=15,000 m^3/day (PDWF)
	WWTP (Nn-w2)	OD process: Half of total capacity (2/2)	Q=15,000 m^3/day (PDWF)
	Sewer Network (Nn-s1)	Trunk/Sub-trunk line Half of total length (1/2)	Dia.100-900mm L=29 km
	Sewer Network (Nn-s2)	Trunk/Sub-trunk line Half of total length (1/2), Branch sewer (1/2)	Dia.100-900mm L=29 km Dia.100-310mm L=102 km
	Sewer Network (Nn-s3)	Branch sewer (2/2)	Dia.100-310mm L=102 km
Moala	WWTP (Nm-w1)	TF process: Half of total capacity (1/2)	Q=10,000 m^3/day (PDWF)
	WWTP (Nm-w2)	TF process: Half of total capacity (2/2)	Q=9,000 m^3/day (PDWF)
	Sewer Network (Nm-s1)	Trunk/Sub-trunk line Half of total length (1/2)	100-900mm L=53 km
	Sewer Network (Nm-s2)	Trunk/Sub-trunk line Half of total length (1/2), Branch sewer (1/2)	Dia.100-900mm L=52 km Dia.100-400mm L=80 km
	Sewer Network (Nm-s3)	Branch sewer (2/2)	Dia.100-400mm L=81 km

Source: JET

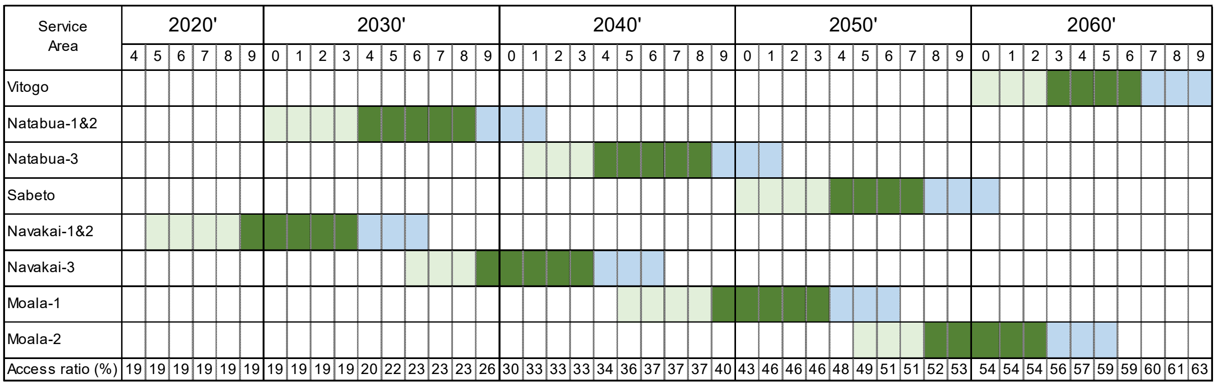
5-1-3 Implementation Schedule

In consultation with the WAF, the development of the Navakai and Natabua service areas, which already have a high population and commercial facilities, should have a high priority in the Municipal Sewerage M/P. In addition, the WAF concept of priority for sewerage development is as follows.

- Legal compliance of the quality of treated wastewater from existing treatment plants.
- Upgrading and expansion of trunk and sub-trunk sewers to collect wastewater from private developments such as residential and commercial properties.

- Developing branch sewer system for increasing the proportion of the population. (Part of the sewerage system of private developers within residential complexes and commercial areas, as well as connecting pipes to trunk lines/sub trunk lines owned by WAF, will be installed by private contractors and are outside the scope of WAF).

The development schedule based on the results of the above discussion is shown in **Figure 5-1.1**. The construction periods for each project are adjusted so that construction periods do not overlap. The sewerage population development rate in 2036 is estimated to be 23%.



Source: JET

Figure 5-1.1 Proposed Staged Development Schedule

The proposed schedule shown in **Figure 5-1.1** is based on the duration for each phase shown in **Table 5-1.3**.

Table 5-1.3 Assumed Duration for Each Phases

Phase	Duration (year)
F/S study	1
Consultant Selection	1
Detailed Design	1
Bidding procedure for the contractor	1
Construction (Natabua, Navakai, Moala)	5
Construction (Vitogo, Sabeto)	4
House connection	3

Source: JET

5-1-4 Selection of Priority Projects

Priority projects for Pre-FS shall be selected taking into account the following points. This policy and the priority projects will be decided after consultation with the WAF in the early stages of the Pre-FS.

- Urgency of the project
- Beneficiary population
- Efficiency of investment

In the current discussion with WAF, the following components are listed as candidates for priority projects.

- Rehabilitation and expansion of Navakai WWTP (Nn-w1),
- Development and upgrading of the trunk and sub-trunk lines in the Navakai service area (Nn-s1),
- Rehabilitation and expansion of the Natabua WWTP in Lautoka (Ln-w1),
- Construction of new septage treatment plant at Natabua WWTP (Ln-w3)

5-2 Costs Estimation

(1) Condition of Cost Estimation

Outline design of each facility was conducted in the Municipal Sewerage M/P. Outline construction cost was estimated by multiplying the approximate quantity of civil related items by the unit price. The consideration and precondition for estimating outline construction costs are as follows.

- For civil engineering works, the construction cost was estimated by multiplying the approximate quantity by the unit price.
- The unit price of Fiji was used as a reference for the main items of civil engineering work, and the unit price that is difficult to obtain was adopted with reference to the examples of Japan and third countries.
- Mechanical and electrical costs were estimated based on the ratio of civil engineering costs and mechanical and electrical costs in Japanese experience.
- The land acquisition cost for the WWTPs were included based on the comment from MOE[6]. However, since the unit price of land varies greatly depending on the type of land for WWTP's site, etc., the land acquisition cost calculated here need to be revised in the later phase.
- Approximate unit prices are before the COVID-19 pandemic and 2022 Russian invasion to Ukraine.

The cost estimation results for each facility are shown below.

(2) WWTP Construction Costs

The construction costs have been estimated based on the approximate number of civil works for each treatment process shown in 4-5-2 and 4-5-3 above, based on the capacity of the WWTPs. **Table 5-2.1** shows the construction costs for the five proposed WWTPs. Land acquisition costs are included in the WWTP construction costs.

[6] MOE: before organizational restructuring; current Ministry of Finance (MOF)

Table 5-2.1 WWTP Construction Costs

Municipality	WWTP	Treatment Process	Design Flow (ADWF) (m^3/day)	Construction Cost （million FJD）
Lautoka	Vitogo	Trickling Filter	6,400	77
	Natabua	Trickling Filter	40,500	405
Nadi	Sabeto	Trickling Filter	6,400	78
	Navakai	Oxidation Ditch	27,100	312
	Moala	Trickling Filter	17,500	196

*1 FJD = 67.55 JPY (April 2024)
Source: JET

(3) WWTP O&M Costs

The O&M costs for WWTPs have been calculated using Japanese cost experience as shown in **Table 5-2.2**.

Table 5-2.2 WWTP O&M Costs

Municipal	WWTP	Treatment Process	Construction Cost （1000 FJD/year）
Lautoka	Vitogo	Trickling Filter	1,350
	Natabua	Trickling Filter	3,866
Nadi	Sabeto	Trickling Filter	1,350
	Navakai	Oxidation Ditch	3,150
	Moala	Trickling Filter	2,433

*1 FJD = 67.55 JPY (April 2024)
Source: JET

(4) Construction and O&M Costs for the Sewer Network

The construction cost of the sewer network was estimated by taking the approximate quantity of pipe length by section shown in **Table 4-2.1** and multiplying it by the unit price per meter of pipe by section and depth set.

For the sewer network O&M costs, the unit price per meter based on Japanese experience was used to estimate the O&M costs. **Table 5-2.3** shows the construction and maintenance costs of sewer pipes.

Table 5-2.3 Construction Cost and O&M Cost of Sewer Network

Service Area	Sewer Length （km）	Construction Cost (million FJD)	O&M Cost (1000 FJD/year)
Vitogo	112	200	112
Natabua	207	301	207
Sabeto	126	324	126
Navakai	261	398	261
Moala	264	366	264

*1 FJD = 67.55 JPY (April 2024)
Source: JET

(5) Construction Cost and O&M Cost of Pumping Stations

The number of pumping stations in each service area was determined by studying the longitudinal section of the sewerage network. The unit price of pumping stations was set based on the approximate quantity expected from existing pumping stations. The maintenance cost was determined as the unit price for a pump station based on pump capacity and power consumption. **Table 5-2.4** shows the construction and maintenance costs of the pumping stations.

Table 5-2.4 Construction and O&M Costs for Pumping Stations in Each Service Area

Service Area	Number of Pumping Stations	Construction Cost (million FJD)	O&M Cost (1000 FJD/year)
Vitogo	21	17	1,285
Natabua	52	41	3,182
Sabeto	62	48	3,795
Navakai	67	52	4,100
Moala	102	76	6,242

*1 FJD = 67.55 JPY (April 2024)
Source: JET

5-3 Economic and Financial Analysis

5-3-1 Purpose of Economic and Financial Analysis

The purpose of financial analysis is to evaluate the feasibility of implementing a project from the perspective of financial viability for the project proponent. On the other hand, the purpose of economic analysis is to verify the validity of project implementation from the viewpoint of national economy.

In the analysis, With or Without Project Cases regarding the Municipal Sewerage M/P are set as follows.

- With Project Case
  Implement the Municipal Sewerage M/P. Wastewater treatment capacity of target municipalities will be increased. Carry out the development and expansion of the wastewater treatment system in line with National Development Plan (2017-2036).
- Without Project Case
  Do not implement the Municipal Sewerage M/P. The wastewater treatment capacity of target municipalities remains at current levels. Installation and expansion of wastewater treatment system of National Development Plan will not be implemented.

By comparing the above With and Without cases, the relevance of project implementation from the economic and financial perspective of the Municipal Sewerage M/P is examined.

5-3-2 Financial Analysis

(1) Indicator for Financial Analysis

The financial evaluation of the Municipal Sewerage M/P is conducted by calculating the incremental income and expenditure and analyzing the following indicator.

1) Financial Internal Rate of Return (FIRR)

The financial internal rate of return is the discount rate that becomes zero when the cumulative difference between income and expenditure in the analysis period is converted to the present value.

(2) Preconditions for Financial Analysis

1) Period of Analysis

From year 2029 to year 2054 for 25years

2) Average Amount of Wastewater Treated, Construction Period of Treatment plant, Pumping Stations and Preparation Period for Connection

Table 5-3.1 shows the average treated wastewater volume and construction period of each wastewater treatment plant. The amount of processing during the connection preparation period shall be proportional to the connection rate.

Table 5-3.1 Average Amount of Wastewater Treated, Construction Period of Treatment plant, Pumping Stations and Preparation Period for Connection

Area	Place	Average Treated Water (m^3/day)	Construction Period (year)	Connection Preparation Period (year)
Lautoka	Vitogo	6,365	2048-2051	2052-2054
	Natabua	40,434	2034-2038	2039-2041
Nadi	Sabeto	6,393	2044-2047	2048-2050
	Navakai	27,003	2029-2033	2034-2036
	Moala	17,483	2039-2043	2044-2046

Source : JET

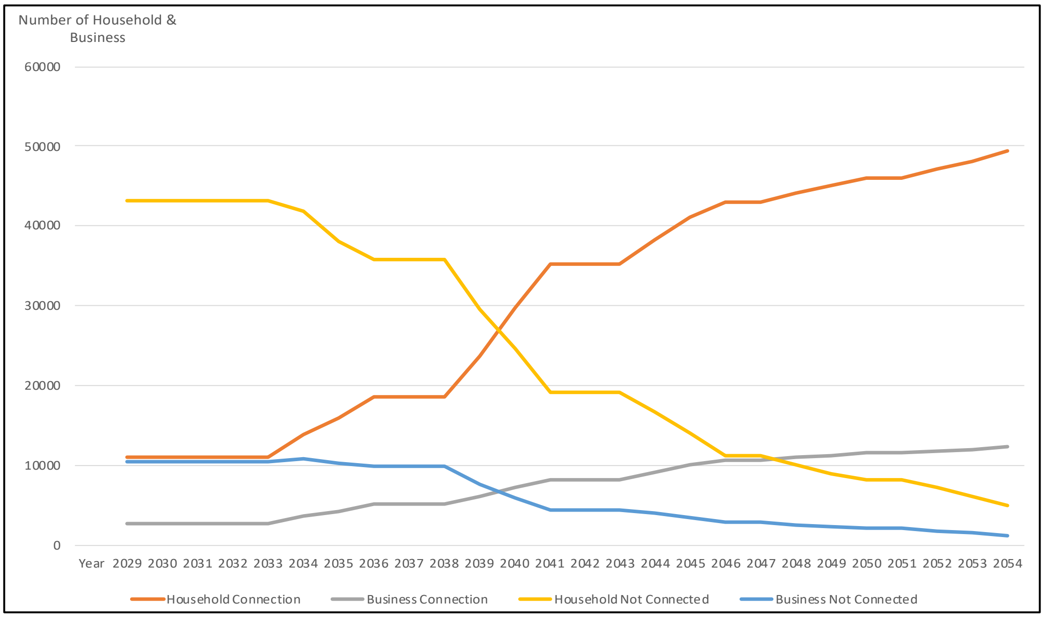
3) Connections of Households and Business, and Non-Connections

Table 5-3.2 below shows the number of connected and non-connected domestic household and business customers during the analysis period, and **Figure 5-3.1** shows the transition of connections.

Table 5-3.2 Connections of Households and Business, and Non-Connections

Year	Household Connected	Business Connected	Household Not Connected	Business Not Connected
2029	11,111	2,678	43,220	10,417
2030	11,111	2,678	43,220	10,417
2031	11,111	2,678	43,220	10,417
2032	11,111	2,678	43,220	10,417
2033	11,111	2,678	43,220	10,417
2034	13,889	3,602	41,778	10,835
2035	15,889	4,267	38,065	10,222
2036	18,609	5,171	35,722	9,926
2037	18,609	5,171	35,722	9,926
2038	18,609	5,171	35,722	9,926
2039	23,720	6,117	29,612	7,636
2040	29,720	7,227	24,611	5,985
2041	35,184	8,238	19,147	4,483
2042	35,184	8,238	19,147	4,483
2043	35,184	8,238	19,147	4,483
2044	38,184	9,168	16,625	3,992
2045	41,184	10,098	14,041	3,443
2046	43,056	10,678	11,276	2,796
2047	43,056	10,678	11,276	2,796
2048	44,056	10,966	10,139	2,524
2049	45,056	11,253	9,009	2,250
2050	46,058	11,541	8,273	2,073
2051	46,058	11,541	8,273	2,073
2052	47,058	11,769	7,145	1,787
2053	48,058	11,996	6,023	1,504
2054	49,420	12,306	4,911	1,223

Source：JET



Source：JET

Figure 5-3.1 Connections of Households, Business Entity, and Non-Connections

4) Capital Expenditure (CAPEX)

The project CAPEX is the total of the civil engineering, construction, machinery and electricity expenditure as incremental project CAPEX measured in the financial analysis. **Table 5-3.3** shows the O&M expenditure of the WWTPs, and **Table 5-3.4** shows the O&M expenditure of the sewer network (sewer pipes and pumping stations). CAPEX for Municipal Sewerage M/P does not include the expenditure for price fluctuation contingency, interest during construction, consultant fee and taxes.

Table 5-3.3 CAPEX: WWTPs

Area	Place	CAPEX (1000 FJD)
Lautoka	Vitogo	99,795
	Natabua	520,266
Nadi	Sabeto	101,050
	Navakai	328,950
	Moala	251,123
Total		1,301,184

Source：JET

Table 5-3.4 CAPEX: Sewer Network

Area	Place	CAPEX(1000 FJD)
Lautoka	Vitogo	216,306
	Natabua	341,795
Nadi	Sabeto	372,573
	Navakai	449,291
	Moala	442,839
Total		1,822,802

Source：JET

A portion of CAPEX for WWTPs are as follows.

- Construction period 5-year WWTPs (Natabua, Navakai, Moala): 1st year 4%, 2nd year 15%, 3rd year 34%, 4th year 36%, 5th year 11%
- Construction period 4-year WWTPs (Vitogo, Sabeto): 1st year 5%, 2nd year 26%, 3rd year 49%, 4th year 20%

A portion of CAPEX for the sewer network (pipes and pumping stations) is as follows.

- Construction period 5-year Sewer Network (Natabua, Navakai, Moala): 1st year 20%, 2nd year 20%, 3rd year 20%, 4th year 20%, 5th year 20%
- Construction period 4-year Sewer Network (Vitogo, Sabeto): 1st year 25%, 2nd year 25%, 3rd year 25%, 4th year 25%

5) Preparation period for Sewer connections

The connection rate at the end of each year is as follows, with a preparation period of three years after the completion of the construction of the WWTPs and sewer network.

- Connection rate：1st year 59%、2nd year 77%、3rd year 100%

6) O&M expense

O&M expense[7] at each WWTP and Sewer Network is shown in **Table 5-3.5** and **Table 5-3.6**, respectively. O&M during the connection preparation period is proportional to the connection rate. Incremental expense

[7] Refer to the cost function in Japan and the prefectural wastewater concept formulation manual.

of O&M shall be calculated by deducting 1000 FJD/year[9] from the total O&M expense, as the existing expense without project in the financial analysis.

Table 5-3.5 WWTP O&M Expenditure

Area	Place	O&M (1000 FJD)
Lautoka	Natabua	3,866
	Vitogo	1,350
Nadi	Navakai	3,150
	Moala	2,433
	Sabeto	1,350
Total		12,149

Source：JET

Table 5-3.6 Sewer Network O&M Expenditure

Area	Place	O&M (1000 FJD)
Lautoka	Natabua	3,389
	Vitogo	1,397
Nadi	Navakai	4,361
	Moala	6,506
	Sabeto	3,921
Total		19,575

Source：JET

7) Salvage Value

The salvage value of capital goods that can be used continuously in the final year and beyond, or that can be diverted to other uses, is recorded as a negative expense in the final year. The value is calculated by the following formula by applying the straight-line method (assuming scrap value = 10% of the initial investment).

- Salvage Value ＝ CAPEX of asset facility・equipment ×(1.0-0.9 ×years of use ÷ Depreciation period based on statutory useful life
- In this formula:
  Useful life：50 years for civil engineering facilities and pipes
  15 years for mechanical and electrical equipment

Applying the CAPEX and service life of WWTP facility, pipe & pumps, and equipment in **Table 5-3.7** below, the calculated residual value are recorded as a negative expense in 2054, the final year of analysis.

[9] Refer to WAF inhouse financial data report in 2019.

Table 5-3.7 Salvage Value

WWTP	CAPEX category	CAPEX (1,000 FJD)	Period in Use (year)	Salvage Value (1,000 FJD)
Vitogo	C/A (WWTP, pipe & pump)	252,525	2	243,434
	M/E	57,322	2	50,443
	Land	6,254	-	6,254
	Total	316,101		300,131
Natabua	C/A (WWTP, pipe & pump)	559,963	15	408,773
	M/E	274,785	15	27,478
	Land	2,288	-	2,288
	Total	837,036		438,539
Sabeto	C/A (WWTP, pipe & pump)	389,571	6	347,497
	M/E	75,994	6	48,636
	Land	5,330	-	5,330
	Total	8,058		401,463
Navakai	C/A (WWTP, pipe & pump)	553,327	20	354,129
	M/E	207,276	15	20,728
	Land	17,638	-	17,638
	Total	778,241		392,495
Moala	C/A (WWTP, pipe & pump)	512,956	10	420,624
	M/E	164,558	10	65,823
	Land	16,448	-	16,448
	Total	693,962		502,895

* C/A＝Civil/Architecture、M/E=Mechanical/Electrical equipment
Source：JET

8) Wastewater Income

Incremental wastewater treatment volume is calculated as income. The annual increment is calculated using the following formula. The amount of processing during the connection preparation period is proportional to the connection rate.

- Annual income from wastewater treatment = (Average treated volume of wastewater per day x 365 – treated volume without project x 365) x Tariff(FJD/m^3)
- In this formula；

  Average volume of treated water：Total treated volume of wastewater by each WWTP
  Treated volume without project：15,600 m^3
  Tariff：The current tariff 0.20 FJD/m^3

9) Income from New Connection Charge

Income from new connection is calculated by the following formula.

- Income from New Connection Charge = Increment of new connection x Application Fee
- In this formula:

  Application Fee：Household 22 FJD
  Business customer 101 FJD

10) Income related to Sludge Acceptance

Income related to sludge accepted from unconnected households and businesses is calculated using the following formula.

- Income related to sludge accepted = Number of sludge acceptance per year x Fee for Sludge acceptance
- In this formula:
  Fee for Sludge acceptance[10] : Household 12 FJD (every 5 years)
  Business Customer 12 FJD (every year)

(3) Result of Financial Analysis

The results of the financial analysis based on the expenditure and income calculated under the above assumptions are described below. The cash flow table used for this calculation is shown in **APPENDIX 5-1**.

1) FIRR

FIRR = - 3.4%

FIRR shows a negative return of 2.1%. Sensitivity analysis for change of expenditure/income is not performed because FIRR in the base scenario is a negative figure.

2) Financial Viability

The FIRR result is well below the yield on Fiji government bonds in recent years. Therefore, it is not viable to implement the Municipal Sewerage M/P from the financial point of view of the project implementing entity.

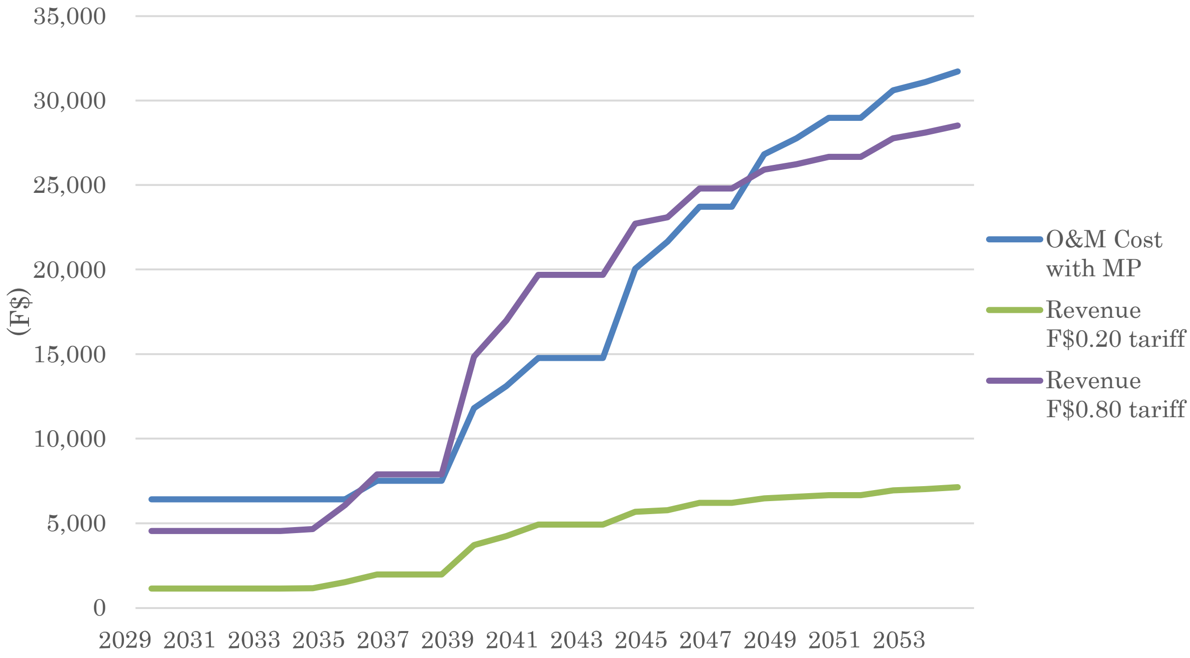
3) Tariff rate required to finance O&M expense of Municipal Sewerage M/P

Even if the project proponent regarding the entire CAPEX as a grant, the wastewater income equal to or more than the O&M expense[11] is required for the continuation of the wastewater operation. The wastewater tariff required to finance O&M expense is calculated at 0.77 FJD/m^3 at least.

With the income from the current tariff which is 0.20 FJD/m^3, the more the water volume treated due to the increase in connections, the more government budget for O&M will be required as subsidy to cover operating loss. **Figure 5-3.2** below shows the comparison between the O&M expense required for the implementation of the Municipal Sewerage M/P and the revenue arise from the tariff 0.20 FJD/m^3, and 0.80 FJD/m^3.

[10] For the acceptance fee per household, refer to the septic tank sludge collection fee described in Progress Report 2, Chapter 4-4-4.

[11] This O&M expense maintenance cost is cash outflow and does not include depreciation cost for accounting term.



Source : JET

Figure 5-3.2 Comparison of O&M Expense for Municipal Sewerage M/P and the Revenue

5-3-3 Economic Analysis

(1) Indicator for Economic Analysis

The economic evaluation of the Municipal Sewerage M/P is conducted by calculating the incremental costs and benefits of implementation and analyzing the following indicator.

1) Economic Internal Rate of Return : EIRR

The economic internal rate of return is the discount rate that becomes zero when the cumulative difference between costs and benefits in the analysis period is converted to the present value.

(2) Preconditions for Economic Analysis

1) Analysis Period

Same as financial analysis.

2) Average Amount of Wastewater Treated, Construction Period of Treatment Plant, Pumping Stations and Preparation Period for Connection

Same as financial analysis.

3) Connections of Households and Business, and Non-Connections

Same as financial analysis.

4) Capital Cost

The project cost is the total of the civil engineering, construction, machinery and electricity costs as incremental project costs measured in the economic analysis. **Table 5-3.8** shows the operating cost of the wastewater treatment plant, and **Table 5-3.9** shows the operating cost of the sewers and pumping stations. Project cost for Municipal Sewerage M/P does not include land cost, price fluctuation contingency, interest during construction, consultant fee and taxes.

Table 5-3.8 Cost of WWTP

Area	Place	CAPEX (1000 FJD)
Lautoka	Vitogo	94,465
	Natabua	495,241
Nadi	Sabeto	95,720
	Navakai	314,260
	Moala	239,163
Total		1,238,849

Source：JET

Table 5-3.9 Cost of Pipes & Pump Facility

Area	Place	CAPEX (1000 FJD)
Lautoka	Vitogo	215,382
	Natabua	339,507
Nadi	Sabeto	369,845
	Navakai	446,343
	Moala	438,351
Total		1,809,426

Source：JET

5) Preparation Period for Connection

Same as financial analysis.

6) Operation and Maintenance Cost

O&M expense in the financial analysis are regarded as non-tradable goods and multiplied by the standard conversion factor (SCF) [12] to obtain economic costs. Here the SCF is 0.96.

- Economic cost of O&M= O&M expenditure 0.96(SCF)

  The formula for calculating SCF is stated below.

$$\begin{aligned} \text{SCF} = {} & (\text{Total Import Amout} + \text{Total Export Amount}) \\ & \div [(\text{Total Import Amout} + \text{Total Import Tax Revenue}) \\ & + (\text{Total Export Amout} - \text{Total Export Tax Revenue})] \end{aligned}$$

Table 5-3.10 Trade Figure for Standard Conversion Factor Calculation

Standard Conversion Factor (SCF) *		
Import (CIF)	3,210,000	1000 US$
Import tax	261,560	1000 US$
Export (FOB)	2,650,000	1000 US$
Export tax	8,252	1000 US$
SCF=	**0.96**	

*Trade figures refer to 2019 World Bank data and Fiji Budget Statement.
Source：JET

[12] Standard conversion factor (SCF) is used as a factor when converting non-tradable goods to international prices.

7) Salvage Value

The same amount of residual value of civil engineering, construction, machinery and electricity costs measured in financial analysis is treated as a negative economic cost in the final year of the analysis.

8) Benefit of Wastewater Usage

Incremental wastewater consumption is calculated as user benefit. Volume of the incremental treated wastewater is the same the financial analysis, on the other hand, the affordable amount to pay (ATP) [13] is used as a proxy for the willingness to pay to calculate the benefits.

- Annual user benefit = (Average daily wastewater volume x 365 – Daily treated water volume before project implementation x 365) x ATP /m^3
- In this formula:
  Daily treated water volume before project implementation: 15,600 m^3
  ATP: 1.05 FJD/m^3

9) Benefits by Eliminating the Septic Tanks

The septic tank installation cost and water pumping cost that are unnecessary due to the sewer pipe connection are calculated as user benefits using the following formula.

- Benefit = increase in the number of connections x (septic tank installation cost + bailing cost)
- In this formula:
  Installment cost for sceptic tank：
  Household 8,000 FJD/house ÷ 20 years of use =200 FJD/year
  Business customer 8,000 FJD /business x 2 ÷ 20 years of use = 400 FJD/year
  Bailing cost of sceptic tank：
  Household 300 FJD/every 5 years = 60 FJD /year
  Business customer 600 FJD/every year = 600 FJD/year

10) Benefit due to Elimination of Sceptic Tank Installation Space

The cost of the septic tank installation space [14], which becomes unnecessary due to the wastewater connection, is calculated as the user benefit using the following formula.

- Benefit = Incremental number of connections x Cost of space for septic tank installation
- In this formula:
  Cost of septic tank space: Household 1,200 FJD/year, Business customer 2,400 FJD/year

[13] ATP is calculated in Progress Report 2, Chapter 4-7-6.

[14] The space for installing a septic tank is considered to be the same as the parking space for one passenger car, and the benefit is equivalent to the annual parking cost of one car for general households and the cost of two cars for business customer.

11) Benefits from New Connection Charge

Income from new connection charge in financial analysis is calculated as the operator's benefit.

12) Benefits related to Sludge Acceptance

Income related to sludge acceptance in financial analysis is calculated as the operator's benefit.

(3) Result of Economic Analysis

The results of the economic analysis based on the costs and benefits calculated under the above preconditions are described below. The cash flow table used for calculation is shown in **APPENDIX 5-1**.

1) EIRR

EIRR = 1.2%

The economic analysis shows the positive return of 1.2%. The target EIRR[15] for the implementation of development projects is 9%, or 6.0% for projects such as prevention of environmental pollution, poverty reduction in rural areas, and mitigation of natural disasters. The EIRR of Municipal Sewerage M/P is below both targets.

2) Sensitivity Analysis of EIRR

A sensitivity analysis for cost changes is shown in **Table 5-3.11** below. The benefit is assumed to be constant because it is calculated by using ATP. The result shows that EIRRs are positive in all the range of cost change from plus 20% to minus 20%, however, even in the case of cost minus 20%, EIRR is 2.2%, which does not reach the project implementation guideline.

Table 5-3.11 Sensitivity Analysis of EIRR

Cost	Down 20%	Down 10%	Unchanged	Up 10%	Up 20%
EIRR	2.2%	1.7%	1.1%	0.8%	0.5%

Source：JET

5-3-4 Recommendations from Economic and Financial Analysis

(1) The implementation of the Municipal Sewerage M/P is not viable from the viewpoint of economic and financial analysis using FIRR and EIRR as evaluation indicators. However, the National Development Plan of each country are different and varies, therefore, the significance of project implementation is also different based on national interests. FIRR and EIRR are just one of evaluation methods. It should not be simplified for policy maker to judge the validity of project implementation based on the results of these indicators only.

(2) Although the purpose of Municipal Sewerage M/P is not to focus on the ripple effect on other industries, such positive effect can be fully assumed as a result of sanitation effect. For example, tourism is an

[15] Based on Asian Development Bank's Cost-Benefit Manual (2017).

important industry in Fiji for around 40% of GDP, and Nadi, Lautoka are center of tourism. Needless to say, that the wastewater development and expansion plan, which is the cornerstone of public health in the western cities of Fiji, is indispensable for the development of the tourism industry and will bring about positive economic effects. In fact, the Fiji Tourism Department has shown great interest in implementing the Municipal Sewerage M/P through participation in stakeholder meetings. These qualitative economic effects should also be considered as project implementation factors.

(3) Sewerage is a highly public utility that is indispensable for improving living standards through sanitation, and the profitability of investment is not everything for business operators. However, stable business continuity requires at least an income that can cover daily operation and maintenance costs. The current fixed sewerage charge of 0.20 FJD/m^3 is not sufficient, and financial analysis has shown that it is essential to secure income from sewerage charges of at least 0.77 FJD/m^3 or higher for operation and maintenance. WAF should raise the price to this level with the understanding of sewerage users.

CHAPTER 6 O&M OF THE SEWERAGE SYSTEM

6-1 Necessary O&M Activities

6-1-1 Necessity of Appropriate O&M

(1) SewerNetworks

In order for sewer pipes to fully perform their functions, it is essential to check the condition of the pipes and implement countermeasures according to the condition. Otherwise, wastewater may overflow onto the ground.

If a pipe is damaged, cracked, or misaligned at a joint, groundwater and surrounding earth and sand will flow in, creating a cavity in the ground and causing a road collapse accident.

In addition, hydrogen sulfide is generated in places where wastewater tends to accumulate in sewer pipes, which can cause odors. If such a situation occurs, the sewer pipe will not be able to function, and there is a risk that it will interfere with people's lives and urban functions. (Importance of Sewer Pipe Management - Japan Sewer Pipe Management Association, 2021)

Therefore, proper maintenance of sewer pipes is a very important task in the management of sewerage works. The maintenance of sewer pipes is divided into preventive maintenance through patrols, inspections, and surveys, and corrective maintenance such as removal of clogging.

1) Patrols, inspections and surveys of sewer pipe networks

The management of sewer pipes begins with understanding the condition of the pipes. The first step in understanding the condition is patrol. Visually check the condition of the manhole cover and the road where the pipeline is buried from the ground, and abnormalities such as overflow of sewerage, subsidence of road surface, rattling of manhole cover, level difference with road surface, etc. are detected.

If any abnormal conditions are found in patrols and inspections, surveys will be conducted to understand the situation in detail. TV cameras are used to survey pipes of less than 800 mm that people cannot enter, and people or TV cameras are used to survey pipes of 800 mm or more. In addition, in order to grasp the state of deterioration of pipes, surveys are carried out systematically by determining survey areas.

Various types of abnormal conditions such as damage, corrosion, and infiltration inflow are found in pipe inspections and surveys, and the degree of abnormal condition is ranked to carry out pipe diagnosis.

The Sewerage Act revised in 2015 established maintenance and repair standards for sewerage facilities, and specified maintenance standards for pipes. The standard stipulates that patrols and inspections should be carried out at appropriate frequency, and that necessary measures should be taken if any abnormal conditions are detected. In addition, for pipes that are likely to corrode, inspections are required at least once every five years.

2) Cleaning of sewer pipe clogging

A frequent abnormal condition of sewer pipes is clogging due to the accumulation of various substances in the pipes. Blockages can be caused by tree roots, lard (oil), mortar, earth/sands, and in some areas by stalactites.

When clogging is confirmed, the cause is removed using high-pressure washing vehicles, etc. and powerful suction vehicles are used to suck and bring it out of the pipe for restoring the original function. Removed items are transferred to a disposal site.

3) Repair and replacement of damaged sewer pipes

If the abnormal condition of the pipe cannot be resolved by cleaning, repair or replacement works is needed according to the state and extent of the abnormal condition. If the damage is partial, it will be repaired. If the damage extends to the entire pipe between manholes, as replacement of the pipe itself or pipe rehabilitation will be carried out.

4) Stock management

Stock management in the sewerage-works is to manage sewerage facilities systematically and efficiently, for implementing sustainable sewerage-works, based on the role of sewerage business, with clear goals, while objectively grasping and evaluating facilities with predicting the long-term status of facilities. (Ministry of Land, Infrastructure, Transport and Tourism)

Table 6-1.1 shows the effects expected from the introduction of stock management.

Table 6-1.1 Effects of Introducing Stock Management

Effect		Details
1	Ensuring facility safety and maintaining good facility conditions	Appropriate inspections and surveys enable to grasp the condition of sewerage facilities and prevent troubles from occurring, thereby ensuring the safety and maintaining good conditions of facilities
2	Reducing lifecycle costs for the entire facility	It is possible to reduce the life cycle cost of the entire facility while maintaining good facility conditions.
3	Implementing appropriate and rational facility management	Appropriate and rational facility management is possible by taking measures in consideration of the order of priority based on risk assessment for deteriorated facilities.
4	Explaining of appropriate and rational facility management to residents, etc.	In order to obtain understanding of the necessity of the sewerage-works, it will be possible to explain information on facility conditions and maintain functional to residents in a visible form.

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

6-1-2 Operation Plan of Wastewater Treatment Plants

WWTPs consist of a wide variety of facilities and equipment, as well as associated devices, and if any one of these is out of order, it will adversely affect the whole.

Since wastewater treatment is generally a biological treatment, once an abnormal condition occurs and even if the cause has disappeared it takes a long time to obtain good effluent quality again. The most important thing is to manage it properly. Sewerage facilities are important social capital, and in today's social context, it is required to effectively utilize limited resources to realize a "sustainable society." It is important to systematically manage the facilities, effectively utilize the facilities for as long as possible (extend the service life) and reduce costs. In addition, continuity of management records, analysis of records and continuous review of management works are necessary. (Guidelines for sewerage maintenance and management 2014)

For systematic O&M of WWTPs, it is necessary to formulate the plans shown in **Table 6-1.2** first, and then implement O&M according to the plans.

Table 6-1.2 Plans Needed to be Formulated for Systematic O&M of Sewerage Treatment Facilities

1	**Operation**	
	Operation plan	Formulating an operation plan to comply with effluent standards, considering cost reduction related to treatment and response to abnormal condition
	Water quality management plan	Formulating a water quality management plan to comply with effluent standards and for obtaining optimal operating conditions for influent volume/quality, and activated sludge conditions
	Crisis management plan	Formulating a crisis management plan showing the management system and countermeasures against power-cut, fires, water outages, inundation, chemical leaks, equipment failures, etc.
	Health & safety plan	Formulating a H&S plan stipulating management systems/methods to prevent work-related accidents
2	**Daily inspection**	
	Daily inspection plan	Formulating a daily inspection plan defining inspection items, routes, methods (visual inspection numerical values, etc.), frequency (once/day, twice/week, etc.), and inspection standards (appropriate numerical range, etc.)
3	**Periodical Inspection, Administration of Repair**	
	Importance rank of equipment	Using the facility ledger, setting of an Important rank based on the impact on treatment functions, the impact on safety, the presence of stand-by, repair costs, years since installation, etc.
	Selection of administration method	Selecting preventive/corrective maintenance according to equipment Importance
	Setting of administration standards	Setting inspection criteria showing the range of abnormal condition Establishing repair standards indicating the necessary state of repair
	Administration plan, performance sheet	Creating a table of periodic inspections for each facility specifically showing implementation year, month, and implementation results

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

(1) O&M

According to the established operation plan, O&M of the treatment facility will be carried out so as to comply with the effluent standards at all times and to reduce treatment costs.

The activated sludge process such as OD process proposed in this project and IDEA process owned by WAF should be operated while paying attention to the points shown in **Table 6-1.3**.

Table 6-1.3 Notes on O&M of Activated Sludge Treatment Process

Facility		Notes
Wastewater treatment	Screen	• Transporting the screenings (preferably after washing) to the disposal site as soon as possible. • Cleaning the facility at least once a day for odor control
	Reaction tank	• Supplying the necessary amount of air (oxygen) to the tank. • Maintaining the activated sludge concentration required for treatment • Withdrawing Excess sludge so as to obtain an appropriate activated sludge concentration. • Operating at an appropriate return sludge ratio. (OD process) • Securing enough time for the activated sludge to settle. (IDEA process)
	Final settling tank	• Adjusting the returned sludge ratio so that activated sludge does not accumulate in the tank.
	Disinfection	• Adjusting the chlorine dosage so that the number of *E.coli* is below the standard value.
Sludge Treatment	Gravity thickener	• Determining the inflow sludge volume to ensure an appropriate thickened sludge concentration and prevent the sludge from rotting.
	Anaerobic digester	• Determining the inflow sludge volume so that methane fermentation proceeds sufficiently. • Making sure that the sludge agitator in the tank works well.
	Aerobic digester (using in Navakai)	• Determining the inflow sludge volume so that aerobic digestion proceeds sufficiently.
	Mechanical dewaterer	• Selecting and adding coagulant to achieve an appropriate sludge moisture content. • Supplying the amount of sludge suitable for the capacity of the dewaterer.
	Drying bed (Using in Navakai)	• Operating according to the weather conditions.

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014 and O&M status of WAF facilities

(2) Water Quality Management

Water quality examinations at WWTPs include (1) examinations to ensure compliance with effluent standards, and (2) examination to operate treatment facilities under optimal operating conditions for the amount and quality of influent and the properties of activated sludge.

The examinations are usually carried out with water samples, analyzing parameters, and frequency determined based on the water quality management plan. At the site of WWTPs, it is common practice to grasp the treatment status in real time using a simple analyzing method.

The most common methods are transparency and sludge volume (SV). The transparency is an index for the suspended solids (SS) and BOD concentration, and the SV is an index for the activated sludge concentration and sedimentation property of the activated sludge, so it is an extremely useful analysis.

(3) Crisis Management Plan

In sewerage facilities, emergencies may occur even if maintenance is sufficiently implemented. Emergency situations at sewerage facilities are listed in **Table 6-1.4.**

In order to minimize the damage to the surrounding residents and the functions of sewerage facilities, a crisis management plan that stipulates a communication system between related organizations, a management system for emergencies, response methods, etc. has to be formulated.

In the plan, it is necessary to clearly specify the implementation method and frequency of training for staff assuming an emergency situation, and to actually implement training on a regular basis.

Table 6-1.4 Emergency Situations at Sewerage Facilities

Emergency situation	Damages for the function of sewerage facilities
Power cut	Shutdown of equipment (if there is no generator)
Fire	Long-term stop operation due to equipment damage at a fire facility H&S issues
Water outage	Inability to secure cleaning water for equipment H&S issues
Inundation	Damage caused by submersion of equipment H&S issues
Chemical leakage	Damage on equipment H&S issues for staff and surrounding residents
Machine trouble	Long-term impact on the function of facility (if prompt repairs are not made)
Damage of pipe	Long-term impact on the function of facility (if prompt repairs are not made)

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

(4) Health and Safety plan

Even if no occupational accidents have occurred in a workplace, it does not necessarily mean that the workplace is "free from the risk of occupational accidents." It must be recognized that the risk of occupational accidents is always inherent. (Guidelines for maintenance of sewerage facilities 2014)

It is necessary to establish an "occupational Health and Safety (hereinafter referred to as "H&S") committee" to manage H&S in the workplace, and to formulate a H&S plan that indicates the H&S management system and management method.

1) Management system

It is necessary for each workplace to establish a management system that appoints personnel responsible for dangerous work such as scaffold assembly, oxygen deficiency work, crane work, etc., and appoints qualified personnel for electrical work, gas welding, boiler handling, etc.

2) Management method

i) Health and safety education

H&S education is important for staff to acquire the knowledge necessary for H&S issues that arise in the performance of their duties. The education is necessary when hiring new staff, when changing work content, and when staff performs dangerous or harmful work.

Table 6-1.5 shows examples of implementation items for H&S education. In addition to the items listed in the table, for example, arc welding, electrical work, crane work, and work in hazardous locations where there is a lack of oxygen, it is necessary to provide specified education for safe work execution.

Table 6-1.5 Examples of Implementation Items for H&S Education

1	Dangers of, hazards of, and handling methods of machinery and materials
2	Function and handling method of safety devices, hazardous substance control devices, and personal protective equipment (PPE)
3	Standard operation procedure (SOP)
4	Inspection at the start of work
5	Causes of work-related illnesses and preventive measures
6	Sort, Set in order, Shine, Standardize, Sustain
7	First-aid measures for accidents, Evacuation

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

ii) Hazards at workplace

The H&S committee on each workplace has to grasp various hazards hidden in the workplace (such as falling, lack of oxygen, toxic gas, rotating equipment, high voltage, etc.) and take necessary measures (such as proper clothing, set in order, safety inspection, enforcement of SOP, evacuation drills in the event of a disaster, etc.) to safely carry out of works.

iii) Secure work environment

Based on national safety standards and work standards, each workplace has to ensure working environment such as air environment (odor, harmful gas, oxygen, etc.), thermal environment (temperature, humidity), illuminance environment (brightness suitable for work), workspace (passage width, floor maintenance).

iv) First aid

In addition to the communication system and emergency transportation destinations in the event of an occupational accident, it is necessary to consider first-aids at workplace

The sewerage facilities deals with polluted sewerage and dangers such as lack of oxygen are also latent. Therefore, it is necessary to invite experts as instructors and conduct regular training on wound care, hemostasis, artificial respiration, etc.

v) Safety devices, personal protective equipment (PPE)

Staff has to use helmets and safety shoes at work sites. It is necessary to prepare safety belts for work at heights, ventilators, air respirators, oxygen analyzers, gas detectors, dust masks, earplugs, etc. for work in confined spaces. It is necessary to conduct regular training on how to use them.

6-1-3 Daily Inspection

Daily inspection is basic task to properly maintain facilities, and is an important duty that complements O&M and periodic inspection/repair.

Daily inspection work involves patrol inspections using the inspector's five senses, indicated values of instruments, simple tools and measuring instruments, etc., to understand daily trends in operation conditions and the presence of abnormalities, etc. for preventing failures and functional deterioration. This work is equivalent to a simple diagnosis related to the operational status of equipment.

It is important to continuously record the results of daily inspections in order to perform planned maintenance of equipment properly. (Guidelines for Maintenance of Sewerage Facilities 2014)

Therefore, a daily inspection plan that defines inspection items, routes, methods (visual, numerical values, etc.), frequency, and inspection standards (appropriate numerical range, etc.) has to be formulated. And based on this, daily inspections are carried out and inspection records are created.

Table 6-1.6 shows examples of daily inspection items.

Table 6-1.6 Examples of Daily Inspection Items

Inspection item	Details
Sensory inspection	Check for abnormal noise, odor, vibration, heat generation, etc.
Indicating value of gauge	Check whether the indicated gauge values such as current value and pressure are within the normal range
lubrication state	Check oil temperature, level, leakage
Connecting part of equipment	Check for looseness
State of deterioration	Check deterioration such as rust, corrosion, deformation, cracks, and damage
Environmental conditions	Check for abnormal noise, odor, dirt, etc. on the inspection route

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014)

6-1-4 Periodical Inspection, Repair Management

Periodic inspection and repair management will be carried out in the order of (1) setting importance rank of equipment, (2) selecting management methods, (3) setting management standards, and (4) creating a management plan and performance table.

i) Setting importance rank of equipment

The importance of equipment is ranked based on the evaluation items shown in **Table 6-1.7**.

Table 6-1.7 Evaluation Items of Importance Rank of Equipment

1	Impact on treatment function
2	Impact on safety (man-made disasters, pollution, secondary disasters)
3	Presence or absence of stand-by machine (or backup capacity)
4	Impact on repair/replacement costs and repair/replacement period
5	Passed years after installation of equipment
6	Impact on operation load (daily operation, emergency operation)
7	Presence or absence of legal restrictions

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014)

ii) Selecting management methods

"Preventive maintenance" is selected for facilities judged to be of high importance by the importance ranking so as not to cause failures and outages. “Corrective maintenance” is selected for equipment of low importance and that with stand-by.

iii) Setting management standards

In order to systematically repair equipment and replace parts, it is necessary to confirm the state of deterioration numerically. Management standards for judging the state of deterioration such as wear for facility are set, and carry out repairs and parts replacement according to the standards.

iv) Creating a management plan and performance table

In order to guarantee the reliability of facilities from a long-term perspective and to develop economical and efficient facility management, a management plan that indicates management items and frequency is formulated. It is necessary not only to make a plan for a single year, but also to create a mid-term and long-term plan based on a macro perspective spanning several years.

Table 6-1.8 is an example of a mid-term management plan for a submersible pump, showing the inspection frequency and inspection details for the main body, bearings, submersible motors, and protective device, as well as the frequency of parts replacement and repair by the manufacturer.

Table 6-1.8 Example of Mid-Term Management Plan

Submersible Pump	Inspection frequency								Inspection items	Spare parts & Manufacturer maintenance
	day	week	1 month	3 months	6 months	1 year	2 years	3 years		
Main Machine	*					✔			*: noise, vibration, pressure ✔: wear, corrosion	Spare parts: 2~5 years Manufacturer maintenance: 5~8 years
Bearing							✔		✔: refueling, Exchange	
Submersible motor					✔				✔: insulation, Resistance	
Protection device						✔			✔:conduction, operation check	

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

6-2 Operation Plan of Sewerage Facility

The organizational structure and division of work for proper operation and maintenance of the sewer pipelines, pumping stations, and wastewater treatment plants in the service area proposed in this project are shown below.

6-2-1 Budget and Implementation System

For appropriate O&M of sewerage facilities, it is important to secure a budget and determine various implementation systems as well as establish O&M system.

(1) Budget for O&M

At present, due to lack of personnel and budget, WAF has hardly performed even basic maintenance for ME equipment such as oil changes, and various ME equipment installed at WWTPs and pump stations is markedly degraded. By recognizing that the total cost can be reduced by extending the service life of equipment through priority maintenance based on the judgment of importance and diagnosis of deterioration, and by using the equipment beyond its normal service life, it is necessary to secure a budget for replacement parts and consumables for preventive maintenance.

In addition, even if proper maintenance is performed, equipment may fail and stop. For such failures, it is always necessary to secure a budget for prompt repairs according to the importance of the facility.

(2) Improvement of Working Conditions

The experience and expertise of staff are extremely important for O&M of sewerage facilities. According to the WAF, salaries for staff are not as low as those of private sectors, but there have been frequent cases of experienced staff leaving their jobs and moving to countries with higher salaries such as Australia. It makes difficult to inherit knowledge at sewerage facility. In order to improve this situation, it is necessary to review the staff salary system. If it is difficult to improve salaries, it is necessary to consider outsourcing a large amount of work to the private sector for ensuring the quality of O&M.

(3) Simplification of Procedures for Implementation of Outsourced Work

Even when proper maintenance is performed for mechanical and electrical equipment, failures and outages may occur. It is necessary to predetermine the priority of each facility according to its importance, the presence/absence of standby machine, etc., and to quickly conclude a repair contract with a manufacturer or a repairer so that emergency repairs can be made in the event.

(4) Outsourcing of O&M of Complex Treatment Facilities

In the case of introduction of facilities such as digestion gas power generation, the O&M of ME equipment will be extremely complicated, so it is necessary to consider outsourcing the O&M to manufacturers. Therefore, it is necessary to secure the required budget and smoothly conclude a contract with the manufacturer.

6-2-2 Sewer Pipes

(1) Proposal of Work Content and Implementation Method

The maintenance of sewer pipes are divided into preventive maintenance, which is planned maintenance based on patrols, inspections, and surveys, and corrective maintenance, which deals with troubles such as pipe clogging. Currently, WAF is not able to implement preventive maintenance at all, and the staffs in charge are busy with corrective maintenance.

