フィジー共和国
フィジー水道公社（WAF）

フィジー共和国
フィジー国西部地区
汚水処理マスタープラン策定
プロジェクト

ファイナルレポート
Part 4：優先事業のPre-F/S

2024年10月

独立行政法人
国際協力機構（JICA）

株式会社 日水コン
八千代エンジニヤリング株式会社

環境
JR
24-075

序文

フィジー国西部地区汚水処理マスタープラン策定プロジェクトのファイナルレポート（F/R）は次に示す 4 部構成になっている。

・Part 1：要約

・Part 2：西部地区汚水処理マスタープラン

・Part 3：都市下水道マスタープラン

・Part 4：優先事業の Pre-F/S

このレポートは、F/R の「Part 4：優先事業の Pre-F/S」である。

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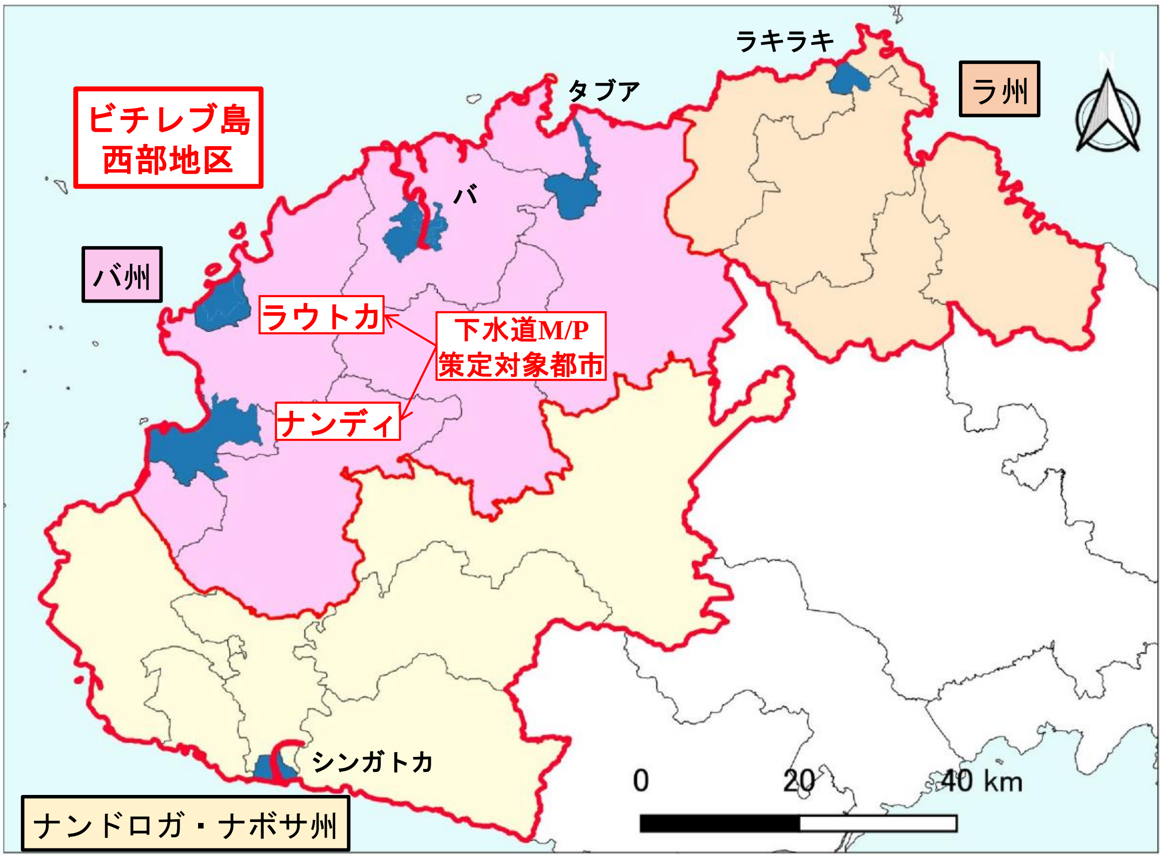
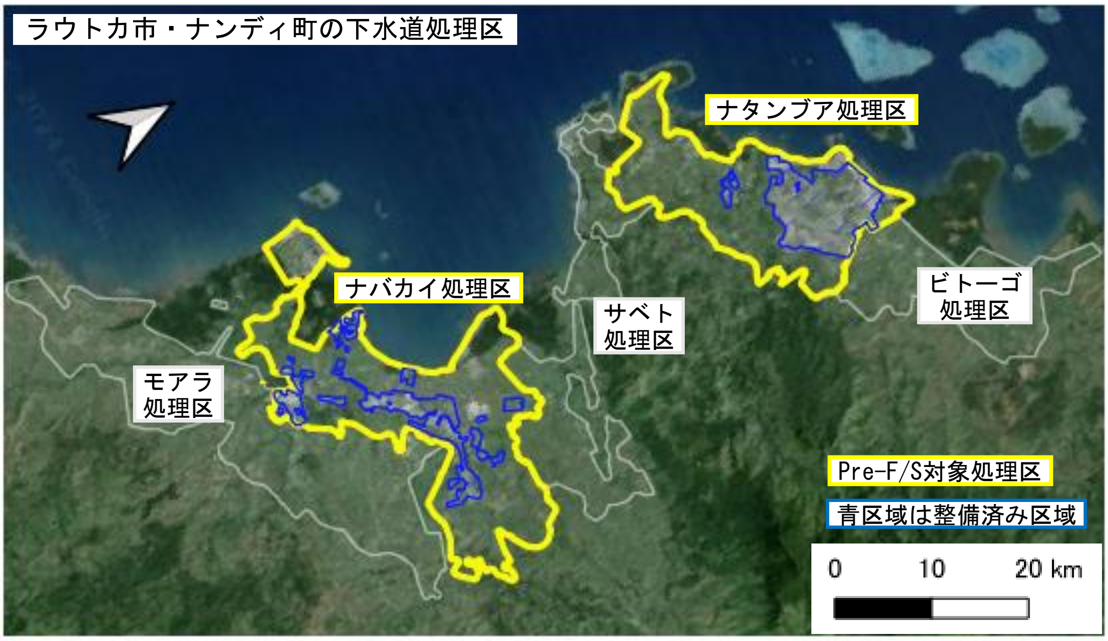
APPENDIX