The sewer pipes that were laid in Nadi in the 1970s and Lautoka in the 1980s have deteriorated year by year and are in a state of remarkable deterioration. Therefore, it will be necessary to carry out planned repairs and replacements of these pipes by introducing stock management. In addition, in the Western Division, it is necessary to expand the service area according to the M/P currently being formulated, and it is essential to expand the organizational structure related to the maintenance of sewer pipes.

As shown in **Table 6-2.1**, there are three options for improving the sewer pipe maintenance system, depending on how private contractors are used for post-maintenance.

Table 6-2.1 Improvement Method of Sewer Pipe Maintenance System in WAF West

<table>
<tr><th></th><th>Maintenance</th><th>Sharing</th><th>Detail</th><th>Rating</th></tr>
<tr><td rowspan="2">1</td><td>Preventive</td><td>WAF</td><td>Recruit the staff necessary for preventive maintenance.</td><td rowspan="2">Employment of staff required for preventive maintenance is necessary.
Employment of staff to carry out corrective maintenance using equipment is necessary.
Maintenance work for equipment will be newly generated.
⇒ Not recommended.</td></tr>
<tr><td>Corrective</td><td>WAF</td><td>Since all the work, including the work which is currently outsourced to the private sector such as works using the jet cleaning machine, , will be carried out by the WAF, it is necessary to recruit additional staff and procure equipment.</td></tr>
<tr><td rowspan="2">2</td><td>Preventive</td><td>WAF</td><td>Recruit the staff necessary for preventive maintenance.</td><td rowspan="2">Employment of staff required for preventive maintenance is necessary.
When pipe clogging occurs, WAF responds first, and when it cannot, it outsources to a private sector, which delays response.
⇒ Not recommended.</td></tr>
<tr><td>Corrective</td><td>WAF, Private</td><td>The WAF will handle minor pipe clogging, and the private sector will handle clogging that WAF cannot handle, which is the same sharing of duties as the present.
It is necessary to recruit staff as the service area expands.</td></tr>
<tr><td rowspan="2">3</td><td>Preventive</td><td>WAF</td><td>For the time being, patrol and inspection works will be conducted by the existing sewer pipe maintenance staff.
The pipe survey will be conducted by staff increase in stages.
Increasing staff as the sewerage area expands.</td><td rowspan="2">For the time being, there is no need to increase staff as the existing staff will conduct patrols and inspections.
It is realistic because of the gradual increase of staff.
All pipe clogging are dealt with by private sector, so the response is quick.
⇒ Recommended.</td></tr>
<tr><td>Corrective</td><td>Private</td><td>Since all corrective maintenance work is outsourced to the private sector, WAF does not need any staff in corrective maintenance.</td></tr>
</table>

Source: JET

Option 1 requires increase of staff required for preventive and corrective maintenance of sewer pipes, and maintenance of equipment necessary for pipeline maintenance.Therefore, it is not realistic for WAF, which currently cannot implement equipment maintenance at all.

Option 2 requires additional personnel for preventive maintenance of pipelines, but it is easy for WAF to deal with because corrective maintenance will be implemented in the same way as it is now. However, since the WAF staff will handle the repair of blocked pipes first, and if it cannot, it will be outsourced to a private sector, so the response may be delayed. Therefore, in the future, it is recommended that all corrective maintenance should be outsourced to the private sector for prompt response.

In Option 3, all corrective maintenance will be outsourced to the private sector, so all WAF staff will be able to work on preventive maintenance, and there will be no need to increase the number of staff for the time being.

Currently, WAF often provides free of charge for pipe clogging in private lands. However, in Plan 3, the residents will pay the fee to the private sector for trouble on the residential land, and the WAF will pay the fee to the private sector for trouble on the public area; therefore, there is an advantage that the payment division becomes clear.

Hence, Option 3 is the most recommended. On the other hand, since private sectors are entrusted with dealing with all corrective maintenance works, it is necessary to prepare materials, equipment and personnel the works, and WAF needs to provide guidance and training for private sector.

It is difficult to introduce the Option 3 to the WAF at an early stage, and it is appropriate to divide it into three stages as shown in **Table 6-2.2**.

Table 6-2.2 Introduction of Preventive and Corrective Maintenance in Sewer Pipe Maintenance

1st stage	Preparation for preventive maintenance	Preventive maintenance	*Staff training on preventive maintenance *Review of the sewer pipe ledger created by the GIS unit
		Corrective maintenance	*Increase in the number of cases of pipe clogging response outsourced to the private sector *Preparation of construction records *Training of private sector
2nd stage	Stepwise introduction of preventive maintenance	Preventive maintenance	*Commencement of patrols throughout the entire area based on the pipe ledger *Implementation of inspections for locations where pipe troubles have occurred
		Corrective maintenance	*Implementation of preventive maintenance by large-scale outsourcing to the private sector
3rd stage	Full implementation of preventive maintenance	Preventive maintenance	*Conducting detailed surveys using television cameras, etc., for areas where damages were found during patrols and inspections *Prioritize repair/replacement based on risk matrix on survey results, and formulate repair/replacement plan
		Corrective maintenance	*Entirely outsourced to the private sector

Source: JET

In the first stage, the preventive maintenance will be prepared by WAF. Trainings will be provided to improve the capacity of staff to perform preventive maintenance, and the activities to check whether the pipe ledger by the GIS section is correct. With regard to corrective maintenance, WAF will support for developing private sector and create an atmosphere that facilitates outsourcing.

In the second stage, the preventive maintenance will be gradually introduced. Regular patrols of pipe facilities and pumping stations will be started based on the ledger, and inspections will be carried out focusing on areas where pipe trouble has occurred to grasp the state. Regarding the corrective maintenance, a large amount of work will be outsourced to well-developed private sector.

In the third stage, the preventive maintenance will be completely implemented. And detailed surveys using television cameras, etc., are carried out for areas where pipe damages were found during patrols and inspections. And based on the results of the detailed surveys, priority is given to repair/replacement works based on the risk matrix, and a repair/replacement plan is formulated. Concerning the corrective maintenance, Pipe troubles will be fully outsourced to the private sector.

(2) Proposal of Organization

Table 6-2.3 shows the organizational structure for the phased introduction of preventive maintenance of sewer pipes and the phased outsourcing of corrective maintenance to the private sector such as response to pipe clogging, which is shown in **Table 6-2.2**.

Table 6-2.3 Organization Structure for Maintenance of Sewer Pipes (Proposed)

Municipality	Title	Current number of staff	1st stage	2nd stage	3rd stage
			Preparation	Stepwise introduction	Complete implementation (Increase of sewerage service area)
Nadi	Pipe fitter	3	3	3	5
	Technical Assistant	3	3	3	5
	Other	2	2	2	3
Lautoka	Pipe fitter	2	3	3	5
	Technical Assistant	3	3	3	5
	Other	0	2	2	3
Ba	Pipe fitter	4	4	4	4
	Technical Assistant	2	2	2	3
	Other	0	0	0	2
Sigatoka	Pipe fitter	1	2	2	4
	Technical Assistant	1	2	2	3
	Other	0	0	0	2
Total	Pipe fitter	10	12	12	18
	Technical Assistant	9	10	10	16
	Other	2	4	4	10

Source: JET based on the WAF data

In the first stage, in order to eliminate differences between municipalities, the number of staff will be increase by 3 in Lautoka and 2 in Sigatoka, and start reviewing the pipe ledgers.

In the second stage, the number of WAF staff will not be increased, and corrective maintenance work will be largely outsourced to the private sector.

In the third stage, the number of personnel will be increased by 18 in order to start detailed surveys of pipes using TV cameras in addition to patrols and inspections. If it is difficult to increase the number of staff, it is also necessary to consider outsourcing the detailed survey of the pipe to the private sector.

6-2-3 Pumping Stations

(1) Proposal of Work Content and Implementation Method

For appropriate O&M of the pumping station, a mid-term management plan, an example of which is shown in **Table 6-1.8**, should be prepared and It is necessary to carry out planned inspections and periodic maintenance of the facilities accordingly.

Currently, the sewer pipe maintenance team is in charge of dealing with clogging of pumps, and the ME team is in charge of patrols, inspections, surveys, and repairs of pumping stations.

However, due to a shortage of personnel, patrols are being carried out, but detailed inspections and surveys by disassembling the equipment have not been carried out, and the deterioration of the equipment is progressing remarkable. For improving the situation, it is necessary to carry out regular maintenance involving planned inspections and parts replacement by increasing the number of members of the ME team and . However, according to WAF the turnover rate of mechanical and electrical staff is high, making it difficult to significantly increase the number of staff.

Therefore, it is appropriate to gradually shift to outsourcing the response to pump clogging to the private sector, to have the pipe maintenance management team conduct patrols (daily inspections) of pumping stations, and to conduct periodic inspections, investigations, and repairs by the ME team.

The proposed division of duties of the sewer pipe maintenance team and the ME team is shown in **Table 6-2.4**.

Table 6-2.4 Division of Duties in Pump Station Maintenance

Sewer Pipe Maintenance team	1. Gradual outsourcing of response to clogged pumps to the private sector 2. Cleaning of pumping stations, and preparation of record of cleaning 3. Implementation of daily inspections by patrolling pumping stations based on the mid-term management plan 4. Create patrol records 5. Sharing records with ME team and the management level of WAF West
ME team	1. Periodic inspection of wear, deterioration and damage of pumps, instrumentation panels, piping, etc., referring to patrol records 2. Conduct a detailed survey based on the inspection results, and determine the necessity of repair according to a predetermined priority based on the importance of the equipment and the presence/absence of stand-by equipment. 3. Based on the survey results, if it is determined that parts replacement or repair is necessary, it will be carried out by WAF or outsourced to a contractor.

Source: JET

In order for WAF West to carry out the above maintenance, it is essential to create a facility ledger, a mid-term and long-term management plan for the facility, and to secure personnel and budget, which is difficult to implement immediately. Therefore, it is realistic to make step-by-step improvements as shown in **Table 6-2.5**.

Table 6-2.5 Step-by-Step Improvement of Pump Station Maintenance

1st stage	Sewer pipe maintenance team	· Promoting outsourcing of corrective maintenance of sewer pipe facilities, including pumping stations, to the private sector · Creating a mid-term, long-term management plan for pumping station equipment in collaboration with the ME team and the WAF West management level · Patrols of pumping stations, detection and recording of abnormal conditions, and sharing of patrol results with other parties
	ME team	· Increase of the number of staff · Creation of equipment ledger · Preparation of a mid-term, long-term management plan for pumping station facilities in collaboration with sewer pipe maintenance team and WAF West management level · Pump repair (same as the current work)
2nd stage	Sewer pipe maintenance team	· Promotion of further outsourcing of corrective maintenance of pipe facilities to the private sector · Outsourcing pump cleaning works to the private sector · Patrols of pumping stations, detection and recording of abnormal conditions, and sharing of patrol results with other parties
	ME team	· Further increase the number of staff (if it is difficult, consider further outsourcing to the private sector) · Implementation of regular inspections of equipment based on the mid-term, long-term management plan · Implementation of regular maintenance of equipment based on the mid-term, long-term management plans · Pump repair (same as the current work)

Source: JET

As mentioned above, the turnover rate of mechanical and electrical personnel is high, and it is not easy to increase the number of personnel significantly. It is also necessary to consider outsourcing inspection works to the private sector.

(2) Proposal of Organization

As shown in **Table 6-2.1**, the sewer pipe maintenance team is in charge of routine patrols and cleaning of pumps, and the organizational structure is shown in **Table 6-2.3**. And the ME team is in charge of preventive maintenance through periodic inspection and maintenance of pump facilities, as well as preventive maintenance of WWTP facilities.

The ME team maintains not only the sewerage system but also the water supply system. It is considered to be efficient in Fiji where it is difficult to secure mechanical and electrical technicians.

In order to implement preventive maintenance of various water supply and sewerage facilities in the western division, the organization of Case-1 shown in **Table 6-2.6** is required.

Table 6-2.6 Organization Structure of ME Team (Proposed)

	Case-1			Case-2 (Outsourcing Periodical maintenance and major machine repairs to the private sector)		
	Inspection-1	Inspection-2	Repair	Inspection-1	Inspection-2	Repair
Supervisor (Mechanical)	1			1		
Mechanic	2	3	1	1	1	1
Electrician	1	1	1	1	1	1
Technical support	2	2	2	1	1	2

Source: JET based on the discussion with ME team
Inspection-1: In charge of Nadi, Sigatoka
Inspection-2: Lautoka, Ba, Tavua, Rakiraki

Staff in charge of inspection and maintenance and staff in charge of repair will be placed under the supervisor. Since inspection and maintenance will basically be carried out at the site where the equipment is installed, the staff in charge will be divided into those in charge of Nadi and Sigatoka and those in Lautoka, Ba, Rakiraki and Tabua, and will carry out regular maintenance such as regular inspection and grease replacement. The repair staff basically repairs equipment failures at the ME team workshop in Lautoka. The current number of staff is 9, but in order to implement preventive maintenance of equipment, the number of staff will need to increase to 16.

On the other hand, if the periodical maintenance of complex equipment and heavy machinery repairs are outsourced to the private sector, the required number of staff will be 11, as shown in Case-2 of **Table 6-2.6**, avoiding a significant increase in staff. When outsourcing work to the private sector, it is necessary to improve the procurement system so that contracts can be signed quickly.

6-2-4 WWTP

(1) Proposal of Work Content and Implementation Method

The O&M of a sewerage treatment plant varies depending on the wastewater treatment process. In order to obtain optimum effluent quality in the activated sludge process such as IDEA process used in Navakai WWTP in Nadi and OD process, appropriate operation of various equipment installed, and frequent change of operation factors such as activated sludge concentration is necessary.

Therefore, it is necessary for operation staff to conduct patrols, inspections, and simple water quality tests to constantly grasp the operation status.

On the other hand, in the stabilization pond process used at the Natabua WWTP in Lautoka, etc., there is basically no operation, so patrol monitoring by one or two staff members is sufficient.

Table 6-2.7 shows daily patrol and inspection works at the WWTP using the activated sludge process. O&M staff will inspect and record the items shown in the table at the treatment site.

Table 6-2.7 Daily Patrol and Inspection Works at Activated Sludge Process WWTPs

Item	Details of work
Visual inspection of treatment status	• Offensive odors: For example, rotten odors from screen facilities, depositing site of screenings, reaction tanks, sedimentation tanks, gutters, etc. • Abnormal colors: For example, blackening due to decay of activated sludge or effluent
Operating status of mechanical and electrical equipment	• Failure stop, abnormal noise, abnormal vibration, etc. • Operating status of machinery equipment • Check and record of indicated value of gauges, such as temperature, current, voltage

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

In Japan, WWTPs where staffs are stationed are instructed to implement simple water quality tests such as air temperature, water temperature, transparency, pH, and activated sludge sedimentation rate (SV) at fixed times every day. (Guidelines for Maintenance of Sewerage Facilities 2014)

But at the 4 WWTPs in the Western Division, no such test is carried out, except for monthly tests conducted by the WAF Central Water Quality Laboratory. This is because field staffs do not have knowledge of the importance of water quality measurement and how to measure it, and the most importantly, they do not have the equipment necessary for the tests. Routine water quality testing is an important task for judging the O&M status, and WAF has to improve the situation.

Table 6-2.8 shows recommended daily water quality test parameters, test objectives, and implementation methods for WWTPs using the activated sludge treatment process. Measurement of dissolved oxygen of activated sludge (MLDO) in the table requires a relatively expensive instrument, and until WAF can procure it, measurement of transparency and activated sludge settling rate (SV) will be recommended.

Table 6-2.8 Daily Water Quality Test Works in Activated Sludge WWTPs

Parameter	Objective of test	Measuring method
Transparency	It is possible to measure only by using a cylinder. The transparency of effluent is correlated with the suspended solids (SS) and BOD and serves as an indicator of effluent quality.	Measure the effluent transparency at the same time every day and record it Periodically graph the transparency data (horizontal axis: day, vertical axis: transparency) and observe monthly and yearly fluctuation. Graph the transparency and SV data (horizontal axis: transparency, vertical axis: SV) and analyze the effect on effluent quality when the activated sludge concentration in the reaction tank is high or low.
activated sludge settling rate (SV)	It is possible to measure only by a cylinder. It serves as an indicator for activated sludge concentration. For the IDEA process, the settling time required in the IDEA tank can be estimated from the settling properties of the sludge.	Measure the SV of the activated sludge in the reaction tank at the same time every day and record it. Periodically graph the SV data (horizontal axis: day, vertical axis: SV) and use it as an indicator for the excess sludge withdrawal from the reaction tank.
dissolved oxygen of activated sludge (MLDO)	Serves as an indicator for controlling the air supply. It is possible to monitor the active condition of microorganisms in activated sludge.	Measure the dissolved oxygen concentration (MLDO) in the reactor at the same time every day and record it. If the MLDO is too low, the activity of activated sludge microorganisms will drop and the treatment performance will decrease.

Source: JET based on the Guidelines for Maintenance of Sewerage Facilities 2014

Excess sludge is not removed periodically in the IDEA tank of the Navakai WWTP, and the sludge concentration sometimes becomes too high, resulting in the deterioration of effluent quality.

Therefore, as shown in the table, it is necessary to continuously measure the effluent transparency and SV for accumulating data, and graphically showing the relationship between the two based on the data, to understand how much the SV increases (the activated sludge concentration increases) and the transparency of the treated water decreases (the effluent quality deteriorates)

This relationship can then be used to estimate the appropriate sludge withdrawal interval.

The results of patrols, inspections, and water quality tests shall be recorded in the prescribed record form and stored appropriately. If an abnormality is found, a report including the items shown in **Table 6-2.9** shall be prepared and submitted. Upon receipt of the report, the supervisor writes instructions on how to respond in the report. The report will be valuable information for O&M, so it should be saved properly.

Table 6-2.9 Items in the Report of Abnormal Condition

Reporting items	Name of staff who found
	Date and time found
	Abnormal facilities and equipment:
	Specific condition of the anomaly:
	Possible causes:
	Possible counter measures
Instruction of supervisor	Name of supervisor
	Instructions on how to respond to reports
Response to the instruction	Name of staff who respond
	Date and time responded
	Result of response
	Need for further action

Source: JET

It is necessary to provide training to the O&M staff at WWTPs on the meaning of patrols/inspections, and regular water quality tests, how to conduct them, and how to record and report them.

(2) Proposing Organization

The organizational structure for implementing O&M of WWTPs differs depending on the sewerage and sludge treatment process. **Table 6-2.10** shows the treatment process and capacity, as well as the proposing O&M methods of the five WWTPs proposed in Nadi and Lautoka.

Table 6-2.10 Treatment Process/Capacity and Proposing O&M Method for WWTPs

Municipality	WWTP	Wastewater Treatment		Sludge Treatment	O&M method
		Process	Capacity (m^3/day)		
Nadi	Navakai	OD	29,800	Excess sludge: Thickening⇒Mechanical dewatering ⇒Sun drying	M-1
	Moala	TF	19,300	Primary sludge: Thickening⇒Transport to Natabua Excess sludge: Mechanical dewatering ⇒Sun drying	M-2
	Sabeto	TF	7,100	Primary sludge: Thickening⇒Transport to Natabua Excess sludge: Mechanical dewatering⇒Sun drying	M-3
Lautoka	Natabua	TF	44,400	Primary sludge: Thickening⇒Anaerobic digestion ⇒Mechanical dewatering ⇒Sun drying Excess sludge: Anaerobic digestion ⇒Mechanical dewatering⇒Sun drying Septage: Anaerobic digestion ⇒Mechanical dewatering⇒Sun drying * Accepting primary sludge from other WWTPs into the digester *Accepting septage from 6-city/town into the digester	M-1
	Vitogo	TF	7,100	Primary sludge: Thickening⇒Transport to Natabua Excess sludge: Mechanical dewatering⇒Sun drying	M-3

Source: JET

Table 6-2.11 shows specific O&M implementation methods for each of M-1 to M-3 shown in the O&M method of **Table 6-2.10.**

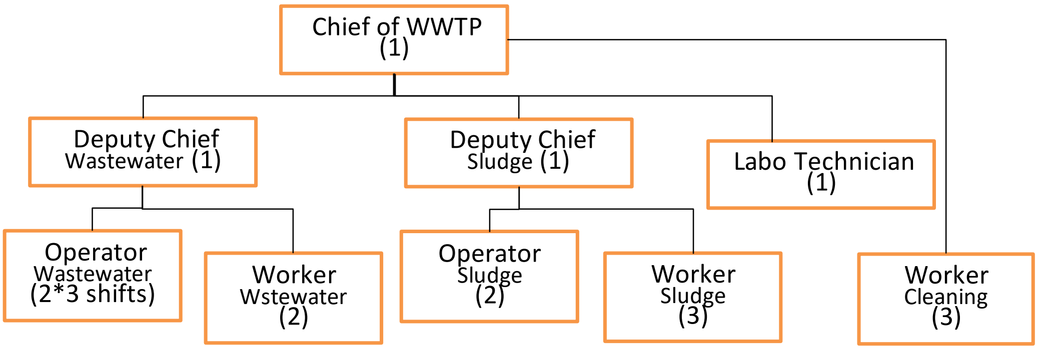
Table 6-2.11 O&M Implementation Method

M-1	Operation	Operation of sewerage/sludge treatment facilities in 3 shift
	Maintenance	Patrol/inspection/maintenance works during daytime
	Water quality test	Simple test of pH, transparency, SV (in OD process), Dissolved Oxygen
M-2	Operation	Operation of sewerage/sludge treatment facilities in 2 shifts, Remote monitoring from the core WWTP at night
	Maintenance	Patrol/inspection/maintenance works during daytime
	Water quality test	Simple test of pH, transparency
M-3	Operation	Resident operation of sewerage/sludge treatment facilities during the daytime, Remote monitoring from the core WWTP at night
	Maintenance	Patrol/inspection/maintenance works during daytime
	Water quality test	Simple test of pH, transparency

Source: JET

1) Navakai WWTP

OD process in sewerage treatment and mechanical dewatering/sun drying in sludge treatment is proposed in Navakai WWTP in Nadi. Since the treatment capacity is large and the effluent must comply with the SEZ, it is necessary to pay attention to operation compared to other WWTPs. The proposed organization is shown in **Figure 6-2.1**, and the proposed duties of each staff in charge in the figure are shown in **Table 6-2.12**.



Source: JET

Figure 6-2.1 Proposing Organization Structure of Navakai WWTP

Table 6-2.12 Proposing Duties of Staff in Charge of Navakai WWTP

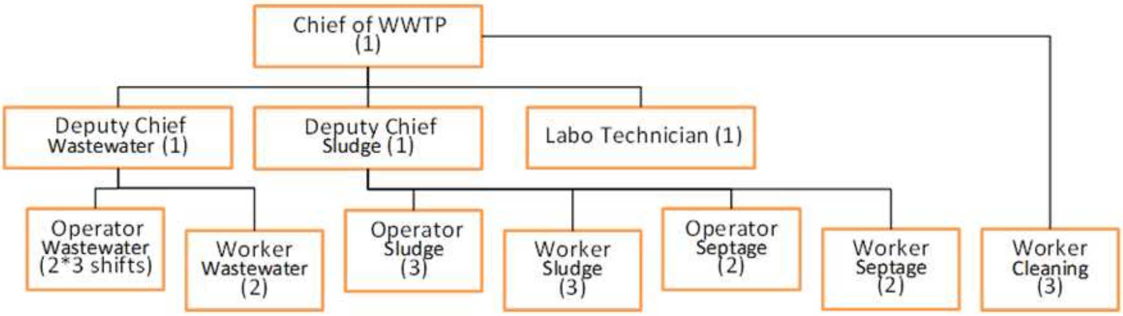
Position		Main duties
Chief of WWTP		• Management of WWTP
Wastewater treatment	Deputy Chief (Wastewater)	• Operation management of sewerage treatment facilities • Management of daily/monthly reports
	Operator (Wastewater)	• 3 shifts • Operation of sewerage treatment facilities • Visual inspection of treatment status • Checking the operation status of mechanical/electrical equipment • Preparation of daily reports
	Worker (Wastewater)	• Support for visual inspection and inspection of operation status • Screenings/scum removal works
Sludge treatment	Deputy Chief(Sludge)	• Operation management of sludge treatment facilities • Management of daily/monthly reports
	Operator (Sludge)	• Operation of sludge treatment facilities • Preparation of coagulant liquid • Measurement of sludge moisture contents • Preparation of daily reports
	Worker (Sludge)	• Support for preparation of coagulant liquid • Cleaning of sludge treatment facilities
Laboratory Technician		• Implementation of simple water quality test • Preparation of daily water quality reports • Management of water quality data of other WWTPs
Worker (Cleaning)		• Housekeeping, cleaning of WWTP • Routine tasks

Source: JET

2) Natabua WWTP

In Natabua WWTP in Lautoka, 2-stage trickling filter process is proposed for sewerage treatment, and thickening/anaerobic digestion/mechanical dewatering/ sun drying process is for sludge treatment. The WWTP plans to receive thickened sludge from 3 other WWTPs (excluding Navakai WWTP), and septage from Ba and Ra provinces to the anaerobic digesters. Since the operation of the biogas utilization facility to be constructed at the WWTP will be outsourced to the private sector, O&M of the digesters and biogas utilization facility will not be included in the proposed organization.

The proposing organization structure of the WWTP is shown in **Figure 6-2.2,** and the proposing duties of each staff in charge in the figure are shown in **Table 6-2.13**.



Source: JET

Figure 6-2.2 Proposing Organization Structure of Natabua WWTP

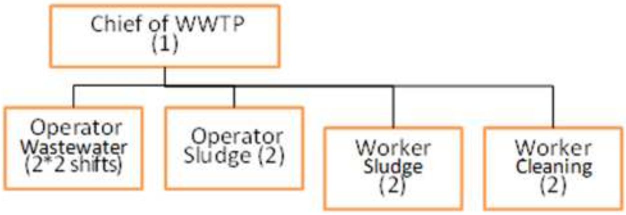
Table 6-2.13 Proposing Duties of Staff in charge of Natabua WWTP

Position		Main duties
Chief of WWTP		• Management of WWTP
Wastewater treatment	Deputy Chief (Wastewater)	• Operation management of sewerage treatment facilities • Management of daily/monthly reports
	Operator (Wastewater)	• 3 shifts • Operation of sewerage treatment facilities • Visual inspection of treatment status • Checking the operation status of mechanical/electrical equipment • Preparation of daily reports
	Worker (Wastewater)	• Support for visual inspection and inspection of operation status • Screenings/scum removal works
Sludge treatment	Deputy Chief (Sludge)	• Operation management of sludge treatment facilities • Operation management of septage acceptance/ treatment facilities • Management of daily/monthly reports
	Operator (Sludge)	• Operation of sludge treatment facilities • Preparation of coagulant liquid • Measurement of sludge moisture contents • Preparation of daily reports
	Worker (Sludge)	• Support for preparation of coagulant liquid • Cleaning of sludge treatment facilities
Septage treatment	Operator (Septage)	• Septage accepting works • Operation of septage treatment facilities • Preparation of septage acceptance and treatment reports
	Worker (Septage)	• Support for septage acceptance • Support for operation of septage treatment facilities • Cleaning of septage acceptance and treatment facilities
Laboratory Technician		• Implementation of simple water quality test • Preparation of daily water quality report • Management of water quality data of other WWTPs
Worker (Cleaning)		• Housekeeping, cleaning of WWTP • Routine tasks

Source: JET

3) Moala WWTP

The effluent standard of Moala WWTP in Nadi is General standards, and the primary sludge is transported to Natabua WWTP, so the implementation of O&M is easier than the above 2 WWTPs. Therefore, it is proposed that O&M will be carried out by 2 shifts stationed only during the daytime, and remote monitoring from the Navakai WWTP will be carried out at night. As for simple water quality tests conducted at WWTP, a laboratory technician in Navakai WWTP will make daily patrols and implement tests. The proposing organization structure of the WWTP is shown in **Figure 6-2.3**, and the proposed duties of each staff in charge in the figure are shown in **Table 6-2.14**.



Source: JET

Figure 6-2.3 Proposing Organization Structure of Moala WWTP

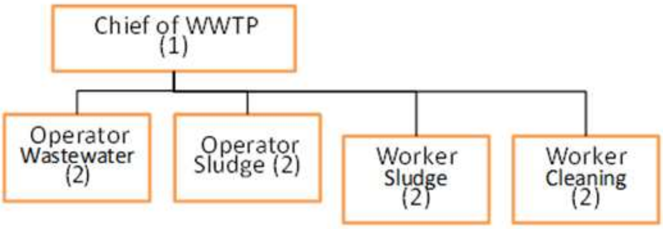
Table 6-2.14 Proposing Duties of Staff in Charge of Moala WWTP

Position	Main duties
Chief of WWTP	• Management of WWTP • Operation management of sewerage treatment facilities • Management of daily/monthly reports
Operator (Wastewater)	• 2 shifts • Operation of sewerage treatment facilities • Visual inspection of treatment status • Checking the operation status of mechanical/electrical equipment • Preparation of daily reports
Operator (Sludge)	• Operation of sludge treatment facilities • Preparation of coagulant liquid • Measurement of sludge moisture contents • Preparation of daily reports
Worker (Sludge)	• Support for preparation of coagulant liquid • Cleaning of sludge treatment facilities
Worker (Cleaning)	• Housekeeping, cleaning of WWTP • Routine tasks

Source: JET

4) Sabeto, Vitogo WWTP

Since Sabeto and Vitogo WWTP is small in scale and O&M is much easy than others, it is proposed that WWTPs will be stationed during the daytime and remote monitoring at night from Navakai and Natabua WWTP, respectively. The proposing organization structure of the WWTP is shown in **Figure 6-2.4**, and the proposing duties of each staff in charge in the figure are shown in **Table 6-2.15**.



Source: JET

Figure 6-2.4 **Proposing Organization Structure of Sabeto and Vitogo WWTP**

Table 6-2.15 Proposing Duties of Staff in Charge of Sabeto and Vitogo WWTP

Position	Main duties
Chief of WWTP	• Management of WWTP • Operation management of sewerage treatment facilities • Management of daily/monthly reports
Operator (Wastewater)	• Operation of sewerage treatment facilities • Visual inspection of treatment status • Checking the operation status of mechanical/electrical equipment • Preparation of daily reports
Operator (Sludge)	• Operation of sludge treatment facilities • Preparation of coagulant liquid • Measurement of sludge moisture contents • Preparation of daily reports
Worker (Sludge)	• Support for preparation of coagulant liquid • Cleaning of sludge treatment facilities
Worker (Cleaning)	• Housekeeping, cleaning of WWTP • Routine tasks

Source: JET

CHAPTER 7 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

7-1 Project Components Related to Environmental and Social Impacts

A purpose of environmental and social considerations in the Master Plan (M/P) stage is to examine the environmental and social implications as early as possible and take into account their impacts in decision making for an individual project planning, so that significant environmental and social impacts can be avoided and minimized in the development stage. The Regional Wastewater M/P, the superordinate plan of this M/P, was developed to formulate a comprehensive framework with applying the principles of strategic environmental assessment (SEA) for improvement of wastewater treatment, including on-site and off-site, in the Western Division of Fiji. In this Municipal Sewerage M/P, a SEA at municipality level is conducted based on a current status of the wastewater treatment, and environmental and social aspects in Lautoka and Nadi for more detailed environmental and social considerations, taking into account the SEA results of the Regional Wastewater M/P.

Possible project components at this M/P stage are shown in **Table 7-1.1** and **Table 7-1.2**. It should be noted that the scale of land acquisition for a sewerage treatment plant depends on how many service areas are set up, and what treatment system is employed. Based on the Regional Wastewater M/P, maximum 2 service areas are considered for Lautoka, and 3 service areas for Nadi.

Table 7-1.1 Possible Project Components (Lautoka)

Project Component Facility	Description
Sewerage treatment plant	Rehabilitation of the existing plant with land acquisition (Natabua) Construction of new plant (Vitogo)
Pumping stations	Construction of new pumping stations, and rehabilitation of the existing pumping stations with or without land acquisition
Sewer lines	Sewer line construction and rehabilitation to connect to sewerage system (trunk sewers, sub-trunk sewers, collecting sewers etc.)
Sludge recycling plant	Construction of a biogas plant (Natabua)
Septage treatment/recycling plant	Construction of a septage treatment/recycling plant (Natabua)

Source: JET

Table 7-1.2 Possible Project Components (Nadi)

Project Component Facility	Description
Sewerage treatment plant	Rehabilitation of the existing plant with land acquisition (Navakai) Construction of new plant (Sabeto and Moala)
Pumping stations	Construction of new pumping stations, and rehabilitation of the existing pumping stations with or without land acquisition
Sewer lines	Sewer line construction and rehabilitation to connect to sewerage system (trunk sewers, sub-trunk sewers, collecting sewers etc.)

Source: JET

7-2 Environmental and Social Consideration System and Organization

Laws and regulations for environmental and social consideration, and related organizations are summarized in **APPENDIX 8-1**. There are no bylaws related for environmental and social considerations developed by Lautoka City Council or Nadi Town Council.

7-3 Gaps between JICA Guidelines and Fijian Regulations

As the basic framework of environmental and social considerations, comparison between the JICA Environmental and Social Considerations Guidelines (hereinafter referred to as "JICA Guidelines") and Fijian regulations are summarized in **Table 7-3.1** with proposed measures for observed significant gaps.

Table 7-3.1 Comparison between JICA Guidelines and Fijian Regulations

#	Item	JICA Guidelines	Fijian legislation	Gaps	Proposed measures
1.	Underlying Principles	Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan. (Appendix 1)	Under Environmental Management Act 2005, EIA is required for Sewerage related projects, that include alternative analysis, mitigation measures. However, SEA has not been regulated yet.	There is no regulation to apply SEA for master plan planning.	SEA is applied for master plan development in accordance with JICA Guidelines.
2.	Information Disclosure	- EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them. - EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted. (Appendix 2)	EIA Process Regulations 2007 requires: - Public consultation meetings in scoping and EIA report stages - Use of common languages in the project area - Disclosure of EIA report for public review	There is no gaps observed between JICA Guidelines and Fijian Legislation.	-
3.	Stakeholder meetings	- For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local residents, must be conducted via disclosure of information at an early stage, at which time	EIA Process Regulations 2007 states that public participation in scoping involves discussions with the proponent, the	There is no gaps observed between JICA Guidelines and Fijian Legislation.	-

#	Item	JICA Guidelines	Fijian legislation	Gaps	Proposed measures
		alternatives for project plans may be examined. The outcome of such consultations must be incorporated into the contents of project plans. (Appendix 1) - In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared. (Appendix 2) - Consultations with relevant stakeholders, such as local residents, should take place if necessary throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared. (Appendix 2)	approving authority (if not the processing authority), scientific institutions, local community leaders and others to include all the possible issues and concerns raised by these various groups.		
4.	Assessment items	- The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. These also include social impacts, including migration of population and involuntary resettlement, local economy such as employment and livelihood, utilization of land and local resources, social institutions such as social capital and local decision-making institutions, existing social infrastructures and services, vulnerable social groups such as poor and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working	Although the EIA Process Regulations 2007 requires various groups participation in the EIA developing process, there is no specific social consideration items to be considered.	From the Fiji Legal Framework, there does not appear to be any specific requirements for the social impact assessment, with regards to giving special attention and good practice to the needs and concerns of the vulnerable groups like women, youth, elderly, the disabled, people in poverty, indigenous people, refugees, displaced persons and minorities.	Social consideration is taken into account in master plan and individual projects in accordance with JICA Guidelines.

#	Item	JICA Guidelines	Fijian legislation	Gaps	Proposed measures
		conditions including occupational safety. (Appendix 1) - In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project. (Appendix 1)			
5.	Monitoring, grievance mechanism etc.	- Project proponents etc. should make efforts to make the results of the monitoring process available to local project stakeholders. (Appendix 1) - When third parties point out, in concrete terms, that environmental and social considerations are not being fully undertaken, forums for discussion and examination of countermeasures are established based on sufficient information disclosure, including stakeholders' participation in relevant projects. Project proponents etc. should make efforts to reach an agreement on procedures to be adopted with a view to resolving problems. (Appendix 1)	Not observed in Fijian regulations.	In Fijian regulations, there is no specific description of requirement to disclose monitoring results to local stakeholders, or specific grievance mechanisms.	Disclosure of monitoring results of a project, and grievance mechanism development is considered in accordance with JICA Guidelines.
6.	Ecosystem and Biota	- Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests. (Appendix 1)	The Environmental Management Act 2005 is for "protecting the environment" means the establishment of measures to ensure the protection of human health, safety, property, legitimate uses of the environment, species of flora and fauna, ecosystems, aesthetic properties and cultural resources, or preventing nuisance or	There is no gaps observed between JICA Guidelines and Fijian Legislation.	-

#	Item	JICA Guidelines	Fijian legislation	Gaps	Proposed measures
			risk of harm to any such value, on a sustainable basis.		
7.	Indigenous Peoples	Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. When, after such an examination, avoidance is proved unfeasible, effective measures must be taken to minimize impacts and to compensate indigenous peoples for their losses. (Appendix 1)	The Environmental Management Act 2005 states "A person required to perform any function under this Act relating to the use and utilization of natural and physical resources must recognize and have regard to the following matters of national importance: (d) the relationship of indigenous Fijians with their ancestral lands, waters, sites, sacred areas and other treasures."	There is no gaps observed between JICA Guidelines and Fijian Legislation.	-

Source: JET

7-4 Environmental and Social baselines

7-4-1 Designated Areas for Conservation of Nature and Cultural Heritages

In Fiji, protected areas are designated by various organizations such as the National Protected Areas Committee, Locally Managed Marine Area (LMMA) Network, Birdlife International, and Ministry of Forest, and most of the protected activities involve local communities. According to World Database on Protected Areas (WDPA)[16], there are currently 146 protected areas, including 117 marine protected areas and 28 terrestrial protected areas.

There are no protected areas found in and near the M/P target areas of Lautoka and Nadi. However, according to National Ocean Policy 2020-2030, the government is planning to increase marine protected areas up to 30% of Fijian ocean (including coastal zones) by 2030, and various surveys and planning have been ongoing; Thus, coastal areas and mangrove stands in Lautoka and Nadi may be designated as marine protected areas in the future.

7-4-2 Biodiversity[17]

Fiji has rich mangroves stands in the coastal intertidal zone, which is the third largest among all Oceanian Island countries. However, the area tends to become smaller from 46,150 ha in 1991 to 43,650 ha in 2007,

[16] https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA
[17] National Biodiversity Strategy and Action Plan for Fiji 2020-2025, and Biophysically Special, Unique Marine Areas of Fiji

possibly caused by urbanization, tourism development, waste disposal, and wastewater discharge. Mangrove forest degradation causes destruction of the vulnerable ecosystem, leading to loss of important habitats, difficulty of local people's mangrove use, malfunction of water filtration system, and loss of carbon sinks as a mitigation measure against climate change. DOE drafted the mangrove management plan in 2013, but it has never been approved as an official document, resulted in no comprehensive policies of mangrove protection for a long time. Currently, the Mangrove Conservation and Management Regulations is under preparation and expected to be issued soon. According to DOE[18], at a development project stage, disturbance of mangrove forests or any other vulnerable areas should be avoided as first priority, but depending on situations, mangrove offsets (e.g., 6 mangrove planting per 1 cutting) and compensation may be accepted in the project EIA for mangrove conservation.

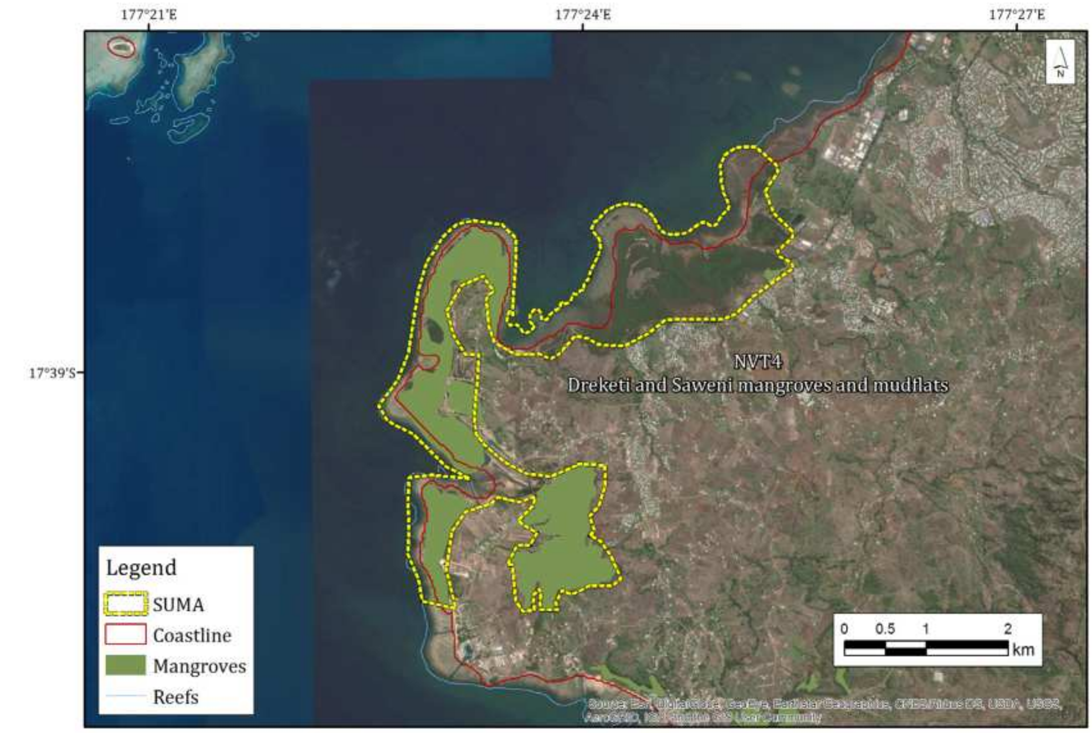
The coastal areas in the northern Viti Levu consist of mangrove stands, wetlands, and tidal flats with nearshore coral reefs. However, these areas, especially Nadi Bay, are now facing serious problems with sedimentation caused by upstream land development, and with mangrove deforestation by the coastal area development. Juvenile fish of threatened species such as Scalloped Hammerhead Sharks (known as Critically Endangered (CR) in IUCN Red List) and Blacktip Reef Sharks (known as Vulnerable (VU) in IUCN Red List), are found at estuaries of the northern Viti Levu. In addition, these areas are used as fishing grounds by the local people for their livelihood. Therefore, if any project has potential to give adverse impacts on these areas, special attention on the natural and social environment conservation shall be paid. DOE and Ministry of Fisheries studied areas that have important marine ecosystem, and identified Special Unique Marine Areas (SUMAs).**Table 7-4.1, Figure 7-4.1** to **Figure 7-4.3** shows SUMAs in Lautoka and Nadi. It is observed that Navakai treatment plant in Lautoka is adjacent to SUMA, and Sabeto and Moala candidate sites in Nadi are partially overlapped with SUMAs.

Table 7-4.1 Special Unique Marine Areas (SUMAs)

SUMA code	Name	Biophysical Justification
Lautoka		
NVT4	Dreketi and Saweni Mangroves and mudflats	Coastal and inland mangrove connectivity, mud crabs, mud lobsters, juvenile reef fish, shorebirds.
Nadi		
NVT5	Sabeto Delta Naisoso/Vulani Islands	Coastal mangroves and mudflats, river estuaries, seagrass, hammerhead sharks, blacktip reef sharks.
NTV7	South Denarau Mangroves	Coastal mangroves and mudflats, river estuaries, seagrass beds, juvenile tiger, hammerhead and blacktip reef sharks and endemic fish.

Source: Biophysically Special, Unique Marine Areas of Fiji

[18] JET had interview with DOE on July 26, 2022.

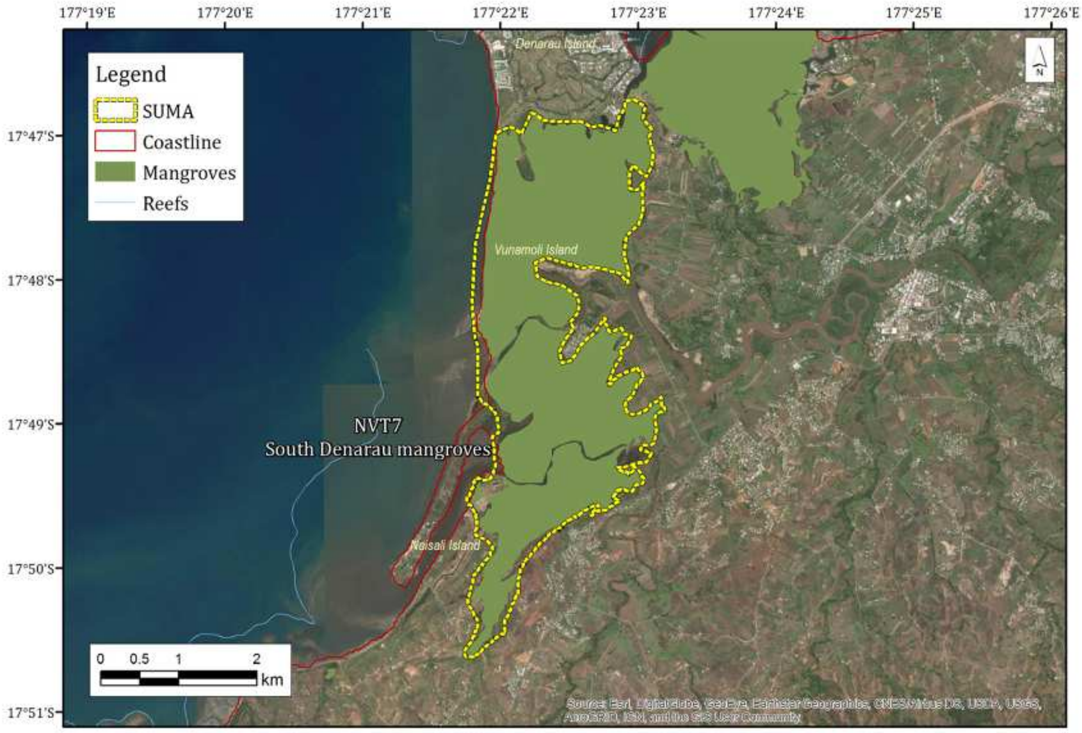


Source: Biophysically Special, Unique Marine Areas of Fiji

Figure 7-4.1 SUMA in Lautoka (NVT4)

Source: Biophysically Special, Unique Marine Areas of Fiji

Figure 7-4.2 SUMA in Nadi (NVT5)



Source: Biophysically Special, Unique Marine Areas of Fiji

Figure 7-4.3 SUMA in Nadi (NVT7)

7-4-3 Floods

Floods occur every year in Fiji after heavy rain during rainy season, sometimes even during dry season. Floods and inundation happened locally in the Western Division are mostly caused by poor drainage system, but degradation of the upper watershed associated with land development also affects the problem. Occurrence status of floods around the existing sewerage treatment plants and candidate sites are summarized below.

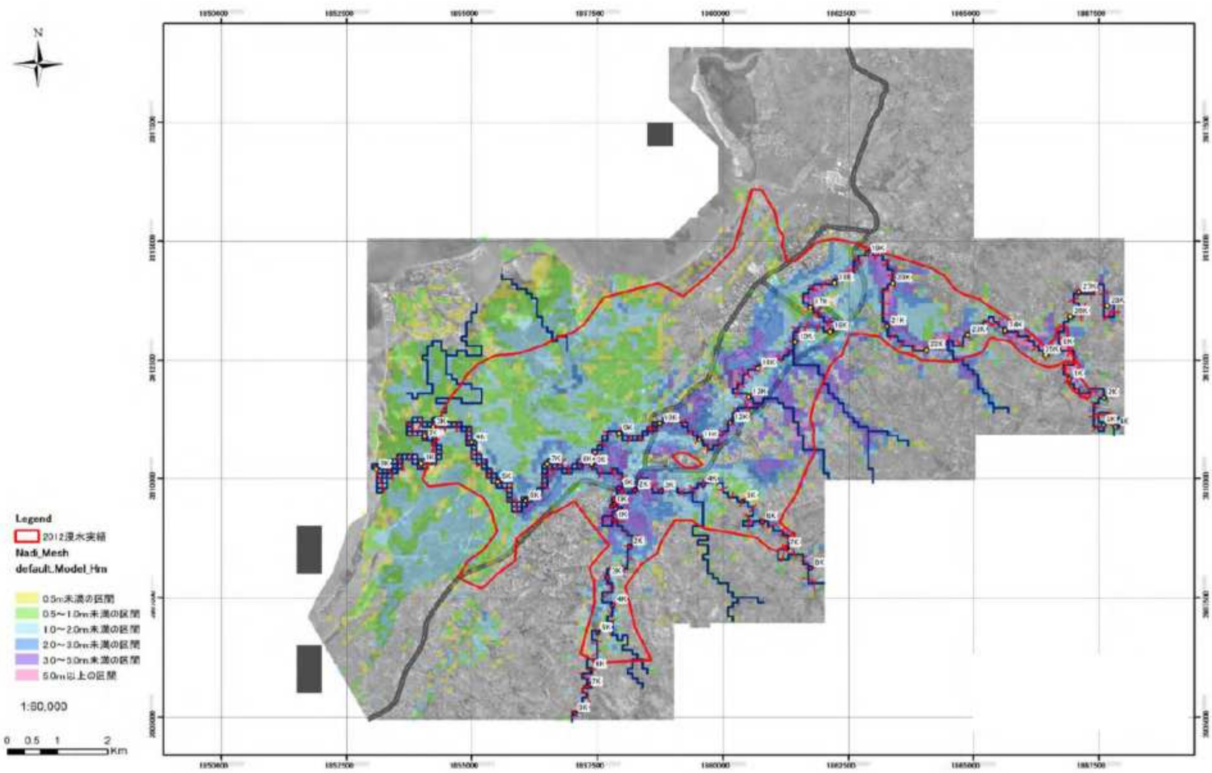
[Lautoka]

Natabua: The existing plant is located in a flood prone area, and floods occurred twice in 2017.

Vitogo: Vitogo River was flooded in 2012 caused by heavy rain and earthquake, and there was not only equipment damage but also injuries. As a long-term impact, people were resettled due to land degradation and housing damage.

[Nadi]

All area: The Nadi River watershed recently experiences more floods impacting on structures and agricultural products due to degradation of vegetation in the upstream area and land development in the downstream. The government of Fiji, supported by JICA and other donors, is currently preparing the Nadi River Flood Control Project. According to JICA's final report of the Flood Control Project, simulated maximum flood depths of the 2012 food was up to 1.0 m at Navakai treatment plant and Moala candidate site (**Figure 7-4.4**).



Source: Nadi River Flood Control Project Final Report (2016)

Figure 7-4.4 Simulation Results of the March 2012 Flood (Maximum Flood Depth)

7-4-4 Socio-economic status

Socio-economic status in the Western division and Fiji is shown in **Table 7-4.2.** Lautoka and Nadi in the Western Division are the largest cities after the Capital Suva, so the socio-economic level is nearly the average of Fiji. However, agricultural population and the poverty rate are slightly higher than the average. The unemployment rate is low at 7.4%, but it does not take into account daily wage and temporary workers, so the real rate is assumed higher. Women tend to be unemployed compared to men.

Table 7-4.2 Socioeconomic Status in the Western Division and Fiji

Contents	Fiji	Western Division
Population	864,132	330,434
Urban	477,500 (55.3%)	176,498 (53.4%)
Rural	386,632 (44.7%)	153,936 (46.6%)
Population age structure		
Age 0-14	29.3%	28.4%
Age 15-64	64.6%	65.2%
Age 65+	6.1%	6.4%
Male-headed households	80.9%	81.3 %
Household members	4.3 people/household	4.1 people/household
Poverty rate (rate less than the national poverty line*)	258,053 (29.9% of the population)	106,988 (32.4% of total population in the division)
Urban	97,602 (20.4% of the urban population)	41,206 (23.3 % of the urban population in the division)
Rural	160,450 (41.5 % of the rural population)	65,782 (42.7 % of the rural population in the division)
Average income per household	$26,248.6	—
Urban	$30,500.7	$28,107.7
Rural	$20,738.1	$20,318.0
Unemployment rate	7.4%	
Male	5.1%	—
Female	11.7%	

*1 A single national poverty line was set at $2,179.39 per adult equivalent (AE) per year, or $41.91 per AE per week.
Source: Fiji Bureau of Statistics, Household Income and Expenditure Survey Main Report 2019-2020 (2021).

7-4-5 Ethnic Groups

Fiji's ethnic groups consist of native Fijian, known as iTaukei (62.0%), Indo-Fijian (34.2%) who immigrated during the British colonial era, and other groups (3.8%) including Rotuman, other Oceanians, and Chinese (FBS, 2021). English is spoken as a common language, and Fijian and Hindi are also used. Christianity is popular among iTaukei people while Hindu among Indo-Fijian. The poverty rate of iTaukei is highest, occupying more than 70% of the total poverty population.

In Fiji, land ownership of iTaukei has been legally protected for a long time, even before the nation's independence in 1970, and their land is now collectively managed by TLTB. Hunting, fishing, and collecting wild resources at the iTaukei land as well as mangrove stands and coastal area where iTaukei traditionally uses are allowed under laws and regulations such as Forest Act and Fisheries Act. The fishing grounds (beach, barrier reefs, mangrove stands, wetlands etc.) where local communities traditionally use are called as Quoliqoli Area, and the communities possess the exclusive fishing rights. The Quoliqoli Area used to be known for the fishing right protection, but now widely recognized as the rights of the coastal area use. If a person from outside of the local communities wants fishing or swimming in the area, the person has to consult with the communities for permission. Most of the marine protected areas such as LMMAs are Quoliqoli Areas.

iTaukei is a major ethnic group in Fiji and structures the mainstream of Fijian society and culture. The national system incorporates the iTaukei rights and customary system, and the language that iTaukei speak is adopted as one of the official languages together with English and Hindi. Therefore, iTaukei is not recognized as Indigenous Peoples defined in OP4.10 of the World Bank safeguard policies[19].

7-5 Scoping

In order to select important environmental and social items related to the sewerage system, scoping analysis is conducted as follows for each project component (**APPENDIX 8-2**). At the Municipal Sewerage M/P stage, there is a difficulty in evaluating impacts in detail because any project components together with special and temporal conditions have not been decided yet. Therefore, the impact levels are assumed based on the Regional Wastewater M/P, and the local characteristics of the areas, and general information of each facility.

7-6 Alternative Analysis

7-6-1 Without Project Scenario

This M/P aims to achieve "70% of the population to connect to centralized treatment systems by 2036" in accordance with the National Development Plan, based on the Regional Wastewater M/P that delineates the framework of the sewerage system development in the Western Division. Unless the sewerage system development is strategically implemented in Lautoka and Nadi where the population and businesses are concentrated, the objectives would not be achieved by 2036.

7-6-2 Development Scenarios in the Municipal Master Plan

The following aspects are taken into account to set up municipal sewerage development scenarios for Lautoka and Nadi.

(1) Service area: It would be difficult to rehabilitate the existing plants with large scale land acquisition due to unavailability of land around the existing sewerage treatment plants, and also inefficient to transport sewerage for a long distance via pumping stations. Thus, multi-service area system of sewerage treatment is considered, including new construction of a treatment plant (maximum 2 service areas in Lautoka, and 3 areas in Nadi).

(2) Effluent quality criteria and treatment process: An applicable treatment process in a plant differs depending on the General or SEZ criteria to be applied for the effluent. In case of the treatment processs that are only applicable for the General criteria. i.e., AL process and TF process, an ocean

[19] According to OP4.10, Indigenous Peoples possess the following characteristics:
a. self-identification as members of a distinct indigenous cultural group and recognition of this identity by others;
b. collective attachment to geographically distinct habitats or ancestral territories in the project area and to the natural resources in these habitats and territories
c. customary cultural, economic, social, or political institutions that are separate from those of the dominant society and culture; and
d. an indigenous language, often different from the official language of the country or region

outfall pipe will be installed for quick dispersion.

- Treatment processes applicable only for General criteria: AL and TF (with an ocean outfall pipe for effluent discharge). In general, footprint requirement of TF process WWTP is much smaller than that of AL process.
- Treatment processes applicable for the SEZ criteria: Mechanical treatment process that is relatively modernized such as OD, IDEA, MBBR.

Based on the above, the development scenarios of Lautoka and Nadi is set up as shown below and analyzed in a viewpoint of environmental and social considerations. It should be noted, however, that the preferrable scenario is to be finalized in consideration with other aspects such as development cost and O&M.

Table 7-6.1 Sewerage System Development Scenarios (Lautoka)

# of service areas	Case	WWTP Location	Effluent quality level	Treatment process	
				AL with ocean outfall	TF with ocean outfall or Mech. 1)
1 area	L1	Natabua	SEZ /General		X
2 areas	L2a	Natabua	SEZ / General		X
		Vitogo	SEZ / General		X
	L2b	Natabua	SEZ / General		X
		Vitogo	General	X	
	L2c	Natabua	General	X	
		Vitogo	General	X	

1) Considering required areas, TF with ocean outfall is categorized with Mechanical treatment, but TF can only achieve the General criteria only.
Source : JET

Table 7-6.2 Sewerage System Development Scenarios (Nadi)

# of service areas	Case	WWTP Location	Effluent quality level	Treatment process	
				AL with ocean outfall	TF with ocean outfall or Mech. 1)
1 area	N1	Navakai	SEZ 2)		X
2 areas	N2a	Navakai	SEZ		X
		Sabeto	SEZ/General		X
	N2b	Navakai	SEZ		X
		Sabeto	General	X	
3 areas	N3a	Navakai	SEZ		X
		Sabeto	SEZ/General		X
		Moala	SEZ/General		X
	N3b	Navakai	SEZ		X
		Sabeto	General	X	
		Moala	General	X	

1) Considering required areas, TF with ocean outfall is categorized with Mechanical treatment, but TF can only achieve the General criteria only.
2) Navakai WWTP can apply Mechanical treatment only.
Source: JET

7-6-3 Scenario Analysis Results

The development scenarios are compared in each important environmental and social item, using the following classification and associated rating. The results are shown in **Table 7-6.3** and **Table 7-6.4** (the detail analysis is in **APPENDIX 8-3**). Rating is given to relative evaluation with 3 levels based on qualitative (quantitative if possible) assessment of the available information and data. Weighing is not considered.

1:
- Least environmental and social implications.
- Low risk to ESCs.
- Positive impacts

2:
- Some environmental and social implications.
- Medium risk to ESCs.
- Less positive impacts

3:
- Most environmental and social implications.
- High risk to ESCs.
- Negative Impacts.

Results of the scenario evaluation is summarized below. Each scenario has advantages and drawbacks in terms of environmental and social aspects, and as a result, there are no significant gaps among the total scores. However, there was a general tendency that muti-service areas got a higher total score compared to multi-service areas. The same tendency was found for TF/mechanical treatment processes, compared to the AL process option.

[Lautoka] The highest total score is given to L2a, i.e., 2 service areas (Natabua and Vitogo) with both mechanical or TF treatment, following L1 (a single area with mechanical treatment in Natabua), L2b (2 service areas with mechanical or TF in Natabua, and AL in Vitogo), and L2c (2 service areas with AL in both Natabua and Vitogo).

[Nadi] The highest total score is given to N3a, i.e., 3 service areas with all mechanical treatment in Navakai, Sabeto, and Moala, following N3b (mechanical or TF treatment in Navakai, and AL in both Sabeto and Moala), and N2a (mechanical or TF in both Navakai and Sabeto).

Table 7-6.3 Scenario Analysis Results (Lautoka)

	L1	L2a	L2b	L2c	Analysis summary
Water pollution	2	2	2	2	While mechanical treatment can achieve the SEZ criteria, AL and TF treatment can only achieve the General criteria. However, AL or TF treatment with offshore outfall would reduce water pollution in receiving water bodies. Poor wastewater treatment in any method could result in water pollution of the receiving water bodies unless proper O&M is done.
Waste	2	3	2	1	Sludge generation in mechanical treatment is generally larger than AL treatment.
Soil and groundwater contamination	2	1	1	1	A larger sewerage system is at risk having more points of failure if not maintained well and could result in soil and groundwater contamination together with overflow.
Noise and vibration	2	2	2	1	Mechanical treatment would generate more noise and vibration than Al or TF treatment due to mechanical equipment such as motors.
Odor	1	1	2	3	The AL treatment at Natabua and Vitogo would generate slightly more odor compared with mechanical or TF treatment due to the large surface area of the ponds if they are overcapacity.
Biodiversity	2	2	2	2	There is a chance that if the any WWTPs with either mechanical, TF, or AL treatment are not managed well, nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term.
Involuntary resettlement and land acquisition	1	1	2	3	AL treatment needs more land acquisition.
Existing Social Infrastructure and Services	2	1	1	1	If with a single sewerage area system, the existing pump stations and sewer trunk need to be rehabilitated with disturbing the existing social infrastructure and services of Lautoka.
TOTAL	17	15	16	16	
Preferred alternative	2	1	2	2	

Source: JET

Table 7-6.4 Scenario Analysis Results (Nadi)

	N1	N2a	N2b	N3a	N3b	Analysis summary
Water pollution	2	2	2	2	2	While mechanical treatment can achieve the SEZ criteria, AL and TF treatment can only achieve the General criteria. However, AL and TF treatment with offshore outfall would reduce water pollution in receiving water bodies. Poor wastewater treatment in any method could result in water pollution of the receiving water bodies unless proper O&M is done.
Waste	3	3	2	2	1	Sludge generation in mechanical treatment is generally larger than AL treatment.
Soil and groundwater contamination	3	2	2	1	1	A larger sewerage system is at risk having more points of failure if not maintained well and could result in soil and groundwater contamination together with overflow.
Noise and vibration	2	2	2	2	2	Mechanical treatment would generate more noise and vibration than Al treatment due to mechanical equipment such as motors.
Odor	1	1	2	1	3	The AL treatment at Sabeto and Moala would generate slightly more odor compared with mechanical treatment due to the large surface area of the ponds if they are overcapacity.
Biodiversity	2	2	2	2	2	There is a chance that if the any WWTPs with either mechanical, TF, or AL treatment are not managed well, nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term.
Involuntary resettlement and land acquisition	1	1	2	1	3	AL treatment needs more land acquisition.
Existing Social Infrastructure and Services	3	2	2	1	1	If with a single sewerage area system, the existing pump stations and sewer trunk need to be rehabilitated with disturbing the existing social infrastructure and services of Nadi.
TOTAL	17	15	16	12	15	
Preferred alternative	4	2	3	1	2	

Source: JET

7-7 Stakeholder meetings

In order to obtain opinions of the Municipal Sewerage M/P, stakeholder meetings were held at the scoping stage and the draft M/P stage. Comments from the participants were discussed among WAF and JET and incorporated into the Municipal Sewerage M/P or otherwise to be incorporated into individual development projects as needed. In the municipal M/P stage, in addition to key stakeholders of the Regional Wastewater M/P (division offices of the federal government, targe municipalities, infrastructure providers etc.), more local stakeholders in Nadi and Lautoka are participated in the meetings, such as resort developers, industries, communities near the existing sewerage plants and candidate construction sites.

(1) Scoping Stage

A stakeholder meeting was held at each municipality on the following dates to collect comments exhaustively from key stakeholders. The tourism industry is flourishing in Nadi, so many tourism-related groups and companies such as hotels, resort developers were participated. On the other hand, Lautoka is an industrial city so manufacturing companies, and housing developers are came to the meeting. Both meetings were covered by local media (TV and newspaper).

While any participants did not express concerns on the sewerage area zoning (a single service area or multiple service areas) or candidate sites of new plants, it is suggested by some participants that WAF should closely consult with the local communities and landowners of the candidate sites at the early stage.

The 1st stakeholder meeting for Nadi	
Date: February 8, 2023 Venue: Conference Room, Tokatoka Resort, Nadi Participants: 58	
Major comments and questions from the participants	• The projected population could be more or less doubled if tourism was included. Future tourism population and resort development should be taken into account the M/P. [Nadi Chamber of Commerce and Industry] • Nadi is more of a residential area and urban area expansion efforts would have to be done so in a horizontal manner as people cannot construct high rise buildings due to the Nadi International Airport. Therefore, expansion would go horizontally towards the east to cater for the growing demand of housing. [Investment Fiji] • The 50 Year Masterplan is funded by the Ministry of Economy[20] and is currently in the draft stage. DTCP will share the related document to the participants. (received). [DTCP] • Denarau is drawing water from the Nadi River to water the golf course and plants within the vicinity. The quality of water in which they are sourcing from the river is equivalent to sewerage water. It seemed that the overloaded system at Navakai aren't coping at all and it would require remedial action on the part of Denarau or someone else for the next four to five years. [Denarau Corporation Limited] • A community member questioned WAF regarding the discharge into the river, which then flows into their areas of Sikituri and Yavusania Villages. [Community representatives] →WAF is conducting conditional assessments of the treatment plant in Navakai along with the effluent pipeline. In the assessment, WAF is also looking at extending the outfall towards the shore for better circulation and dilution and are considering an extended outfall with of course the approvals from the DoE, Ministry of Fisheries, and the Tourism industry. [WAF] • WAF, DoE and other organizations have greater participation at school level throughout Fiji, as they are the ones who would likely be affected in the future. [Nadi Chamber of Commerce and Industry]
	

20 MOE: before organizational restructuring; current Ministry of Finance (MOF)

The 1st stakeholder meeting for Lautoka	
Date: February 9, 2023 Venue: Conference Room, Tanoa Waterfront Hotel, Lautoka Participants: 48	
Major comments and questions from the participants	• Nadi's treatment plant has lagoons which had been installed in 2007 and 2008. However, there is only one aerator in operation. WAF's capacity to maintain mechanical systems at the WWTP is questioned, should they be installed. Mechanical systems would allow for a reduced footprint, nevertheless, if the wastewater is not properly treated, WAFs discharge would not be friendly for the environment. [WasEng Consulting] • Once all these developments are done especially in the rural areas, the community members would question on additional costs that could potentially be added to their expenses such as the increase in water bills and wastewater connection bills. [DTCP] →The current project will be looking into it as well as operational and capital costs. [WAF] • The provincial council representative works with TLTB and helps and assists when it comes to consultations regarding the rural communities and villages. Consultations have to be taken to the communities. [Provincial Council]
	

(2) Draft M/P Stage

A stakeholder meeting (workshop) at the draft M/P stage was held on August 23, 2023, for key stakeholders of both Nadi and Lautoka. The same as the stakeholder meetings at the scoping stage, not only ministries, and local governments, but also hotels, resort developers, tourism related organizations and companies, manufacturers, and housing developers were participated. Received comments include considerations on neighboring communities and tourism industries around an individual project site at the implementation stage, but any participants did not express great concerns on the contents of the draft M/P.

The 2nd stakeholder meeting for Lautoka and Nadi	
Date: August 23, 2023 Venue: Conference Room, Tanoa Waterfront Hotel, Lautoka Participants: 65	
Major comments and questions from the participants	• How much thought has been done regarding the new developments that are coming into the area? [Vulani Project] →Once organizations have their development plans it then gets referred to WAF and then on a case-by-case basis, they are considered by WAF. The project team is utilizing this forum for developers such as those present in the meeting to register their respective developments and their capacities required at an early stage, so that it can be factored into masterplans such as this current wastewater masterplan. [eCoast/PLANIT] • There are communities that depend on the marine resources for food and income, and is also the tourism that use the coastal waters for recreational purposes and naturally there would be concerns on the discharge of wastewater, particularly if there are floods or if there are problems with the discharge. The importance of the mitigation measures is reiterated so that the fisheries and the people who depend on the coastal zones are safeguarded. It is hoped that EIA will cover these studies too and include the marine environment. • At the end of this year, the masterplan will be produced by Singapore consultant team to the Fijian government for their input and considerations. →There is indeed a 50-year masterplan that the DTCP and the Ministry of Economy[21] have been working on for the Western Division as well as the Greater Suva area that identifies future development areas and future development infrastructure areas which we sewerage trly would all have to consider. [eCoast/PLANIT]

[21] MOE: before organizational restructuring; current Ministry of Finance (MOF)

7-8 PR Activities

The Municipal Sewerage M/P is a plan that relates more closely to the sewerage users, so PR activities for the M/P dissemination and information disclosure has been strengthened with WAF's PR Team at this M/P stage. The PR activities related to this project is summarized below.

Table 7-8.1 PR Activities for the M/P project

Date	Media	Title and website
8th Feb. 2023	FBC	Wastewater master plan is a proactive step: WAF https://www.fbcnews.com.fj/news/wastewater-master-plan-is-a-proactive-step-waf/
8th Feb. 2023	WAF Facebook	https://www.facebook.com/WaterAuthorityofFiji/posts/pfbid0bP4E17oqbokTf42PPW3B9fJwpfegqoSeT9hRZrtE7t8co327s678nTd54tqf4548l 
9th Feb. 2023	Fiji Sun	 DEVELOPMENT Talks in progess for better Nadi water, wastewater treatment management

Source: JET

7-9 Public Awareness

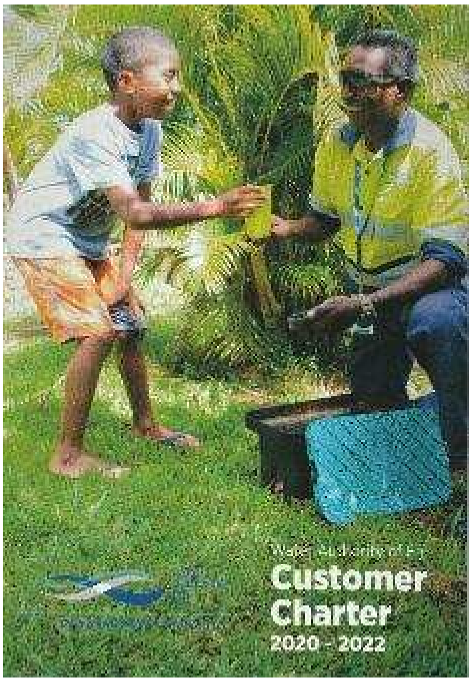
7-9-1 Current situation

Public awareness and PR activities/campaigns by WAF are usually handled by the Corporate Communication Team, while the Customer Service and Community Engagement Team are in change at the field level. One personnel has been assigned as the Community Engagement Officer for the Western Division and carries out public awareness activities on daily basis. Most of the activities are for the water supply, but sometimes for wastewater and trade water as needed.

WAF issues a customer charter every three years to explain WAF's water supply and sewerage services, the goals and achievements, and customer responsibilities. The foundation of public communication has already been established, such as the complaint management system and information posting on SNS (Facebook, Twitter etc.).

At present, awareness-raising activities related to the sewerage business focuses on proper use of the sewerage system, such as “do not flush waste” and prevention of stormwater pipe connection to a sewer line. For example, in areas where clogging often occurs due to inflow of waste at a pump station, WAF staff distributes leaflets to each household with verbal explanation, and the problem is often improved. On the other hand, awareness-raising activities for promotion of sewer connection have not been conducted before, and it is fully up to developers and residents to connect each house.

Poster for proper use of toilet



Customer Charter (cover page)

Source: WAF

Figure 7-9.1 WAF’s Public Awareness-raising Tools for the Wastewater Treatment Service

Some of the complaints received by WAF are about offensive odor from the sewerage treatment plants. In Lautoka, due to urban area expansion coming close to the Natabua plant, WAF often receives complaints on odor. In addition, even for Navakai plant, the neighborhood community report an odor nuisance when the mechanical treatment is not functional properly. Kinoya plant in Suva is adjacent to a residential area, so there are many complaints from the residents. Although WAF responds to the complaints case by case, any planned interaction (periodic briefings, etc.) between the nearby residents and WAF has not been implemented. However, when a large-scale development work is planned, WAF holds consultations with the neighboring communities. For example, when desludging works at each sewerage treatment plant in the Western Division were implemented, WAF held community consultations for nearby communities.

7-9-2 Public Awareness Activity Plan

(1) Framework of Public Awareness Activities

In Fiji, sewerage system is well recognized by the citizens, but promotion activities for sewerage connection have not been actively implemented. Considering the fact that the Western Division is a popular holiday destination from all over the world to enjoy beach resorts, the water environment conservation and sanitary condition improvement would contribute to not only improvement of the people’s living but also the tourism resource values. It is therefore important to continuously explain to the people about importance of sewerage connection and proper sewerage treatment. emphasizing “improvement of the sanitary condition,” “heathy water environment,” and “contribution to the local economy (especially tourism).”

According to interviews with WAF officers, there are many opinions regarding the importance of (1) promotion of sewerage connection, (2) proper use of sewerage (prohibition of waste dumping, etc.), and (3) environmental education. In the M/P implementation, (1) is directly related to the tariff collection, and (2) to efficient operation. As for (3), short-term effects are unlikely to be expected, but it can be very effective to improve not only the sewerage services but the environment of Fiji as a whole in the long-term, as the participants in the stakeholder meetings also requested. Based on the above-mentioned situation of the public awareness activities, this M/P promotes public awareness activities, focusing on the followings.

Promotion on sewerage connection:	Sewerage connection from each household and building is promoted, keeping people informed about the sewerage system in the existing and new service areas to foster an understanding of basics of sewerage system and its advantage, initial cost for the connection, the tariff, and subsidies.
Proper use of sewerage system:	In order to keep the sewerage system functional with avoiding unwanted maintenance, public awareness activities are implemented for no waste littering or no oil releasing to the sewerage.
Environmental education:	Environmental education is provided to foster an understanding of environmental conservation and variety of functions on sewerage system, and to develop human resources for the future sewerage sector.

(2) Activity Contents

Major activities for public awareness and PR for the sewerage system are summarized below. The activities should be effectively implemented in combination with the listed activities, depending on project characteristics, and target areas and groups.

Table 7-9.1 Public Awareness and PR Activities

Activities	Target group	Contents	Organized by	Frequency (tentative)
Community consultation	Residents in sewerage area (new/existing)	Proactively explain about sewerage system and its advantage, cost for connection, sewerage charge, subsidies etc. to make people aware of sewer lines nearby, and to promote immediate connection and proper monthly payment.	- Community Engagement Team - Sewerage Team - Community volunteers	New area: more than once per month Existing area: 1-2 times per year
House-to-house visit	Residents in sewerage area (new/existing)	Visit a household with leaflets to promote early connection to sewers, no littering, and no oil dumping etc.	- Community Engagement Team - Community volunteers	New area: once per month Existing area: 1-2 times per year
Workshop for neighboring communities of WWTP	Neighboring communities of WWTP	Publicly disclose a status of WWTP operation, and monitoring results, and exchange opinions in a regular basis with neighboring communities to understand each other.	- Corporate Communication Team - Community Engagement Team - Sewerage Team	More than once a year
Workshop for business entities	Developers etc.	Explain about the sewerage system to developers etc. for proper connection.	- Community Engagement Team - Sewerage Team	More than once a year
Workshop for plumbers	Plumbers	Explain about the sewer system to plumbers for proper connection.	- Sewerage Team	More than once a year
Study tour	Citizens who are interested in sewerage system	Invite citizens to WWTP for their understanding.	- Corporate Communication Team - Community Engagement Team - Sewerage Team	More than once a year
Environmental education events	Students	Hold an environmental education class (not only lecture but also interactive session, study tour, and painting competition etc.) at schools/universities to teach about the sewerage system and its function, environmental water conservation.	- Community Engagement Team - Sewerage Team - School teachers	More than 4 times a year
PR through SNS and mass media	General public	Enhance people's understanding on the MP and projects for smooth implementation through newspaper, radio, press release, media conference, SNS etc.	- Corporate Communication Team - Sewerage Team	As needed
Leaflet distribution	General public	Depending on target groups, prepare leaflets and distribute them to public facilities, schools, community meetings, and house-to-house visit.	- Corporate Communication Team - Sewerage Team	As needed

Source: Created by JET

7-9-3 Remarks

(1) Securing Human Resources

In the Western Division, public awareness activities related to potable water, wastewater, and trade water is conducted by one Community Engagement Officer with other officer's support, depending on activity characteristics. However, it is still very difficult to implement the activities strategically and continuously with such a shortage of manpower. WAF should consider assigning a few more community engagement officers as well as to coordinate with NGOs for activities, encourage community volunteers, and utilize other human resources such as JOCVs.

(2) Gender Mainstreaming

When interview surveys to residents, information disclosure, public awareness raising activities, and consensus building are implemented, the following items shall be considered for gender mainstreaming actions:

- Women's participation and equal leadership opportunities shall be assured at any level of decision making.
- When a door-to-door survey is conducted, the interviewers shall consist of 2 people, 1 man and 1 woman so that female residents can actively give their opinions. This measure could avoid gaps of the results between men and women.
- Local women's groups shall be asked to support for organizing and implementing local public awareness activities and community meetings to create comfortable environment for women.
- Community meetings targeting for women shall be considered depending on local circumstances and purpose of the public awareness raising. For example, it is important for women, who often do house chores, to understand "do not litter in the toilet" and "don't discharge oils into a kitchen sink." It is also expected to propagate the knowledge to other household members.

CHAPTER 8 CONCLUSION AND RECOMMENDATION

8-1 Conclusion

This Municipal Sewerage M/P has been prepared as a plan to identify the level of investment in sewerage facilities required to meet the National Development Plan for the target city of Lautoka and Nadi. A long-term transition to a sewerage system is necessary to improve the impact on the water environment by responding to future population growth and the increased pollutant loads from commercial development due to increased tourism.

During the M/P study, it was found to be effective to divide the service area into 5 to reduce construction and O&M costs. Lautoka is divided into 2 service areas, i.e. Vitogo and Natabua, and Nadi is divided into 3 service areas, i.e. Sabeto, Navakai and Moala. Regarding the effluent standards to be applied to the proposed WWTPs, the option of discharging the effluent to accordance with the General standards at a point 1 km offshore has been approved through discussions with the DOE in order to reduce O&M costs. This option will apply to the Vitogo, Natabua, Sabeto and Moala WWTPs. The Navakai WWTP in Nadi is located far from the sea and has no option but to discharge into the nearby Nadi River, and the SEZ standard will be applied.

For sludge treatment, a centralized treatment of raw sludge was proposed to be constructed at Natabua WWTP, which will generate electricity from digester biogas in the future. To improve wastewater treatment services in areas where the sewerage system is not yet developed, the effectiveness of a septage collection and treatment system at the Natabua WWTP was confirmed. As for sludge disposal, since acceptance by landfill acceptance and effective use of sludge have not yet been realized, JET has proposed a sludge storage system at each WWTP. As for wastewater collection, an appropriate combination of gravity and pressure flow is proposed, assuming a separate collection system. The outline of the five proposed service areas and the approximate construction costs are summarized below.

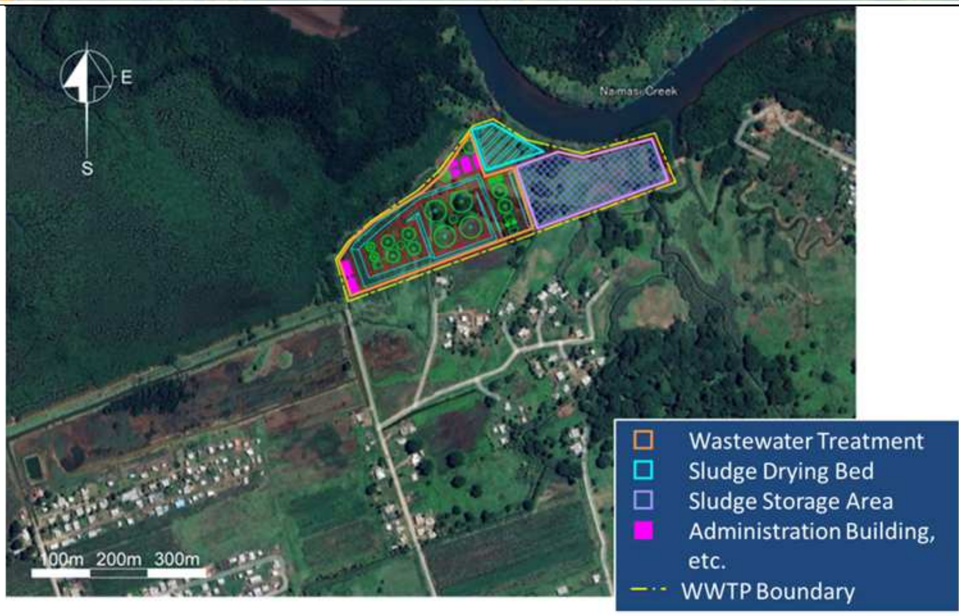
Table 8-1.1 Outlines of Facilities and Construction Costs

Municipality	WWTP	Outlines of facilities		Construction Costs (million FJD)
Lautoka	Vitogo	WWTP	Trickling Filter(Q=7,100 m^3/day*)	120
		Sewer (Trunk/Sub-trunk)	Dia.100-600mm L=41 km	75
		Pumping station (Trunk/Sub-trunk)	12 (Trunk/Sub-trunk)	10
	Natabua	WWTP	Trickling Filter(Q=44,500 m^3/day*)	500
		Septage treatment	Mechanical dewatering	11
		Sewer (Trunk/Sub-trunk)	Dia.100-750mm L=64 km	92
		Pumping station (Trunk/Sub-trunk)	30	24
Nadi	Sabeto	WWTP	Trickling Filter(Q=7,100 m^3/day*)	130
		Sewer (Trunk/Sub-trunk)	Dia.100-400mm L=49 km	120
		Pumping station (Trunk/Sub-trunk)	35	27
	Navakai	WWTP	OD(Q=29,800 m^3/day*)	312
		Sewer (Trunk/Sub-trunk)	Dia.100-900mm L=58 km	94
		Pumping station (Trunk/Sub-trunk)	37	29
	Moala	WWTP	Trickling Filter(Q=19,30 0m^3/day*)	271
		Sewer (Trunk/Sub-trunk)	Dia.100-900mm L=105 km	161
		Pumping station (Trunk/Sub-trunk)	54	40

*: PDWF
Source: JET

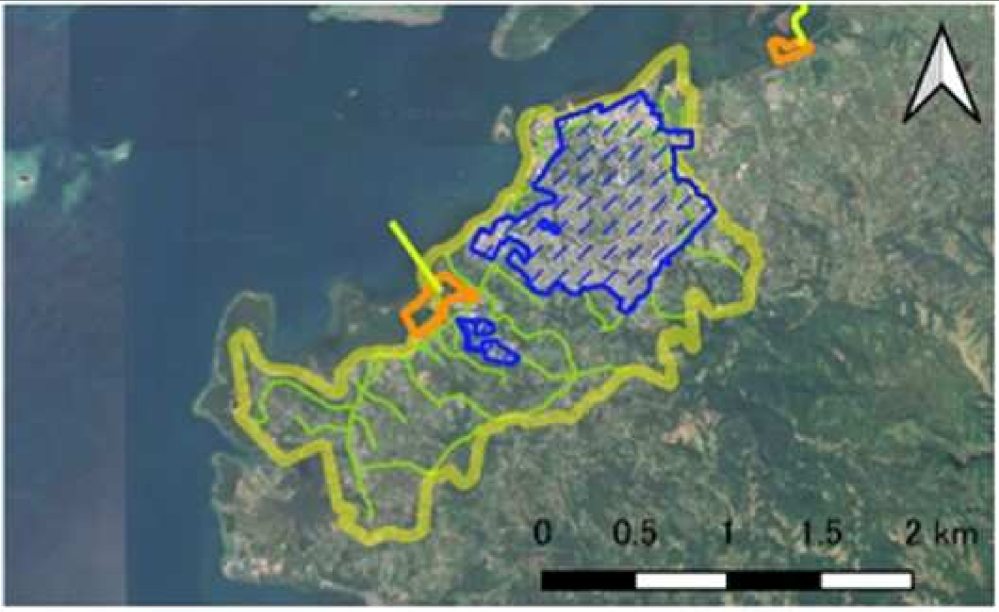
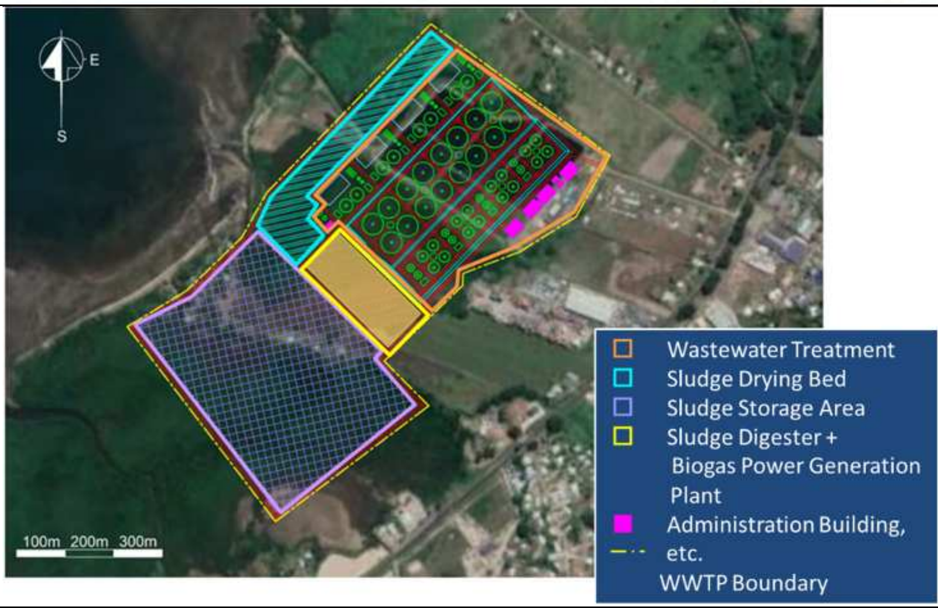
The following tables summarize the Municipal Sewerage M/P for Lautoka and Nadi per service area.

Table 8-1.2 Overview of Vitogo Service Area (Lautoka)

Plan view	
WWTP Facility Layout	
Target Year	2043
Population	15,130
Design Flow	6,365 m^3/day (Daily Average), 7,001 m^3/day (Daily Maximum)
Treatment process	Trickling Filter
Treatment Capacity	7,100 m^3/day (Daily Maximum)
Sludge Treatment	Raw sludge: Gravity thickener --> Natabua WWTP Excess sludge: Dewatering --> Sun drying --> Storage
Discharge Body	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-750mm L = 41 km, Branch: Dia.100- 250mm L=71 km

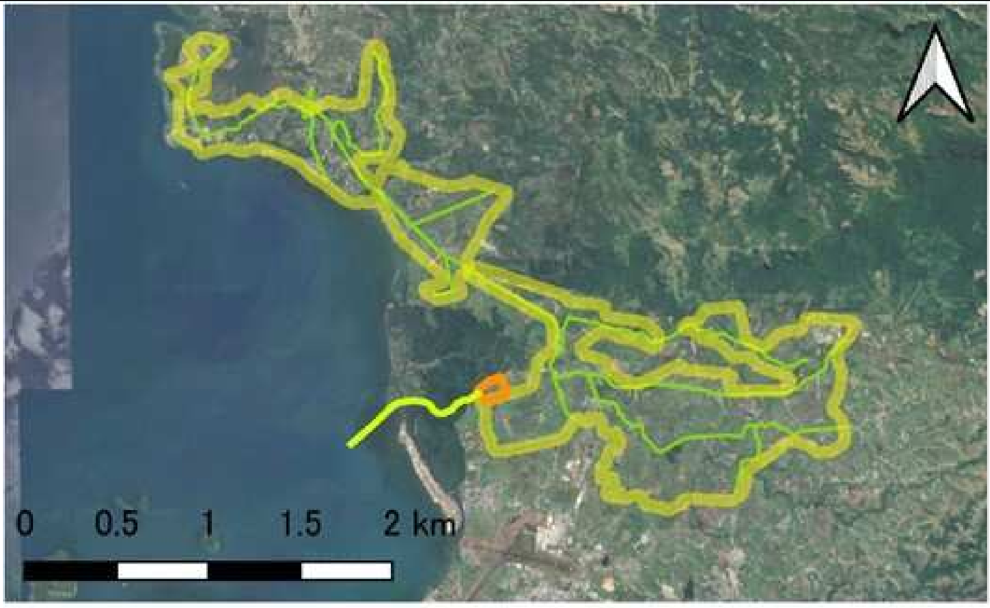
Source: JET

Table 8-1.3 Overview of Natabua Service Area (Lautoka)

Plan view	
WWTP Facility Layout	
Target Year	2043
Population	105,590
Design Flow	40,434 m^3/day (Daily Average), 44,477 m^3/day (Daily Maximum)
Treatment process	Trickling Filter
Treatment Capacity	44,500 m^3/day (Daily Maximum)
Sludge Treatment	Raw/Excess sludge: Gravity concentration --> Digestion --> Dewatering --> Sun drying --> Storage Raw sludge (from other WWTPs): Digestion --> Dewatering --> Sun drying --> Storage Septage: Dewatering --> Sun drying --> Storage
Discharge Body	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-600 mm L = 64 km, Branch: Dia.100- 600mm L=144 km

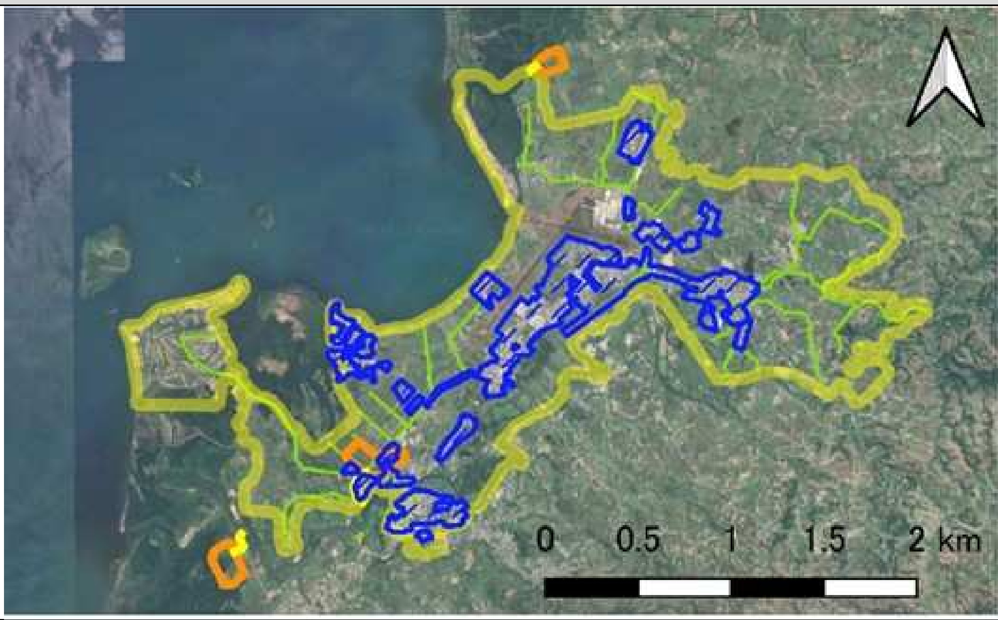
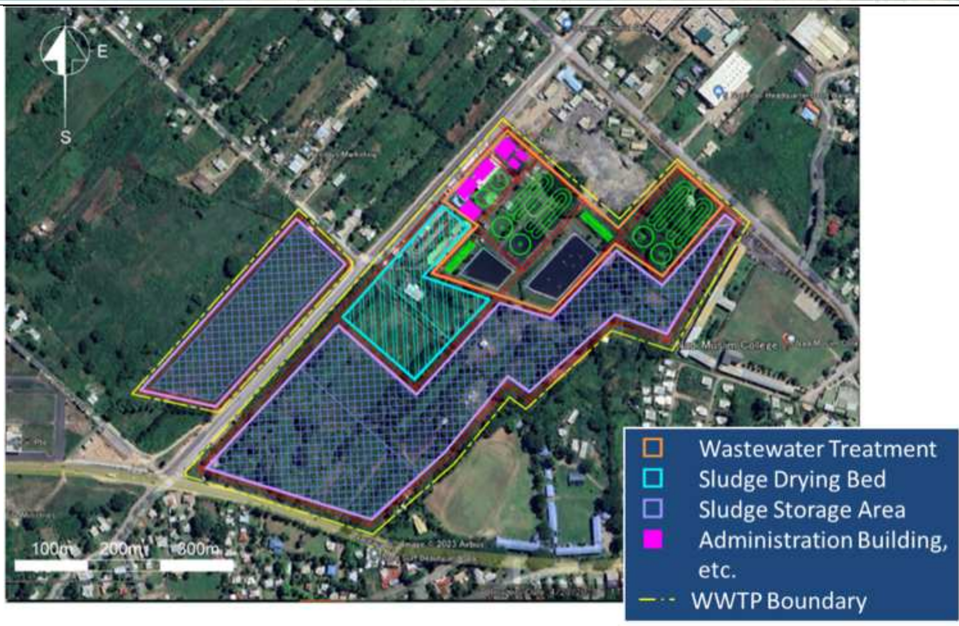
Source: JET

Table 8-1.4 Overview of Sabeto Service Area (Nadi)

Plan view	
WWTP Facility Layout	
Target Year	2043
Population	13,510
Design Flow	6,393 m^3/day (Daily Average), 7,033 m^3/day (Daily Maximum)
Treatment process	Trickling Filter
Treatment Capacity	7,100 m^3/day (Daily Maximum)
Sludge Treatment	Raw sludge: Gravity thickener --> Natabua WWTP Excess sludge: Dewatering --> Sun drying --> Storage
Discharge Body	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-400 mm L=49 km, Branch: Dia.100-400mm L=78 km

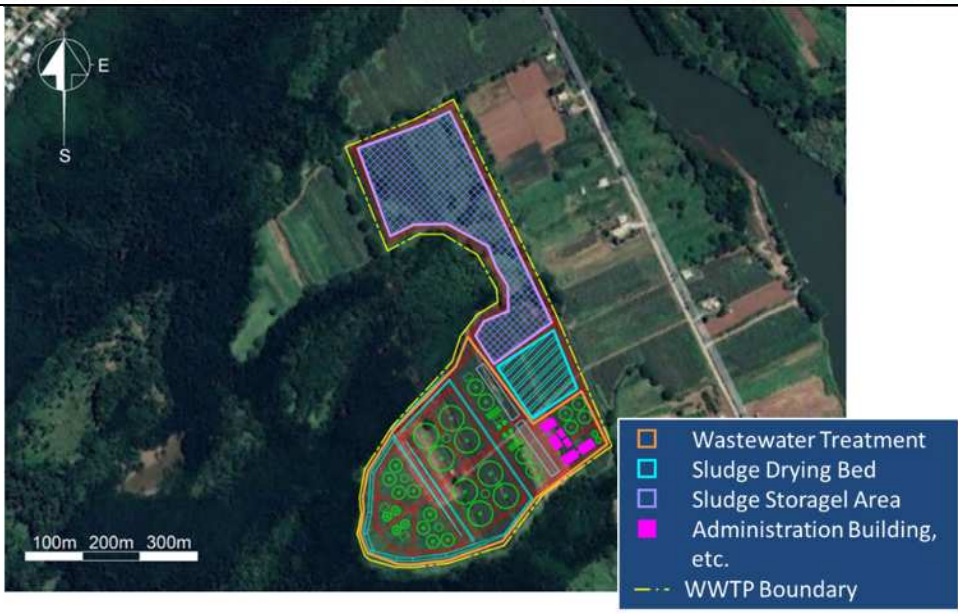
Source: JET

Table 8-1.5 Overview of Navakai Service Area (Nadi)

Plan view	
WWTP Facility Layout	
Target Year	2043
Population	52,740
Design Flow	27,003 m^3/day (Daily Average), 29,703 m^3/day (Daily Maximum)
Treatment process	Oxidation Ditch
Treatment Capacity	29,800 m^3/day (Daily Maximum)
Sludge Treatment	Excess sludge: Dewatering --> Sun drying --> Storage
Discharge Body	Nadi River
Sewer Length	Main trunks/ Sub-trunk: Dia.100-900 mm L = 58 km, Branch: Dia.100-300mm L=204 km

Source: JET

Table 8-1.6 Overview of Moala Service Area (Nadi)

Plan view	
WWTP Facility Layout	
Target Year	2043
Population	35,420
Design Flow	17,483 m^3/day (Daily Average), 19,232 m^3/day (Daily Maximum)
Treatment process	Trickling Filter
Treatment Capacity	19,300 m^3/day (Daily Maximum)
Sludge Treatment	Raw sludge: Gravity thickener --> Natabua WWTP Excess sludge: Dewatering --> Sun drying --> Storage
Discharge Body	Ocean
Sewer Length	Main trunks/ Sub-trunk: Dia.100-900 mm L = 105 km, Branch: Dia.100-400mm L=161 km

Source: JET

8-2 Recommendation

(1) Land for WWTPs

In formulating the Municipal Sewerage M/P, construction of two new WWTPs in Nadi, one new WWTP in Lautoka and the expansion of the existing Natabua WWTP and Navakai WWTP is proposed and showing the candidate land for WWTPs. Those candidate lands indicate only locations on the map where construction or expansion is considered possible, and in order to identify them as WWTP sites, evaluation of potential resettlement issues, and sufficient consultation with the stakeholders concerned after investigation of land negotiation/acquisition processes for existing dwellings.

(2) Environmental Impact Assessment of the Effluent Discharging Areas

Ocean outfall of the effluent is recommended for 2 new WWTPs in Nadi and 1 new WWTP in Lautoka. In addition, the replacement of existing ocean outfall pipe of Natabua WWTP is recommended in the Municipal Sewerage M/P. And it is necessary to conduct an environmental impact assessment (EIA) for the ocean outfall areas.

Regarding the basic data necessary for EIA, it is necessary to indicate the items to be investigated in the Pre-F/S implementation, referring to the survey results of the Kinoya WWTP in Suva, which is also planning to construct an ocean outfall pipe.

(3) Disposal and Effective Use Method of Sewerage Sludge

Currently, there is no disposal site for sewerage sludge in the Western Division, so the Municipal Sewerage M/P recommends the construction of a s site within the premises of Natabua WWTP. However, it requires a large footprint for storing the sludge generated in 20 years, which will be a big issue in increasing construction costs. Therefore, it is an urgent issue to consider disposal method and effective use of sewerage sludge.

As a disposal method, for example, acceptance to a domestic waste disposal site in Lautoka, and as an effective use, agricultural use will be worth consideration.

For the consideration, it is important to grasp the concentration of hazardous substances such as heavy metals in the sludge in the study. However in Fiji, there are only a limited number of laboratories that can implement the analysis, and sufficient analytical equipment has not been installed.

Since the concentration of hazardous substances in sludge will need to be analyzed long into the future, it is necessary to develop a system that allows analysis at the water quality laboratory of WAF.

(4) Information on Existing Pipelines and Exclusive Use of New Pipelines

Although information on existing sewer pipes is basically stored in GIS, there are many items of which numerical values are not entered in GIS information, making it difficult to evaluate the flow capacity, which is in a situation that is not easy to construct additional pipe. Therefore, an investigation of the facility specifications (pipe material, cross section, pipe invert level) including the location of the existing sewer is necessary.

(5) Sound Finance of Sewerage Works

In the Municipal Sewerage M/P, it was clarified that the sewerage servicer charges would need to be four times higher than the current charges in order to cover the O&M costs of the sewerage facilities.

Therefore, it is necessary to consider measures taking into account of the increase in the burden on beneficiaries, such as gradual increases in tolls.

On the other hand, public utility charges, including sewerage charges, have become an important policy issue for the government, making it difficult to revise charges easily. WAF is necessary to demand that the necessary maintenance costs be secured from the national budget.

(6) Organizational Structure on O&M

1) WWTP

Navakai WWTP in Nadi, which is currently the only one among the existing 4 WWTPs in the Western Division that uses a mechanical wastewater treatment process, is unable to comply with the effluent standards due to insufficient treatment capacity for inflow sewerage. In addition, due to the lack of budget and equipment for O&M, the facilities are severely deteriorated, making it difficult to carry out appropriate O&M.

In the future, the introduction of mechanical wastewater treatment such as OD process and trickling filter method into all 5 WWTPs in Nadi and Lautoka is proposed in the Municipal Sewerage M/P, and it is essential to secure the budget and equipment for O&M.

In order to implement appropriate O&M at WWTPs to be constructed in the future, first of all it is necessary to secure O&M budget for the current Navakai WWTP, to strengthen the capacity of staff in WWTPs, and to implement appropriate O&M.

Such capacity building is difficult to implement at WAF, and it would be effective, for example, to strengthen capacity through JICA Technical Cooperation Project and to build an appropriate O&M system for the newly constructed WWTPs.

2) Laboratory

In Fiji, the wastewater discharge standards are set for hazardous substances such as heavy metals and cyanide as well as for general substances such as BOD and SS. However, due to the lack of analytical equipment, the water quality laboratory of WAF is not able to properly analyze all the substances, and the heavy metals in the sludge cannot be analyzed at all. Therefore, it is essential to prepare analytical equipment for the laboratory and strengthen the capacity of the laboratory staff for the wastewater quality and sludge management, and regulation of liquid trade waste.

It will be effective to prepare the necessary equipment and materials through JICA Technical Cooperation Project and to strengthen the capacity of the staff.

3) Sewer Network

According to the National Development Plan that aims for 70% of the population to connect to centralized treatment systems by 2036, the increase of newly constructed sewer pipes by the expansion of service area and the deterioration of existing pipes will progress year by year. And the management of sewer pipe assets will be an extremely important issue.

Currently, sewer network maintenance is basically carried out by WAF. But for the future, WAF should set a policy that for example, WAF will mainly conduct inspections and surveys of pipes, and private sector will be entrusted to implement sewer pipe repairs such as removing clogging, and based on the policy WAF has to prepare the budget, human resources and equipment.

Since WAF has little experience in conducting pipeline inspections and surveys, it is effective to acquire the procedures and know-how through JICA Technical Cooperation Projects.

4) Mechanical and Electrical Equipment

Currently, the mechanical and electrical team is in charge of the maintenance of the mechanical and electrical equipment at all water supply and sewerage facilities in the Western Division.

However, the team has implemented only visual inspection of pumps and repair of some equipment, making the equipment rapid aging.

The reasons are as follows:

i. It is difficult to secure the necessary number of personnel for maintenance due to the outflow of appropriate personnel overseas.
ii. Budget, necessary materials and consumables to implement preventive/predictive maintenance of equipment is not prepared.
iii. Periodical maintenance of equipment by manufacturers has not been implemented due to budget shortages.

In order to improve this situation, first of all, what is the most important is to secure a budget for equipment maintenance.

In addition, so that maintenance can be carried out with a small number of staff, it is important to establish a system that the pipe maintenance team and the operation team in WWTPs carry out visual inspections of the equipment, and the mechanical and electrical team conducts daily and periodical inspections such as grease/oil and spare parts replacement.

Periodical maintenance by manufacturers is important to prevent equipment breakdowns and extend life of the equipment, so WAF has to secure the budget.

5) Liquid Trade Waste

In Fiji, there is a regulation and standard for discharging liquid trade waste into sewer system, but penal clauses are still under consideration in the government, so compulsory regulation is not yet possible.

Reduction of influent quality load to WWTP is important for appropriate O&M of WWTP, so the tightening of regulation by the enforcement of penalty clauses is awaited.

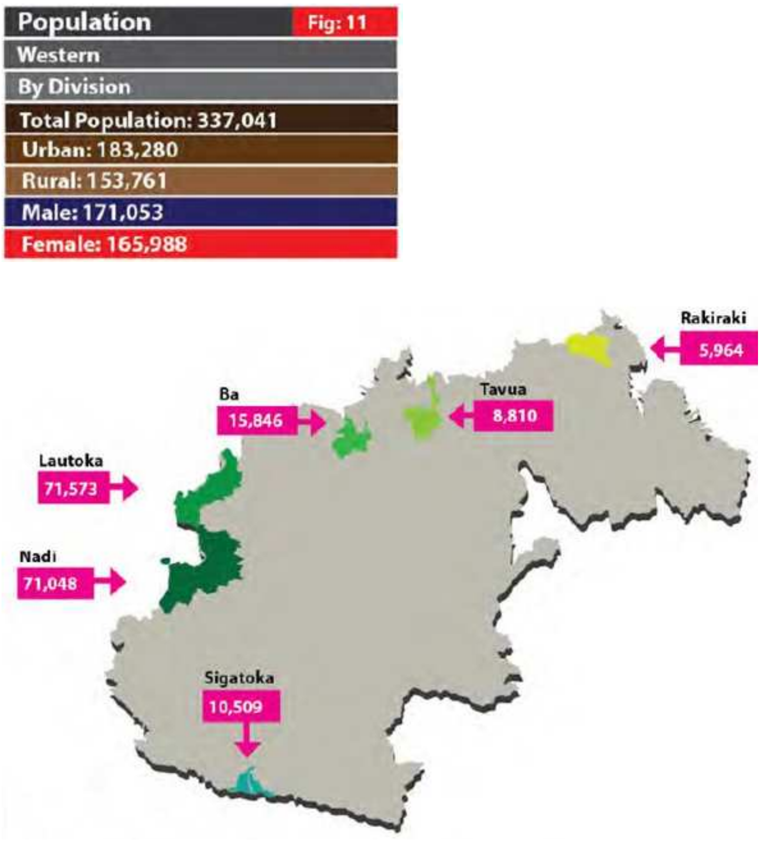
APPENDIX

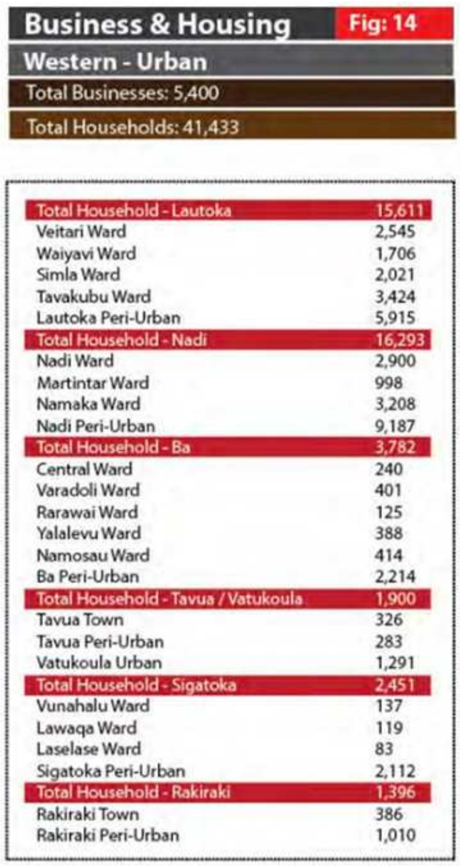
APPENDIX 3-1 Population per Household

Summary of Population Per Household

Municipals	Population	No of Households	Population per Household (population/ household)
Lautoka	71,573	15,611	4.58
Nadi	71,048	16,293	4.36
Ba	15,846	3,782	4.19
Tavua/Vatukoula	8,810	1,900	4.64
Sigatoka	10,509	2,451	4.29
Rakiraki	5,964	1,396	4.27
Total	183,750	41,433	4.43

Source: FBoS, 2017 Population and Housing Census, Infographics Release





Source: FBoS, 2017 Population and Housing Census, Infographics Release

APPENDIX 3-2 Return Coefficient of Sewerage Flow

22 Wastewater characteristics, treatment and disposal

Table 2.7. Ranges of water consumption values, based on 45 municipalities in the State of Minas Gerais, Brazil

	Ranges of per capita water consumption (L/inhab.d)	
Income	Low rainfall	High rainfall
Low	120–165	130–190
High	140–180	150–200

Notes:

- Ranges based on 25 and 75 percentile values from Fig. 2.4
- In larger towns (greater than 200,000 inhabitants), the per capita water consumption was on average approximately 10% higher than in smaller towns
- The ranges present usual values, and it is frequent to observe values outside them

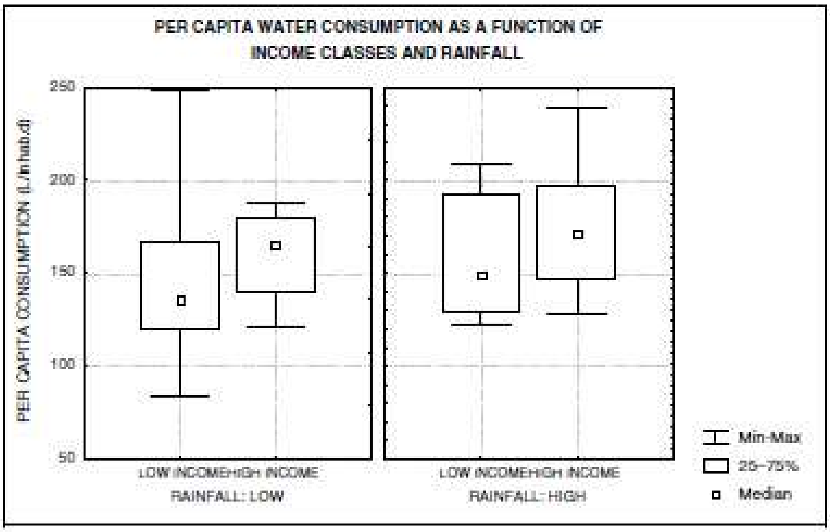


Figure 2.4. Box-and-whisker plot of the per capita water consumption values as a function of categories for per capita income and mean yearly rainfall (45 municipalities in the State of Minas Gerais, Brazil)

be different, due to the fact that part of the water consumed could be incorporated into the storm water system or infiltrate (e.g. watering of gardens and parks). Other influencing factors in a separate sewerage system are: (a) clandestine sewage connections to the storm water system, (b) clandestine connections of storm water into the separate sewerage system and (c) infiltration. The last point is covered separately in Section 2.1.3.

The fraction of the supplied water that enters the sewerage system in the form of sewage is called Return Coefficient (R = sewage flow/water flow). Typical values vary between 60% and 100%, and a value of 80% (R = 0.8) is usually adopted.

APPENDIX 3-3 Setting Influent Water Quality Conditions

(1) Influent Water Quality

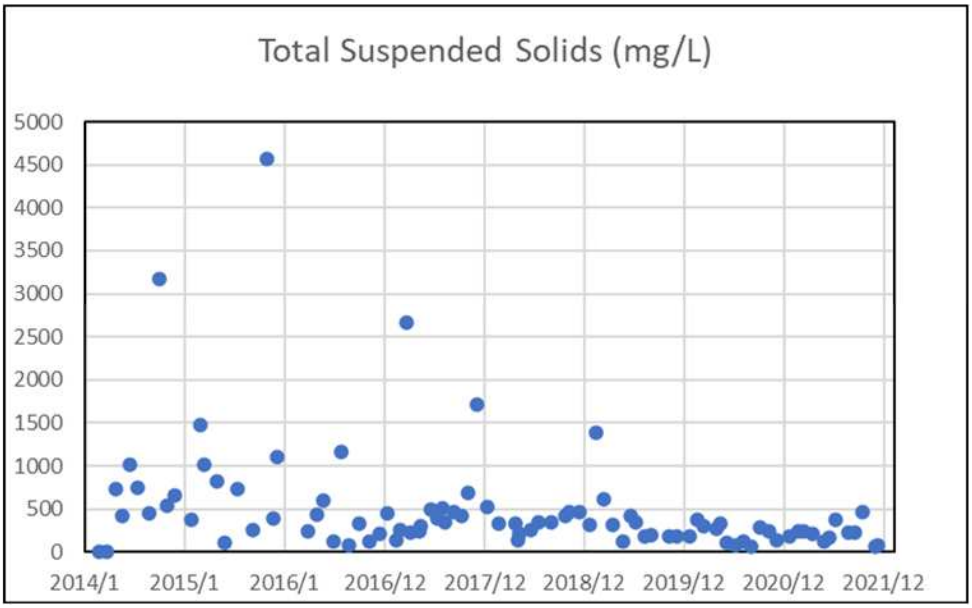
1) Pipeline Sewerage

Existing WWTPs have recorded influent water quality data from 2014-2021, as well as parameter values that were adopted in past Donor projects. In this project, the highest value from these records/reports were adopted for safekeeping.

i) Recorded Influent Data (Raw data)

During the field survey, 8 years' worth (2014-2021) of influent data was provided by WAF; however, due to the COVID-19 pandemic that started in 2019, the tourist population visiting Fiji sharply dropped from 2020, significantly affecting the economy and industrial activities. It is believed that the influent flowrate and water quality of sewerage also was affected by this decrease, producing irregular data. Therefore, in this report the raw data from 2014-2018 was adopted.

In addition, the recorded data showed some unusually high/low results, which were perhaps caused by sample contamination, mismeasurements etc. As an example, Navakai WWTP's TSS data is shown in **Figure A3-3.1**.



Source： Created by JET based of\n WAF laboratory data

Figure A3-3.1 TSS data of Navakai WWTP Influent

Since these abnormally high/low data values can lead to the over/under-estimation of influent water quality, the outlier data (top 5% and bottom 5%) was removed from each data group before calculations. **Table A3-3.1** organizes the annual average of raw influent data for each existing WWTP, as well as their maximum value.

Table A3-3.1 2014-2018 Annual Average of Raw Influent Data, and its Maximum Value

WWTP	2014-2018 Raw Influent Data (Annual Average)					
	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	T-N (mg/L)	T-P (mg/L)	FOG (mg/L)
Navakai (Nadi)	484.1	325.7	712.3	31.2	3.5	75.7
Natabua (Lautoka)	413.0	285.6	559.5	25.9	3.7	83.0
Votua (Ba)	406.2	242.8	558.0	20.3	3.3	52.4
Olosara (Sigatoka)	328.3	251.7	512.4	23.2	3.5	59.0
Maximum Value	484.1	325.7	712.3	31.2	3.7	83.0

Source: Created by JET based on WAF data

ii) Adopted Values in Past Projects

Navakai, Natabua, and Votua WWTP has had past projects designing to increase its' treatment capacities. The adopted influent water quality parameters of each project are organized in **Table A3-3.2** below.

Table A3-3.2 Adopted Influent Water Quality Parameters of Past Donor Projects

Target WWTP	Report Title	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	T-N (mg/L)	T-P (mg/L)
Navakai (Nadi)	Navakai WWTP Upgrade Detailed Design Report (2021)	310	300	659	58	6.0
	Navakai WWTP Upgrade Concept Report (2018)	372	360	792	70	7.0
Natabua (Lautoka)	Consultancy for the Upgrading of Wastewater Treatment Plant at Natabua Options Assessment	300	300	600	60	9.0
	Upgrading of Wastewater Treatment Plant at Natabua (2019)	300	300	624	60	9.0
Votua (Ba)	VotuaWWTP_Options_Memo_Client Issue_221121 (2021)	300	250	550	45	7.0
Maximum Value		372	360	792	70	9.0

Source: Created by JET based on "Navakai WWTP Upgrade Detailed Design Report," "Navakai WWTP Upgrade Concept Report," "VotuaWWTP_Options_Memo_Client Issue_221121"(Hunter H2O), " Consultancy for the Upgrading of Wastewater Treatment Plant at Natabua Options Assessment," "Upgrading of Wastewater Treatment Plant at Natabua" (GHD)

iii) Adopted Influent Water Quality Input Data

Table A3-3.3 organizes the input data of each influent water quality parameter that was adopted based on recorded raw data and past donor projects.

Table A3-3.3 Adopted Input Data for Influent Water Quality

Data Group	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	T-N (mg/L)	T-P (mg/L)	FOG (mg/L)
2014-2018 Data	484.1	325.7	712.3	31.2	3.7	83.0
Past Projects	372.0	360.0	792.0	70.0	9.0	—
Input Data	484.1 →485.0	360.0	792.0	70.0	9.0	83.0

Source： JET

2) Domestic Septage

Since Fiji does not have past records of septage water quality data, the recorded data from "Adoption/Demonstration Experiment Project of Johkaso Sludge Dewatering Machines in Cebu City (Philippines)" (2016) was adopted as a substitute. This project publicly provides actual data of the leachate and sludge cakes of mechanically dewatered Johkaso sludge.

Table A3-3.4 Adopted Water Quality Input Data of Domestic Septage

Leachate			Dewatered Sludge	
TSS	**BOD**	**COD**	**Water Content**	**TSS**
620 mg/L	250 mg/L	200 mg/L	75%	20,000 mg/L

Source: "Adoption/Demonstration Experiment Project of Johkaso Sludge Dewatering Machines in Cebu City (Philippines)" (AMCON INC.) (2016)

(2) Influent Water Temperature

The influent water temperature was set based on actual data recorded at Suva's Kinoya WWTP.

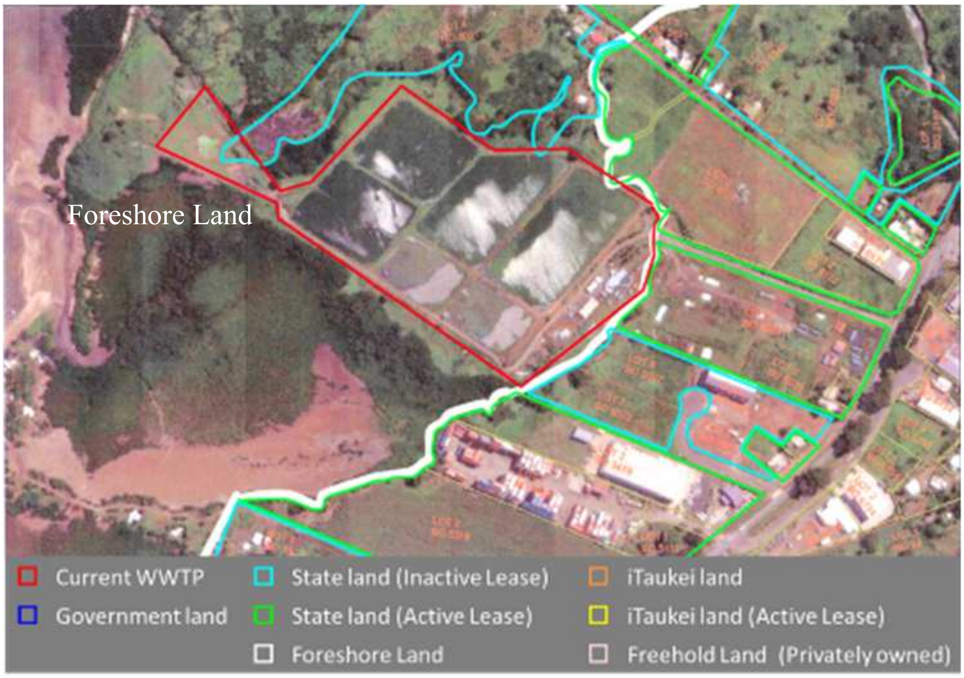
In the capacity calculation of WWTPs, safer-side results are produced by adopting lower water temperatures. The lowest water temperature recorded at Kinoya WWTP during 2007-2021 was 17.6°C. However, during this 15-year period this was the only instance when the influent temperature fell below 18°C, suggesting that this was an abnormal value.

On the other hand, influent temperatures between 19.4～19.8°C was recorded multiple times. From the above data analysis results, the water temperature in this project's calculations was set at 20°C.

APPENDIX 4-1 Current Land Use Situation around Existing and Future WWTP Site Candidates

(1) Natabua WWTP (Lautoka)

Data collected from the Ministry of Land showed that the current land use of Natabua WWTP's surrounding area were composed of mainly foreshore land, state land (inactive lease), and state land (active lease).



Source：Created by JET based on Ministry of Land data

Figure A4-1.1 Current Land Use Situation of Natabua WWTP Area

Table A4-1.1 Current Land Use Situation of Natabua WWTP Area

Land Use	Description
(State) Foreshore land	State-owned land that has not been surveyed in the past. To acquire and develop the land, surveys and environmental assessments must be conducted along with various procedures/document submissions.
State land (Inactive Lease)	State-owned land which does not have an active lease contract. It should be noted that these include land that is currently going through renewal procedures of the lease contract.
State land (Active Lease)	State-owned land which is currently under an active lease contract.

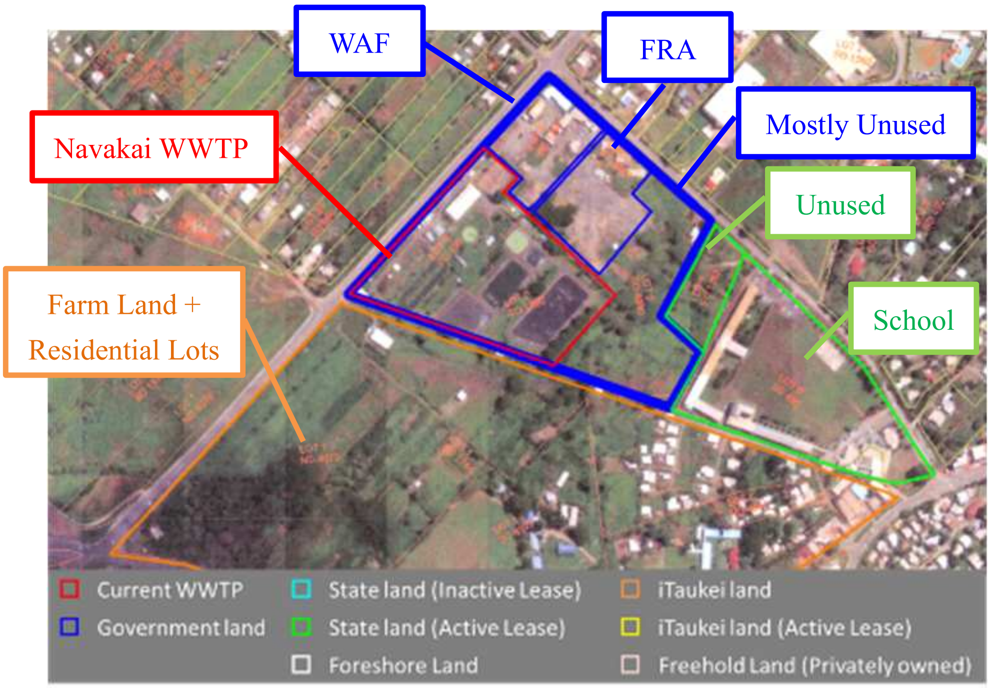
Source：Created by JET based on Ministry of Land data

The foreshore land adjacent to Navakai WWTP's current boundary currently has no legal owner or lease contractor, but upon land acquirement and development it will be necessary to carry out surveys, environmental assessments, and various procedures. The time requirement for these processes should be considered when plannning the WWTP's detailed construction period.

The remaining state land is are currently vacant lots that do not seem to be in active use, but a majority of it are currently under active lease contracts, and degotioastions are expected for its acquirement.

(2) Navakai WWTP (Nadi)

Data collected from the Ministry of Land showed that the current land use of Natabua WWTP's surrounding area were composed of mainly government land, iTaukei land, and state land (active lease).



Source: Created by JET based on Ministry of Land data

Figure A4-1.2 Current Land Use Situation of Navakai WWTP Area

Table A4-1.2 Current Land Use Situation of Navakai WWTP Area

Land Use	Description
Government land	Land secured for government-related use and institutions
iTaukei land	iTaukei-owned land. A minimum 60% approval from the owning iTaukei group members is necessary for its acquirement.
State land (Active Lease)	State-owned land which is currently under an active lease contract.

Source: Created by JET based on Ministry of Land data

The foreshore land adjacent to Navakai WWTP's current boundary currently has no legal owner or lease contractor, but upon land acquirement and development it will be necessary to carry out surveys, environmental assessments, and various procedures. The time requirement for these processes should be considered when plannning the WWTP's detailed construction period.

The remaining state land is are currently vacant lots that do not seem to be in active use, but a majority of it are currently under active lease contracts, and degotioastions are expected for its acquirement.

About half of the government land outside of Navakai WWTP's current boundaries are being currently used by WAF's Water Division and Fiji Road Authority (FRA); if this land is necessary for site expansion, negotiations with these parties will be necessary. The remaining government land is partly used as farmland and households, but the majority is covered by vegetation and not in use.

The iTaukei land located south-west of the WWTP is currently used as agricultural land and residential areas; acquirement of this land requires a minimum 60% consent of the owning iTaukei group, and expected to require time.

(3) Future WWTP Candidate Sites

In cases where additional land acquisition is difficult for existing WWTPs, or when multi-service areas for a single municipal is more efficient, other sites must be acquired for the establishment of new WWTPs. Two sites in Lautoka, and four sites in Nadi were brought up as possible candidate sites for future WWTPs, and their land use data was collected.

The below conditions were taken into consideration when choosing the candidate sites. At the point of November 2022, there were no other candidate sites meeting these conditions

- A certain amount of footprint is available in the surrounding area
- Location is close by to coastal lines and/or rivers where treated effluent can be discharged to
- Areas where resident relocation can be reduced as much as possible
- Avoid already-developed urban areas as much as possible (with the exception of existing WWTPs)
- Areas where the clearing of mangrove forests can be reduced as much as possible

Source：Created by JET based on Ministry of Land data

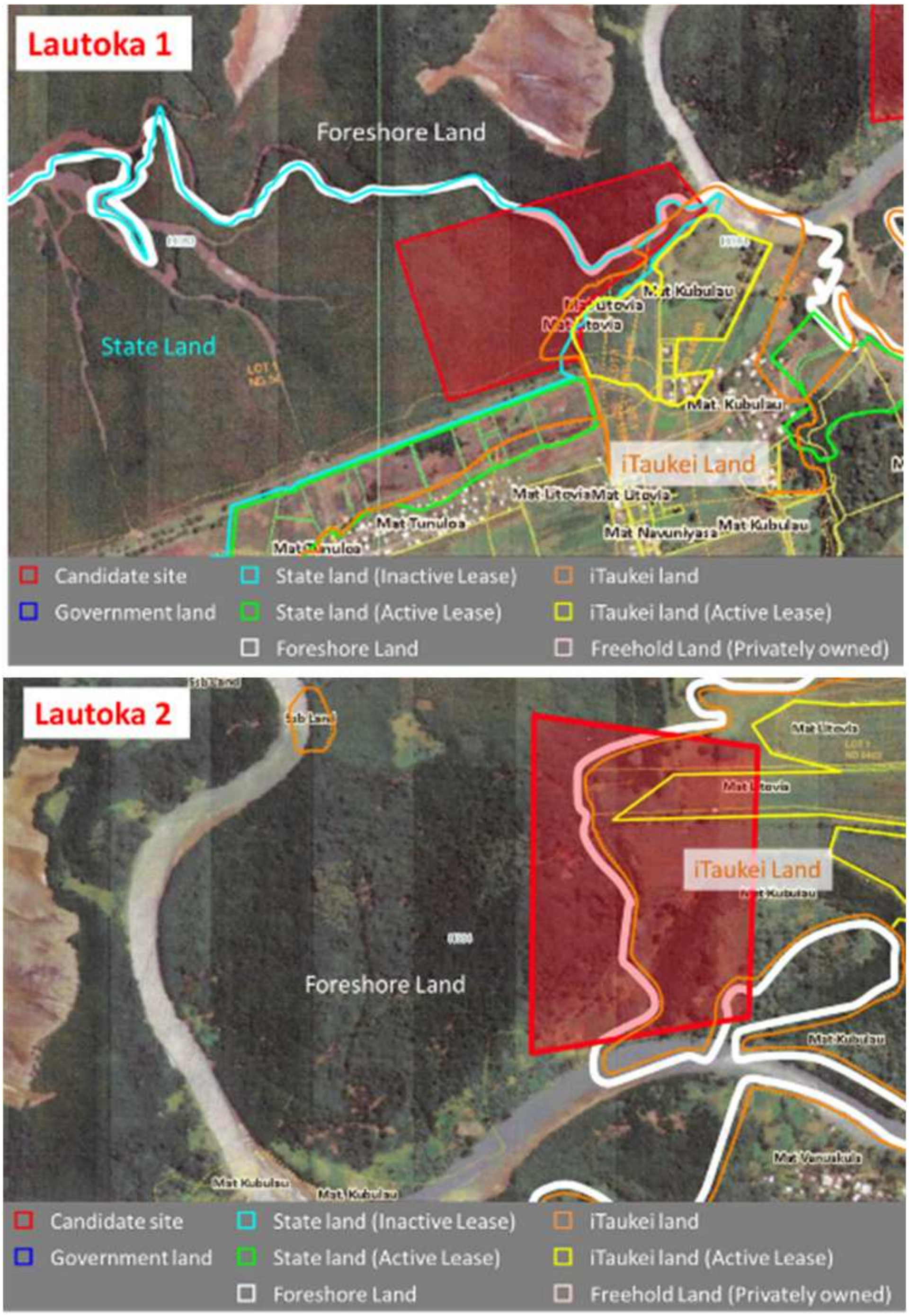
Figure A4-1.3 New WWTP Candidate Sites in Lautoka

Source：Created by JET based on Ministry of Land data

Figure A4-1.4 New WWTP Candidate Sites in Nadi

1) Lautoka

The land use situation of Lautoka's two candidate sites, Lautoka 1 and Lautoka 2 are organized as follows:



Source：Created by JET based on Ministry of Land data

Figure A4-1.5 Land Use of New WWTP Candidate Sites in Lautoka

Table A4-1.3 Land Use of New WWTP Candidate Sites in Lautoka

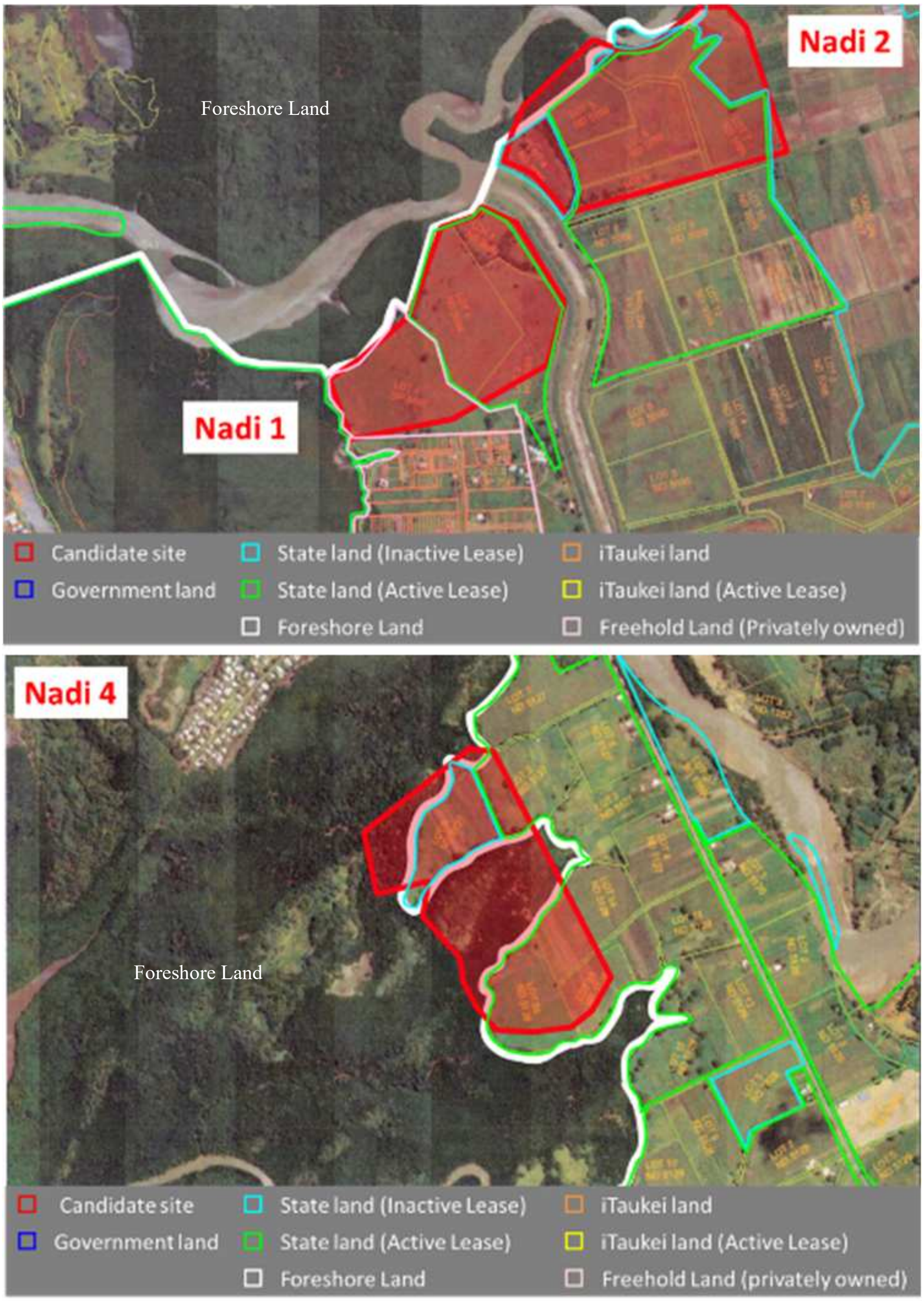
Land Use	Description
(State) Foreshore land	State-owned land that has not been surveyed in the past. To acquire and develop the land, surveys and environmental assessments must be conducted along with various procedures/document submissions.
State land (Inactive Lease)	State-owned land which does not have an active lease contract. It should be noted that these include land that is currently going through renewal procedures of the lease contract.
iTaukei land	iTaukei-owned land. A minimum 60% approval from the owning iTaukei group members is necessary for its acquirement.
iTaukei land (Active Lease)	iTaukei-owned land which is currently under an active lease contract.

Source：Created by JET based on Ministry of Land data

It was found that most of Lautoka 1 is state land (inactive lease) and foreshore land, while Lautoka 2 is composed of foreshore land, iTaukei land, and iTaukei land (active lease). As mentioned above, for acquirement foreshore land requires surveys and various document procedures, and iTaukei land requires negotiations to obtain the approval of 60% or more of the group owning the land. Such factors should be taken into account when planning the WWTP's construction period.

2) Nadi

Out of the four Nadi candidate sites Nadi 1 through Nadi 4, Nadi 3 was already going through document procedures for the lease contract and development plans by a private company, and was eliminated from the candidate list. Information of the remaining three sites were collected from the Ministry of Land.



Source：Created by JET based on Ministry of Land data

Figure A4-1.6 Land Use of New WWTP Candidate Sites in Nadi

Table A4-1.4 Land Use of New WWTP Candidate Sites in Nadi

Land Use	Description
(State) Foreshore land	State-owned land that has not been surveyed in the past. To acquire and develop the land, surveys and environmental assessments must be conducted along with various procedures/document submissions.
State land (Inactive Lease)	State-owned land which does not have an active lease contract. It should be noted that these include land that is currently going through renewal procedures of the lease contract.
State land (Active Lease)	State-owned land which is currently under an active lease contract.
Freehold land	Privately owned land

Source：Created by JET based on Ministry of Land data

As a result, the majority of all candidate sites are composed of state land (active lease); as for the remainder, Nadi 1 is composed of freehold land, Nadi 2 is state land (inactive lease), and Nadi 4 is state land (inactive lease) and foreshore land. As mentioned previously, if any land must be acquired from these sites, negotiations with current lease contractors (active lease lands), and surveys/document procedures are required.

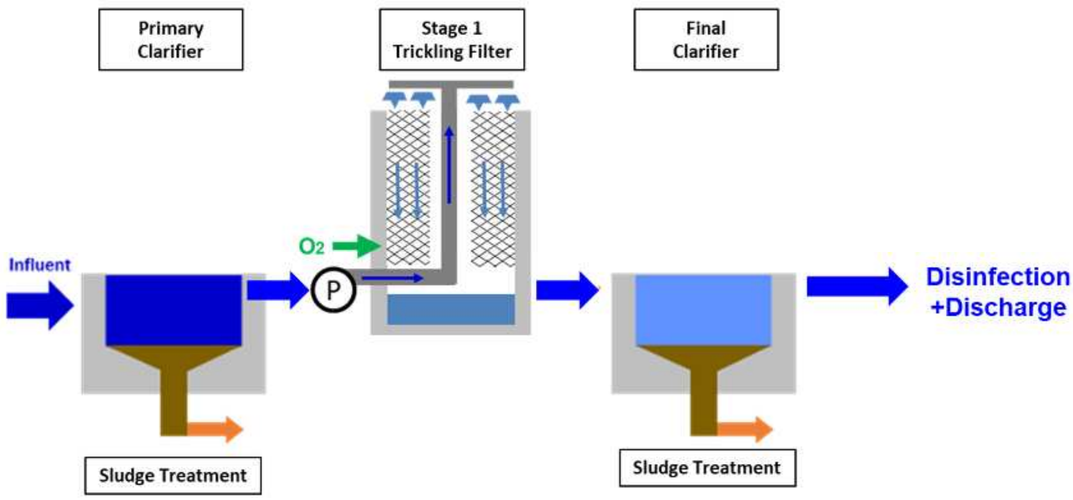
Site visits showed that the land is mostly used as farmland or grazing fields, and no other specific traces of development, land use was found at the time.

APPENDIX 4-2 Examination of the Trickling Filter Process

(1) Examination of The Trickling Filter Process

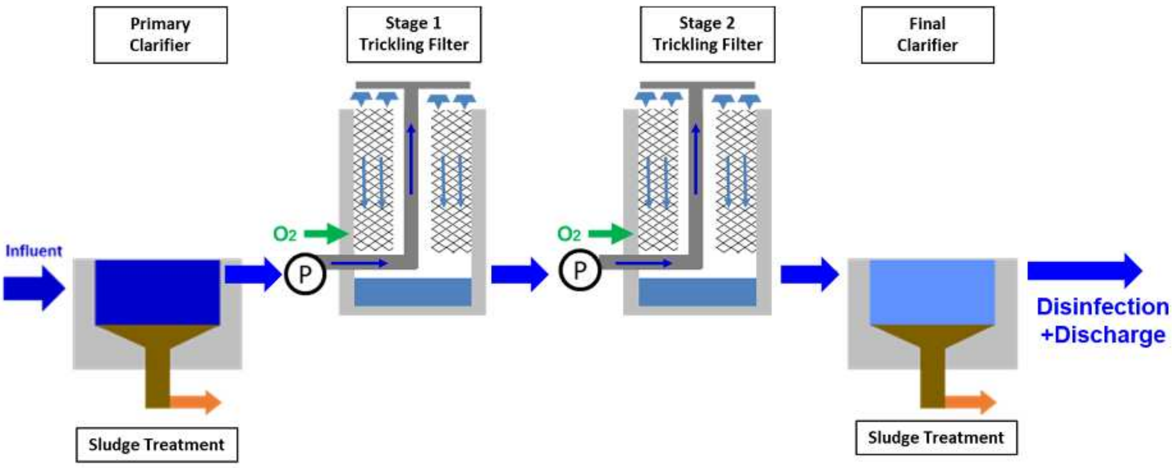
In addition to the wastewater treatment processes that were studied as possible processes in the Regional Wastewater M/P, the trickling filter process (hereinafter referred to as the "TF" process) was requested by WAF to be added to the candidate list.

WAF initially requested for a single-stage TF system (**Figure A4-2.1**), similar to the system adopted at Kinoya WWTP. However, the BOD removal rate of single-stage TF systems are limited to about 67-80%, and a simplified study estimated that when the system receives the Municipal Sewerage M/P's influent (with BOD 360 mg/L for the WWTP influent, and BOD 480 mg/L when return flow of the WWTP is added), its treated effluent BOD will be about 58 mg/L, not complying with General standards. Therefore, taking into consideration the system's treatment performance and other WAF requests (elimination of recirculation pumps to minimize O&M works/costs, etc.), the two-stage TF system (**Figure A4-2.2**) was adopted as the candidate process.



Source: : JET

Figure A4-2.1 Treatment Flow of Single-stage Trickling Filter Process



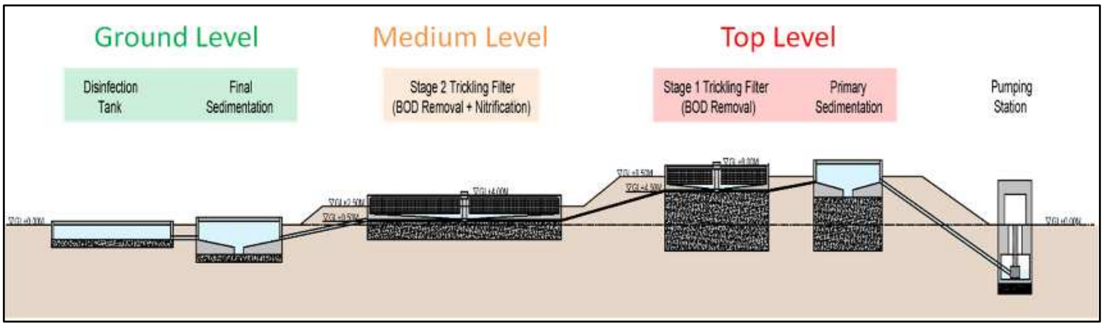
Source: : JET

Figure A4-2.2 Treatment Flow of Two-stage Trickling Filter Process

(1) Composition of the Two-stage Trickling Filter Process

Upon examining the TF process, WAF indicated its policy emphasizing the cost and labor reduction of O&M works, in return of additional construction costs. Upon further requests, the TF process layout was arranged by placing its components on two different-height embankments, so no pumps were required to send wastewater to the top of the trickling filter towers: instead, gravitational flow will naturally flow the sewerage down the plant (**Figure A4-2.3**).

(As for records, when arranging the gravity-flow type TF facilities, explanations were made that even if the pumps at each TF tower were eliminated, the onsite pumping station's lifting height (at the very start of the treatment flow) will need to be greatly increased to 10 meters or more; estimations were made that the power consumptions of the pumps will total up to be about equal for both case scenarios, but the gravity flow method was adopted due to the strong request of WAF.)



Source: : JET

Figure A4-2.3 Cross Sectional Image of the Gravitationally-flowed Two-stage TF Process

APPENDIX 4-3 Capacity Calculations of Wastewater Treatment Processes

(1) Stabilization Pond：10,000 m³/day Model

Stabilization Pond_10,000m3/day Model

0) Input Data

Design Flow

ADWF (with Septage)	10,000	m3/day
Max Daily Flow Rate	11,000	m3/day
Max Hourly Flow Rate	20,000	m3/day
PWWF(with Septage)	50,000	m3/day

Design Qualitiy

Influent Water Quality

BOD	360	mg/L
TSS	484	mg/L
TKN	70	mg/L
TP	9	mg/L
COD	792	mg/L

Required Effluent Water Quality(General Standards)

BOD	40	mg/L
TSS	60	mg/L
TN	25	mg/L
TP	5	mg/L

1) Anaerobic Pond

① **Pond Capacity**

AaDa=Q x Li_an / λv

AaDa : anaerobic pond working Volume, m3
Q : average flow, m3/d
Li_an : raw sewage strength, mg BOD/L
λv : volumetric loading, g/m3/d

Anaerobic Pond Depth： 4 m

Facultative Pond Temperature(℃)	Volumetric Loading λv (g BOD/m³/day)	BOD removal (%)
< 10	100	40
10-20	20T-100	2T + 20
20-25	10T+100	2T +20
>25	350	70

Source: Duncan Mara, Domestic Wastewater Treatment in Developing Countries (2003), p109

T= 20 Celsius
λv = 10 x 20 + 100 = 300 g/m3/d

Li_an = Influent BOD = 360 mg/L

AaDa=Q x Li_an / λv
AaDa = 10,000 x 360 / 300
= 12,000 m3
→ **4 m x 100 m x 10 m x 4** ponds = 16,000 m3
→ Pond Capacity:OK

HRT = Van / Q

Van : Volume of Anaerobic Pond, m3

HRT : Hydraulic Retention Time for Aeration

= 1 days

(Metcalf & Eddy, Westewater Engineering, 4th Ed. P841)

Q : average flow, m3/d

HRT = 16,000 / 10,000

= $\boxed{1.6 \text{ days}}$ > 1 day

→ HRT: OK

② Effluent BOD

Le_an= Li_a -(Li_a x [BOD Rem. Of Anaerobic Pond] x [Reduced Removal rate]

Le_an : Effluent BOD from anaerobic pond, mg/L

Li_an : Influent BOD, mg/L

Facultative Pond Temperature(℃)	BOD removal (%)
< 10	40
10-20	2T + 20
20-25	2T +20
>25	70

Source: Duncan Mara, Domestic Wastewater Treatment in Developing Countries (2003), p109

T= 20 Celsius

BOD removal % = 2T + 20 = 2 x 20 + 20 = 60 %

Assuming Reduced Removal rate of anaerobic pond is: 75 % .

Li_an = 360 mg/L

Le_an = Li_a -(Li_a x BOD Rem. x 75 %)

= 360 -(360 x 60 % x 75 %)

= $\boxed{198 \text{ mg/L}}$

2)Facultative Pond

① Pond Capacity

a) Surface Loading-base Calculation

$Af=Qx10xLi\_f/\lambda s$

Af : Surface Area of Faculative Pond, m2

Q : average flow, m3/d = 10,000 m3/d

Li_f : Influent BOD into faculative pond, mg/L = 198 mg/L

λs : Surface BOD loading, kg/ha・d

※ 10: unit conversion factor

Surface BOD loading(λs) Calculation

Facultative Pond	Surface Loading kg BOD/ ha day	Facultative Pond Effluent BOD, mg/L
Primary Pond	$350 \times (1.107-0.002\ T)^{(T-25)}$	$Li/(1+k_1\theta_f)$, $k_1=k_{(20)}(1.05)^{T-20}$, $k_{(20)}=0.3$
Secondary Pond	$350 \times (1.107-0.002\ T)^{(T-25)}$	$Li/(1+k_1\theta_f)$, $k_1=k_{(20)}(1.05)^{T-20}$, $k_{(20)}=0.1$

Source: Duncan Mara, Domestic Wastewater Treatment in Developing Countries (2003), pp118-121

※Primary Pond: Pond without preceeding anaerobic pond, Secondary Pond: Pond following Anaerobic Pond

Faculatative Pond : Secondary Pond

T = 20 Celsius

λs = 350 x(1.107 - 0.002 x 20)^ (20 - 25)

= 253.07 kg/ha/d

$Af=Qx10xLi\_f/\lambda s$

Af = 10,000 x 10 x 198 / 253.07

= 78,238 m2

→ **100 m x 320 m x 4** ponds

= 128,000 m2

→ Pond Area: OK

a)Hydraulic Retention Time

θ_f = 2xAfxDf/(2 x Q-0.001 x e x Af)

θ_f : Retention time (days)

Af = 128,000 m2

Df = 1.8 m : Depth of Facultative Pond (Range: 1.0 ~ 1.8 m)

Q = 10,000 m3/d : Average Daily Flowrate

e = 5 mm/d : net evaporation rate

θ_f = 2 x 128,000 x 1.8 /(2 x 10,000 - 0.001 x 5 x 128,000)

= 23.8 days

Minimum Retention Time:

<20°C : 5 days

≧20°C : 4 days

→ HRT: **OK**

②Effluent BOD

Facultative Pond	Surface Loading kg BOD/ ha day	Facultative Pond Effluent BOD, mg/L
Primary Pond	$350 \times (1.107-0.002\ T)^{(T-25)}$	$Li/(1 + k_1 \theta_f)$, $k_1 = k_{(20)}(1.05)^{T-20}$, $k_{(20)} = 0.3$
Secondary Pond	$350 \times (1.107-0.002\ T)^{(T-25)}$	$Li/(1 + k_1 \theta_f)$, $k_1 = k_{(20)}(1.05)^{T-20}$, $k_{(20)} = 0.1$

Source: Duncan Mara, Domestic Wastewater Treatment in Developing Countries (2003), pp118-121
※Primary Pond: Pond without preceeding anaerobic pond, Secondary Pond: Pond following Anaerobic Pond

Le_f : Effluent BOD out of faculative pond, mg/L
Li_f : Influent BOD into faculative pond, mg/L = 198 mg/L
θ_f : Hydraulic Retention Time, d = 23.8 d
T : Water Temeperature = 20.0 Celsius

k1 = 0.1 x (1.05)^ (20 ー 20)
= 0.1

Le_f = 198 /(1+ 0.1 x 23.8)
= $\boxed{59 \text{ mg/L}}$

3)Maturation Pond

① Pond Capacity

a) HRT-base Calculation

Vm = θm x Q

Vm : Volume of Maturation Pond, m3
θm : Hydraulic Retention Time
= 3 days (Duncan Mara, p.143)
Q : average flow, m3/d

= 3 x 10,000
= 30,000 m3

DL = Maturation Pond Depth :
= 1.3 m

→ **1.3 m x 100 m x 200 m x 4** ponds = 104,000 m3
※1 pond per treatment line → Pond Capacity: OK

θm = Vm / Q

Vm : Volume of maturation, m3
θm : Hydraulic Retention Time
Q : average flow, m3/d

θm = 104,000 / 10,000
= 10.4 days   HRT Range: Minimum 3 days
→ HRT: OK

b) Surface Loading

$$\lambda s\_m = \frac{10 \times Li\_m \times Dm}{\theta m}$$

λs_m : Surface Loading of Maturation Pond
Li_m : Unfiltered BOD influent into maturation pond = 59 mg/L
Dm : Depth of maturation pond = 1.3 m
θm : Hydraulic Retention Time = 10.4 d

$$\lambda s\_m = \frac{10 \times 59 \times 1.3}{10.4}$$

= 73.2 kg BOD/ ha/day

Check: Surface loading of maturation pond must be 70% or less of the faculative pond

Max λs_m = 253.1 x 70%
= 177.2 kg BOD/ ha/day < 73.2 kg BOD/ ha/day , OK

③ Effluent BOD

a)Soluble BOD

$$Le\_m = \frac{Li\_m}{1 + k1 \times \theta}$$

Le_m	: Effluent BOD from maturation pond, mg/L			
Li_m	: Influent BOD into maturation pond, mg/L	=	58.6	mg/L
θ	: Retention time, d	=	10.4	d
k1	= 0.05 /d			

$$Le\_m = \frac{Li\_m}{1 + k1 \times \theta}$$

$= 58.6 \; / (1 + 0.05 \times 10.4)$

$= \boxed{38.54 \text{ mg/L}} \leqq 40$ mg/L : General in Concentration Standards of National Liquid Waste Standards

→ Effluent BOD: OK

d) Check: Total Effluent BOD

Mora Equation

Effluent BOD from maturation pond = Effluent BOD from facultative pond x 20%

$= 59 \times 0.2 = \boxed{11.7 \text{ mg/L}} < 40$ mg/L

: General in Concentration Standards of National Liquid Waste Standards

→ Effluent BOD: OK

4)Sludge Treatment

a) Sludge Produced

For Q= 10,000 m3/d

Estimated Total Sludge Volume

= V_an × 30% + V_f × 20%

=(16,000 × 30% + 104,000 × 20%)

= **25,600 m3**

Estimated Desludging Period

= 10 years

Annual Desludging Volume

= 25,600 / 10 = 2,560 m3/year

b)Desludging Period

Desludging shall be done every n years, when the Anaerobic Pond gets 1/3 full of sludge

n = V_an / 3Ps

V_an : Volume of Anaerobic Pond, m3 = 16,000 m3

P : Population served by Q, persons

s : Sludge accumulation rate, m3/person year = 0.04 m3/person year

P = Q / p

Q : sewerage flowrate, m3/d = 10,000 m3/d

p : sewerage produced per person, L/person = 200 L/person

P = 10,000 m3/d / 200 × 1000

= 50,000 persons served

n = V_an / 3Ps

= 16,000 /(3 × 50,000 × 0.04)

= 2.7 Years

→ **2 years**

c) Sludge Dewatering

Desludging to be done once in **2 years**

Desludged volume per desludging event = 25,600 m3 × (2 / 2)

= **25,600** m3/desludging event

= **25,600** m3/2 yrs

= **12,800** m3/yrs

(Desludge all AN, FA, MA ponds at one desludging event)

Sludge Volume(Dewatered) = V x TSS / Solids Concentration （Dewatered Sludge)

Sludge TSS

= 20,000 mg/L

Dewatered Sludge Solids Concentration

= 25 %

Desludge Volume(Dewater)

= V x TSS /

= 25,600 x 20,000 / 1,000,000

x 1,000 / 0.25 / 1,000

= 2,048 m3 dewatered sludge total/desludging event

c) Sludge Drying Bed

Number of pond trains: 4

Let:

Desludging/sludge drying all ponds at once

Amountof sludge to be dried= 2,048 m3 dewatered sludge / 1

= 2,048 m3 dewatered sludge

Sludge thickness = h= 0.3 m

Drying period : 5 months

Dry Sludge Area = 2,048 / 0.3 = 6,827 m3

→ 100 m x 100 m = 10,000 m2

→ Drying Bed Area OK

60 m x 166.67

d) Sludge Storage Pit

Sludge Volume(Dewatered) = V x TSS / Solids Concentration (Dewatered Sludge)

V = per-year volume of desludged sludge produced in 2 years

= 25,600 m3 / 2 years

= 12,800 m3/year

TSS = 20,000 mg/L

Solids concentration of sun-dried sludge: 25%

= V x TSS / SC

= 12,800 x 20,000 / 1,000,000

x 1,000 / 0.3 / 1,000

= 1,024 m3/ year

Sludge Storage Period: 20 years

Sludge Depth: 3 m

Sludge Storage Volume = 1,024 x 20

= 20480 m3

→ 3 m x 100 m x 70 m = 21000 m3

7000

→ Storage Space: OK

5) Pond Dimensions

Pond Dimensions

AN	Anaerobic Pond	Surface Area	4,000 m^2	W 100 m
		Volume	16,000 m^3	L 10 m
		Average depth	4 m	4 Ponds
		Pond Strucuture Depth	4.5 m	
FA	Facultative Pond	Surface Area	128,000 m^2	W 100 m
		Volume	230,400 m^3	L 320 m
		Average depth	1.8 m	4 Ponds
		Pond Strucuture Depth	2.3 m	
MA	Maturation Pond	Surface Area	80,000 m^2	W 100 m
		Volume	104,000 m^3	L 200 m
		Average depth	1.3 m	4 Ponds
		Pond Strucuture Depth	1.8 m	
SDB	Sludge Drying Bed	Surface Area	10,000 m^2	W 100 m
		Volume	3,000 m^3	L 100 m
		Average Sludge depth	0.3 m	1 Bed
		Bed Structure Depth	0.8 m	
SS	Sludge Storage Pit	Surface Area	7,000 m^2	W 100 m
		Volume	21,000 m^3	L 70 m
		Average Depth	3 m	1 Pit
		Structure Depth	3.5 m	

(2) Aerated Lagoon：10,000 m^3/day Model

Aerated Lagoon_10,000 m3/day Model

0) Input Data

Design Flow

ADWF（with Septage)	10,000	m3/day	
Max Daily Flow Rate	11,000	m3/day	
Max Hourly Flow Rate	20,000	m3/day	
PWWF(with Septage)	50,000	m3/day	

Design Qualitiy

Influent Water Quality

BOD	360	mg/L
TSS	484	mg/L
TKN	70	mg/L
TP	9	mg/L
COD	792	mg/L

Required Effluent Water Quality(General Standards)

BOD	40	mg/L
TSS	60	mg/L
TN	25	mg/L
TP	5	mg/L

1) Anaerobic Pond

① **Pond Capacity**

AaDa=Q x Li_an / λv

AaDa : anaerobic pond working Volume, m3
Q : average flow, m3/d
Li_an : raw sewage strength, mg BOD/L
λv : volumetric loading, g/m3/d

Anaerobic Pond Depth： 3 m

Facultative Pond Temperature(℃)	Volumetric Loading λv (g BOD/m^3/day)	BOD removal (%)
< 10	100	40
10-20	20T-100	2T + 20
20-25	10T+100	2T +20
>25	350	70

Source: Duncan Mara, Domestic Wastewater Treatment in Developing Countries (2003), p109

T= 20 Celsius
λv = 10 x 20 + 100 = 300 g/m3/d

Li_an = Influent BOD = 360 mg/L

AaDa=Q x Li_an / λv
AaDa = 10,000 x 360 / 300
= 12,000 m3
→ **3 m x 40 m x 30 m x 4** ponds = 14,400 m3
→ Pond Capacity: OK

HRT = Van / Q

Van : Volume of Anaerobic Pond, m3

HRT : Hydraulic Retention Time for Aeration

= 1 days

(Metcalf & Eddy, Westewater Engineering, 4th Ed. P841)

Q : average flow, m3/d

HRT = 14,400 / 10,000

= $\boxed{1.4 \text{ days}}$ > 1 day

$\boxed{\rightarrow \text{HRT: OK}}$

② **Effluent BOD**

Le_an= Li_a -(Li_a x [BOD Rem. Of Anaerobic Pond] x [Reduced Removal rate]

Le_an : Effluent BOD from anaerobic pond, mg/L

Li_an : Influent BOD, mg/L

Facultative Pond Temperature(℃)	BOD removal (%)
< 10	40
10-20	2T + 20
20-25	2T +20
>25	70

Source: Duncan Mara, Domestic Wastewater Treatment in Developing Countries (2003), p109

T= 20 Celsius

BOD removal % = 2T + 20 = 2 x 20 + 20 = 60 %

Assuming Reduced Removal rate of anaerobic pond is: 50 % .

Li_an = 360 mg/L

Le_an = Li_a -(Li_a x BOD Rem. x 50 %)

= 360 -(360 x 60 % x 50 %)

= $\boxed{252 \text{ mg/L}}$

2)Aerated Facultative Pond

① Pond Capacity

a) Aeration HRT-base Calculation

Vf = HRT x Q

Vf : Volume of Faculative Pond, m3
HRT : Hydraulic Retention Time for Aeration
= 6 days
(Duncan Mara, p.214)
Q : average flow, m3/d

Faculative Pond Depth : 3 m

Vf = θf x Q
= 6 x 10,000 = 60,000 m3
→ **3 m x 40 m x 130 m x 4 ponds** = 62,400 m3
→ Pond Capacity: OK

b) Actual Retention Time

θf = Vf /Q
= 62,400 / 10,000
= 6.2 d

② Power Requirement for Aeration

Ef = E x Vf / Q

Ef : Total Electricity consumption of Faculative Pond Aerateors
E : Electricity consumption of aerator to treat 1,000m3 wastewater
= 8 KW/10^3 m3 (Metcalf & Eddy, Westewater Engineering, 4th Ed. P841)
Vf : Volume of Faculative Pond
Q : Average Flow, m3/d

Ef = 8 x 62,400 / 1,000
= 500 kw

Pf=Ef x t x d

Pf : Total Power consumption of Faculative Pond Aerateors, kWh
Ef : Total Electricity consumption of Faculative Pond Aerateors, kW
t : operating hours of aerators per day, hr/d
d : days of operation per year, d/year

t = 12 hrs operation/d
d = 365 days operation/year

Pf =Ef x t x d
= 500 x 12 x 365
= 2,190,000 kWh/year

Check: Power consumption per m3 wastewatertreated

= Ef x t /ADWF

= 500 x 12 / 10,000

= 0.6 kWh/m3 wastewater treated

③Effluent BOD

a) Soluble (Non-biooxidized) BOD

$$Se\_f = \frac{Li\_f}{1 + k1 \times \theta f}$$ (Duncan Mara, p.214)

Se_f	: Soluble Effluent BOD from anaerobic pond, mg/L			
Li_f	: Influent BOD into faculative pond, mg/L	=	252	mg/L
k1(20)	: 2.5 at 20°C, day^-1			
θ f	: Hydraulic Retention Time of Faculative Pond,d	=	6.2	d

Se_f = 252 /(1 + 2.5 x 6.2)

= $\boxed{15.2 \text{ mg/L}}$

b) Insoluble (algal) BOD

$$X = \frac{Y(Li\_f - Se\_f)}{1 + bd \times \theta f}$$

X	: Concentration of microorganisms in pond, mg/L			
Y	: Yield Coefficient of microorganisms (mg X/mg BOD)	=	0.65	
Se_f	: Soluble Effluent BOD from faculative pond, mg/L	=	15.2	mg/L
Li_f	: Influent BOD into faculative pond, mg/L	=	252	mg/L
bd	: Death rate coefficient of microorganisms, 1/d	=	0.07	/d
θ f	: Retention Time, d	=	6.2	d

$$X = \frac{0.65 \times (252 - 15)}{1 + (0.07 \times 6.2)}$$

= $\boxed{107 \text{ mg/L}}$

c) Total Effluent BOD

Le_f = Se +0.94X

Le_f	: Total Effluent BOD from faculative pond, mg/L			
Se_f	: Soluble Effluent BOD from faculative pond, mg/L	=	15.2	mg/L
X	: Concentration of microorganisms in pond, mg/L	=	107	mg/L
	(0.94 = Conversion factor of algal cell mass→BOD5)			

Le_f = 15.2 + 0.94 x 107

= $\boxed{115.89 \text{ mg/L}}$

3)Maturation (Sedimentation) Pond

① Pond Capacity

a) HRT-base Calculation

Vm = HRT x Q

Vm : Volume of Maturation Pond, m3
HRT : Hydraulic Retention Time for Aeration
= 1 days (Duncan Mara, p.220)
Q : average flow, m3/d

= 1 x 10,000
= 10,000 m3

DL = Maturation Pond Liquid Depth：
= 1.5 m

→ **1.5 m x 40 m x 50 m x 4** ponds = 12,000 m3

→ Pond Capacity: OK

HRT = Van / Q

Vf : Volume of Faculative Pond, m3
HRT : Hydraulic Retention Time for Aeration
= 1 days
(Duncan Mara, p.220)
Q : average flow, m3/d

HRT = 12,000 / 10,000
= 1.2 days   HRT Range: 6 hr~2 days

→ HRT: OK

b) Sludge Layer Depth

$$\mathbf{Ds} = \frac{\mathbf{Mn/Am}}{\mathbf{0.15 \times 1060}}$$

Ds : Sludge layer depth of maturation pond, m
Mn : Total mass of suspended solids in the maturation pond at n years, kg/yr
Am : Surface Area of Maturation Pond, m2 = 8000 m2
※ 0.15: Average Sludge compaction: 15% solids
Density of Accumulated sludge: 1060 kg/m3

M = 365Q (SSrw+X-SSe) x 10^-3

M : Total mass of suspended solids added per year, kg/yr
Q : average flow, m3/d = 10,000 m3/d
SSrw : SS of raw influent (mg/L) = 484 mg/L
X : Concentration of microorganisms in pond, mg/L = 107 mg/L
Sse : SS of final effluent (mg/L)
(Assuming 90% removal of insoluble BOD =algae)
= 0.9 x X = 0.9 x 107
= 96.4 mg/L

M = 365 x 10,000 x(484 + 107 - 96.4) x 10^-3
= 1,805,705 kg/yr

Mfs = Mass of fixed SS, kg/yr = 0.3M = 541,711 kg/yr
Mvs = Mass of volatile SS, kg/yr = 0.7M = 1,263,993 kg/yr

Mn = N x (Mfs +0.25Mvs)
Mn : Total mass of suspended solids in the maturation pond at n years, kg/yr
N : Frequency of maturation pond desludging = Once in **2 year**

Mn = 2.0 x (541,711 + 0.25 x 1,263,993)
= 1,715,419 kg/yr
1,715

$$\mathbf{Ds} = \frac{\mathbf{Mn/Am}}{\mathbf{0.15 \times 1060}} = \frac{\mathbf{1{,}715{,}419 \;/\; 8000}}{\mathbf{0.15 \times 1060}}$$

= $\boxed{1.4 \text{ m}}$

c) Total Working Depth of Maturation Pond

Dm = DL + Ds
= 1.5 + 1.4
= $\boxed{2.9 \text{ m}}$

Maturation Pond Dimension:
→ $\boxed{\textbf{2.9 m x 40 m x 50 m x 4} \text{ ponds}}$

③ Effluent BOD

a)Soluble BOD

$$\mathbf{Se\_m} = \frac{\mathbf{Si\_m}}{\mathbf{1 + k1 \times \theta}}$$

Se_m : Effluent BOD from maturation pond, mg/L
Si_m : Total Influent BOD into maturation pond, mg/L = 15.2 mg/L
θ : Retention time, d = 1.2 d
k1 = 0.05 /d

$$Se\_m = \frac{Si\_m}{1 + k1 \times \theta}$$

= 15.2 /(1 + 0.05 x 1.2)
= $\boxed{14.321 \text{ mg/L}}$

b) Insoluble (algal) BOD

Assuming: 90% of insoluble (algal) BOD percipitates in maturation pond

Ie_m = (1- 0.9) x 0.94 X

Ie_m : Insoluble Effluent BOD from maturation pond, mg/L
X : Concentration of microorganisms in pond, mg/L = 107 mg/L
(0.94 = Conversion factor of algal cell mass→BOD5)

Ie_m = (1- 0.9) x 0.94 x 107
= $\boxed{10.071 \text{ mg/L}}$

c) Total Effluent BOD

Le_m = Se_m + Ie_m
= 14.321 + 10.07
= $\boxed{24.392 \text{ mg/L}}$ < 40 mg/L : General in Concentration Standards of National Liquid Waste Standards

→ Effluent BOD: OK

d) Check: Total Effluent BOD

Mora Equation

Effluent BOD from maturation pond = Effluent BOD from facultative pond x 20%
= 115.89 x 0.2 = $\boxed{23.2 \text{ mg/L}}$ < 40 mg/L
: General in Concentration Standards of National Liquid Waste Standards

→ Effluent BOD: OK

4)Sludge Treatment

a)Desludging Period

Desludging shall be done every n years, when the Anaerobic Pond gets 1/3 full of sludge

n = V_an / 3Ps

V_an	: Volume of Anaerobic Pond, m3	=	14,400	m3
P	: Population served by Q, persons			
s	: Sludge accumulation rate, m3/person year	=	0.04	m3/person year

P = Q / p

Q	: sewerage flowrate, m3/d	=	10,000	m3/d
p	: sewerage produced per person, L/person	=	200	L/person

P = 10,000 m3/d / 200 × 1000
= 50,000 persons served

n = V_an / 3Ps
= 14,400 /(3 × 50,000 × 0.04)
= 2.4 Years
→ **2 years**

b) Sludge Produced

Total mass of SS removed by AL treatment in 2 years

Mn = 2 x (541,711 + 0.25 x 1,263,993)
= 1,715,419 kg/2 yrs
= 1,715 t/2 yrs
= 858 t yrs

c) Sludge Dewatering

Desludging to be done once in **2 years**

Desludged volume per desludging event = 1,715 t × (2 / 2)
= **1,715** t/desludging event
(Desludge all AN, FA, MA ponds at one desludging event)

Dewatered Sludge Solids Concentration
= 25 %

Desludge Volume(Dewater)
= 1,715 t-SS / 25 % × m3/t
= 6,862 m3 dewatered sludge total/desludging event
2年分の汚泥

c) Sludge Drying Bed

Number of pond trains: 4

Amountof sludge to be dried= 6,862 m3 dewatered sludge / **2**
= 3,431 m3 dewatered sludge

Sludge thickness = h= 0.3 m
Drying period : 5 months
Dry Sludge Area = 3,431 / 0.3 = 11,436 m2
→ 100 m x 120 m = 12,000 m2
→ Drying Bed Area OK

395 m x 30.38 m

d) Sludge Storage Pit

Sludge Volume(Dewatered) = V x TSS / Solids Concentration (Dewatered Sludge)

V = per-year volume of desludged sludge produced in 2 years
= 1,715 t-SS/ 2 years
= 858 t/year

Solids concentration : 25%
= 858 t-SS / 25% × m3/t
= 3,431 m3 dried Sludge/yr

Sludge Storage Period: 20 years
Sludge Depth: 3 m

Sludge Storage Volume = 3,431 m3 dried sludge x(20 years)
= 68,617 m3
→ 3 m x 60 m x 385 m = 69300 m3
→ Storage Space: OK

5) Pond Dimensions

Pond Dimensions

AN	Anaerobic Pond	Surface Area	4,800 m^2	W 40 m
		Volume	14,400 m^3	L 30 m
		Average depth	3 m	4 Ponds
		Pond Strucuture Depth	3.5 m	
FA	Facultative Pond	Surface Area	20,800 m^2	W 40 m
		Volume	62,400 m^3	L 130 m
		Average depth	3.0 m	4 Ponds
		Pond Strucuture Depth	3.5 m	
MA	Maturation Pond	Surface Area	8,000 m^2	W 40 m
		Volume	23,200 m^3	L 50 m
		Average depth	2.9 m	4 Ponds
		(Liquid Depth)	1.5 m	
		(Sludge Depth)	1.4 m	
		Pond Strucuture Depth	3.4 m	
SDB	Sludge Drying Bed	Surface Area	12,000 m^2	W 100 m
		Volume	3,600 m^3	L 120 m
		Average Sludge depth	0.3 m	1 Bed
		Bed Structure Depth	0.8 m	
SS	Sludge Storage Pit	Surface Area	23,100 m^2	W 60 m
		Volume	69,300 m^3	L 385 m
		Average Depth	3 m	1 Pit
		Structure Depth	3.5 m	

Aerators

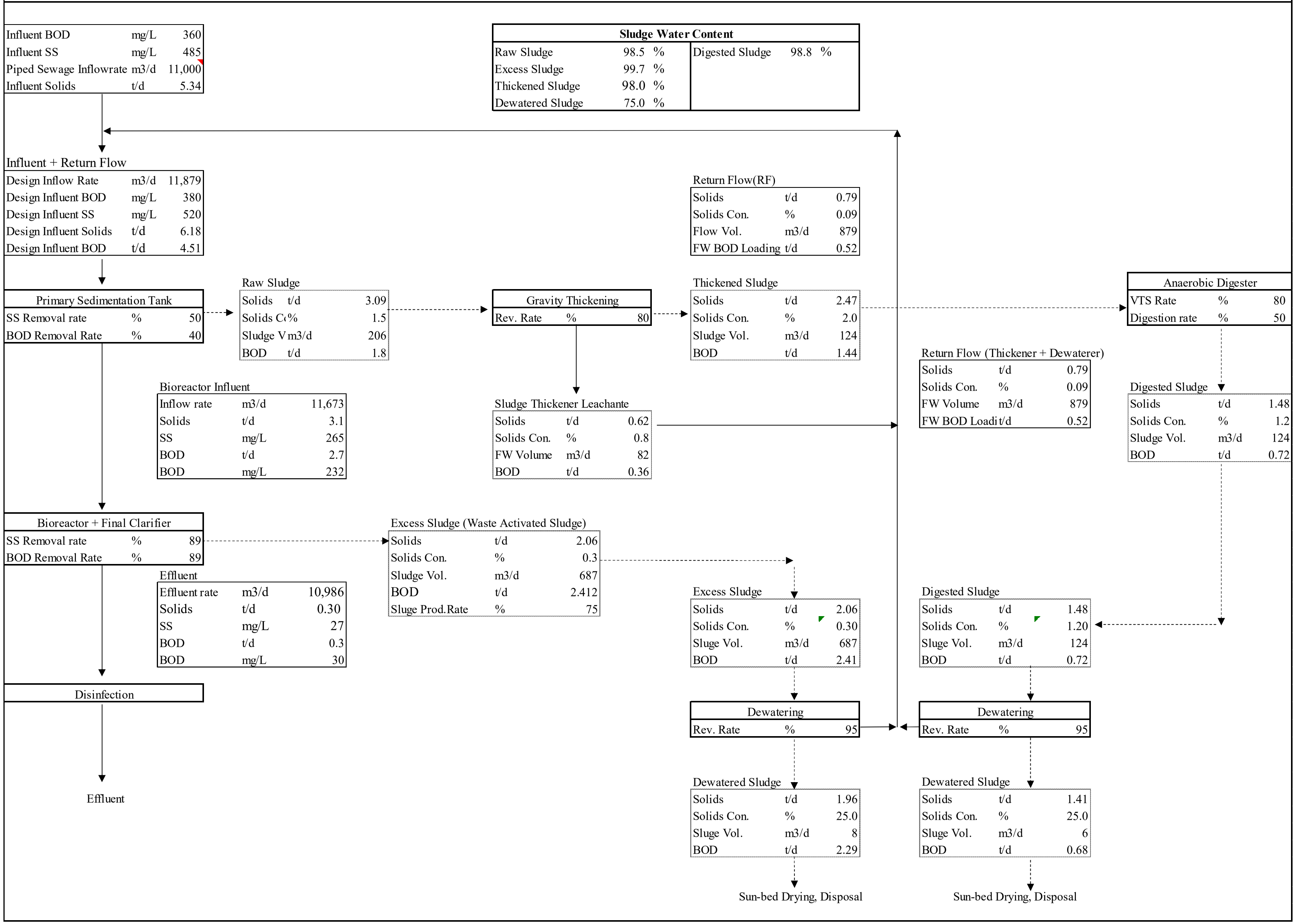
FA	Facultative Pond	No. of operating aerators	4 aerators
		Total electricity consumption	500 kW
		Total power consumption	2,190,000 kWh/yr

(3) Trickling Filter：10,000 m^3/day Model

Item	Calculation
1. Design Parameters	
1-1 Outline of Wastewater Treatment	
(1) Type of Collection System	Separate Sewer System
(2) Water Treatment Process	Two-stage Trickling Filter (TF)
1-2 Design Flowrate	
【Pipeline Sewerage】	
(1) Average Daily Flowrate	10,000 m^3/d
(2) Peak Dry Weather Flowrate	20,000 m^3/d
(3) Peak Wet Weather Flowrate	50,000 m^3/d
【Trucked-in Domestic Septage】	
(1) Average Daily Quantity	0 m^3/d
(2) Peak Daily Quantity	0 m^3/d
【Total Influent Flowrate】	
(1) Average Daily Flowrate	10,000 m^3/d
(2) Maximum Daily Flowrate	11,000 m^3/d
(3) Maximum Hourly Flowrate	20,000 m^3/d
(4) Peak Wet Weather Flowrate	50,000 m^3/d
1-3 Influent Wastewater Quality	
【Pipeline Sewerage】	
(1) BOD	360 mg/L
(2) SS	485 mg/L
【Trucked-in Domestic Septage】	
(1) BOD	250 mg/L
(2) SS	620 mg/L
【Total Influent Flowrate】	
(1) BOD	360 mg/L
(2) SS	485 mg/L
1-4 Design Influent Wastewater Quality (Influent ＋RF)	
(1) BOD	490 mg/L
(2) SS	460 mg/L
1-5 Removal Efficency	
(Primary Clarifier)	
(1) BOD	40 %
(2) SS	50 %
(Primary TF)	
(1) BOD	49%
(2) SS	49%
(Secondary TF + Final Clarifier)	
(1) BOD	80%
(2) SS	80%

Item	Calculation
(Total)	
(1) BOD	94 %
(2) SS	95 %
1-6 Effluent Wastewater Quality	
(1) BOD	30 ng/L
(2) SS	24 ng/L
Sludge Production (Maximum Daily Flowrate)	
1-7 Excess Sludge	Solids＝ Maximum Daily Flowrate × Influent SS × $0.95\times0.75\times10^{-6}$ Solids＝ 11,000 m3/d × 460 mg/L × 95 %×0.75× 10^-6 ＝ 3.6 ds-t/d Solid Concentration ＝ 0.3 % Sludge ＝ Solids÷Solids Concentration×10^{2} Sludge ＝ 3.60 t/d ÷ 0.3 % × 10^2 Sludge(OUT) ＝ 1,200 m^3/d
1-8 Raw Sludge	Solids ＝ 2.27 ds-t/d Solid Concentration ＝ 1.5 % Sludge ＝ 2.27 t/d ÷ 1.5 % × 10^2 Sludge(OUT) ＝ 152 m^3/d
1-9 Dewatering	Solids (Excess) ＝ 3.6 ds-t/d Solids (Raw) 2.3 ds-t/d Solids (IN) ＝ 5.9 ds-t/d Solids(OUT) ＝ WAS × Recovery Rate×10^{-2} Solids (OUT) ＝ 5.87 t/d × 95 % × 10^-2 Recovery Rate ＝ 95 % ＝ 5.6 ds-t/d Sludge(OUT) ＝ Solids÷Solids Concentration×10^{2} Sludge(OUT) ＝ 5.60 t/d ÷ 25 % × 10^2 Solid Concentratio ＝ 25 % Sludge(OUT) ＝ 23 m^3/d

2. Solids Mass Balance



Item	Calculation
3. Primary Clarifier	
3-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 11,000 m^3/d
Maximum hourly Flowrate	= 20,000 m^3/d
Overflow rate	= 35 $m^3/m^2/d$
Required Area for settling	= 11,000 ÷ 35 = 315 m^2
Diameter of Basin	= 14 m
No. of basin	= 2 basins
Effective Area	= 14 ^ 2 ÷ 4 × π × 2 = 308 m^2
Depth of basin	= 2.5 m Diameter vs. Depth: 6 : 1 Range: 6:1~12:1 → OK
Overflow rate	= 11,000 m^3/d ÷ 308 m^2 = 35.7 $m^3/m^2/d$ Range: 35～70m3/m2/d → OK
Settling Time	= (308 × 2.5 × 24) ÷ 11,000 = 1.7 hrs Range:About 1.5 hrs → OK
Req. Length of weir	= (14 − 1.6) × π = 39 m (Outer Weir) = (14 − 2.6) × π = 35.8 m (Inner Weir)
Weir Loading rate	= 11,000 ÷ (39 +) ÷ 2 = 141 $m^3/m/d$ Range:About 250 m3/2/d NO
4. Primary Trickling Filter	
4-1 Reactor Requirements	
Design Flowrate	
Maximum Daily Flowrate	= 11,000 m^3/d
Maximum hourly Flowrate	= 20,000 m^3/d
Number of Reactor	n = 4 Reactors
Treatment Capacity	Qin = 2,750 m3/d per reactor
Sludge Return Rate	Rr = 0.5 (Maximun: 1.0)

Item	Calculation
4-2 Trickling Filter Media	
Media Type	Plastic Cross-flow or vertical-flow bundle
Material	Plastic
4-3 Reactor Volume	
(1) Design Parameters	
Maximum Daily Flowrate	= 11,000 m^3/d
Design PrimClar Flowrate	= 12,316 m^3/d
Design Reactor Flowrate	= 12,165 m^3/d
BOD loading ※	= 1.20 kg-BOD/(m3･d)
Influent BOD (PC)	= 490 mg/L
BOD removal rate of Primary Clarifier	= 40 %
Filter Media Height	= 2.0 m (Range: 1.5 ~ 2 m)
Influent BOD into TR	= c_{BOD} x $(1-R_{BOD\ removal})$ = 490 mg-BOD/L x (1- 0.4) = 294 mg/L
(2) Hydraulic Loading	
Hydraulic Loading	$= \dfrac{\text{BOD loading} \times \text{Filter Media Height}}{c_{BOD\_Tfinflow}}$ $= \dfrac{1.20\ \text{kg-BOD}}{(\text{m3・d})} \cdot \dfrac{2.0\ \text{m}}{1} \cdot \dfrac{\text{L}}{294\ \text{mg-BOD}} \cdot \dfrac{1{,}000}{1}$
Hydraulic Loading	= 8.16 $m^3/m^2/d$
Diameter of TF	22 m (Max 45 m)
No. of basin	= 4 basins
Effective Area	= 22 ^ 2 ÷ 4 × π × 4 = 1,521 m^2
Actual Hydraulic Loading	= Q/A = 8.16 m3/m2/d = 12,165 m3/d ÷ 1,521 m2 = 8 $m^3/m^2/d$ < 8.16 $m^3/m^2/d$ → OK
Clearance of Filter Media~Tower Top	= 0.5 m
Filter Bottom Collection	= 1.0 m
Height of TF Tower	= 2.0 m + 0.5 m + 1.0 m = 3.5 m

Item	Calculation
(3) Effluent BOD	see below

$$\frac{S_i}{S_e} = \frac{1}{1 + k_{IWEM} \cdot \theta^{(T-15)} \cdot \left(\frac{a^m}{VLR^n}\right)} \qquad (13.54)$$

Where,

S_i = influent BOD_5 (mg/L);
k_{IWEM} = kinetic coefficient ($m^{m-1}\, d^{n-1}$);
θ = temperature coefficient;
a = media specific surface area (m^2/m^3);
m = reduction factor for surface loss with increasing area;
VLR = volumetric hydraulic loading rate ($m^3/d \cdot m^3$) of trickling filter media; and
n = hydraulic rate coefficient.

Equation 13.52 has reported coefficients that account for 90% of data variability:

- k_{IWEM} = 0.0204 (rock and random); 0.40 (modular plastic).
- θ = 1.111 (rock and random); 1.089 (modular plastic).
- m = 1.407 (rock and random); 0.732 (modular plastic).
- n = 1.249 (rock and random); 1.396 (modular plastic).

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TABLE 13.25 Physical properties of commonly used trickling filter media (lb/cu ft × 16.02 = kg/m^3 [b] sq ft/cu ft × 3.281 = m^2/m^3)

Media type	Material	Nominal size, m (feet)	Bulk density, kg/m^3 (lb/cu ft)	Specific surface area m^2/m^3 (sq ft/cu ft)	Void space, percent
Rock (river)		0.024–0.076 (0.08–0.25)	1442 (90)	62.3 (19)	50
Rock (slag)		0.076–0.128 (0.25–0.42)	1601 (100)	45.9 (14)	60
Corrugated plastic modules[a]					
60° crossflow	PVC	0.61 × 0.61 × 1.22 (2 × 2 × 4)	24.0–44.9 (1.5–2.8)	100 and 223.1 (30, 48, and 68)	95
Vertical flow	PVC	0.61 × 0.61 × 1.22 (2 × 2 × 4)	24.0–44.9 (1.5–2.8)	101.7 and 131.2 (31 and 40)	95
Random pack[b]	PP	0.185 ø × 0.051 H 7.3" ø × 2" H	27.2 (1.7)	98.4 (30)	95

[a] Manufacturers of corrugated plastic modules are (formerly) BF Goodrich, American Surf-Pac, NSW, Munters, (currently) Brentwood Industries, Jaeger, and Marley (SPX Cooling).
[b] Manufactures of random media are (formerly) NSW Corp. and (currently) Jaeger.
[c] Manufacturers of plastic strips are (formerly) NSW corp. and (currently) Jaeger.

k_IWEM	=	0.4	
Θ	=	1.089	
m	=	0.732	
n	=	1.396	
VLR	=	8	m^3/m^2/d
T	=	20	℃
a	=	100	m2/m3

Eq. 13.54 Denominator

$$= 1 + 0.4 \times 1.089^{(20-15)} \times \frac{(100 \wedge 0.732)}{(8.00 \wedge 1.396)}$$

$$= 1 + 0.4 \times 1.53 \times 1.597$$

$$= 1.978$$

Se = Si / 1.978
= 294 / 1.978
= $\boxed{\text{148.6 mg-BOD/L}}$

Item	Calculation
4-4 Forced air Ventilation	
(1) Need of Forced Air Ventilation	
	Sewer-air temperature difference requirement for natural draft ventilation: ± 2.8 ℃
	2007~2021
	Monthly Average air temperature vs. monthly average sewage temperature
	Minimum : Δ 0.95 ℃
	Maximum: Δ 1.37 ℃
	→ Forced air venti;ation required
5. Secondary Trickling Filter	
5-1 Reactor Requirements	
Design Flowrate	
Maximum Daily Flowrate	＝ 11,000 m^3/d
Maximum hourly Flowrate	＝ 20,000 m^3/d
Number of Reactor	n ＝ 4 Reactors
Treatment Capacity	Qin ＝ 2,750 m3/d per reactor
5-2 Trickling Filter Media	
Media Type	Plastic Cross-flow or vertical-flow bundle
Material	Plastic
5-3 Reactor Volume	
(1) Design Parameters	
Maximum Daily Flowrate	＝ 11,000 m^3/d
Design Reactor Flowrate	＝ 12,165 m^3/d
BOD loading	＝ 0.16 kg-BOD/(m3･d) ((loading for 75% N-Nitrification)
Influent BOD (TF1)	＝ 148.6101 mg/L
Filter Media Height	＝ 2.0 m (Range: 1.5 ～ 2 m)
Influent BOD into TR	＝ 148.61 mg/L
(2) Hydraulic Loading	$= \frac{\text{BOD loading} \times \text{Filter Media Height}}{c_{BOD\_Tfinflow}}$
	$= \frac{0.16 \text{ kg-BOD}}{(m3\cdot d)} \times \frac{2.0 \text{ m}}{1} \times \frac{L}{149 \text{ mg-BOD}} \times \frac{1{,}000}{1}$
Hydraulic Loading	＝ 2.15 $m^3/m^2/d$
Diameter of TF	43 m (Max 45 m)
No. of basin	＝ 4 basins

Item	Calculation
Effective Area	= 43 ^ 2 ÷ 4 × π × 4 = 5,809 m^2
Actual Hydraulic Loading	= Q/A = 2.15 m3/m2/d = 12,165 m3/d ÷ 5,809 m2 = 2.1 $m^3/m^2/d$ < 2.15 $m^3/m^2/d$ → OK
Clearance of Filter Media~Tower Top	= 0.5 m
Filter Bottom Collection	= 1.0 m
Height of TF Tower	= 2.0 m + 0.5 m + 1.0 m = 3.5 m
(3) Effluent BOD	$\frac{S_i}{S_e} = \frac{1}{1 + k_{IWEM} \cdot \theta^{(T-15)} \cdot \left(\frac{a^m}{VLR^n}\right)}$ (13.54) Where, S_i = influent BOD_5 (mg/L); k_{IWEM} = kinetic coefficient ($m^{m-1}\,d^{n-1}$); θ = temperature coefficient; a = media specific surface area (m^2/m^3); m = reduction factor for surface loss with increasing area; VLR = volumetric hydraulic loading rate ($m^3/d \cdot m^3$) of trickling filter media; and n = hydraulic rate coefficient. Equation 13.52 has reported coefficients that account for 90% of data variability: • k_{IWEM} = 0.0204 (rock and random); 0.40 (modular plastic). • θ = 1.111 (rock and random); 1.089 (modular plastic). • m = 1.407 (rock and random); 0.732 (modular plastic). • n = 1.249 (rock and random); 1.396 (modular plastic). k_IWEM = 0.4 Θ = 1.089 m = 0.732 n = 1.396 VLR = 2.1 $m^3/m^2/d$ T = 20 ℃ a = 100 m2/m3 Eq. 13.54 Denominator $= 1 + 0.4 \times 1.089^{(20-15)} \times \frac{(100 \wedge 0.732)}{(2.10 \wedge 1.396)}$ = 1 + 0.4 × 1.53 × 10.33 = 7.330
Se	= Si / 7.330 = 148.6 / 7.330 = $\boxed{\text{20.28 mg-BOD/L}}$

Item	Calculation
(4) Nitrogen Removal	
Nitrification Rate	= 75%
Influent N	= 70 mg/L
Effluent Ammonia-N	= 70 mg/L × (1- 75%)
	= 18 mg/L
	※ Assume: All Nitrified N is denitrified into N2 gas in process of Final sedimentation
Effluent T-N Standard	= 20 mg/L (General Standards)
	⇒ OK
6. Final clarifier/Denitrification Tank	
6-1 Basin Volume	
(1) Overflow Rate	
Design Flowrate	
Maximum Daily Flowrate	= 11,000 m^3/d
Maximum hourly Flowrate	= 20,000 m^3/d
Overflow rate	= 12 $m^3/m^2/d$
Required Area for settling	= 11,000 ÷ 12 = 917 m^2
Diameter of Basin	27 m
No. of basin	= 2 basins
Effective Area	= 27 ^ 2 ÷ 4 × π × 2
	= 1,145 m^2
Depth of basin	= 3 m
	Diameter vs. Depth: 9 : 1
	Range: 6:1~12:1 → OK
Overflow rate	= 11,000 m^3/d ÷ 1,145 m^2
	= 9.6 $m^3/m^2/d$ Range: 8～12m3/m2/d → OK
Req. Length of weir	= (27 − 1.6) × π = 79.8 m
	(Outer Weir)
Weir Loading rate	= 11,000 ÷ (79.8 +) ÷ 2
	= 68.9 $m^3/m/d$

Item	Calculation
(2) Denitrification Rate	
A. Required Denitrification Rate	$K_{DN} = (L_{NOX,DN} \times 10^6) / (24V_{DN} \cdot X)$ ....(6.7.37)
	Lnox,dn = NOx-N returned to denitrification tank (kg-N/day)
	Vdn = Denitrification tank volume (m3)
	X = MLSS concentration (mg/L)
Lnox,dn	= Influent N * Nitrification Rate
	= 70 mg/L × 75%
	= 52.5 mg/L
X	= 2000 mg-MLSS/L
Vdn	= 1718 m3/basin
Kdn_required	= (53 × 10^6) ÷ (24× 1718 × 2,000)
	= 0.637 mg-N/(g-MLSS・hr)
MLSS concentrration	= 2,000 mg/L
Vdn	= 1718 m3/basin
MLSS	= 3435 kg-SS (per basin)
BOD concentration	= 20.28 mg-BOD/L
Q	= 11000 m^3/d
BOD loading	= 223 kg-BOD/d
	= 111.5 kg-BOD/d (per basin)
BOD-SS Loading	= 111.5 kg-BOD/d ÷ 3435 kg-SS
	= 0.032 kg-BOD/kg-SS・d
B. Expected Denitrification Rate	
Kdn_expected	= 8.613 × 0.03 kg-BOD/kg-SS・d + 0.374
	= 0.65 mg-N/(g-MLSS・hr) > 0.637 mg-N/(g-MLSS・hr)
	⇒ OK
7. Disinfection	
7-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 11,000 m^3/d
Maximum hourly Flowrate	= 20,000 m^3/d
Peak Wet Weather Flowrate	= 50,000 m^3/d
Chlorine Contact Time	= 15 minutes
	= 900 seconds
Req. Volume	= 50,000 ÷ 24 ÷ 60 ÷ 60 × 900
	= 521 m^3
Depth	= 2 m
Width	= 2 m
Length	= 131 m

Item	Calculation
Volume	= 2 × 2 × 131
	= 524 m^3
Actual Contact Time	= 524 ÷ 50,000 × 24× 60
	= 15.09 min → OK
7-2 Sludge Thickening	
Target: Raw Sludge Only	
Solids (IN)	= 3.09 t/d
Solid Concentration	= 1.50 %
Sludge(IN)	= 206.00 m3/d
Solid Concentration(OUT)	= 2.00 %
SS loading	= 60 kg-DS/m2/d
Tank Depth	= 4 m
Number of Thickeners	= 2 tanks
Required Surface Area	= 3.09 t/d × 1000 kg/t) ÷ 60 kg-DS/m2/d
	= 51.50 m2
Diameter of Basin	= 6 m
Effective Area	= 6 ^ 2 ÷ 4 × π × 2 tanks
	= 57.0 m^2
	> 51.5 m^2
	→OK
Actual Loading	= 3.09 t/d × 1000 kg/t) ÷ 57.0 m^2
	= 54.21 kg-DS/m2/d
	< 60.0 kg-DS/m2/d
	→OK
7-3 Sludge Dewatering	
【Excess Sludge】	
Solids (IN)	= 2.06 t/d
Solid Concentration	= 0.30 %
Sludge(IN)	= 687.0 m3/d
【Digested Sludge】	
Solids (IN)	= 1.48 t/d
Solid Concentration	= 1.20 %
Sludge(IN)	= 124.0 m3/d
Operation Conditions	7 hrs in one day and 5 days in a week
Ship-out of Thickened Raw Sludge	5 days in a week

Item	Calculation
(1) Sludge Storage Tanks	
Operation	5 days in a week
Storage	2 days worth
Thickened Raw Sludge Collection	Collected once in 7 days
Required Volume	
【Excess Sludge】	= 687 m3/d × 2 d = 1374 m3
【Thickened Raw Sludge】	= 124 m3/d × 7 d = 868 m3
Storage Tank Depth	= 4 m
Tank Size	
【Excess Sludge】 r	= (1374 m3 ÷(4 m ×π))^0.5 ÷ 2 tanks
	= 11.00 m
【Thickened Raw Sludge】 r	= (868 m3 ÷(4 m ×π))^0.5 ÷ 1 tanks
	= 9.00 m
(2) Mechanical Dewaterer	
【Excess Sludge Only】	
Solids	= 2.06 × 7 ÷ 5 ÷ 7
(Required Dewatering Cap.)	× 1,000
	= 412.0 kg/d
Actual Dewatering capacity	= 400 kg/d
Number of Units	= 2 (Standby: 1)
Solids (OUT)	= 1.96 t/d
Solid Concentration(OUT)	= 25.00 %
Sludge(OUT)	= 8.0 m3/d
【Raw Sludge Only】	
Solids (OUT)	= 1.41 t/d
Solid Concentration(OUT)	= 25.00 %
Sludge(OUT)	= 6.00 m3/d
7-4 Sludge Drying Bed	
Sludge Drying Period	= 3 month
Drying Bed Volume	= 5 month's worth sludge
	= 150 d
【Excess Sludge Only】	
Sludge Volume	= 8 m3/d × 150 d
	= 1200 m3
Sludge Depth	= 0.3 m
Required Drying Bed Area	= 1200 m3 ÷ 0.3 m
	= 4000 m2

Item	Calculation
Drying Bed Area	＝ 30 m × 140 m
	＝ 4200 m2 → OK
【Digested Raw Sludge】	
Sludge Volume	＝ 6 m3/d × 150 d
	＝ 900 m3
Sludge Depth	＝ 0.3 m
Required Drying Bed Area	＝ 900 m3 ÷ 0.3 m
	＝ 3000 m2
Drying Bed Area	＝ 25 m × 140 m
	＝ 3500 m2 → OK
7-5 Sludge Storage Space	
Sludge Storage Period	＝ 20 yrs
【Excess Sludge Only】	
Sludge Volume	＝ 8 m3/d × 20 yrs × 365 d
	＝ 58400 m3
Sludge Depth	＝ 3.0 m
Required Storage Area	＝ 58400 m3 ÷ 3.0 m
	＝ 19,467 m2
Sludge Storage Area	＝ 50 m × 400 m
	＝ 20,000 m2 → OK
【Digested Raw Sludge Only】	
Sludge Volume	＝ 6 m3/d × 20 yrs × 365 d
	＝ 43800 m3
Sludge Depth	＝ 3.0 m
Required Storage Area	＝ 43800 m3 ÷ 3.0 m
	＝ 14,600 m2
Sludge Storage Area	＝ 30 m × 400 m
	＝ 12,000 m2 → NO

Item	Calculation
8. Primary Treatment (Rainwater)	
Design Flowrate	＝ 4* Maximum Daily Flowrate
	＝ 4* 11,000 m^3/d
	＝ 44,000 m^3 /d
Required Retention Time	＝ 2.50 hrs
Required Volume	＝ 44,000.00 m3/d × 2.50 hrs ÷ 24
	＝ 4,584 m^3
Design Depth	＝ 3 m
Required Surface Area	＝ 1,528 m2
Maturation Pond Volume	＝ 80 m × 20 m × 3 m
	＝ 4800 m3 ＞ 4,584 m^3
	→ OK

(4) Oxidation Ditch : 10,000 m^3/day Model

Item	Calculation
1. Design Parameters	
1-1 Outline of Wastewater Treatment	
(1) Type of Collection System	Separate Sewer System
(2) Water Treatment Process	Oxidation ditch
1-2 Design Flowrate	
【Pipeline Sewerage】	
(1) Average Daily Flowrate	10,000 m^3/d
(2) Peak Dry Weather Flowrate	20,000 m^3/d
(3) Peak Wet Weather Flowrate	50,000 m^3/d
【Trucked-in Domestic Septage】	
(1) Average Daily Quantity	0 m^3/d
(2) Peak Daily Quantity	0 m^3/d
【Total Influent Flowrate】	
(1) Average Daily Flowrate	10,000 m^3/d
(2) Maximum Daily Flowrate	11,000 m^3/d
(3) Maximum Hourly Flowrate	20,000 m^3/d
(4) Peak Wet Weather Flowrate	50,000 m^3/d
1-3 Influent Wastewater Quality	
【Pipeline Sewerage】	
(1) BOD	360 mg/L
(2) SS	485 mg/L
【Trucked-in Domestic Septage】	
(1) BOD	250 mg/L
(2) SS	620 mg/L
【Total Influent Flowrate】	
(1) BOD	360 mg/L
(2) SS	485 mg/L
1-4 Design Influent Wastewater	
(1) BOD	340 mg/L
(2) SS	450 mg/L
1-5 Removal Efficency (Total System)	
(1) BOD	96 %
(2) SS	96 %
1-6 Effluent Wastewater Quality	
(1) BOD	14 mg/L
(2) SS	18 mg/L

Item	Calculation
Sludge Production (Maximum Daily Flowrate)	
1-7 Waste Activated Sludge	Solids＝ Maximum Daily Flowrate × Influent SS × $0.95\times0.75\times10^{-6}$ Solids＝ 11,000 m3/d × 450 mg/L × 96 %×0.75× 10^-6 ＝ 3.6 ds-t/d Solid Concentration ＝ 0.3 % Sludge ＝ Solids÷Solids Concentration×10^2 Sludge ＝ 3.60 t/d ÷ 0.3 % × 10^2 Sludge(OUT) ＝ 1,200 m^3/d
1-8 Dewatering	Solids (IN) ＝ 3.6 ds-t/d Solids(OUT) ＝ WAS × Recovery Rate×10^{-2} Solids (OUT) ＝ 3.60 t/d × 95 % × 10^-2 Recovery Rate ＝ 95 % ＝ 3.5 ds-t/d Sludge(OUT) ＝ Solids÷Solids Concentration×10^2 Sludge(OUT) ＝ 3.50 t/d ÷ 25 % × 10^2 Solid Concentratio ＝ 25 % Sludge(OUT) ＝ 14 m^3/d

2. Solids Mass Balance (Final Stage)

Influent BOD	mg/L	360
Influent SS	mg/L	485
Inflowrate	m3/d	11,000
Influent Solids	t/d	5.34

Influent + Return Flow

Design Inflow Rate	m3/d	12,315
Design Influent BOD	mg/L	340
Design Influent SS	mg/L	450
Design Influent Solids	t/d	5.54
Design Influent BOD	t/d	4.19

OD+Final Clarifier

SS Removal rate	%	96
BOD Removal rate	%	96

Effluent

Effluent flowrate	m3/d	10,985
Solids	t/d	0.16
SS	mg/L	15
BOD	t/d	0.2
BOD	mg/L	10

Effluent

Excess Sludge

Rem.Solids	t/d	3.99
Solids Con.	%	0.3
Sludge Vol.	m3/d	1330
BOD	t/d	4.02
Sluge Prod.Rate	%	75

Return Flow (RF)

Solids	t/d	0.20
Solids Con.	%	0.02
Flow Vol.	m3/d	1315
FW BOD Loading	t/d	0.20

Excess Sludge

Solids	t/d	3.99
Solids Con.	%	0.3
Sluge Vol.	m3/d	1330
BOD	t/d	4.02

Dewatering

Rev. Rate	%	95

0

Dewatered Sludge

Solids	t/d	3.79
Solids Con.	%	25.0
Sluge Vol.	m3/d	15
BOD	t/d	3.82

0

Sun-bed Drying, Disposal

Filtered Water (FW)

Solids	t/d	0.20
Solids Con.	%	0.02
Sluge Vol.	m3/d	1315
FW BOD Loading	t/d	0.20

Item	Calculation
3. Oxidation Ditch	
3-1 Reactor Volume	
Design Flowrate	
Maximum Daily Flowrate	= 11,000 m^3/d
Maximum hourly Flowrate	= 20,000 m^3/d
Hydraulic Retention Time	= 24 hours
Req. Volume	= 11,000.00 m3/d × 24.00 hrs ÷ 24
	= 11,000 m^3
Shape of Reactor	Oval
Water Depth	D = 3.5 m
Width	W = 6.0 m
Length	L = 120 m
Area	A = Width ×Water depth - 0.3 ×0.3×2/2
	= 6.00 m × 3.50 m − 0.3 × 0.3 × 2 ÷ 2
	= 20.9 m^2
Volume per Reactor	v = (L-2W)*2A+πWA
	= (120 - 2* 6.0)*2* 20.90 +π* 6.0 * 20.9
	= 4908.3 m3/reactor
Number of Reactor	n = 2 Reactors
Total Volume	V = n*v = 2 * 4,908
	= 9,817 m^3
Actual	HRT = V÷Q*24
Hydraulic Retention Time	= 9,817 ÷ 11,000 *24
	= 21.4 hrs Range(Japan): 24~36hr NO
	Range(Metcalf&Eddy): 16~30hr
3-2 Aerator	→ OK
(1) Design Parameters	
Maximum Daily Flowrate	= 11,000 m^3/d
Influent BOD	= 340 mg/L
Influent S-BOD	= 170 mg/L
Influent SS	= 450 mg/L
Influent Kj-N	= 70 mg/L
MLSS	= 4,000 mg/L
Effluent BOD	= 40 mg/L
Aerobic volume ratio	= 0.5
HRT	= 16 hrs

Item	Calculation
(2) ASRT	
ASRT	$= \frac{t_a}{24} \times \frac{X_A \times V}{X_W \times Q_W}$
	$= \frac{t_a}{24} \times \frac{X_A \times V}{Q \times X_I \times \alpha}$
	ASRT ; Aerobic Sludge Retention Time
	ta ; Aeration Time in a day
	= 12 hours
	Xw ; SS in WAS, mg/L
	V ; Reactor Volume, m3
	Qw ; Volume of WAS, m3
	Q ; Maximum Daily Flowrate/Reactor
	= 11,000 ÷ 2 = 5,500 m3/d
	X_I ; Influent SS = 450 mg/L
	α ; Sludge production rate per SS
	0.75
ASRT	$= \frac{12 \times 4{,}000 \times 4{,}908}{24 \times 5{,}500 \times 450 \times 0.75}$
	= 5.3 days
(3) Empirical ASRT	
	ASRT > 29.7 EXP (-0.102 × T)
	T ; Lowest water temperature in monthly average
	= 20 Celsius
ASRT	= 29.7 exp (-0.102 × 20)
	= 3.90 days < 5.30 days
	→ OK
(4) Prediction of C-BOD based on ASRT	
T	= 20 Celsius
C-BOD	= 9.75 × ASRT ^ -0.671
	= 9.75 × 5.3 ^ -0.671
	= 3.19 mg/L
	Assumming BOD/C-BOD is 3
BOD	= 3 × C-BOD
	= 3 × 3.19
	= 9.6 mg/L < 40 mg/L OK
	(General standard)
	= 9.6 mg/L < 20 mg/L OK
	(Significan Eco Zone standard)

Item	Calculation
(5) Oxygen requirement for OD1	$=$ A × (Removed BOD − Denitrified N × K)
	A ; Reqired O_2/Removed BOD
	= 0.6 kg as O_2/kg as BOD
	K ; Consumed BOD by Denitrification
	= 2.5 kg as BOD/kg as N
	Removed BOD = (0.34 - 0.04) × 11,000
	= 3,300 kg as BOD/d
	Denitrified N ; Assuming all nitrified N is denitrified.
OD1	= 0.6 × (3,300 − 770 × 2.5)
	= 825 kg as O_2/d
(6) Oxygen requirement for OD2	= B × Va × MLVSS
	B ; O_2 Volume for internal aspiration
	= 0.1 kg as O^2/kg as MLVSS/d
	Va ; Aerobic zone volume
	= Volume ÷ 2
	Assuming MLVSS/MLSS is 0.8
OD2	= 0.1 × 9,816 ÷ 2 × 4 × 0.8
	= 1,571 kg as O_2/d
(7) Oxygen requirement for OD3	= C × Nitrified N
	C ; O_2 consumed by nitrification
	= 4.57 kg as O_2/kg as N
	Nitrified N ; Amount of nitrifired nitrogen
	; Influent N − Effluent nitrified N
	− nitrogen of WAS
	Influent N ; 0.070 × 11,000
	= 770 kg as N/d
	Effluent N ; Assuming all N is nitrified
	Nitrogen of WAS = 0.07 (kg as N/kg as MLSS)
	× Qw×Xx

Item	Calculation
	$Q_W \times X_X = Q_{in}(a \times C_{S-BOD,in} + b \times C_{ss,in} - c \times X_A \times \tau_A) \times 10^{-3}$
	a ; Rate of Sludge coversion from S-BOD ＝ 0.5 gMLSS/gS-BOD
	$C_{S\text{-}BOD}$; Influent soluble BOD ＝ 170 mg/L
	b ; Rate of Sludge production from SS ＝ 0.75 gMLSS/gSS
	c ; Decay rate ＝ 0.04 1/d
	τ_A ; Aeration time ＝ 0.5 d
	Qw×Xa ＝ 11,000 ×(0.5 × 170 ＋ 0.75 × 450 － 0.04 × 4,000 × 0.5)× 10^-3
	＝ 3,768 kg/d
	Nitrogen of WAS ＝ 0.07 × 3,768
	＝ 263.8 kg as N/d
OD3	＝ 4.57 ×(770 － 0 － 263.8)
	＝ 2,314 kg as O_2/d
(8) Oxygen requirement in Effluent	
	Assuming Sludge return rate of: 100 %
OD4	＝ Oxygen in effluent
	＝ 1.5 × 11,000 ×(1+ 1.00) × 10^-3
	＝ 33 kg as O_2/d
(9) Actual Oxygen Requirement	
AOR	＝ OD_1 ＋ OD_2 ＋ OD_3 ＋ OD_4
	＝ 825 ＋ 1,571 ＋ 2,314 ＋ 33
	＝ 4,743 kg as O_2/d
(10) Standard Oxygen Requirement	
SOR	＝ $\dfrac{AOR \times C_{SW}}{1.024^{(t-20)} \times \alpha \times (\beta \times C_S - C_a)} \times \dfrac{760}{P}$
	C_{SW} ; Oxygen saturation concentration in clean water at 20 Celsius
	＝ 8.84 mg/L
	Ca ; Average DO
	＝ 1.5 mg/L
	Cs ; Oxygen saturation concentration in clean water at t Celsius
	＝ 8.84 mg/L
	t ＝ 20.0 Celsius

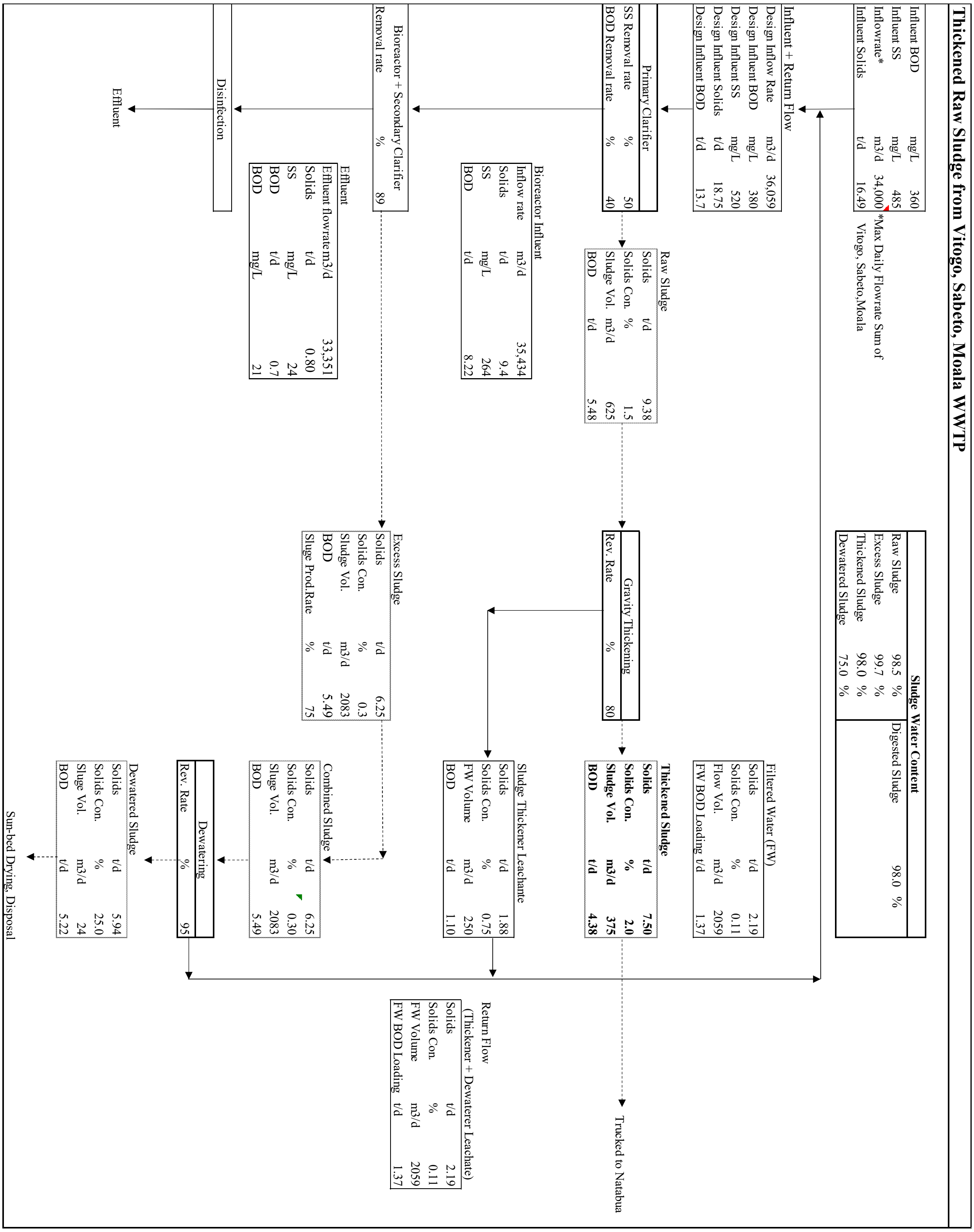
Item	Calculation
	α ; 0.93
	β ; 0.97
	P ; 760
Number of Reactor	= 2 Reactors
SOR	= 6,372 kg as O_2/d
SOR/reactor	= 3187 kg as O_2/d (per reactor)
	Required Oxygen
	$= \frac{6,372}{0.34 \times 11,000} =$ 1.8 kg as O_2/kg per unit BOD
4. Final Clarifier	
4-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 11,000 m^3/d
Maximum hourly Flowrate	= 20,000 m^3/d
Overflow rate	= 12 $m^3/m^2/d$
Required Area for settling	= 11,000 ÷ 12 = 917 m^2
Diameter of Basin	29 m
No. of basin	= 2 basins
Effective Area	= 29 ^ 2 ÷ 4 × π × 2
	= 1,321 m^2
Depth of basin	= 3 m
Overflow rate	= 11,000 m^3/d ÷ 1,321 m^2
	= 8.3 $m^3/m^2/d$ Range: 8～12m3/m2/d
	→ OK
Settling Time	= (1,321 × 3 × 24)
	÷ 11,000
	= 8.6 hrs Range: 6～12hr →OK
Req. Length of weir	= (29 − 1.6) × π = 86.1 m
	(Outer Weir)
	= (29 − 2.6) × π = 82.9 m
	(Inner Weir)
Weir Loading rate	= 11,000 ÷ (86.1 +) ÷ 2
	= 63.9 $m^3/m/d$
	Range: 25~100m3/m/d
	→OK

Item	Calculation							
5. Disinfection								
5-1 Basin Volume								
Design Flowrate								
Maximum Daily Flowrate	=	11,000	m^3/d					
Maximum hourly Flowrate	=	20,000	m^3/d					
Peak Wet Weather Flowrate	=	50,000	m^3/d					
Chlorine Contact Time	=	15	minutes					
	=	900	seconds					
Req. Volume	=	50,000	÷	24	÷	60	÷	60
			×	900				
	=	521	m^3					
Depth	=	2	m					
Width	=	2	m					
Length	=	131	m					
Volume	=	2	×	2	×	131		
	=	524	m^3					
Actual Contact Time	=	524 ÷	50,000	× 24× 60				
	=	15.09 min		OK				
6. Sludge Treatment								
6-1 Sludge Dewatering								
Solids (IN)	=	3.6	t/d					
Solid Concentration	=	0.30	%					
Sludge(IN)	=	1,200	m3/d					
Operation Conditions		7	hrs in one day and	5	days in a week			
Solids	=	3.6	×	7	÷	5	÷	7
(Required Dewatering Cap.)			×	1,000				
	=	720.0	kg/d					
Actual Dewatering capacity	=	400	kg/d					
Number of Units	=	2						
Solids (OUT)	=	3.79	t/d					
Solid Concentration(OUT)	=	25.00	%					
Sludge(OUT)	=	15	m3/d					

Item	Calculation
6-2 Sludge Drying Bed	
Sludge Drying Period	= 3 month
Drying Bed Volume	= 5 month's worth sludge
	= 150 d
Sludge Volume	= 15 m3/d × 150 d
	= 2250 m3
Sludge Depth	= 0.3 m
Required Drying Bed Area	= 2250 m3 ÷ 0.3 m
	= 7500 m2
Drying Bed Area	= 80 m × 100 m
	= 8000 m2 → OK
6-3 Sludge Storage Space	
Sludge Storage Period	= 20 yrs
Sludge Volume	= 15 m3/d × 20 yrs × 365 d
	= 109500 m3
Sludge Depth	= 3.0 m
Required Storage Area	= 109500 m3 ÷ 3.0 m
	= 36500 m2
Sludge Storage Area	= 370 m × 100 m
	= 37000 m2 →OK
	3.7 ha

Item	Calculation
7. Primary Treatment (Stormwater)	
Design Flowrate	= 4* Maximum Daily Flowrate
	= 4* 11,000 m^3/d
	= 44,000 m^3/d
Required Retention Time	= 2.50 hrs
Required Volume	= 44,000.00 m3/d × 2.50 hrs ÷ 24
	= 4,584 m^3
Design Depth	= 3 m
Required Surface Area	= 1,528 m2
Maturation Pond Volume	= 80 m × 20 m × 3 m
	= 4800 m3 > 4,584 m^3
	→ OK

(5) Raw Sludge Produced from Vitogo, Sabeto, Moala WWTP

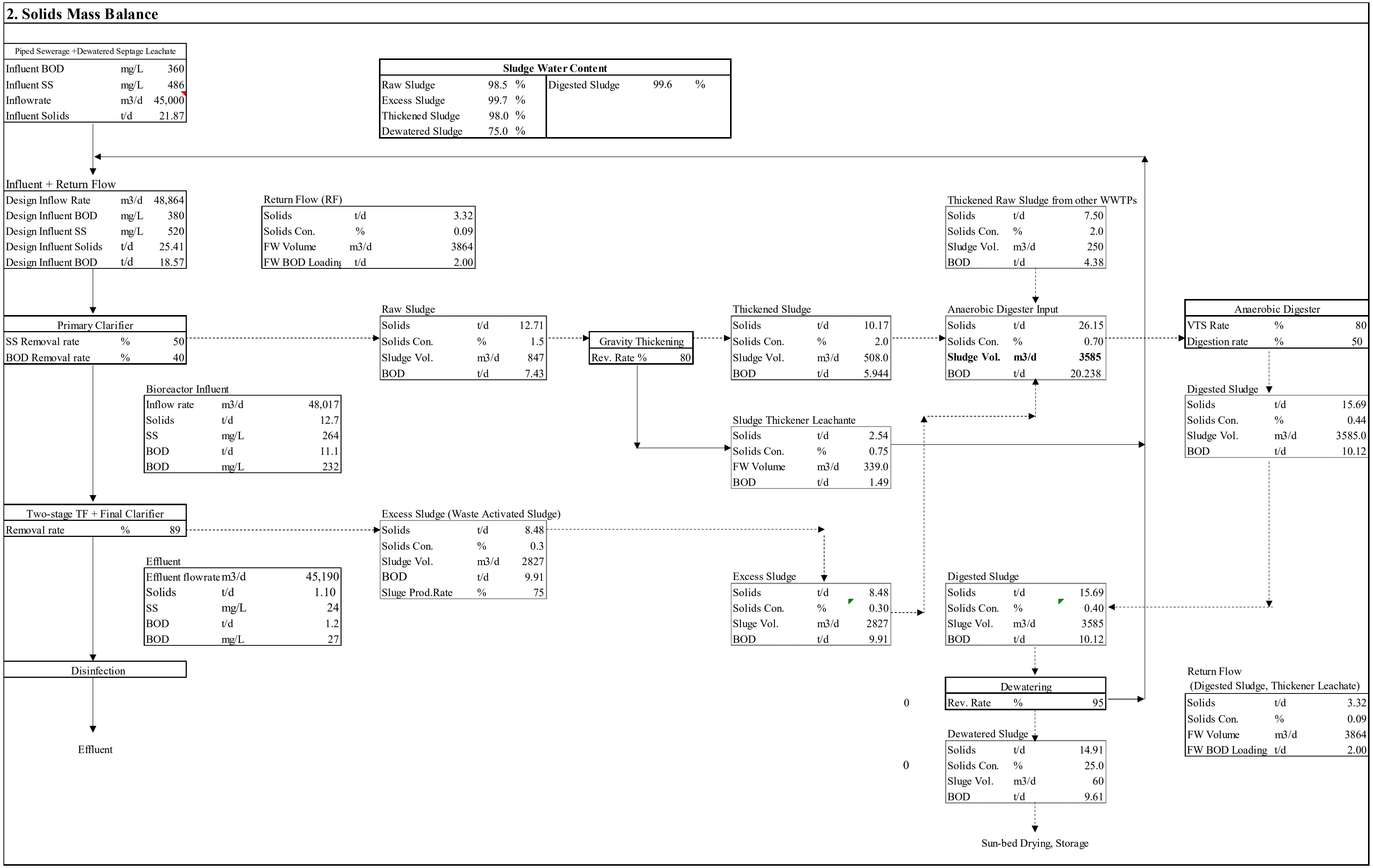


(6) Natabua Wastewater Treatment Plant: 27,100 m^3/day (Including Sludge Digestion)

Item	Calculation
1. Design Parameters	
1-1 Outline of Wastewater Treatment	
(1) Type of Collection System	Separate Sewer System
(2) Water Treatment Process	Two-stage Trickling Filter (with ventilation / no recirculation)
1-2 Design Flowrate	
【Pipeline Sewerage】	
(1) Average Daily Flowrate	40,434 m^3/d
(2) Peak Dry Weather Flowrate	44,477 m^3/d
(3) Peak Wet Weather Flowrate	202,170 m^3/d
【Bailed Domestic Septage】	
(1) Peak Daily Quantity	65 m^3/d
(2) Dewatered Leachate	59 m^3/d
【Total Influent Flowrate】	
(1) Average Daily Flowrate	41,000 m^3/d
(2) Maximum Daily Flowrate	45,000 m^3/d
(3) Maximum Hourly Flowrate	81,000 m^3/d
(4) Peak Wet Weather Flowrate	203,000 m^3/d
1-3 Influent Wastewater Quality	
【Pipeline Sewerage】	
(1) BOD	360 mg/L
(2) SS	485 mg/L
【Bailed Domestic Septage Dewatered Leachate】	
(1) BOD	250 mg/L
(2) SS	620 mg/L
【Total Influent Flowrate】	
(1) BOD	360 mg/L
(2) SS	486 mg/L
1-4 Design Influent Wastewater (Including Return Flow)	
(1) BOD	380 mg/L
(2) SS	520 mg/L
1-5 Removal Efficency	
(Primary Clarifier)	
(1) BOD	40 %
(2) SS	50 %
(Primary TF)	
(1) BOD	50%
(2) SS	50%

Item	Calculation
(Secondary TF + Final Clarifier)	
(1) BOD	80%
(2) SS	80%
Total	
(1) BOD	94 %
(2) SS	95 %
1-6 Effluent Wastewater Quality	
(1) BOD	23 mg/L
(2) SS	27 mg/L
Sludge Production (Maximum Daily Flowrate)	
1-7 Excess Sludge	Solids＝ Maximum Daily Flowrate × Influent SS × $0.95\times0.75\times10^{-6}$ Solids＝ 45,000 m3/d × 520 mg/L × 95 %×0.75× 10^-6 ＝ 16.7 ds-t/d Solid Concentration ＝ 0.3 % Sludge ＝ Solids÷Solids Concentration×10^{2} Sludge ＝ 16.70 t/d ÷ 0.3 % × 10^2 Sludge(OUT) ＝ 5,567 m^3/d
1-8 Raw Sludge	Solids ＝ 2.27 ds-t/d Solid Concentration ＝ 1.5 % Sludge ＝ 2.27 t/d ÷ 1.5 % × 10^2 Sludge(OUT) ＝ 152 m^3/d
1-9 Thickening	Solids (IN) ＝ 16.7 ds-t/d Solids(OUT) ＝ WAS × Recovery Rate×10^{-2} Solids (OUT) ＝ 16.70 t/d × 85 % × 10^-2 Ricovery Rate ＝ 85 % ＝ 14.2 ds-t/d Sludge(OUT) ＝ Solids÷Solids Concentration×10^{2} Sludge(OUT) ＝ 14.20 t/d ÷ 2 % × 10^2 Solid Concentratio ＝ 2 % Sludge(OUT) ＝ 710 m^3/d
1-10 Trucked-in Thickened Raw Sludge (from other WWTPs)	Solids (IN) ＝ 7.5 ds-t/d Sludge(IN) ＝ 250 m^3/d
1-11 Anaerobic Digestion	Solids (Excess) ＝ 16.7 ds-t/d Solids (Raw) ＝ 14.2 ds-t/d Solids (Raw from other WWTP) ＝ 7.5 ds-t/d Solids (IN) ＝ 38.4 ds-t/d Solids(OUT) ＝ Input Sludge×VTS rate×Digestion Rate×10^{-2} Solids (OUT) ＝ 38.40 t/d × 95 % × 10^-2 VTS Rate ＝ 95 % Digestion Rate

Item	Calculation
1-12 Dewatering	Solids(OUT) ＝ Input Sludge × Recovery Rate×10^{-2} Solids (OUT) ＝ 38.40 t/d × 95 % × 10^-2 Recovery Rate ＝ 95 % ＝ 36.5 ds-t/d Sludge(OUT) ＝ Solids ÷ Solids Concentration×10^{2} Sludge(OUT) ＝ 36.50 t/d ÷ 25 % × 10^2 Solid Concentratio ＝ 25 % Sludge(OUT) ＝ 146 m^3/d Solids (Excess) ＝ 16.7 ds-t/d Solids (Raw) 2.3 ds-t/d Solids (IN) ＝ 19.0 ds-t/d Solids(OUT) ＝ WAS × Recovery Rate×10^{-2} Solids (OUT) ＝ 18.97 t/d × 95 % × 10^-2 Recovery Rate ＝ 95 % ＝ 18.1 ds-t/d Sludge(OUT) ＝ Solids ÷ Solids Concentration×10^{2} Sludge(OUT) ＝ 18.10 t/d ÷ 25 % × 10^2 Solid Concentratio ＝ 25 % Sludge(OUT) ＝ 73 m^3/d


2. Solids Mass Balance
Piped Sewerage +Dewatered Septage Leachate
Influent BOD mg/L 360
Influent SS mg/L 486
Inflowrate m3/d 45,000
Influent Solids t/d 21.87
Sludge Water Content
Raw Sludge 98.5 %
Excess Sludge 99.7 %
Thickened Sludge 98.0 %
Dewatered Sludge 75.0 %
Digested Sludge 99.6 %
Influent + Return Flow
Design Inflow Rate m3/d 48,864
Design Influent BOD mg/L 380
Design Influent SS mg/L 520
Design Influent Solids t/d 25.41
Design Influent BOD t/d 18.57
Return Flow (RF)
Solids t/d 3.32
Solids Con. % 0.09
FW Volume m3/d 3864
FW BOD Loading t/d 2.00
Thickened Raw Sludge from other WWTPs
Solids t/d 7.50
Solids Con. % 2.0
Sludge Vol. m3/d 250
BOD t/d 4.38
Primary Clarifier
SS Removal rate % 50
BOD Removal rate % 40
Raw Sludge
Solids t/d 12.71
Solids Con. % 1.5
Sludge Vol. m3/d 847
BOD t/d 7.43
Gravity Thickening
Rev. Rate % 80
Thickened Sludge
Solids t/d 10.17
Solids Con. % 2.0
Sludge Vol. m3/d 508.0
BOD t/d 5.944
Anaerobic Digester Input
Solids t/d 26.15
Solids Con. % 0.70
Sludge Vol. m3/d 3585
BOD t/d 20.238
Anaerobic Digester
VTS Rate % 80
Digestion rate % 50
Bioreactor Influent
Inflow rate m3/d 48,017
Solids t/d 12.7
SS mg/L 264
BOD t/d 11.1
BOD mg/L 232
Sludge Thickener Leachante
Solids t/d 2.54
Solids Con. % 0.75
FW Volume m3/d 339.0
BOD t/d 1.49
Digested Sludge
Solids t/d 15.69
Solids Con. % 0.44
Sludge Vol. m3/d 3585.0
BOD t/d 10.12
Two-stage TF + Final Clarifier
Removal rate % 89
Excess Sludge (Waste Activated Sludge)
Solids t/d 8.48
Solids Con. % 0.3
Sludge Vol. m3/d 2827
BOD t/d 9.91
Sluge Prod.Rate % 75
Effluent
Effluent flowrate m3/d 45,190
Solids t/d 1.10
SS mg/L 24
BOD t/d 1.2
BOD mg/L 27
Excess Sludge
Solids t/d 8.48
Solids Con. % 0.30
Sluge Vol. m3/d 2827
BOD t/d 9.91
Digested Sludge
Solids t/d 15.69
Solids Con. % 0.40
Sluge Vol. m3/d 3585
BOD t/d 10.12
Disinfection
Dewatering
0
Rev. Rate % 95
Return Flow
(Digested Sludge, Thickener Leachate)
Solids t/d 3.32
Solids Con. % 0.09
FW Volume m3/d 3864
FW BOD Loading t/d 2.00
Dewatered Sludge
Solids t/d 14.91
0
Solids Con. % 25.0
Sluge Vol. m3/d 60
BOD t/d 9.61
Effluent
Sun-bed Drying, Storage

Item	Calculation
3. Primary Clarifier	
3-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 45,000 m^3/d
Maximum hourly Flowrate	= 81,000 m^3/d
Overflow rate	= 35 $m^3/m^2/d$
Required Area for settling	= 45,000 ÷ 35 = 1,286 m^2
Diameter of Basin	14 m
No. of basin	= 8 basins
Effective Area	= 14 ^ 2 ÷ 4 × π × 8 = 1,232 m^2
Depth of basin	= 2.5 m Diameter vs. Depth: 6 : 1 Range: 6:1~12:1 → OK
Overflow rate	= 45,000 m^3/d ÷ 1,232 m^2 = 36.5 $m^3/m^2/d$ Range: 35～70m3/m2/d → OK
Settling Time	= (1,232 × 2.5 × 24) ÷ 45,000 = 1.6 hrs Range:About 1.5 hrs → OK
Req. Length of weir	= (14 − 1.6) × π = 39 m
Weir Loading rate	= 45,000 ÷ (39 +) ÷ 8 = 144.2 $m^3/m/d$
4. Primary Trickling Filter	
4-1 Reactor Requirements	
Design Flowrate	
Maximum Daily Flowrate	= 45,000 m^3/d
Maximum hourly Flowrate	= 81,000 m^3/d
Number of Reactor	n = 4 Reactors
Treatment Capacity	Qin = 11,250 m3/d per reactor
Sludge Return Rate	Rr = 0.5 (Maximun: 1.0)
4-2 Trickling Filter Media	
Media Type	Plastic Cross-flow or vertical-flow bundle
Dimensions	
Material	Plastic

Item	Calculation
4-3 Reactor Volume	
(1) Design Parameters	
Maximum Daily Flowrate	= 45,000 m^3/d
Design PrimClar Flowrate	= 48,864 m^3/d
Design Reactor Flowrate	= 48,017 m^3/d
BOD loading ※	= 1.20 kg-BOD/(m3･d)
Influent BOD (PC)	= 490 mg/L
BOD removal rate of Primary Clarifier	= 40 %
Filter Media Height	= 2.0 m (1.5 ~ 2 m)
Influent BOD into TR	= c_{BOD} x (1-$R_{BOD\ removal}$)
	= 490 mg-BOD/L x (1- 0.4)
	= 294 mg/L
(2) Hydraulic Loading	
Hydraulic Loading	= $\dfrac{\text{BOD loading} \times \text{Filter Media Height}}{c_{BOD\_Tfinflow}}$
	= $\dfrac{1.20\ \text{kg-BOD}}{(\text{m3}\cdot\text{d})} \times \dfrac{2.0\ \text{m}}{1} \times \dfrac{\text{L}}{294\ \text{mg-BOD}} \times \dfrac{1{,}000}{1}$
Hydraulic Loading	= 8.16 $m^3/m^2/d$
Diameter of TF	22 m (Max 45 m)
No. of basin	= 16 basins
Effective Area	= 22 ^ 2 ÷ 4 × π × 16
	= 6,082 m^2
Actual Hydraulic Loading	= Q/A = 8.16 m3/m2/d
	= 48,017 m3/d ÷ 6,082 m2
	= 7.9 $m^3/m^2/d$ < 8.16 $m^3/m^2/d$
	→ OK
Clearance of Filter Media~Tower Top	= 0.5 m
Filter Bottom Collection	= 1.0 m
Height of TF Tower	= 2.0 m + 0.5 m + 1.0 m
	= 3.5 m
(3) Effluent BOD	$$\frac{S_e}{S_i} = \frac{1}{1 + k_{IWEM} \cdot \theta^{(T-15)} \cdot \left(\frac{a^m}{VLR^n}\right)} \quad (13.54)$$ Where, S_i = influent BOD_5 (mg/L); k_{IWEM} = kinetic coefficient ($m^{m-1}\ d^{n-1}$); θ = temperature coefficient; a = media specific surface area (m^2/m^3); m = reduction factor for surface loss with increasing area; VLR = volumetric hydraulic loading rate ($m^3/d \cdot m^3$) of trickling filter media; and n = hydraulic rate coefficient. Equation 13.52 has reported coefficients that account for 90% of data variability: • k_{IWEM} = 0.0204 (rock and random); 0.40 (modular plastic). • θ = 1.111 (rock and random); 1.089 (modular plastic). • m = 1.407 (rock and random); 0.732 (modular plastic). • n = 1.249 (rock and random); 1.396 (modular plastic).

Item	Calculation

k_IWEM = 0.4
Θ = 1.089
m = 0.732
n = 1.396
VLR = 7.9 $m^3/m^2/d$
T = 20 ℃
a = 100 m2/m3

13-146 **Design of Municipal Wastewater Treatment Plants**

TABLE 13.25 Physical properties of commonly used trickling filter media (lb/cu ft × 16.02 = kg/m³ [b] sq ft/cu ft × 3.281 = m²/m³)

Media type	Material	Nominal size, m (feet)	Bulk density, kg/m³ (lb/cu ft)	Specific surface area m²/m³ (sq ft/cu ft)	Void space, percent
Rock (river)		0.024–0.076 (0.08–0.25)	1442 (90)	62.3 (19)	50
Rock (slag)		0.076–0.128 (0.25–0.42)	1601 (100)	45.9 (14)	60
Corrugated plastic modules[a]					
60° crossflow	PVC	0.61 × 0.61 × 1.22 (2 × 2 × 4)	24.0–44.9 (1.5–2.8)	100 and 223.1 (30, 48, and 68)	95
Vertical flow	PVC	0.61 × 0.61 × 1.22 (2 × 2 × 4)	24.0–44.9 (1.5–2.8)	101.7 and 131.2 (31 and 40)	95
Random pack[b]	PP	0.185 ø × 0.051 H 7.3" ø × 2" H	27.2 (1.7)	98.4 (30)	95

[a] Manufacturers of corrugated plastic modules are (formerly) BF Goodrich, American Surf-Pac, NSW, Munters, (currently) Brentwood Industries, Jaeger, and Marley (SPX Cooling).
[b] Manufactures of random media are (formerly) NSW Corp. and (currently) Jaeger.
[c] Manufacturers of plastic strips are (formerly) NSW corp. and (currently) Jaeger.

Eq.13.54 Denominator

$$= 1 + 0.4 \times 1.089^{(20 - 15)} \times \frac{(100 \wedge 0.732)}{(7.90 \wedge 1.396)}$$

$$= 1 + 0.4 \times 1.53 \times 1.625$$

$$= 1.996$$

Se = Si / 1.996
= 294 / 1.996
= $\boxed{147.31953 \text{ mg-BOD/L}}$

4-4 Forced air Ventilation
(1) Natural Draft vs. Forced Air Ventilation

Sewer-air temperature difference requirement for natural draft ventilation: ± 2.8 ℃

2007~2021
Monthly Average air temperature vs. monthly average sewage temperature
Minimum : Δ 0.95 ℃
Maximum: Δ 1.37 ℃

→ Forced air venti;ation required

Item	Calculation
5. Secondary Trickling Filter	
5-1 Reactor Requirements	
Design Flowrate	
Maximum Daily Flowrate	＝ 45,000 m^3/d
Maximum hourly Flowrate	＝ 81,000 m^3/d
Number of Reactor	n ＝ 4 Reactors
Treatment Capacity	Qin ＝ 11,250 m3/d per reactor
5-2 Trickling Filter Media	
Media Type	Plastic Cross-flow or vertical-flow bundle
Dimensions	
Material	Plastic
5-3 Reactor Volume	
(1) Design Parameters	
Maximum Daily Flowrate	＝ 45,000 m^3/d
Design Reactor Flowrate	＝ 48,017 m^3/d
BOD loading	＝ 0.16 kg-BOD/(m3・d) (loading for 75% N-Nitrification)
Influent BOD (TF1)	＝ 147.3195 mg/L
Filter Media Height	＝ 2.0 m (1.5 ～ 2 m)
Influent BOD into TR	＝ 147.31953 mg/L
(2) Hydraulic Loading	＝ BOD loading x Filter Media Height / $C_{BOD\_Tfinflow}$
	$= \frac{0.16 \text{ kg-BOD}}{(\text{m3・d})} \frac{2.0 \text{ m}}{1} \frac{\text{L}}{147 \text{ mg-BOD}} \frac{1{,}000}{1}$
Hydraulic Loading	＝ 2.17 $m^3/m^2/d$
Diameter of TF	43 m (Max 45 m)
No. of basin	＝ 16 basins
Effective Area	＝ 43 ^ 2 ÷ 4 × π × 16 ＝ 23,235 m^2
Actual Hydraulic Loading	＝ Q/A ＝ 2.17 m3/m2/d ＝ 48,017 m3/d ÷ 23,235 m2 ＝ 2.07 $m^3/m^2/d$ < 2.17 $m^3/m^2/d$ → OK
Clearance of Filter Media~Tower Top	＝ 0.5 m
Filter Bottom Collection	＝ 1.0 m
Height of TF Tower	＝ 2.0 m ＋ 0.5 m ＋ 1.0 m ＝ 3.5 m

Item	Calculation
(3) Effluent BOD	

$$\frac{S_i}{S_e} = \frac{1}{1 + k_{IWEM} \cdot \theta^{(T-15)} \cdot \left(\frac{a^m}{VLR^n}\right)} \qquad (13.54)$$

Where,

S_i = influent BOD_5 (mg/L);
k_{IWEM} = kinetic coefficient ($m^{m-1} d^{n-1}$);
θ = temperature coefficient;
a = media specific surface area (m^2/m^3);
m = reduction factor for surface loss with increasing area;
VLR = volumetric hydraulic loading rate ($m^3/d \cdot m^3$) of trickling filter media; and
n = hydraulic rate coefficient.

Equation 13.52 has reported coefficients that account for 90% of data variability:

- k_{IWEM} = 0.0204 (rock and random); 0.40 (modular plastic).
- θ = 1.111 (rock and random); 1.089 (modular plastic).
- m = 1.407 (rock and random); 0.732 (modular plastic).
- n = 1.249 (rock and random); 1.396 (modular plastic).

k_IWEM	=	0.4	
Θ	=	1.089	
m	=	0.732	
n	=	1.396	
VLR	=	2.07	$m^3/m^2/d$
T	=	20	℃
a	=	100	m2/m3

13-146 **Design of Municipal Wastewater Treatment Plants**

TABLE 13.25 Physical properties of commonly used trickling filter media (lb/cu ft × 16.02 = kg/m^3 [b] sq ft/cu ft × 3.281 = m^2/m^3)

Media type	Material	Nominal size, m (feet)	Bulk density, kg/m^3 (lb/cu ft)	Specific surface area m^2/m^3 (sq ft/cu ft)	Void space, percent
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Corrugated plastic modules[a]					
60° crossflow	PVC	0.61 × 0.61 × 1.22 (2 × 2 × 4)	24.0–44.9 (1.5–2.8)	100 and 223.1 (30, 48, and 68)	95
Vertical flow	PVC	0.61 × 0.61 × 1.22 (2 × 2 × 4)	24.0–44.9 (1.5–2.8)	101.7 and 131.2 (31 and 40)	95
Random pack[b]	PP	0.185 ø × 0.051 H 7.3" ø × 2" H	27.2 (1.7)	98.4 (30)	95

[a] Manufacturers of corrugated plastic modules are (formerly) BF Goodrich, American Surf-Pac, NSW, Munters, (currently) Brentwood Industries, Jaeger, and Marley (SPX Cooling).
[b] Manufactures of random media are (formerly) NSW Corp. and (currently) Jaeger.
[c] Manufacturers of plastic strips are (formerly) NSW corp. and (currently) Jaeger.

Eq13.54 Denominator

$$= 1 + 0.4 \times 1.089^{(20-15)} \times \left(\frac{100 \wedge 0.732}{2.07 \wedge 1.396}\right)$$

$= 1 + 0.4 \times 1.53 \times 10.54$
$= 7.458$

Se $=$ Si / 7.458
$=$ 147.31953 / 7.458
$=$ $\boxed{19.752956 \text{ mg-BOD/L}}$

Item	Calculation
(4) Nitrogen Removal	
Nitrification Rate	= 75%
Influent N	= 70 mg/L
Effluent Ammonia-N	= 70 mg/L × (1- 75%)
	= 17.5 mg/L
	※ Assume: All Nitrified N is denitrified into N2 gas in process of Final sedimentation
Effluent T-N Standard	= 20 mg/L (General Standards)
	⇒ OK
6. Final Clarifier/Denitrification Tank	
6-1 Basin Volume	
(1) Overflow Rate	
Design Flowrate	
Maximum Daily Flowrate	= 45,000 m^3/d
Maximum hourly Flowrate	= 81,000 m^3/d
Overflow rate	= 12 $m^3/m^2/d$
Required Area for settling	= 45,000 ÷ 12 = 3,750 m^2
Diameter of Basin	27 m
No. of basin	= 8 basins
Effective Area	= 27 ^ 2 ÷ 4 × π × 8
	= 4,580 m^2
Depth of basin	= 3 m
	Diameter vs. Depth: 9 : 1
	Range: 6:1~12:1 → OK
Overflow rate	= 45,000 m^3/d ÷ 4,580 m^2
	= 9.8 $m^3/m^2/d$ Range: 8～12m3/m2/d → OK
Req. Length of weir	= (27 − 1.6) × π = 79.8 m
	(Outer Weir)
Weir Loading rate	= 45,000 ÷ (79.8 +) ÷ 8
	= 70.5 $m^3/m/d$

Item	Calculation
(2) Denitrification Rate	
A. Required Denitrification Rate	
	$K_{DN} = (L_{NOX,DN} \times 10^6) / (24V_{DN} \cdot X)$ ……………………………………(6.7.37)
	Lnox,dn = NOx-N returned to denitrification tank (kg-N/day)
	Vdn = Denitrification tank volume (m3)
	X = MLSS concentration (mg/L)
Lnox,dn	= Influent N * Nitrification Rate
	= 70 mg/L × 75%
	= 52.5 mg/L
X	= 2000 mg-MLSS/L
Vdn	= 1717.5 m3/basin
Kdn required	= (52.5 × 10^6) ÷ (24× ### × 2000)
	= 0.6368268 mg-N/(g-MLSS・hr)
MLSS concentration	= 2,000 mg/L
V	= 1717.5 m3/basin
MLSS	= 3435 kg-SS (per basin)
BOD concentration	= 20.275138 mg-BOD/L
Q	= 45000 m^3/d
BOD loading	= 912.3812 kg-BOD/d
	= 114.04765 kg-BOD/d (per basin)
BOD-SS Loading	= 114.04765 kg-BOD/d ÷ 3435 kg-SS
	= 0.0332016 kg-BOD/kg-SS・d
B. Expected Denitrification Rate	
Kdn_expected	= 8.6131 × 0.03 kg-BOD/kg-SS・d + 0.374
	= 0.66 mg-N/(g-MLSS・hr) > 0.637 mg-N/(g-MLSS・hr)
	⇒ OK
7. Disinfection	
7-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 45,000 m^3/d
Maximum hourly Flowrate	= 81,000 m^3/d
Peak Wet Weather Flowrate	= 203,000 m^3/d
Chlorine Contact Time	= 15 minutes
	= 900 seconds
Req. Volume	= 203,000 ÷ 24 ÷ 60 ÷ 60 × 900
	= 2115 m^3

Item	Calculation
Depth	= 2 m
Width	= 2 m
Length	= 530 m
Volume	= 2 × 2 × 530
	= 2120 m^3
Actual Contact Time	= 2120 ÷ 203,000 × 24× 60
	= 15.04 min → OK
7-2 Sludge Thickening	
Target: Natabua Raw Sludge Only	
Solids (IN)	= 12.71 t/d
Solid Concentration	= 1.50 %
Sludge(IN)	= 847 m3/d
Solid Concentration(OUT)	= 2.00 %
SS loading	= 60 kg-DS/m2/d
Tank Depth	= 4 m
Number of Thickeners	= 8 tanks
Required Surface Area	= 12.71 t/d × 1000 kg/t ›÷ 60 kg-DS/m2/d
	= 211.83 m2
Diameter of Basin	= 6 m
Effective Area	= 6 ^ 2 ÷ 4 × π × 8 tanks
	= 226.0 m^2
	> 211.8 m^2
	→OK
Actual Loading	= 12.71 t/d × 1000 kg/t ›÷ ### m^2
	= 56.24 kg-DS/m2/d
	< 60.0 kg-DS/m2/d
	→OK

Item	Calculation
7-3 Sludge Dewatering	
(1) Input Sludge	
【Septage】	
Solids (IN)	= 1.56 t/d
Solid Concentration	= 0.02 %
Sludge(IN)	= 65 m3/d
【Digested Sludge】	
Solids (IN)	= 15.69 t/d
Solid Concentration	= 0.40 %
Sludge(IN)	= 3585 m3/d
(2) Sludge Storage/Receiving Tank	
Sludge Dewatering Operation	5 days in a week
Storage	2 days worth
Receival	1 days worth
Required Volume	
【Septage Storage】	= 65 m3/d × 2 d = 130 m3
【Digested Sudge Receival】	= 3,585 m3/d × 1 d = 3585 m3
Storage Tank Depth	= 4 m
Tank Size	
【Septage】 r	= (130 m3 ÷(4 m ×π))^0.5
	= 4.00 m
【Digested Sudge】 r	= (3585 m3 ÷(4 m ×π))^0.5 ÷ 3 tanks
	= 6.00 m
Operation Conditions	7 hrs in one day and 5 days in a week
(3) Septage Dewatering	
Sludge(IN)	= 65 m3/d
(All septage collected to Natabua)	
SS	= 24,000 mg/L
Solids	= V × SS ×10^-6
	= 65 × 24,000 × 10^-6
	= 1.56 ds-t/d
Dewatering	Solids (IN) = 1.56 ds-t/d
	Solids(OUT) = Septage×Recovery Rate×10^{-2}
	Solids (OUT) = 1.56 t/d × 95 % × 10^-2
	Recovery Rate = 95 %
	= 1.50 ds-t/d
	Sludge(OUT) = Solids÷Solids Concentration×10^{2}
	Sludge(OUT) = 1.50 t/d ÷ 25 % × 10^2
	Solid Concentration = 25 %
	Sludge(OUT) = 6 m^3/d
	Leachate(OUT) = 59 m^3/d

Item	Calculation
(4) Digested Sludge Dewatering	
Dewatering	Solids (IN) = 15.69 ds-t/d
	Solids(OUT) ＝ Septage×Recovery Rate×10^{-2}
	Solids (OUT) ＝ 15.69 t/d × 95 % × 10^-2
	Recovery Rate ＝ 95 %
	＝ 15.00 ds-t/d
	Sludge(OUT) ＝ Solids÷Solids Concentration×10^{2}
	Sludge(OUT) ＝ 15.00 t/d ÷ 25 % × 10^2
	Solid Concentration ＝ 25 %
	Sludge(OUT) ＝ 60 m^3/d
7-4 Sludge Drying Bed	
Sludge Drying Period	＝ 3 month
Drying Bed Volume	＝ 5 month's worth sludge
	＝ 150 d
【Septage】	
Sludge Volume	＝ 6 m3/d × 150 d
	＝ 900 m3
Sludge Depth	＝ 0.3 m
Required Drying Bed Area	＝ 900 m3 ÷ 0.3 m
	＝ 3,000 m2
Drying Bed Area	＝ 30 m × 100 m
	＝ 3,000 m2 → OK
【Digested Raw Sludge】	
Sludge Volume	＝ 60 m3/d × 150 d
	＝ 9,000 m3
Sludge Depth	＝ 0.3 m
Required Drying Bed Area	＝ 9,000 m3 ÷ 0.3 m
	＝ 30,000 m2
Drying Bed Area	＝ 300 m × 100 m
	＝ 30,000 m2 → OK

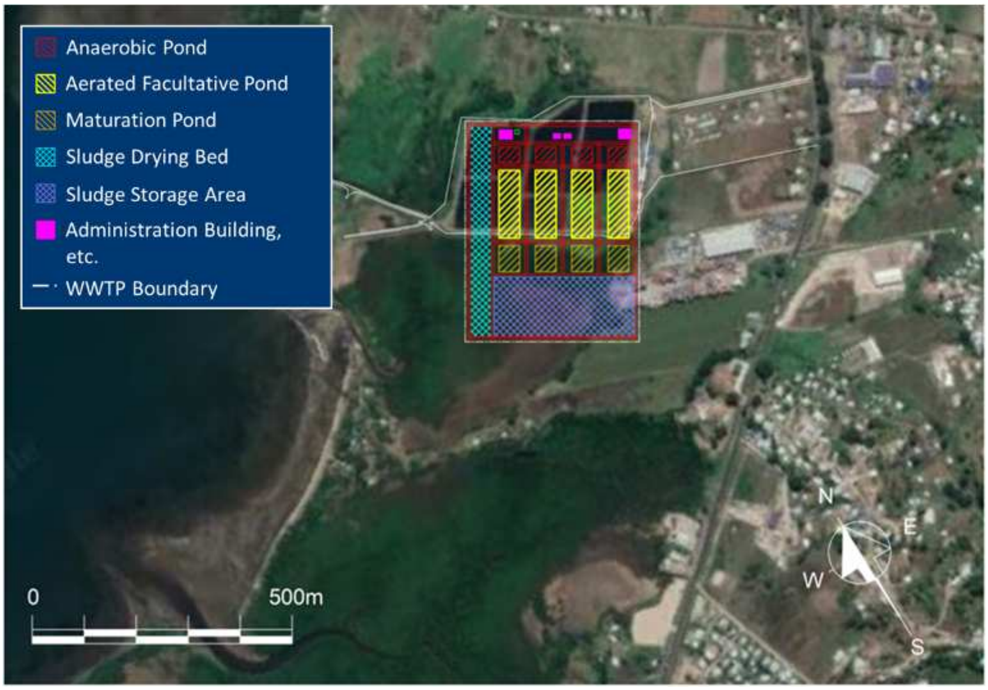
Item	Calculation
7-5 Sludge Storage Space	
Sludge Storage Period	＝ 20 yrs
【Septage Only】	
Sludge Volume	＝ 6 m3/d × 20 yrs × 365 d
	＝ 43,800 m3
Sludge Depth	＝ 3.0 m
Required Storage Area	＝ 43,800 m3 ÷ 3.0 m
	＝ 14,600 m2
Sludge Storage Area	＝ 150 m × 100 m
	＝ 15,000 m2 →OK
【Digested Raw Sludge Only】	
Sludge Volume	＝ 60 m3/d × 20 yrs × 365 d
	＝ 438,000 m3
Sludge Depth	＝ 3.0 m
Required Storage Area	＝ 438000 m3 ÷ 3.0 m
	＝ 146,000 m2
Sludge Storage Area	＝ 1,500 m × 100 m
	＝ 150,000 m2 →OK
8. Primary Treatment (Stormwater)	
Design Flowrate	＝ 4* Maximum Daily Flowrate
	＝ 4* 45,000 m^3/d
	＝ 180,000 m^3 /d
Required Retention Time	＝ 2.50 hrs
Required Volume	＝ 180,000.00 m3/d × 2.50 hrs ÷ 24
	＝ 18,750 m^3
Design Depth	＝ 3 m
Required Surface Area	＝ 6,250 m2
Maturation Pond Volume	＝ 80 m × 80 m × 3 m
	＝ 19200 m3 ＞ 18,750 m^3
	→ OK

APPENDIX 4-4 Footprint Image of Wastewater Treatment Processes (10,000 m^3/day Model)

The footprint requirement of each wastewater treatment process (10,000 m^3/day model) are shown as follows, in comparison to the current Natabua WWTP in Lautoka.

Source: JET

Figure A4-4.1 Stabilization Pond: 10,000 m^3/day Model Footprint



Source: JET

Figure A4-4.2 Aerated Lagoon: 10,000 m^3/day Model Footprint

Source: JET

Figure A4-4.3 Trickling Filter: 10,000 m^3/day Model Footprint

Source: JET

Figure A4-4.4 IDEA: 10,000 m^3/day Model Footprint

Source: JET

Figure A4-4.5 Oxidation Ditch: 10,000 m^3/day Model Footprint

Source: JET

Figure A4-4.6 MBBR Process: 10,000 m^3/day Model Footprint

APPENDIX 4-5 Examination of Anaerobic Digesters and Biogas Power Generation Plant

Ⅰ. Input Parameters

1. Treatment Capacity of WWTPs

WWTP	Treatment Method	ADFW (m3/day)	MDFW (m3/day)	Digester Input
Vitogo	Two-stage TF	6,365	7,100	Thickened raw sludge
Natabua	Two-stage TF	40,434	44,500	Thickened raw sludge + Excess sludge
Sabeto	Two-stage TF	6,393	7,100	Thickened raw sludge
Navakai	Oxidation Ditch	27,003	29,800	No input
Moala	Two-stage TF	17,483	19,300	Thickened raw sludge

2. Sludge

※Reffering from capacity calculation sheets

A. Thickened raw sludge from Vitogo, Sabeto, Moala

Solids	7.50	t/day
Solids Con.	2.0	%
Sludge Vol.	375	m3/day

B. Thickened raw sludge from Natabua

Solids	10.17	t/day
Solids Con.	2.0	%
Sludge Vol.	508	m3/day

C. Excess sludge from Natabua

Solids	8.48	t/day
Solids Con.	0.3	%
Sludge Vol.	2,827	m3/day

D. Total Input

Total actual sludge input

= 375 + 508 + 2,827

= 3,710 m3/day

Total SS = 7.5 + 10.2 + 8.5

= 26.15 t-ds/day

= 9,546 t-ds/year

SS Concetration		Sludge Volume Conversion	
1.0	%	2,615	m3/day
		954,600	m3/year
2.0	%	1,308	m3/day
		477,300	m3/year
3.5	%	747	m3/day
		272,743	m3/year

3. Removed SS

A. Vitogo, Sabeto, Moala WWTP

Total MDWF = 7,100 + 7,100 + 19,300
= 33,500 m3/day
= 12,227,500 m3/year

Input Sludge = Raw Sludge only
SS removal rate = # % (Primary Clarifier)

Influent SS = 486 mg/L
Effluent SS of primary clarifier = 486 mg/L x (100%－ # %)
= 243 mg/L
SS removed by primary clarifier = 486 － 243
= 243 mg/L

Annual removed SS = 243 mg/L x 12,227,500 m3/year ÷ 1,000,000
= 2,972 t-ds/year

Volume Conversion

SS Concetration		Volume Conversion
1.0	%	297,200 m3/year
2.0	%	148,600 m3/year
3.5	%	84,915 m3/year

B. Natabua WWTP

Total MDWF = 44,500 m3/day
= 16,242,500 m3/year

Input Sludge = Raw Sludge + Excess Sludge
SS removal rate = # % (Primary Clarifier)

Influent SS = 486 mg/L
Effluent SS of treatment system = 486 mg/L x (100%－ # %)
= 24.4 mg/L
SS removed by treatment system as raw/excess sludge = 486 － 24.353
= 462 mg/L

Annual removed SS = 462 mg/L x 16,242,500 m3/year ÷ 1,000,000
= 7,499 t-ds/year

Volume Conversion

SS Concetration		Volume Conversion
1.0	%	749,900 m3/year
2.0	%	374,950 m3/year
3.5	%	214,258 m3/year

C. Total Sludge Input into Anaerobic Digester

Total MDWF	=	33,500	+	44,500
	=	78,000	m3/day	
	=	28,470,000	m3/year	
Annual SS Removed	=	2,972	+	7,499
	=	28.7	t-ds/day	
	=	10,471	t-ds/year	

Volume Conversion

SS Concetration		Volume Conversion	
1.0	%	2,869	m3/day
		1,047,100	m3/year
2.0	%	1,434	m3/day
		523,550	m3/year
3.5	%	820	m3/day
		299,171	m3/year

Ⅱ. Biogas and Power Genertation

Category	No.	Parameter	Unit	Value	Calculation
WWTP Influent	①	Maximum daily flow rate of all input WWTPs	m^3/日	78,000	Input
	②	Annual total flow	m^3/年	28,470,000	Input
	③	Influent SS concetration	mg/l	486	Input
	④	SS removed	t-ds/year	10,471	Input

Category	No.	Parameter	Unit	Value	Calculation
Thickened Sludge	⑤	SS removed	t-ds/year	10,471	Input
	⑥	SS removed (2% concentration)	m3/year	523,550	Input

Category	No.	Parameter	Unit	Value	Calculation
Calculation Constants	⑦	Ratio of organic matter		80%	－
	⑧	Biogas production per unit organic matter	(Nm3/t-VS)	550	－
	⑨	Ratio of methane in produced biogas		60%	－
	⑩	Heating value of methane gas	(MJ/Nm3)	35.8	－
	⑪	Power generation efficiency		32%	－

Category	No.	Parameter	Unit	Value	Calculation
Biogas	⑫	Annual biogas production	Nm^3/year	4,607,240	= ⑤×⑦×⑧
	⑬	Annual methane gas production	Nm^3/year	2,764,344	= ⑫×⑨
	⑭	Hourly methane gas production	Nm^3/hr	316	= ⑬÷365÷24

Category	No.	Parameter	Unit	Value	Calculation
Power Generation	⑮	Annual energy production from methane gas	MJ/year	98,963,516	= ⑬×⑩
	⑯	Annual biogas power generation	kWh/year	8,796,757	= ⑮×⑪÷3.6
	⑰	Annual biogas power generation	MWh/year	8,797	=⑯÷1000
	⑱	Daily biogas power generation	kWh/day	24,101	=⑯÷365
	⑲	Hourly biogas power generation	kW	1,004	=⑱÷24

Ⅲ. Construction and O/M Costs

1. Anaerobic Digester

Category	Field	No.	Parameter	Units	Value	Calculation
Construction Cost	Input	①	Input Sludge Volume (1%SS Concetration)	m3/day	2,615	Input
	Civil/Architectural	②	Cost	million JPY	1,174.7	= 0.169×①^0.539 ×100
	Mechanical/Electrical	③	Cost	million JPY	1,067.6	= 0.516×①^0.385 ×100
	TOTAL	④	Construction Cost	million JPY	2,242.3	= ②+③
		⑤		million FJD	35.7	= ⑥÷62.9

Category	Field	No.	Parameter	Units	Value	Calculation
O/M Costs	Input	⑥	Input Sludge Volume (1%SS Concetration)	m3/year	954,600	Input
	Labor,celectricity, consumables, etc.	⑦	Cost	million JPY	36.7	= 0.171×⑥^0.390
	Repairs and Maintenance	⑧	Cost	million JPY	21.4	= ③×0.02
	TOTAL	⑨	O/M Cost	million JPY	58.1	= ⑦+⑧
		⑩		million FJD	0.9	= ⑨÷62.9

2. Biogas Power Generation Plant

Category	Field	No.	Parameter	Units	Value	Calculation
Construction Cost	Input	①	Power Generation	kW	1,004	Input
	Civil/Architectural	②	Construction Cost	million JPY	32.2	= 0.0263×①+5.8284
	Mechanical/Electrical	③	Construction Cost	million JPY	1,318.5	= 1.3132×①
	TOTAL	④	Construction Cost	million JPY	1,350.7	= ②+③
		⑤		million FJD	21.5	= ④÷62.9

Category	Field	No.	Parameter	Units	Value	Calculation
O/M Cost	Input	⑥	Power Generation	kW	1,004	Input
	TOTAL	⑦	O/M Cost (Including labor and electricity)	million JPY	58.1	= 0.0579×⑧
		⑧		million FJD	1.0	= ⑨÷62.9

3. Total

Category	Construction Cost* (million FJD)	O/M Cost (million FJD)
Anaerobic Digestor	35.7	0.9
Biogas Power Generation Facility	21.5	1.0
TOTAL	57.2	1.9

* Does not include land acquisition cost

Ⅳ. Required Foot Print and Land Acquisition Costs

1. Anaerobic Digester

No.	Parameter	Value	Unit	Calculation
①	Total Actual daily input to Digester	3,710	m3/day	Input
②	Digester Retention Time	40	days	Constant
③	Total Digester Volume	148,400	m3	= ①×②
④	Digesrer Footprint	22,127	m2	= 0.1491×③
⑤	Digesrer Footprint	2.2	ha	= ④÷10000

2. Biogas Power Generation Plant

No.	Parameter	Value	Unit	Calculation
①	Power Generation	1,004	kW	Input
④	Digesrer Footprint	896	m2	= 0.8927×①
⑤	Digesrer Footprint	0.1	ha	= ④÷10000

3. Total

Category	Footprint (ha)	Land Acquisiton Cost (million FJD)
Anaerobic Digestor	2.2	1.4
Biogas Power Generation Facility	0.1	0.1
TOTAL	2.3	1.5

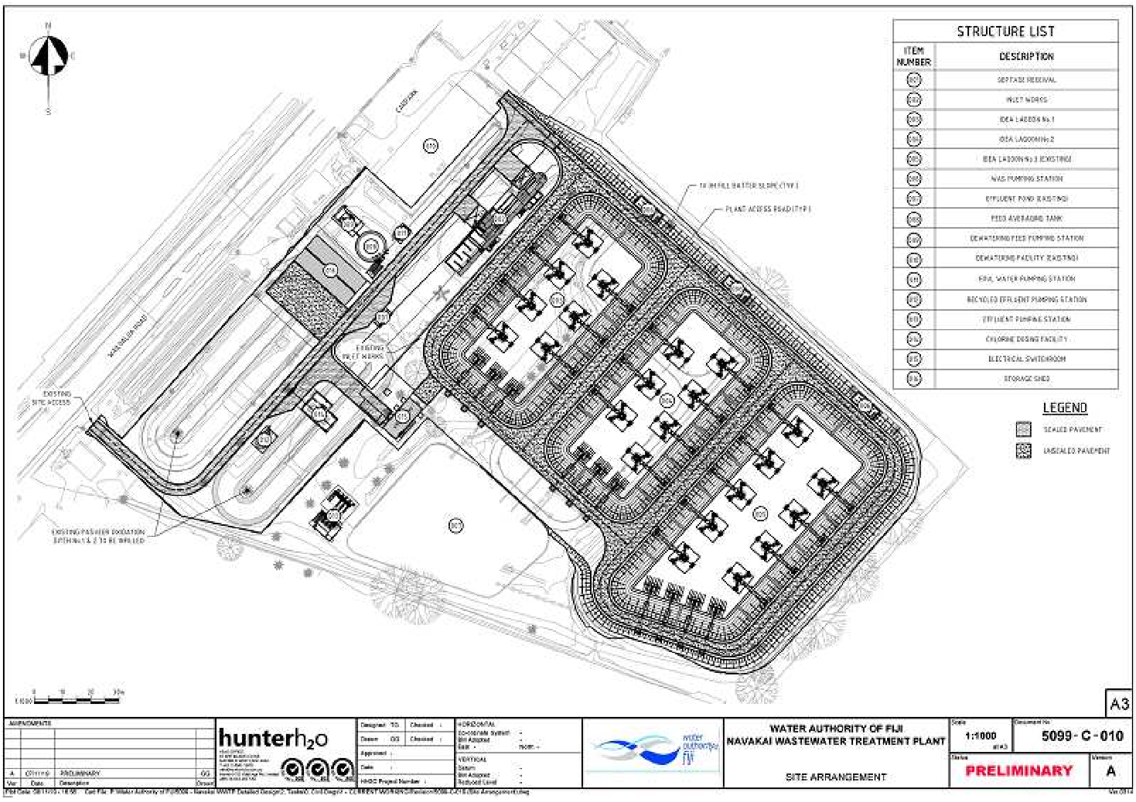
APPENDIX 4-6 Consideration of the Existing Navakai WWTP Detailed Design

(1) Treatment Capacity Expansion Plan of Navakai WWTP: Summary of the Existing DD

Navakai WWTP has had plans/designs formulated in the past for its treatment capacity expansion; in 2021 a detailed design (hereinafter referred to as the “existing DD”) was formulated to upgrade/increase the number. A plan to increase the treatment capacity of Navakai WWTP was formulated in the past, starting from an options assessment project in 2019 by GHD (“PMU087 Consultancy for the Upgrading of Wastewater Treatment at Natabua: Options Assessment”).

In the report six treatment processes, IDEA, SBR, trickling filters, modified Ludzack Ettinger process, activated sludge process, and SBR/IDEA hybrid process were studied; examinations/comparisons concluded that the IDEA process (which is the current process adopted at Navakai) would be the best option, and the project moved on to the formulation of the detailed design by Hunter HO in 2021 (“Navakai WWTP Upgrade Detailed Design Report”)

According to the existing DD, the number of IDEA basins will be increased to three basins within the current site boundary, increasing its capacity up to 15,000 m^3/day (**Figure A4-6.1**). However, multiple differences in the design conditions, such as the influent water quality and target effluent standards, were found when compared with the Municipal Sewerage M/P.



Source: “Navakai WWTP Upgrade Detailed Design Report,” HunterH2O Holdings Pty Ltd.

Figure A4-6.1 Detailed Design od Navakai WWTP

The major differences in the design condition between the existing DD and Municipal Sewerage M/P are listed in **Table A4-6.1**. When in comparison with the Municipal Sewerage M/P, the existing DD's plant is smaller in treatment capacity, lower in the influent BOD, and aims for General standard effluent, instead of SEZ standards. Due to the above points, it was concluded that directly incorporating the existing DD to the Municipal Sewerage M/P was difficult.

Table A4-6.1 Design Condition Differences between the Existing DD and Municipal Sewerage M/P

Parameters	Existing Detailed Design (HunterH2O)	Municipal Sewerage M/P (JET)
Target Year	2036	2043
Design Flow (ADWF)	14,662 m^3/day	27,000 m^3/day
Inflow BOD	300 mg/L	360 mg/L
Target Effluent Standard	General standards	SEZ standards
Included Facilities	• On-site Inlet Works • Wastewater Treatment System (IDEA) • Sludge Treatment System	• On-site pumping station • Wastewater Treatment System • (Oxidation Ditch) • Sludge Treatment System • Sludge Drying Bed • Sludge Disposals Site • Stormwater Retention Pond

Source: Created by JET based on "Navakai WWTP Upgrade Detailed Design Report," HunterH2O Holdings Pty Ltd.

(2) Estimating the Existing DD Treatment Capacity based on Municipal Sewerage M/P Design Conditions

The final report of the Existing DD did not include capacity calculations for the IDEA process, so the accurate re-calculation of the treatment capacity under Municipal Sewerage M/P design conditions could not be conducted. As a substitute, a simplified BOD removal-based calculation was done to estimate the existing DD's capacity to be about 11,143 m^3/day. (**Table A4-6.2**)

Table A4-6.2 Estimated Treatment Capacity of the Existing DD based on Municipal Sewerage M/P Design Conditions

IDEA Treatment System		HunterH2O DD (Original)	Influent/Effluent BOD modified to Municipal Wastewater M/P	Modified HunterH2O DD
Treatment Capacity (ADWF)	m3/d	14,662	14,662	11,143
	EP	73,310	73,310	55,715
Influent BOD	mg/L	300	360	360
	t/d	4.4	5.3	4.0
Target Effluent Quality	—	General Std.	SEZ Std.	SEZ Std.
Target Effluent BOD	mg/L	40	20	20
BOD to be removed by WWTP	mg/L	260	340	340
	t/d	3.8	5.0	3.8

3.8 t/d ÷ 5.0 t/d = 0.76

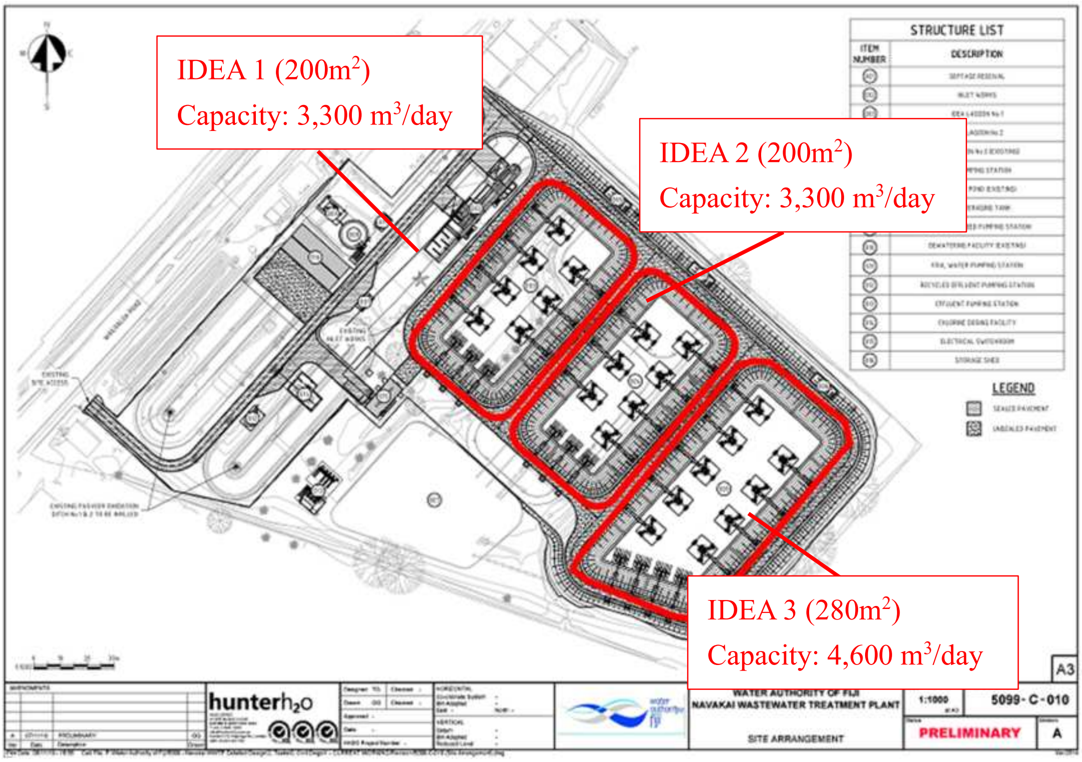
Modified Hunter H2O DD Capacity
=14,662 m3/day * 0.76
=11,143 m3/day

Source: Created by JET based on "Navakai WWTP Upgrade Detailed Design Report," HunterH2O Holdings Pty Ltd.

(3) Comparison of IDEA Process and OD Process

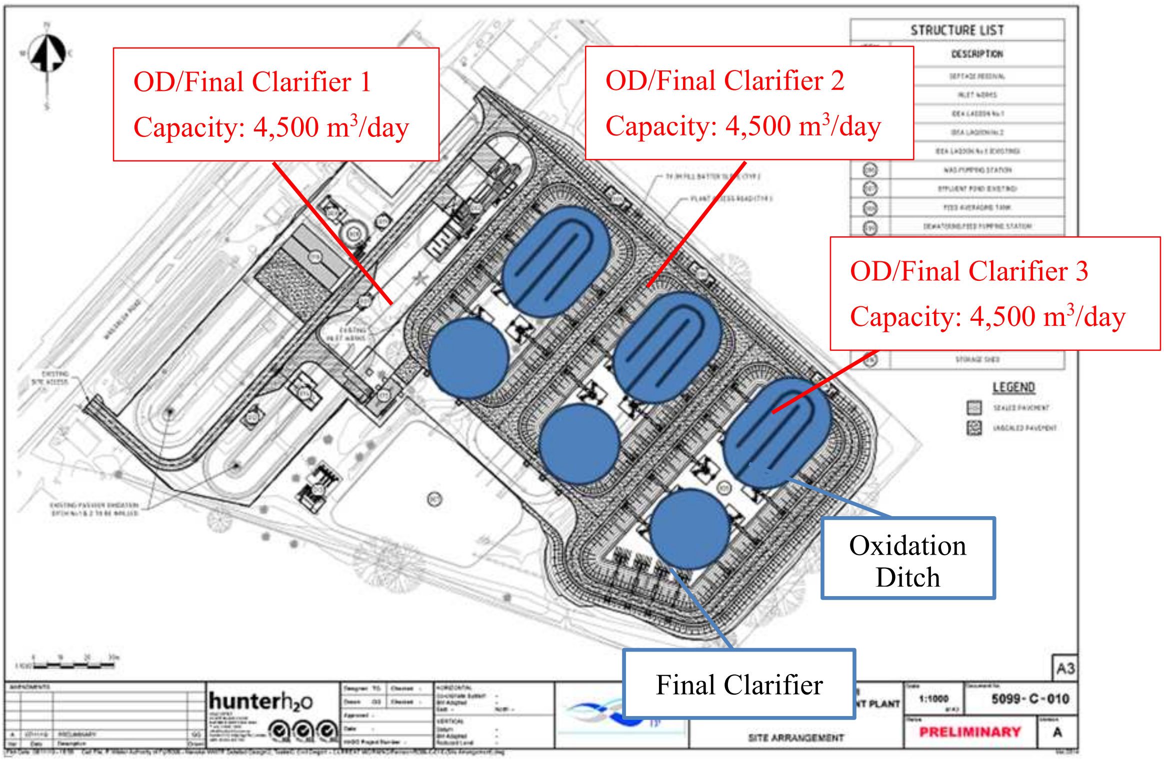
Figure A4-6.2 shows a rough allocation of the re-adjusted IDEA process treatment capacity based on the pond size. The total treatment capacity (11,143 m^3/day) is less than half of the treatment capacity (27,000 m^3/day) ultimately required for Navakai WWTP in the Municipal Sewerage M/P, and additional land acquisition from the surrounding area is essential.

On the other hand, when calculating the footprint requirement of the OD process, when facilities are limited to the wastewater treatment system (excluding the stormwater retention pond, sludge drying bed, and sludge storage area, which is not included in the existing DD's IDEA system), a treatment capacity of 13,500 m^3/day can be secured within the same area as the IDEA process, making more efficient land-utilization possible (**Figure A4-6.3**).



Source: Created by JET based off HunterH2O

Figure A4-6.2 Estimated Treatment Capacity of Existing DD under Municipal Sewerage M/P Design Conditions (IDEA Process)



Source: Created by JET based off HunterH2O

Figure A4-6.3 Estimated Treatment Capacity of OD Wastewater Treatment System in the Current Site Boundary

As a result of discussions with WAF, although funds has been invested in past projects formulating the existing DD, it was concluded to adopt the OD process for Navakai WWTP due to its advantage in treatment capacity per unit footprint. Therefore, in the Municipal Sewerage M/P, the existing DD will not be incorporated, and Navakai WWTP will be planned solely based on the OD process.

APPENDIX 5-1 FIRR EIRR Calculation

Table A5-1.1 Summarized Cash Flow Table for FIRR Calculation

Year	Expenditure Without Project	Capital Expenditure Total	O&M Expenditure Total	Incremental Expenditure Total	Incremental Income Total	Incremental Cash Flow for FIRR
2029	6,419	103,016	0	96,597	229	(96,368)
2030	6,419	139,201	0	132,781	229	(132,553)
2031	6,419	201,701	0	195,282	229	(195,053)
2032	6,419	208,280	0	201,861	229	(201,632)
2033	6,419	126,043	0	119,623	229	(119,395)
2034	6,419	89,170	4,432	87,182	409	(86,773)
2035	6,419	146,399	5,784	145,763	704	(145,059)
2036	6,419	245,249	7,511	246,341	1,188	(245,153)
2037	6,419	255,655	7,511	256,747	1,037	(255,709)
2038	6,419	125,588	7,511	126,680	1,037	(125,643)
2039	6,419	98,613	11,792	103,985	2,944	(101,041)
2040	6,419	126,236	13,098	132,915	3,480	(129,435)
2041	6,419	173,950	14,766	182,297	4,106	(178,191)
2042	6,419	178,972	14,766	187,319	3,884	(183,435)
2043	6,419	116,191	14,766	124,538	3,884	(120,655)
2044	6,419	98,196	20,041	111,817	4,785	(107,032)
2045	6,419	119,416	21,650	134,647	4,870	(129,777)
2046	6,419	142,658	23,706	159,944	5,221	(154,724)
2047	6,419	113,353	23,706	130,640	5,121	(125,519)
2048	6,419	59,066	26,816	79,463	5,441	(74,021)
2049	6,419	80,023	27,765	101,369	5,519	(95,849)
2050	6,419	102,976	28,977	125,534	5,623	(119,911)
2051	6,419	74,035	28,977	96,593	5,572	(91,021)
2052	6,419	0	30,598	24,179	5,885	(18,294)
2053	6,419	0	31,092	24,673	5,962	(18,711)
2054	6,419	(2,035,524)	31,724	(2,010,219)	6,079	2,016,298
					FIRR=	-3.4%

Source：JET

Table A5-1.2 Summarized Cash Flow Table for EIRR Calculation

Year	Cost Without Project	Capital Cost Total	O&M Cost Total	Incremental Cost Total	Incremental Benefit Total	Incremental Cash Flow for EIRR
2029	6,419	101,839	0	95,420	229	(95,191)
2030	6,419	136,408	0	129,988	229	(129,759)
2031	6,419	196,117	0	189,698	229	(189,469)
2032	6,419	202,402	0	195,983	229	(195,754)
2033	6,419	123,837	0	117,418	229	(117,189)
2034	6,419	87,711	4,254	85,546	8,634	(76,912)
2035	6,419	142,188	5,552	141,320	16,284	(125,036)
2036	6,419	236,283	7,211	237,075	26,646	(210,429)
2037	6,419	246,188	7,211	246,979	26,495	(220,485)
2038	6,419	122,378	7,211	123,169	26,495	(96,675)
2039	6,419	97,237	11,320	102,137	47,882	(54,255)
2040	6,419	123,545	12,574	129,699	64,854	(64,845)
2041	6,419	168,986	14,176	176,742	81,278	(95,464)
2042	6,419	173,769	14,176	181,525	81,056	(100,469)
2043	6,419	113,978	14,176	121,735	81,056	(40,679)
2044	6,419	97,247	19,239	110,067	93,671	(16,396)
2045	6,419	117,348	20,784	131,713	102,686	(29,027)
2046	6,419	139,364	22,758	155,702	110,155	(45,547)
2047	6,419	111,605	22,758	127,943	110,055	(17,888)
2048	6,419	58,569	25,743	77,893	114,300	36,408
2049	6,419	78,406	26,654	98,641	117,486	18,845
2050	6,419	100,133	27,818	121,532	120,804	(728)
2051	6,419	72,738	27,818	94,137	120,753	26,616
2052	6,419	0	29,374	22,955	124,757	101,802
2053	6,419	0	29,849	23,429	127,713	104,283
2054	6,419	(1,987,566)	30,455	(1,963,530)	131,723	2,095,253
					EIRR=	1.2%

Source：JET

APPENDIX 8-1 Regulations/Organizations Related to Environmental and Social Considerations

(1) Environmental Laws and Regulations

In Fiji, Environmental Management Act 2005 is the integrated regulatory framework of environmental sector, and based on this act, Environment Management (EIA Process) Regulations and Environment Management (Waste Disposal and Recycling) Regulations were formulated. There have been no bylaws related to environmental management in Lautoka or Nadi. **Table A8-1.1** shows major environmental laws, regulations, and related documents of Fiji.

Table A8-1.1 Environmental Laws, Regulations and Related Documents in Fiji

Name	Summary
Climate Change Act 2021	The act states the integrated climate change mitigation policies, its organizational structures, greenhouse gas measurement, and the MRV system etc.
EIA Guidelines 2008 (revised 2012)	It is similar to what appears in the Environment Management (EIA Process) Regulations but is more specific and states the process step by step in a simpler format and language. The guidelines was revised and issued in 2012 as the 2nd edition.
Environment Management (EIA Process) Regulations 2007	This Regulations outlines main components of the EIA process and provides the EIA procedures.
Environment Management (Waste Disposal and Recycling) Regulations 2007	The purpose of Waste Disposal and Recycling Regulations 2007 is to prevent the pollution of the environment by controlling the discharge of solid/liquid waste and the exhaust gasses, and handling storage and disposal of wastes and hazardous substances properly. The Regulations states that development sites may need waste permits for discharging significant amounts of liquid waste into waters, and exhaust gasses. For liquid waste, frequency of effluent quality analysis, and the effluent quality standards (General and Significant Ecological Zone) are also stated.
Environmental Management Act 2005	This is an act for the protection of the natural resources, for the control and management of developments, and for waste management and pollution control, in addition to the regulatory framework of EIA process. The act also states the establishment of a National Environment Council and DoE's roles and responsibilities.
Endangered and Protected Species Act 2002 (amended 2017)	The act regulates and control the international trade, domestic trade, possession, and transportation of species protected under Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The amended 2017 act adds non-CITES species to be protected.
Ozone Depleting Substances Act 1998	The act regulates use of Ozone Depleting Substances (ODS) based on international agreement on ODS such as the Vienna Convention.
Forest Act 1992	This act regulates not only use of forest resources and set up of forest protected areas but also protect the iTaukei's right of forest use.
Preservation of Objects of Archaeological and Paleontological Interest Act 1940	The act states administrative procedures when archeological and paleontological objects are found, and requires consultation with Fiji Museum in that case.
Mangrove Conservation and Management Regulations (draft)	This regulations is under preparation as of Feb. 2023.

Source: JET

In 2022, DOE drafted the Mangrove Conservation and Management Regulations, and held key stakeholder consultations and public comments; however, the regulations has not been issued yet. While the effluent discharge point of a project is determined depending on the project location and its business characteristics in general, it has been unknown how the regulations states conditions on effluent discharge to mangrove areas. The existing WWTPs are located near shoreline, and it is very likely that new treatment plants be constructed in or near mangrove areas. Therefore, careful attention should be paid to the progress of its issuance.

(2) Environmental Policies, and Plans

Major national environmental policies and plans are shown in **Table A8-1.2**. There are not environmental-related policies or plans formulated in Lautoka and Nadi.

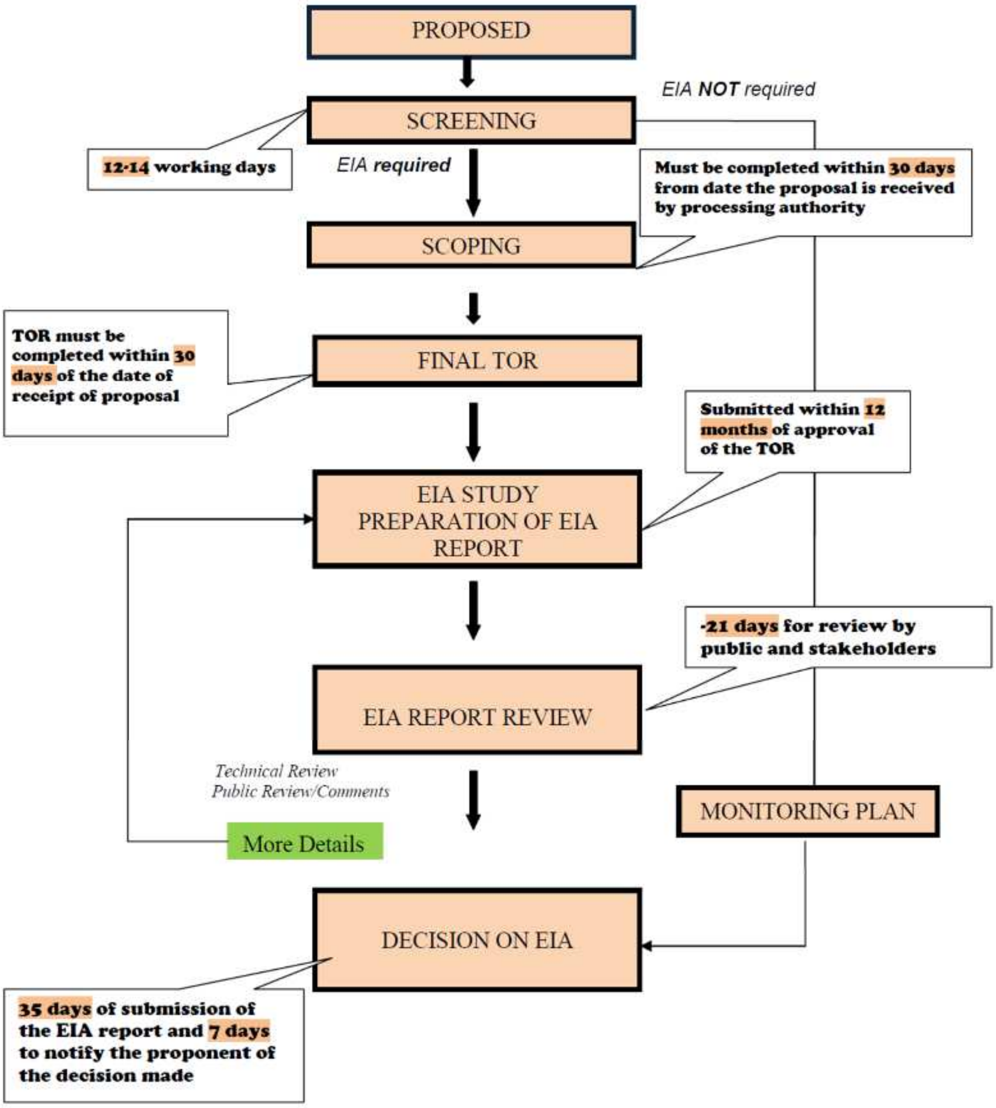
Table A8-1.2 National Environmental Policies and Plans in Fiji

Category	Document	Competent authority
Environmental and social management	• Environmental and Social Management System (2022)	MOE*
Waste	• National Waste Management and Pollution Control Strategy 2018-2028	DOE
Biodiversity	• National Ocean Policy 2020-2030	MOE*
	• National Biodiversity Strategic Action Plan 2020-2025	MOWE
	• Mangrove Management Plan (2013, Draft)	DOE
	• Integrated Coastal Zone Management Framework (2011)	DOE
Forest protection	• Fiji Forest Policy Statement (2007)	Ministry of Forest
Indigenous peoples	• iTaukei Affairs Strategic Development Plan 2018-2023	TLTB
Gender	• Gender Equity and Social Inclusion Policy 2021-2024 and Action Plan 2021-2022	MOE*
	• National Gender Policy (2014)	Ministry of Social Welfare, Women and Poverty Alleviation
Climate change	• Nationally Determined Contribution (2020)	Government of Fiji
	• National Adaptation Plan (2018)	MOE*
	• Low Emission Development Strategy 2018-2050	MOE*
	• National Climate Change Policy 2018-2030	MOE*
	• The NDC Implementation Roadmap 2017-2030	MOE*
	• Green Growth Framework (2014)	Ministry of Strategic Planning, National Development and Statistics

* MOE: before organizational restructuring; current Ministry of Finance (MOF)
Source: JET

(3) EIA Process

Projects that are required for EIA is listed in Schedule 2 of Environmental Management Act. Sewerage related projects fall in “(q) a proposal for the construction of a landfill facility, composting plant, marine outfall or wastewater treatment plant,” and therefore is required to obtain EIA approval. DOE prepared the EIA Guidelines in 2008 (revised in 2012) to explain in detail about the EIA procedures. EIA has to be conducted by a DoE-registered consultant. **Figure A8-1.1** shows the EIA process flow, and the processes for Part 1 projects are summarized in **Table A8-1.3**.



Source: Environmental Impact Assessment Guidelines 2012

Figure A8-1.1 EIA Process in Fiji

Table A8-1.3 EIA Process Summary for Part 1 Projects

Step	Process
Step 1: Screening	1. The proponent submits a Preliminary Form that contains the proponent's contact details and the project summary. DOE conducts a site visit if necessary. 2. Based on the collected information in 1., DOE provides advice informally or request a Screening Application Form with 250FJD. The Form should describe the project summary, site location, land tenure information, major environmental characteristics, public consultation status etc. 3. Based on 2., DOE provides formal notification of the screening decision.
Step 2: Scoping	1. The proponent submits an EIA Processing Form with the processing fee (it depends on the development characteristics) 2. DOE conducts consultation with related parties and simple assessment. DOE conducts a site visit as needed. 3. DOE prepares a scoping report that includes TOR of the EIA and provide it to the proponent (the scoping process is sometimes outsourced). 4. The scoping report is publicly disclosed in Environmental Register. 5. If the proponent suggests EIA consultant when submitting the Processing Form, consultation with DOE is required. 6. DOE notifies the final decision of the TOR to the project proponent.
Step 3: The EIA study and report	1. Based on the approved TOR, EIA consultant start EIA studies and prepare a EIA report. 2. The proponent submits the EIA report to DOE.
Step 4: Review of and decision on the EIA report	1. The review Committee appointed by DOE reviews the EIA report. 2. The EIA report is publicly disclosed in the Environmental Register, and if necessary, notified through newspapers and radio. Public hearing is also required at the project site areas. The public comment shall be open for 28 days. 3. The proponent revises the EIA report and provides supplemental information, based on comments and questions during the review period. 4. DOE issues a decision of the EIA review, such as i) approved with/without conditions, ii) request for supplemental studies, iii) denied with reasons etc. 5. In case of ii), the proponent submits additional information etc., and the project is again reviewed by the Review Committee.

Source: Environmental Management Act 2005, Environmental Management (EIA Process) Regulations 2007, and Environmental Impact Assessment

(4) Regulatory Framework on Land Acquisition and Resettlement

Land ownership in Fiji is generally classified into 3 categories: iTaukei land, freehold land, and state/crown land. **Table A8-1.4** shows laws and regulations related to land acquisition.

Table A8-1.4 Laws and Regulations Related to Land Acquisition

Field		Laws and Regulations
Land acquisition	General	• Constitution of Fiji 2013 • Land Transfer Act 1978 • Subdivision of Land Act 1937 *1
	iTaukei Land	• iTaukei Land Trust Act 1940 • iTaukei Land Trust (Leases and Licenses) Regulations 1984 • iTaukei Lands Act 1905
	Freehold Land	• Land Sales Act 1974
	State/Crown Land	• State Land Act 1945 • State Acquisition of Lands Act 1940 • State Lands (Leases and Licenses) Regulations 1985
Land use		• Regional Land Release Plan for the Greater West and Coastal Region 2019-2039 • Land Use Act 2010 • Land Use Regulations 2011 • Rural Land Use Policy of Fiji 2002 • Agricultural Landlord and Tenant Act, 1997 • Rivers and Streams Act [Cap 139], 1985 • Town Planning Act 1946 • Lautoka/Nadi Town Planning Scheme

*1 Lautoka City has enacted a bylaw regarding Subdivision of Land Act.
Source: JET

The Constitution of Fiji does not allow forced expropriation of land. In case of land acquisition for public use, any land can be expropriated under the laws, and all land and related rights have to be compensated.

1) iTaukei Land

Land rights of iTaukei is not transferrable in order to protect iTaukei rights, except for public use. The iTaukei land can be leased to non-iTaukei people for development purposes in short-term or long-term through TLTB who manages all iTaukei land on behalf of iTaukei owners. For public purpose, the iTaukei land can be transferred to the government body, but have to be returned back to iTaukei people after its use. When iTaukei land is leased, the user shall make a contract with TLTB for the lease payment. The Land Transfer Act specifies land expropriation for public use and compensation. Informal settlers who live iTaukei land without TLTB's proper administration may not be eligible to receive such a compensation.

2) Freehold Land

In accordance with Land Sales Act, freehold land can be purchased, transferred, or leased. However, there are some restrictions for non-Fijian and non-Fijian companies who want to purchase the land. The Land Transfer Act also states land expropriation at freehold land for public use and its compensation.

3) State/Crown Land

In addition to onshore land, all coastlines (land less than the high tide line) and the bottom of water area is classified as state/crown land. State/crown land is not for sale but can be leased by Department of Land (DOL), MLMR. Under the existing regulatory system, mangrove forests is categorized as "State/Crown land" so these areas are allowed to change its land use by DOL under the regulations. However, the EIA clearance related to the land use change has to be obtained in advance. The details are described in State Acquisition of Land Act.

APPENDIX 8-2 Scoping Results

(1) Scoping Results (Lautoka M/P)

Item				Scoping result: Wastewater treatment plant	Sludge / Septage treatment plant	Pump station	Sewer lines	Reasons
Pollution control	1	Air pollution	Const.	X	X	X	X	Const.: Suspended dust and gas emission from the construction machinery are generated in a certain period of time. Ope.: No impact on air quality is expected.
			Ope.					
	2	Water pollution	Const.	X	X	X	X	Const.: Associated with earthworks in the construction of sewerage facilities, turbidity of the water will be likely increased at the downstream sites even if only temporally. Ope.: WWTP is expected to improve water quality in surrounding environment of discharge points.
			Ope.					
	3	Waste	Const.	X	X	X	X	Const.: Waste soil and materials are generated. Ope.: Other than solid waste generated by operators and litter cleanup, sludge/septage from the treatment facilities need to be treated properly.
			Ope.	X	X			
	4	Soil and groundwater Contamination	Const.	X	X	X	X	Const.: Soil contamination may happen caused by oil leakage etc. Ope.: In addition to oil leakage etc., raw sewerage flooding the contamination.
			Ope.	X	X	X	X	
	5	Noise and Vibration	Const.	X	X	X	X	Const.: Noise and vibration are generated from construction work and machinery. Ope.: Pumps and motors at the facilities may generate noise and vibration.
			Ope.	X	X	X		
	6	Ground Subsidence	Const.					Const.: No ground subsidence is expected. Ope: Sewer pipe leakage or corruption may cause ground subsidence.
			Ope.				X	
	7	Offensive Odor	Const.	X				Const.: When rehabilitating the existing treatment plant, offensive odor may be generated due to disturbance of the facilities. Ope: Improvement offensive odor issues is expected with the proper facility installation and operation. On the other hand, low treatment performance of the plants may generate offensive odor.
			Ope.	X	X			
	8	Bottom Sediment	Const.	X	X	X	X	Const.: Bottom sediments of the rivers and coastal area may be disturbed temporarily due to construction of an offshore outfall and discharge pipe. Ope.: The bottom sediment quality in water bodies may be improved together with the better effluent water quality. On the other hand, low treatment performance of the plants may result in the poor bottom sediment quality.
			Ope.	X	X			
Natural Environment	9	Protected Areas	Const./Ope.					There are no protected areas in or nearby Lautoka.
	10	Biodiversity	Const.	X	X			Mangrove stands exist adjacent to Natabua WWTP and the Vitogo candidate site. Const.: Depending on the footprints, mangrove stands need to be reclaimed with mangrove tree cutting. Construction work may temporarily disturb the ecologically important habitat areas. Ope.: Poor facility operation may cause degradation of these areas.
			Ope.	X	X			
	11	Hydrology	Const.	X	X			The area is vulnerable to cyclones and monsoonal floods, windstorm, high tides etc., so the facility planning need to take them into account.
			Ope.					

Item				Scoping result: Wastewater treatment plant	Sludge / Septage treatment plant	Pump station	Sewer lines	Reasons
	12	Topography and Geographical Features	Const.	X	X			Const.: Soil erosion may occur at titled land, so depending on development characteristics and location, topography and geographical features need to be considered.
			Ope.					
Social environment	13	Involuntary Resettlement and Land Acquisition	Const.	X	X	X		Const.: Natabua WWTP expansion and new plant construction need land acquisition and possibly small-scale involuntary resettlement. Pump station construction may need land acquisition as well.
			Ope.					
	14	Poverty	Const.	X	X	X	X	There are informal settlements in the outskirts of the city. These informal settlements have to be taken into account by discussing with the local government.
			Ope.	X	X	X	X	
	15	Minority and Indigenous Peoples	Const./Ope.					There is no Indigenous Peoples classified by the WB's safeguard policy. iTaukei is legally recognized as the indigenous in Fiji and their traditional culture and custom is respected and protected under Fiji's law.
	16	Local Economy (Employment, Livelihood etc.)	Const.	X	X			Construction of the treatment facilities may cut down mangroves and reclaim mudflats, and it is possible that neighboring people cannot fully use their inherited areas. According to the Fiji's regulations, the building-to-land ratio depends on water and sewerage connectivity. It is expected that sewerage reticulation development vitalizes local economy and facilitates citizen's settlement. Work opportunity for local people is expected.
			Ope.					
	17	Land Use and Utilization of Local Resources	Const.					Land use pattern by the government and private sector in the sewerage areas may be changed based on the M/P to be much efficient.
			Ope.					
	18	Water Use	Const.	X	X	X	X	Const: Construction work may temporarily affect water environment the neighboring people use. Ope: It is expected that better quality of discharged water by the sewerage system installation and proper onsite facility management result in improvement of the water environment.
			Ope.					
	19	Existing Social Infrastructure and Services	Const.	X	X	X	X	Const.: Construction of a facility may involve traffic disturbance, specifically when constructing sewer lines that is buried under roads, restriction of user's access may occur such as de-tour, and temporary blocking. Power, gas, water lines may be impacted by the construction work as well.
			Ope.					
	20	Social Institutions such as Local Decision Making Institutions	Const./Ope.					There is the iTaukei system legally institutionalized in Fiji, and no impacts on decision making process and social institutions are expected.
	21	Misdistribution of Benefit and Damage / Local Conflict of Interest	Const.					Ope.: The project covers entire area of the Western Division connecting economically potential areas in the region and misdistribution of the benefit might affect economical balance in the division through the migration. Adequate benefit sharing among the peoples should be considered at the operation.
			Ope.	X	X	X	X	
	22	Cultural Heritage	Const.	X	X	X	X	Const.: There may be traditional sites etc. in iTaukei land. Construction of a facility may involve disturbance to such sites, including its relocation and the access restriction.
			Ope.					
	23	Landscape	Const.	X	X			The Western Division including Lautoka is a

Item				Scoping result: Wastewater treatment plant	Scoping result: Sludge / Septage treatment plant	Scoping result: Pump station	Scoping result: Sewer lines	Reasons
			Ope.					famous tourist destination, so facility designs and construction work need to be considered.
	24	Gender / Children's Right	Const.					No impact on gender or children's right issues is expected, but the consideration may need to be studied, depending on a facility location.
			Ope.					
	25	Sanitation and Infectious Diseases (HIV/AIDS)	Const.	X	X	X	X	Const.: A movement of migrant labor in the region may increase the risk of sexual transmitted diseases and also Covid-19, etc. Ope.: It is expected that improvement of wastewater treatment system in Lautoka makes an advanced sanitary environment and reduce risks on infectious diseases.
			Ope.					
	26	Work environment (including occupational safety) / Accidents	Const.	X	X	X	X	Const.: Work environment for construction workers should be considered. Ope.: Gas poisoning and oxygen deficiency may occur during maintenance, so working environment for the operators should be considered.
			Ope.	X	X	X	X	
Others	28	Global Warming	Const.	X	X	X	X	Const.: CO2 emission from heavy equipment for construction work is expected. Ope.: GHG (CH4 and CO) will be generated from the treatment process.
			Ope.	X	X			

Const.: Before/during construction
Ope.: During operation

(2) Scoping Results (Nadi M/P)

Item				Scoping result: Wastewater treatment plant	Scoping result: Pump station	Scoping result: Sewer lines	Reasons
Pollution control	1	Air pollution	Const.	X	X	X	Const.: Suspended dust and gas emission from the construction machinery are generated in a certain period of time. Ope.: No impacts on air quality is expected.
			Ope.				
	2	Water pollution	Const.	X	X	X	Const.: Downstream of the construction area may be temporarily affected by turbid water from the construction work. Ope.: Wastewater treatment at the plants generally contributes to improvement of ambient water quality. On the other hand, low treatment performance of the plants may result in adverse effect on the local ambient water quality.
			Ope.	X			
	3	Waste	Const.	X	X	X	Const.: Waste soil and materials are generated. Ope.: Other than solid waste generated by operators and litter cleanup, sludge/septage from the treatment facilities need to be treated properly.
			Ope.	X			
	4	Soil and groundwater Contamination	Const.	X	X	X	Const.: Soil contamination may happen caused by oil leakage etc. Ope.: In addition to oil leakage etc., raw sewerage flooding the contamination.
			Ope.	X	X	X	
	5	Noise and Vibration	Const.	X	X	X	Const.: Noise and vibration are generated from construction work and machinery. Ope.: Pumps and motors at the facilities may generate noise and vibration.
			Ope.	X	X		
	6	Ground Subsidence	Const.				Const.: No ground subsidence is expected. Ope: Sewer pipe leakage or corruption may cause ground subsidence.
			Ope.			X	
	7	Offensive Odor	Const.	X			Const.: When rehabilitating the existing treatment plant, offensive odor may be generated due to disturbance of the facilities. Ope: Improvement offensive odor issues is expected with the proper facility installation and operation. On the other hand, low treatment performance of the plants may generate offensive odor.
			Ope.	X			
	8	Bottom Sediment	Const.	X	X	X	Const.: Bottom sediments of the rivers and coastal area may be disturbed temporarily due to construction of an offshore outfall and discharge pipe. Ope.: The bottom sediment quality in water bodies may be improved together with the better effluent water quality. On the other hand, low treatment performance of the plants may result in the poor bottom sediment quality.
			Ope.	X			
Natural Environment	9	Protected Areas	Const./Ope.				There are no protected areas in or nearby Nadi.
	10	Biodiversity	Const.	X			Mangrove stands exist adjacent to the Moala and Sabeto candidate sites. Const.: Depending on the footprints, mangrove stands need to be reclaimed with mangrove tree cutting. Construction work may temporarily disturb the ecologically important habitat areas. Ope.: Poor facility operation may cause degradation of these areas.
			Ope.	X			
	11	Hydrology	Const.	X			The area is vulnerable to cyclones and monsoonal floods, windstorm, high tides etc., so the facility planning need to take them into account.
			Ope.				
	12	Topography and Geographical Features	Const.	X			Const.: Soil erosion may occur at titled land, so depending on development characteristics and location, topography and geographical features need to be considered.
			Ope.				
Social environment	13	Involuntary Resettlement and Land Acquisition	Const.	X	X		Const.: Navakai WWTP expansion and new plant construction need land acquisition and possibly small-scale involuntary resettlement. Pump station construction may need land acquisition as well.
			Ope.				
	14	Poverty	Const.	X	X	X	There are informal settlements in the outskirts of the town.

Item				Scoping result			Reasons
				Wastewater treatment plant	Pump station	Sewer lines	
			Ope.	X	X	X	These informal settlements have to be taken into account by discussing with the local government.
	15	Minority and Indigenous Peoples	Const./Ope.				There is no Indigenous Peoples classified by the WB's safeguard policy. iTaukei is legally recognized as the indigenous in Fiji and their traditional culture and custom is respected and protected under Fiji's law.
	16	Local Economy (Employment, Livelihood etc.)	Const.	X			Construction of the treatment facilities may cut down mangroves and reclaim mudflats, and it is possible that neighboring people cannot fully use their inherited areas. According to the Fiji's regulations, the building-to-land ratio depends on water and sewerage connectivity. It is expected that sewerage reticulation development vitalizes local economy and facilitates citizen's settlement. Work opportunity for local people is expected.
			Ope.				
	17	Land Use and Utilization of Local Resources	Const.				Land use pattern by the government and private sector in the sewerage areas may be changed based on the M/P to be much efficient.
			Ope.				
	18	Water Use	Const.	X	X	X	Const: Construction work may temporarily affect water environment the neighboring people use. Ope: It is expected that better quality of discharged water by the sewerage system installation and proper onsite facility management result in improvement of the water environment.
			Ope.				
	19	Existing Social Infrastructure and Services	Const.	X	X	X	Const.: Construction of a facility may involve traffic disturbance, specifically when constructing sewer lines that is buried under roads, restriction of user's access may occur such as de-tour, and temporary blocking. Power, gas, water lines may be impacted by the construction work as well.
			Ope.				
	20	Social Institutions such as Local Decision Making Institutions	Const./Ope.				There is the iTaukei system legally institutionalized in Fiji, and no impacts on decision making process and social institutions are expected.
	21	Misdistribution of Benefit and Damage / Local Conflict of Interest	Const.				Ope.: The project covers entire area of the Western Division connecting economically potential areas in the region and misdistribution of the benefit might affect economical balance in the division through the migration. Adequate benefit sharing among the peoples should be considered at the operation.
			Ope.	X	X	X	
	22	Cultural Heritage	Const.	X	X	X	Const.: There may be traditional sites etc. in iTaukei land. Construction of a facility may involve disturbance to such sites, including its relocation and the access restriction.
			Ope.				
	23	Landscape	Const.	X			The Western Division, especially Nadi, is a famous tourist destination, so facility designs and construction work need to be considered.
			Ope.				
	24	Gender / Children's Right	Const.				No impact on gender or children's right issues is expected, but the consideration may need to be studied, depending on a facility location.
			Ope.				
	25	Sanitation and Infectious Diseases (HIV/AIDS)	Const.				It is expected that improvement of wastewater treatment system in Nadi makes an advanced sanitary environment and reduce risks on infectious diseases.
			Ope.				
	26	Work environment (including occupational safety) / Accidents	Const.	X	X	X	Const.: Work environment for construction workers should be considered. Ope.: Gas poisoning and oxygen deficiency may occur during maintenance, so working environment for the operators should be considered.
			Ope.	X	X	X	
Others	30	Global Warming	Const.	X	X	X	Const.: CO2 emission from heavy equipment for construction work is expected. Ope.: GHG (CH4 and CO) will be generated from the treatment process.
			Ope.	X			

Const.: Before/during construction
Ope.: During operation

APPENDIX 8-3 Detailed Scenario Analysis

(1) Lautoka

Key items		L1	L2a	L2b	L2c
Soc.	Involuntary Resettlement and Land Acquisition	Footprint required (including sludge storage site): Natabua: 32.4 ha	Footprint required (including sludge storage site): Natabua: 27.4 ha Vitogo: 7.1 ha	Footprint required (including sludge storage site): Natabua: 27.4 ha Vitogo: 10.6 ha	Footprint required (including sludge storage site): Natabua: 50.2 ha Vitogo: 10.6 ha
	Existing Social Infrastructure and Services	The existing pump stations need to be rehabilitated due to long distance sewerage pumping, which is not efficient.	Pump stations newly need to be constructed within efficient distances in the sewerage areas.	Pump stations newly need to be constructed within efficient distances in the sewerage areas.	Pump stations newly need to be constructed within efficient distances in the sewerage areas.
Env.	Topography and Geographical Features	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.
	Groundwater	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. A larger sewerage system is at risk having more points of failure if not maintained and could result in groundwater contamination	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. Two separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination.	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. Two separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination.	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. Two separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination.
	Soil Erosion	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.
	Hydrology	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.
	Coastal Zone	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the

Key items		L1	L2a	L2b	L2c
		WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time. Treated effluent should not be discharged where coastally protected areas nor close to towns.	WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time. Treated effluent should not be discharged where coastally protected areas nor close to towns.	WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time. Treated effluent should not be discharged where coastally protected areas nor close to towns.	WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time. Treated effluent should not be discharged where coastally protected areas nor close to towns.
	Protected areas / Biodiversity	Improvement of the sewer system in the area is expected to improve surrounding natural environment. The existing and proposed WWTPs in Lautoka are not near any Key Biological Areas. The existing Natabua WWTP discharges to Dreketi and Saweni mangroves and mudflat (SUMA) and if the system is not efficiently operated could result in negative implications for local and surround biodiversity.	Improvement of the sewer system in the area is expected to improve surrounding natural environment. The existing and proposed WWTPs in Lautoka are not near any Key Biological Areas. The existing Natabua WWTP discharges to Dreketi and Saweni mangroves and mudflat (SUMA) and if the system is not efficiently operated could result in negative implications for local and surround biodiversity. The proposed Vitigo MWTP does not discharge to any SUMA. Thus, there is less potential risk to important biodiversity.	Improvement of the sewer system in the area is expected to improve surrounding natural environment. The existing and proposed WWTPs in Lautoka are not near any Key Biological Areas. The existing Natabua WWTP discharges to Dreketi and Saweni mangroves and mudflat (SUMA) and if the system is not efficiently operated could result in negative implications for local and surround biodiversity. The proposed Vitigo MWTP does not discharge to any SUMA. Thus, there is less potential risk to important biodiversity.	Improvement of the sewer system in the area is expected to improve surrounding natural environment. The existing and proposed WWTPs in Lautoka are not near any Key Biological Areas. The existing Natabua WWTP discharges to Dreketi and Saweni mangroves and mudflat (SUMA) and if the system is not efficiently operated could result in negative implications for local and surround biodiversity. The proposed Vitigo MWTP does not discharge to any SUMA. Thus, there is less potential risk to important biodiversity.
	Climate change	The contribution would be less than minor should methane be captured and burnt off.	The contribution would be less than minor should methane be captured and burnt off.	The contribution would be slightly more due to the inability to capture the methane from the AL, unless designed to do so.	The contribution would be slightly more due to the inability to capture the methane from the AL, unless designed to do so.
	Air pollution / Odor	If managed correctly, $PM_{2.5}$ and PM_{10} should not be of concern. Mechanical treatment at Natabua WWTP generates relatively less odor.	If managed correctly, $PM_{2.5}$ and PM_{10} should not be of concern. It is expected that both of the MWTPs will generate less odor	If managed correctly, $PM_{2.5}$ and PM_{10} should not be of concern. The MWTP at Natabua will generate relatively less odor compared to the AL treatment at Vitogo WWTP due to	If managed correctly, $PM_{2.5}$ and PM_{10} should not be of concern. The WTPs at Natabua and Vitogo will generate slightly more odor compared with MTP due to the large

Key items		L1	L2a	L2b	L2c
				the large surface area of the ponds.	surface area of the ponds if they are overcapacity.
	Water pollution	Under ideal conditions, treated wastewater quality at the Natabua MWTP would be satisfied to the SEZ criteria. Sewerage system may become overwhelmed, however, if under designed (under capacity) and if it is not regularly maintained nor upgraded to keep pace with the growing population. Based on history, there is the moderate risk that the sewerage system and MWTP will not be well maintained. If this is the case, then water pollution may increase.	Under ideal conditions, treated wastewater quality at the Natabua MWTP would be satisfied to the SEZ criteria. Having two MWTPs and two sewerage networks will reduce the strain on the overall system, which will in turn mean a higher level of treatment	Under ideal conditions, treated wastewater quality at the Natabua MWTP would be satisfied to the SEZ criteria. In contrast, the AL at Vitogo WWTP would be treated to a moderate level to satisfy the 'general criteria'. Therefore, pollution in the receiving environment would be slightly higher in Vitigo compared to Natabua.	Under ideal conditions, the AL at Natabua and Vitogo WWTPs would be treated to a moderate level to satisfy the General criteria.
	Waste/Sludge	Footprint required for sludge storage: Natabua: 13.3 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET	Footprint required for sludge storage: Natabua: 11.3 ha Vitogo: 2.9 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET	Footprint required for sludge storage: Natabua: 11.3 ha Vitogo: 1.7 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET	Footprint required for sludge storage: Natabua: 8.1 ha Vitogo: 1.7 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET

Key items		**L1**	**L2a**	**L2b**	**L2c**
		suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)
	Noise and Vibration	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.
	Ground Subsidence	Ground subsidence is not expected	Ground subsidence is not expected	Ground subsidence is not expected	Ground subsidence is not expected

(2) Nadi

Key items		N1	N2a	N2b	N3a	N3b
Soc.	Involuntary Resettlement and Land Acquisition	Footprint required (including sludge storage site): Navakai: 45.8 ha	Footprint required (including sludge storage site): Navakai: 40 ha Sabeto: 5.8 ha	Footprint required (including sludge storage site): Navakai: 40 ha Sabeto: 9.1 ha	Footprint required (including sludge storage site): Navakai: 24.3 ha Sabeto: 4.9 ha Moala: 15.7 ha	Footprint required (including sludge storage site): Navakai: 24.3 ha Sabeto: 9.1 ha Moala: 24.9 ha
	Existing Social Infrastructure and Services	If with a single sewerage area system, construction work would disturb highly populated areas of Nadi. The existing pump stations need to be rehabilitated due to long distance sewerage pumping, which is not efficient.	Pump stations newly need to be constructed within efficient distances in the sewerage areas compared with L1.	Pump stations newly need to be constructed within efficient distances in the sewerage areas compared with L1.	Pump stations newly need to be constructed within efficient distances in the sewerage areas compared with L1 and L2.	Pump stations newly need to be constructed within efficient distances in the sewerage areas compared with L1 and L2.
Env.	Topography and Geographical Features	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.	It is not expected that any topographical nor geological features will be changed in any significant manner.
	Groundwater	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. A larger sewerage system is at risk having more points of failure if not maintained and could result in groundwater contamination	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. The larger Navakai sewerage system is at risk having more points of failure if not maintained and could result in groundwater contamination. Two separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination.	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. Two separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination. If AL ponds are not constructed to engineering specifications, they could leach or spill over and contaminate groundwater.	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. Three separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination.	Improvement/Replacement of damaged existing sewer pipelines is expected to have positive benefits on the groundwater quality. Three separate sewerage networks are less likely result in point failures in the system. Thus, less chance of groundwater contamination If AL ponds are not constructed to engineering specifications, they could leach or spill over and contaminate groundwater.

Key items		N1	N2a	N2b	N3a	N3b
	Soil Erosion	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.	Soil erosion is expected to be reduced, as wastewater run-off will be less of an issue with the construction of the wider sewerage system network and new wastewater treatment plant facilities.
	Hydrology	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.	It is not expected that any hydrological regime will be impacted as part of the construction phase nor operational phase.
	Coastal Zone	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time.	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time.	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time.	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time.	The impacts to the coastal zones associated with poorly treated wastewater are likely to be significantly improved with WWTP upgrades. There is a chance, however, that if the WWTPs are not manage well that nutrient pollution to the coastal zone could occur, which could implicate local fauna and flora within the immediate area. These impacts could be felt on a medium to long term scale if effluent is mismanaged for a long period of time.
	Protected areas / Biodiversity	Improvement of the sewer system in the area is expected to improve surrounding natural environment.	Improvement of the sewer system in the area is expected to improve surrounding natural environment.	Improvement of the sewer system in the area is expected to improve surrounding natural environment.	Improvement of the sewer system in the area is expected to improve surrounding natural environment.	Improvement of the sewer system in the area is expected to improve surrounding natural environment.

Key items		N1	N2a	N2b	N3a	N3b
		The existing and proposed WWTPs in Nadi are not near any Key Biological Areas. The existing Navakai WWTP does not discharge to any SUMA, so there is less potential risk to important biodiversity.	The existing and proposed WWTPs in Nadi are not near any Key Biological Areas. The existing Navakai WWTP does not discharge to any SUMA, so there is less potential risk to important biodiversity. The proposed Sabeto MWTP (Nadi proposed sites 1 and 2) would discharge to SUMA site NVT5 (Sabeto Delta). Thus, if the MWTP is not operated efficiently, this could result in negative implications for the important biodiversity within this area.	The existing and proposed WWTPs in Nadi are not near any Key Biological Areas. The existing Navakai WWTP does not discharge to any SUMA, so there is less potential risk to important biodiversity. The proposed Sabeto MWTP (Nadi proposed sites 1 and 2) would discharge to SUMA site NVT5 (Sabeto Delta). Thus, if the MWTP is not operated efficiently, this could result in negative implications for the important biodiversity within this area.	The existing and proposed WWTPs in Nadi are not near any Key Biological Areas. The existing Navakai WWTP does not discharge to any SUMA, so there is less potential risk to important biodiversity. The proposed Sabeto MWTP (Nadi proposed sites 1 and 2) would discharge to SUMA site NVT5 (Sabeto Delta). Thus, if the MWTP is not operated efficiently, this could result in negative implications for the important biodiversity within this area. The proposed Nadi South MWTP (Nadi proposed sites 3 and 4) would discharge to SUMA site NVT7 (South Denarau Mangroves). Thus, if the MWTP is not operated efficiently, this could result in negative implications for the important biodiversity within this area.	The existing and proposed WWTPs in Nadi are not near any Key Biological Areas. The existing Navakai WWTP does not discharge to any SUMA, so there is less potential risk to important biodiversity. The proposed Sabeto MWTP (Nadi proposed sites 1 and 2) would discharge to SUMA site NVT5 (Sabeto Delta). Thus, if the MWTP is not operated efficiently, this could result in negative implications for the important biodiversity within this area. The proposed Nadi South MWTP (Nadi proposed sites 3 and 4) would discharge to SUMA site NVT7 (South Denarau Mangroves). Thus, if the MWTP is not operated efficiently, this could result in negative implications for the important biodiversity within this area
	Climate change	The contribution would be less than minor should methane be captured and burnt off.	The contribution would be less than minor should methane be captured and burnt off.	The contribution would be slightly more due to the inability to capture the methane from the AL, unless designed to do so.	The contribution would be less than minor should methane be captured and burnt off.	The contribution would be slightly more due to the inability to capture the methane from the AL, unless designed to do so.

Key items		N1	N2a	N2b	N3a	N3b
	Air pollution / Odor	If managed correctly, PM2.5 and PM10 should not be of concern. Mechanical treatment at Natabua WWTP generates relatively less odor.	If managed correctly, PM2.5 and PM10 should not be of concern. It is expected that both of the MWTPs will generate less odor	If managed correctly, PM2.5 and PM10 should not be of concern. The MWTP at Natabua will generate relatively less odor compared to the AL treatment at Vitogo WWTP due to the large surface area of the ponds.	If managed correctly, PM2.5 and PM10 should not be of concern. It is expected that all three of the MWTPs will generate less odor.	If managed correctly, PM2.5 and PM10 should not be of concern. It is expected that all three of the MWTPs will generate less odor. It expected that the AL in Sabeto and Nadi South will produce more odor compared to the Navakai MWTP, due to the large surface area of the AL ponds.
	Water pollution	Under ideal conditions, treated wastewater quality at the Navakai MWTP would be satisfied to the SEZ criteria. The Navakai sewerage system may become overwhelmed, however, if under designed (under capacity) and if it is not regularly maintained nor upgraded to keep pace with the growing population. Based on history, there is the moderate risk that the sewerage system and MWTP will not be well maintained. If this is the case, then water pollution may increase.	Under ideal conditions, treated wastewater quality at the Navakai and Sabeto MWTPs would be satisfied to the SEZ criteria. Having two MWTPs and two sewerage networks will reduce the strain on the system, which will in turn mean a higher level of treatment. The Navakai sewerage system may become overwhelmed, however, if under designed (under capacity) and if it is not regularly maintained nor upgraded to keep pace with the growing population. Based on history, there is the moderate risk that the sewerage system and	Under ideal conditions, treated wastewater quality at the Navakai MWTP would be satisfied to the SEZ criteria. The Navakai sewerage system may become overwhelmed, however, if under designed (under capacity) and if it is not regularly maintained nor upgraded to keep pace with the growing population. Based on history, there is the moderate risk that the sewerage system and MWTP will not be well maintained. If this is the case, then water pollution may increase. The AL at Sabeto WWTP would treat to a moderate level to	Under ideal conditions, treated wastewater quality at the Sabeto, Navakai, and south MWTPs would be satisfied to the SEZ criteria. Having three MWTPs and three separate sewerage networks will significantly reduce the strain on the overall system, which will in turn mean a higher level of treatment. Potentially more maintenance is required and along with more skilled personal to ensure efficient operations, which is not necessarily bad thing from a local economic point of view	Under ideal conditions, treated wastewater quality at the Navakai MWTP would be satisfied to the SEZ criteria. The ALs at Sabeto and Nadi south WWTPs would treat to a moderate level to satisfy the ‘general criteria’. Therefore, pollution in the receiving environment would be higher at these two sites compared to Navakai. Having one MWTPs and two ALs with three separate sewerage networks will reduce the strain on the overall system, which will in turn mean a higher level of treatment. The ALs are a

Key items		N1	N2a	N2b	N3a	N3b
			MWTP will not be well maintained. If this is the case, then water pollution may increase.	satisfy the 'general criteria'. Therefore, pollution in the receiving environment would be higher in the Sabeto area compared to Navakai. Having one MWTPs and one AL with two separate sewerage networks will reduce the strain on the system, which will in turn mean a higher level of treatment.		simple design with lower capital and maintenance costs compared to MWTPs or Activated sludge plants.
	Waste/Sludge	Footprint required for sludge storage: Navakai: 18.8 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded	Footprint required for sludge storage: Navakai: 16.5 ha Sabeto: 2.4 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded	Footprint required for sludge storage: Navakai: 16.5 ha Sabeto: 1.5 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded	Footprint required for sludge storage: Navakai: 10.0 ha Sabeto: 1.5 ha Moala: 6.5 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge produced was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded	Footprint required for sludge storage: Navakai: 10.0 ha Sabeto: 1.5 ha Moala: 4.0 ha Waste generated from construction activities will be appropriately managed and disposed of according to the measures incorporated into the CEMP. Sludge produced was recently discussed at the meeting with DoE (22 July 2022). WAF has to have a permit from the waste and pollution control unit of DoE for discharge and sludge storage, which would probably be a condition in the EIA approval. JET asked if sludge can be disposed at Naboro LFS, and DoE responded

Key items		**N1**	**N2a**	**N2b**	**N3a**	**N3b**
		that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)	that they will confirm it with DoE staff in charge. However, DoE's position is clear that the sludge has to be decontaminated to avoid environmental and health risks. JET suggested DoE to consider formulating sludge quality standards so that the generated sludge could be reused for agriculture and soil covers of LFSs. Ideas to incinerate or convert the sludge to energy were discussed. DoE suggested WAF to talk with MoA and MoH for sludge recycling (Refer to Appendix A)
	Noise and Vibration	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.	Although noise is unavoidable, noise protection will be adopted as per the measures incorporated into the CEMP during construction. Noise and Vibration are not expected to be an issue during operation.
	Ground Subsidence	Ground subsidence is not expected	Ground subsidence is not expected	Ground subsidence is not expected	Ground subsidence is not expected	Ground subsidence is not expected

APPENDIX 9-1 Minutes of Meeting on JCC

(1) 4th JCC on September 19th, 2023

Minutes of Meetings
on
The Forth Joint Coordinating Committee
For
Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase)
Agreed upon between
Ministry of Public Works, Meteorological Services and Transport
and
Water Authority of Fiji
and
Japan International Cooperation Agency

The Forth Joint Coordinating Committee (hereinafter referred to as "JCC") for the Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase) (hereinafter referred to as "the Project") was convened on 19th September 2023 by the chairperson of the JCC and others.

As a result of the discussions, both sides understood the matters referred to in the document attached hereto.

Suva, September 19th, 2023

Mr. Taitusi VAKADRAVUYACA
Permanent Secretary
Ministry of Public Works,
Meteorological Services and Transport

Mr. Stephen FARRELLY
Chief Asset Management Officer
Water Authority of Fiji

Ms. Mayumi AMAIKE
Resident Representative
JICA Fiji Office

中嶋 宜信

Mr. Yoshinobu NAKAJIMA
Team Leader
JICA Expert Team

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ATTACHED DOCUMENTS

1. **Target Year and Future Population**

The JICA Expert Team (hereinafter referred to as "JET") explained the target year and future population based on the attached ANNEX 1. JCC had no objection to it.

- Target year: 2043
- Future Population in 2043 (entire of Fiji): 1.041 million persons
- Future population in 2043 (Western division): 396 thousand persons

2. **Service Area and Wastewater Flow**

JET explained the need to divide the service area and the considerations for dividing it. The proposed five (5) service areas were identified as Vitogo, Natabua, Sabeto, Navakai and Moala. The estimated amount of wastewater flow in the target year 2043 is summarized as shown in the table below. JCC had no objection to it.

Municipals	Service Area	Wastewater Flow: Average Dry Weather Flow	
		(m^3/day)	(Equivalent Population)
Lautoka	Vitogo	6,400	31,800
	Natabua	40,500	202,200
Nadi	Sabeto	6,400	32,000
	Navakai	27,100	135,000
	Moala	17,500	87,400

Note: Values in m^3/day column is rounded up

3. **Effluent Standard**

JET explained that based on discussions with the Department of Environment (DOE), the effluent standards applied to the five WWTPs at the current stage of the Municipal Sewerage M/P have been set as shown in the table below. General standard + ocean discharge is applied to four treatment plants near the sea, and Kinoya in Suva is also under investigation to apply similar standards.

Municipal	WWTP	Applied Standard
Lautoka	Vitogo	General standards + Ocean outfall
	Natabua	General standards + Ocean outfall
Nadi	Sabeto	General standards + Ocean outfall
	Navakai	Significant Ecological Standards
	Moala	General standards + Ocean outfall

Regarding application of the ocean outfall, the DOE will require further environmental and biological assessment of the outfall area at the F/S stage. Therefore, JET must list the items that should be investigated at the pre-F/S stage. JCC had no objection to it.

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TV

4. Treatment Process Assessment

JET explained the evaluation method and results of the treatment process applied to the five WWTPs. The four WWTPs applying the General Standards were selected from the Stabilization Pond, Aerated Lagoon, and Trickling Filter methods based on a weighted scoring system. The Navakai WWTP, which applies the SEZ standards, was selected based on a weighted scoring system from three types of treatment processes: Oxidation Ditch process, IDEA process, and MBBR process. JCC had no objection to it.

Municipal	WWTP	Applied Treatment Process
Lautoka	Vitogo	Trickling Filter Process
	Natabua	Trickling Filter Process
Nadi	Sabeto	Trickling Filter Process
	Navakai	Oxidation Ditch Process
	Moala	Trickling Filter Process

5. Decentralized System

JET considered options for centralized treatment of septage (sludge from septic tank). After comparing the option of centralized treatment in Natabua (Case 1) and the option of semi-centralized treatment in Vitogo and Moala (Case 2), JET explained that Case 1 is appropriate in terms of cost and maintenance of sludge treatment facilities. JCC had no objection to it.

6. Sludge Treatment and Disposal

The septage will be collected and treated at Natabua WWTP. In addition, in order to generate biogas power as a future option, JET proposed that the raw sludge generated from each WWTP be collected in Natabua WWTP and used for gas power generation. As mentioned above, JET has shown that a lot of sludge will be collected at Natabua WWTP, and a large area will be required for drying and storing the sludge. It is necessary to consider how to utilize the sludge and accept it to the solid waste landfill. JCC had no objection to it.

7. Estimation of Construction and O/M Costs

JET explained the construction and O/M costs of the facilities required in each service area. The breakdown of construction cost shows that the cost of constructing branch sewer network accounts for 25 to 40 percent of the total construction cost. Installation of these branch sewer network also includes installation by private developers who develop within the service area.

8. Implementation Schedule

JET explained a proposal to divide the project components based on the amount required for facility development in the Municipal Sewerage M/P. The priority for

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facility construction is set to be 1) compliance with laws and regulations regarding water quality discharged from existing WWTPs, 2) installation of trunk lines and upgrading of existing trunk lines, and 3) construction of sewer network including branch lines. A development plan has been presented to give priority to Navakai and Natabua service area. JCC had no objection to it.

ANNEX 1: Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase), September 19th, 2023, JICA Expert Team

ANNEX 1

Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase)

Joint Coordination Committee (4th)

19th September 2023

JAPAN INTERNATIONAL COOPORATION AGENCY (JICA)
Nihon Suido Consultants Co., Ltd.
Yachiyo Engineering Co., Ltd.

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Agenda of JCC and Main Purpose

1. Opening Remark from WAF
2. Opening Remark from JICA Fiji Office
3. Explanation of Municipal Sewerage Master Plan
   1) Target Yea and Area
   2) Future Population and Wastewater Flow,
   3) Centralized System , 4) Decentralized System
   5) Sludge Disposal and Reuse , 6) Cost Estimation and F&E Analysis
   7) Proposed Projects and Implementation Schedule
   8) Decentralized System
4. Schedule of Pre-F/S
5. Discussion/ Q&A
6. Closing Remark from MPW

Main Purpose
✓ Making basic consensus about the contents of Municipal Sewerage M/P

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1. Opening Remark from WAF

2. Opening Remark from JCIA Fiji Office

3

2. Brief overview of the Project

1. Background and Introduction

✓ The Fiji "National Development Plan (2017-2036)" targets access to centralized treatment systems for 70% of the population by 2036

✓ The Master Plans needs to be developed as a guiding document to lead the upgrade of the western wastewater sector in the study area which are in line with future developments in order to meet Fiji's National Development Plan.

✓ This Master Plan will outline the essential projects and will be structured to identify constraints and gaps to ensure the improvement of WAF's wastewater services.

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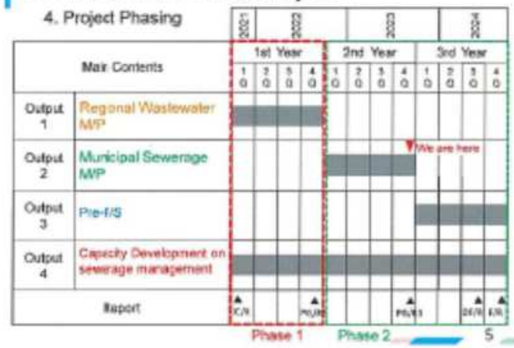
ANNEX 1

2. Brief overview of the Project

4. Project Phasing



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2. Brief overview of the Project

2. Target Area

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3. Contents of Municipal Sewerage M/P

3-1. Target Year and Area
3-2. Future Population and Wastewater Flow
3-3. Centralized System
3-4. Decentralized System
3-5. Sludge Disposal and Reuse
3-6. Cost estimation
3-7. Proposed Projects and Implementation Schedule
3-8. Recommendation

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3-1. Target Year and Area

(1) Target Year

- ✓ National Development Plan (2017-2036): 2036
- ✓ Regional Wastewater M/P: 2036
- ✓ Municipal Sewerage M/P: 2043

→ Considering 20 years plan from 2023

(2) Service Area

- ✓ Same as Regional Wastewater M/P
- ✓ Service area was determined considering to achieve 70 % population access in 2036

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ANNEX 1

3-1. Target Year and Area

Output 2

Target Area for Municipal Sewerage M/P

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3-2. Future Population and Wastewater Flow

(1) Population

✓ Projected population in 2043

- Entire Fiji: Estimated using same trend
- Western Division: 38% of the Entire Fiji
- Provincial Population: Estimated using same trend

Item		2036	2043
Entire Fiji		1,000,000	1,041,000
Western Division		380,000	396,000
Province	Ba	288,800	303,300
	Ra	32,300	32,500
	Nadroga Navosa	58,900	60,200

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3-2. Future Population and Wastewater Flow

(4) Wastewater Flow Estimation

✓ Domestic water consumption: same as Regional Wastewater M/P
✓ WAF apply 220 L/day/capita for water consumption
✓ 90 % will be counted as unit wastewater flow -> 200L/day/capita

✓ Estimation of the amount of Non-domestic water usage: existing water usage and future development.
✓ The future development plan from DTCP and Investment Fiji.

Item	unit	Lautoka	Nadi	Total
Population	person	120,720	101,670	222,390
Domestic Flow	m3/day	24,144	20,334	44,478
Non-Domestic Flow	m3/day	18,400	25,920	44,320
Infiltration water	m3/day	4,254	4,625	8,880
Total Inflow ADWF	m3/day	46,798	50,879	97,878
	EP	234,000	254,400	107,446

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3-3. Centralized System

(1) Setting of WWTP and Service Area

Amount of sewage to be treated will increase due to the expansion of sewerage service area in future

✓ Difficulty of expansion of WWTP land around the existing WWTP (Navakai, Natabua) in the central town/ city.

✓ It is not efficient to pump wastewater over long distances from extended service area.

✓ Examination of multi-WWTP system considering cost and environmental aspects.

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ANNEX 1

3-3. Centralized System

(1) Setting of WWTP and Service Area

Items considered in selecting the location of WWTP

- Downstream location in service area (Lower area)
  -> Collecting sewage by gravity flow
- Discharge point nearby(Sea/ River)
- No/ Less resettlement
- Outside of city/town boundary (Urban area)
  -> except for existing WWTPs
- No/ Less deforestation of mangroves

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3-3. Centralized System

(2) Wastewater Flow for each Service Area in 2043

No.	Item	Unit	Lautoka		Nadi			Total
			Vitogo	Natabua	Sabeto	Navakai	Moala	
1	Population	capita	15,130	105,590	13,510	52,740	35,420	222,390
2	Water Consumption	m³/capita/day	0.220	0.220	0.220	0.220	0.220	
3	Return Ratio	%	90	90	90	90	90	
4	Unit wastewater Flow	m³/capita/day	0.200	0.200	0.200	0.200	0.200	
5	Domestic Flow	m³/day	3,026	21,118	2,702	10,548	7,084	44,478
6	Non-Domestic Flow	m³/day	2,760	15,640	3,110	14,000	8,810	44,320
7	Generated Waste water	m³/day	5,786	36,758	5,812	24,548	15,894	88,798
8	Infiltration ratio	%	10	10	10	10	10	
9	Infiltration water	m³/day	579	3,676	581	2,455	1,589	8,880
10	Total Inflow ADWF	m³/day	6,365	40,434	6,393	27,003	17,483	97,678
11	Equivalent Person	EP	31,800	202,200	32,000	135,000	87,400	488,400

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3-3. Centralized System

(3) Effluent Standard

Target Water Quality Standards
- ✓ General Standards
- ✓ Significant Ecological Zone (SEZ) Standards

Parameter	Units	General Standards	Significant Ecological Zone
BOD5	mg/L	40	20
SS		60	30
TDS		1000	1000
Grease		5	2
T-N		25	10
T-P		5	2
E.coli	c/100mL	400	200

Kinoya WWTP is planning to apply "General Standard + Ocean outfall pipe"

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3-3. Centralized System

(3) Effluent Standard

1) Lautoka

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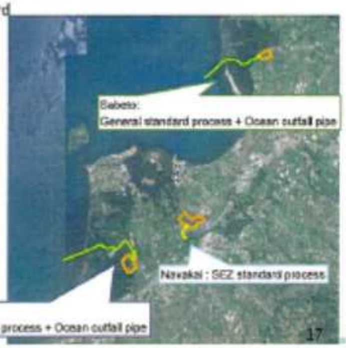
ANNEX 1

3-3. Centralized System

(3) Effluent Standard

2) Nadi



3-3. Centralized System

(3) Effluent Standard

Summary of discussion with DOE

- DOE agreed that in the current Municipal M/P stage, the proposed effluent standards will be applied for each WWTP
- Further studies will be conducted in the F/S stage to determine the outfall-specific effluent standards
  - Environmental/biological assessment of the outfall area
  - EIA Screening applications for the ocean outfall pipes
  - Amount and water quality of discharged effluent
  - Dilution rate of the discharged effluent
  - Allowable carrying (discharge) capacity of the outfall waters

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3-3. Centralized System

(4) Assessment of Treatment Process

Factor & Weight in this M/P

Items	New WWTP	Existing WWTP
Cost (CAPEX of AEC) (mil. FJD/year)	20	20
Cost (OPEX) (mil. FJD/year)	25	25
Amount of Dewatered Sludge (t/year)	5	5
Amount of Raw Sludge (m3/year)	20	10
No. of equipment (Unit)	5	5
Footprint of WWTP (ha)	20	30
GHG Generation (ktCO2/year)	5	5

✓ Scoring points to each WWTP
-> Vitogo, Natabua, Sabeto and Moala: S.P. vs A.L. vs T.F.
-> Navakai: IDEA vs OD vs MBBR

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3-3. Centralized System

(4) Assessment of Treatment Process

Summary of Treatment Process by each service area

Municipal	Service Area	Process	Standard
Lautoka	Vitogo	Trickling Filter + ocean outfall	General
	Natabua	Trickling Filter + ocean outfall	General
Nadi	Sabeto	Trickling Filter + ocean outfall	General
	Navakai	Oxidation Ditch/ IDEA	SEZ
	Moala	Trickling Filter + ocean outfall	General

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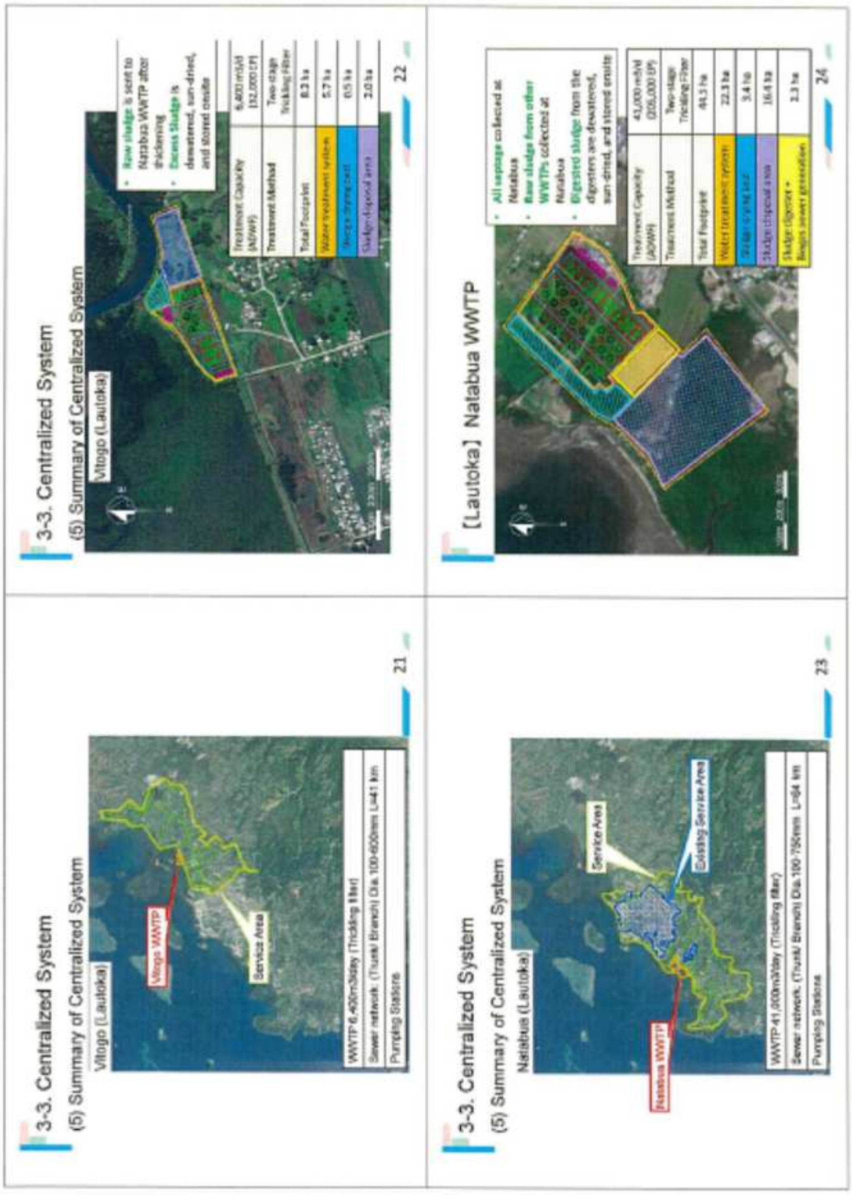
ANNEX 1


3-3. Centralized System
(5) Summary of Centralized System
Vitogo (Lautoka)
Vitogo WWTP
Service Area
Pumping Stations
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Natabua (Lautoka)
Natabua WWTP
Service Area
Existing Service Area
23
【Lautoka】 Natabua WWTP
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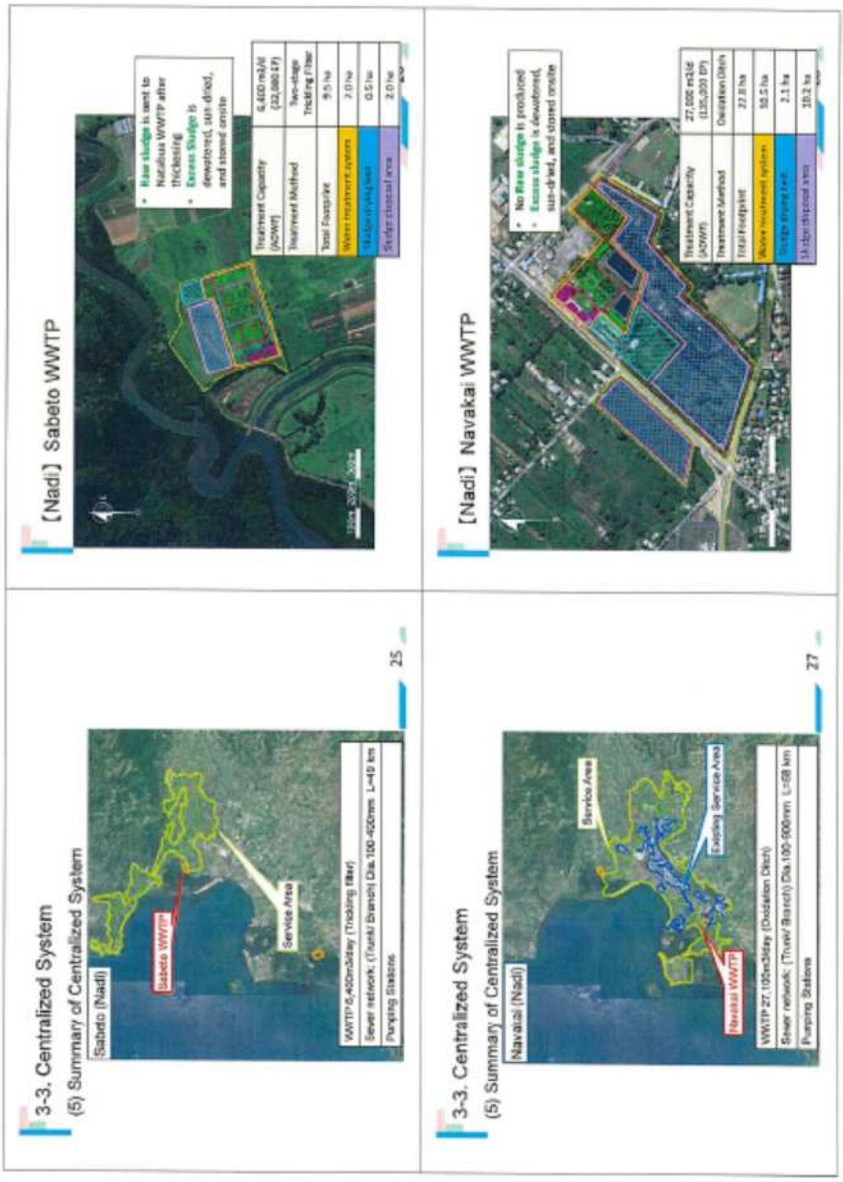
ANNEX 1



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ANNEX 1

3-3. Centralized System

(5) Summary of Centralized System

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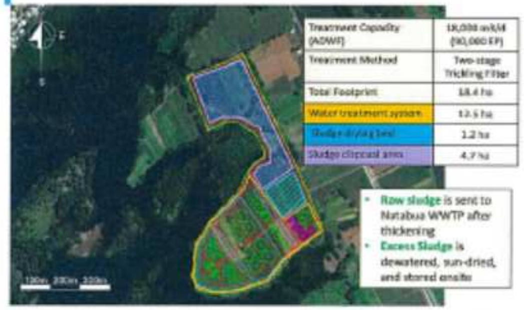
【Nadi】 Moala WWTP



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Odor Control for WWTP

Odor Mitigation

- Design/operational measures to mitigate foul odors
  - Minimize freefall turbulence by controlling water levels
  - Increase frequency of grit/screen residue disposal
  - Containment of odor-source facilities (WWTP inlet, septage receival facility, sludge dewatering)
  - Position odor-source facilities away from surrounding residential areas, facilities etc.
  - Place vegetation in buffer zones to induce turbulence→dilute odorous gases

Consideration of Odor Treatment

- In additon to containment, examine gas collection and odor treatment of above major odor-source facilities

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Odor Control for WWTP

Major Odor Treatment Methods

- Activated Carbon Filters
  - Adsorb odorous components using activated carbon media
  - Required O&M skills are relatively low, but O&M costs will depend on frequency of AC media replacement

- Biological Treatment
  - Break down odorous components using microorganisms residing in soil-bed filters/artificial media
  - Required O&M skills and costs relatively low, requires relatively large footprint

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ANNEX 1

Odor Control for WWTP

Major Odor Treatment Methods

- Chemical Scrubbing
  - Oxidize/entrain odorous components through contact with liquid-phase chemicals
  - Requires relatively high O&M skills/costs and procurement of chemicals

Deodorizing Chemical Scrubber ([illegible] Industries CO.,LTD.)

- Gas Incineration
  - Incinerate odorous gases at high temperatures
  - Required relatively high O&M skills and construction/O&M costs

Odor Gas Incinerator ([illegible] Chemicals Co.,Ltd.)

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3-3. Centralized System

(6) Biogas Power Generation

Basic Concept

- ✓ Target sludge for gas power generation: Raw sludge from primary clarifier
  - Septage is anaerobically digested due to desludging interval (5yrs.)
  - Septage is not suitable for gas power generation.
- ✓ Centralized gas power generation:
  - Thickened sludge is collected from WWTPs
  - Separate power generation is unfeasible.
- ✓ Generated energy will be used at own WWTP.
- ✓ Existing WWTP is a candidate site for biogas power generation to use a generated energy
  - Natabua WWTP which has a largest treatment scale
  - Land availability around Navakai is limited

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3-3. Centralized System

(6) Biogas Power Generation

- ✓ In case 5 WWTP are operated on ultimate inflow, the initial and running cost of biogas power generation and recovered power are as follows.

Item	Value
Initial Cost (million FJD)	57.2
Running Cost (million FJD/ year)	1.90
Generated power (MWh/year)	8,800
Electricity consumption by Natabua WWTP (MWh/year)	4,500
Energy recovery ratio (%)	196

- ✓ For reference:
  Actual Japanese situation: 300,000 MWh/ 118 WWTPs (in 2020)
  → 2,500MWh/1 WWTP
  → Assumed energy recovery ratio: 55 – 196 %

In this M/P, it is assumed that gas power generation will be performed by private companies using PPP etc.

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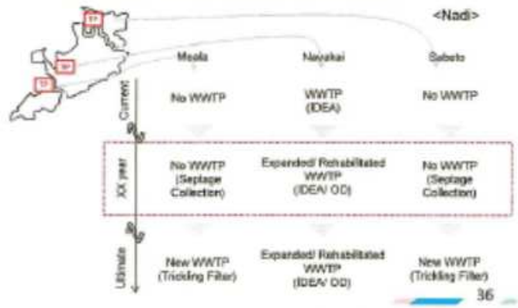
3-4. Decentralized System

- ✓ It is realistic to develop the wastewater management service step by step according to the urbanization of each service area.



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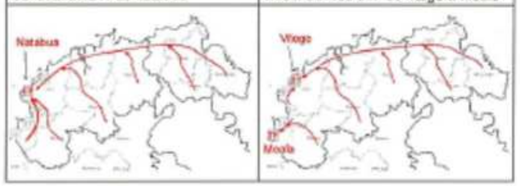
ANNEX 1

3-4. Decentralized System

Option Service Assessment

✓ 2 cases are considered to evaluate the efficiency of Septage Treatment

Case 1	Case 2
Centralized STF at Natabua	Decentralized STP at Vitogo & Moala



STP: Septage Treatment Plant

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3-4. Decentralized System

Option Service Assessment

	Case 1	Case 2
	Centralized treatment at Natabua	Decentralized septage treatment at Vitogo & Moala
Initial cost O&M cost	<Better> Centralized equipment for wastewater and sludge treatment	WWTP and STPs need to be maintained separately
Land acquisition	<Better> Natabua WWTP land expansion is high priority. Required STP area is small and included in WWTP expansion	Small land acquisition for STP area is required at Vitogo and Moala.
Annual trip length of bailing truck	779,000 km/year (maximum year)	<Better> 587,000 km/year (maximum year)
Environmental aspect	Many bailing truck pass the Nadi-Lautoka corridor, affecting environmental situation.	<Better> Less number of bailing truck pass the Nadi-Lautoka corridor comparing with Case 1.

STP: Septage Treatment Plant

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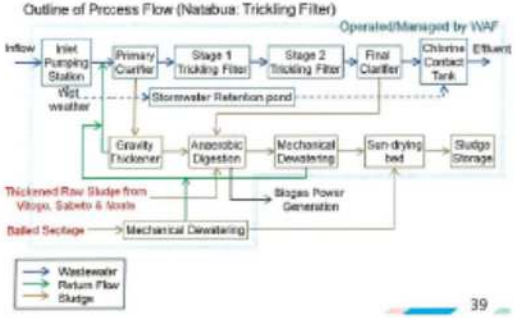
3-5. Sludge Disposal and Reuse

(1) Receiving Sludge at Natabua WWTP

Outline of Process Flow (Natabua: Trickling Filter)



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3-5. Sludge Disposal and Reuse

(1) Receiving Sludge at Natabua WWTP

- All septage collected at Natabua
- Raw sludge from other WWTPs collected at Natabua

Natabua WWTP

Treatment Capacity (ADWF)	41,000 m3/d (205,000 EP)
Treatment Method	Two-stage Trickling Filter
Total Footprint	44.8 ha
Sludge Digester + Biogas Power Generation	2.0 ha
Water treatment system + Sludge Drying bed	26.4 ha
Sludge disposal area	16.4 ha

Since the area of the sludge disposal is large, it is necessary to consider how to utilize the sludge and accept it to the dumping site of solid waste.

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ANNEX 1

3-5. Sludge Disposal and Reuse

(2) Sludge Disposal and Reuse

Results of Analysis for Sewage Sludge generated in Kinoya WWTP (2020)

Sample	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ca (%)	Mg (%)	Na (%)
Sample 1	17,030	131	260	112	<0.01	4	18	<0.01	0.57	0.35	0.05
Sample 2	26,225	134	879	211	<0.01	18	29	<0.01	1.71	0.65	0.1
Sample 3	18,018	95	850	216	<0.01	14	30	<0.01	1.68	0.47	0.16
Sample 4	18,672	28	847	211	<0.01	8	22	<0.01	1.3	0.39	0.14
Sample 5	18,104	73	915	190	<0.01	18	27	<0.01	2.22	0.40	0.14
Sample 6	19,358	73	877	194	<0.01	14	28	<0.01	2.57	0.47	0.12
Sample 7	18,179	44	909	242	<0.01	17	29	0.1	1.76	0.31	0.06

Referential Guideline (EPA, WHO and AWA)

Sample	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	As (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ca (%)	Mg (%)	Na (%)
EPA *1			250	200	20	250		3			
WHO *2					8	84		4			
AWA *3 Grade C2			2500	2500	60	420	500-3000	20			

*1 [illegible]
*2 [illegible]
*3 [illegible]

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3-5. Sludge Disposal and Reuse

(2) Sludge Disposal and Reuse

✓ Based on the results of sewage sludge analysis of Kinoya WWTP
- The levels of lead, cadmium, and arsenic, which are particularly hazardous, are below the EPA standards.
- The levels of copper and zinc , which are the essential trace elements, exceeds EPA standards.
- Concentration is extremely low compared to the standards indicated as Grade C2, which is "should be avoided" in the standards for the use of sewage sludge in Australia.(Australian Water Association)
- There is still the possibility of its use under some regulation.

✓ Sewage sludge analysis for Navakai & Natabua WWTP will be conducted.
- Mercury, Cadmium, Lead, Arsenic, Selenium, Zinc, Copper, Nickel, Chromium and Molybdenum

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3-6. Cost Estimation and F&E Analysis

Construction Cost

Item		Vitogo	Natabua	Saweni	Navakai	Moala
WWTPs (million FJD)	WWTP	77	474	78	312	196
	Ocean Outfall	43	26	52	0	75
Network (million FJD)	Trunk/Branch	75	92	120	94	161
	Tertiary	125	209	205	304	205
Pumping Station (million FJD)		17	41	48	52	76
Total (million FJD)		337	842	503	762	713

O/M Cost

Item	Vitogo	Natabua	Saweni	Navakai	Moala
WWTPs (1000 FJD/year)	1,350	3,866	1,350	3,150	2,433
Collection Network (1000 FJD/year)	112	207	126	281	264
Pumping Station (1000 FJD/year)	1,285	3,182	3,795	4,100	6,242
Total (1000 FJD/year)	2,747	7,255	5,271	7,511	8,939

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3-6. Cost Estimation and F&E Analysis

✓ FIRR= -3.4%
- When the tariff is 0.20(FJD/m3) same as current tariff

✓ EIRR= 1.2%
- When the tariff is set as 1.05(FJD/m3) considering affordability to pay

✓ Tariff: 0.77(FJD/m3)
- To cover the O/M cost

✓ Although the primary focus of the Municipal Sewerage M/P is on sanitation for residents, it must have positive effects on other industries, and lead to economic benefits.
✓ These qualitative economic impacts should be taken into account during project implementation.

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ANNEX 1

3-7. Proposed Projects and Implementation Schedule

Lautoka

Project	Contents
Vitogo	WWTP 6,400m3/day (Trickling filter) Ocean outfall pipe Sewer network: (Trunk/ Branch) L=41 km Pumping Stations
Natabua (Phase1)	WWTP 21,000m3/day (Trickling filter) Ocean Outfall pipe Septage Treatment
Natabua (Phase2)	WWTP 20,000m3/day (Trickling filter) Sewer network: (Trunk/ Branch) L=64 km Pumping Stations
Natabua (Phase3)	Sewer network: (Tertiary) L=144 km Pumping Stations

Basic concept of phased development in Natabua & Navakai
- Phase 1: compliance of effluent standard from WWTP
- Phase 2: Network upgrade and some extension (Trunk & main branch)
- Phase 3: some extension by WAF + (Other development project by Developers)

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3-7. Proposed Projects and Implementation Schedule

Nadi

Project	Contents
Sabeto	WWTP 6,400m3/day (Trickling filter) Ocean outfall pipe Sewer network: (Trunk/ Branch) L=49 km Pumping Stations
Navakai (Phase1)	WWTP 13,500m3/day (Mechanical Process)
Navakai (Phase2)	WWTP 13,500m3/day (Mechanical Process) Sewer network: (Trunk/ Branch) L=58km Pumping Stations
Navakai (Phase3)	Sewer network: (Tertiary) L=203 km Pumping Stations
Moala (Phase1)	WWTP 9,000m3/day (Trickling filter) Ocean outfall pipe Sewer network: (Trunk/ Branch) L=104 km Pumping Stations
Moala (Phase2)	WWTP 9,000m3/day (Trickling filter) Sewer network: (Tertiary) L=160 km Pumping Stations

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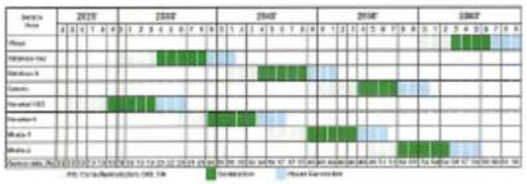
3-7. Proposed Projects and Implementation Schedule



- F/S, Consultant Selection Detailed Design and Tender: 4 years
- Construction: 5years.
- House connection: 3years.

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3-8. Recommendation

✓ Determination the disposal method of sewage sludge outside the WWTPs
- Currently, there is no disposal site for sewage sludge
- In this M/P, a place to store sludge in the WWTPs are planned.
- The area of the sludge storage area is huge, causing high initial cost.
- It is necessary to consider effective utilization and acceptance of solid waste dumping sites.

✓ Possibility of biogas power generation
- If sewage sludge (raw sludge) is collected and gas power is generated, it may be possible to cover the electricity bill for one WWTP.
- It is expected that gas power generation including other organic waste will contribute to the achievement of FIJI NET ZERO 2050.

✓ Examination of the impact of ocean outfall
- As obtained through discussions with DOE, it is necessary to consider the impact on outfall waterbody at the F/S stage.
- It is necessary to examine and organize the materials necessary for analysis

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ANNEX 1

3-8. Recommendation

✓ Revision of Municipal Sewerage M/P
- This M/P has been formulated on the basis of the assumed social situation 20 years from 2023.
- Moala, Sabeto and Vitogo will start its implementation 20 years later.
- It is necessary to review the M/P, including the social situation, about 10 years later.

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4.Activities in the 3rd year (Pre-F/S)

Formulation of Pre-F/S for Priority Project Identified in the Municipal Sewerage M/P

(1) Selection of Priority Project
Technical Committee will be held on 6th November
(2) Verify Need and Validity of the Project
(3) Outline Design of Sewerage Network and Pumping Stations
(4) Outline Design of WWTP
(5) Organization Structure and Financial Plan
(6) Formulate O&M Plan
(7) Estimation of Project Costs
(8) Environmental Impact Assessment
(9) Proposal of Additional Surveys for the F/S
(10) Survey Public Opinion regarding Connecting to Sewer, etc.
(11) Prepare and Discuss Draft Final Report
(12) Prepare and Submit Final Report

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5. Q&A session

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6. Closing Remark from MPW

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