表リスト

図リスト

調査位置図


ビチレブ島
西部地区
ラキラキ
タブア
ラ州
バ
バ州
ラウトカ
下水道M/P
策定対象都市
ナンディ
シンガトカ
ナンドロガ・ナボサ州
0
20
40 km


ラウトカ市・ナンディ町の下水道処理区
ナタンブア処理区
ナバカイ処理区
サベト
処理区
ビトーゴ
処理区
モアラ
処理区
Pre-F/S対象処理区
青区域は整備済み区域
0
10
20 km

略 語 表

ADB	Asian Development Bank	アジア開発銀行
ADWF	Average Dry Weather Flow	晴天時日平均水量
AHP	Analytic Hierarch Process	階層化意思決定法
AL	Aerated Lagoon	エアレーテッドラグーン
AS	Australian Standards	オーストラリア工業・サービス規格
ATP	Affordable To Pay	支払い可能額
BOD	Biochemical Oxygen Demand	生物化学的酸素要求量
CAPEX	Capital Expenditure	初期投資費用
CD	Capacity Development	能力開発
CBH	Central Bureau of Health	中央保険局
COD	Chemical Oxygen Demand	化学的酸素要求量
C/P	Counter Part	カウンターパート
CWIS	Citywide Inclusive Sanitation	包括的汚水管理・汚水処理サービス
DBOM	Design Build Operation Maintain	設計、構築、運用、保守
DD	Detailed Design	詳細設計
DF/R	Draft Final Report	ドラフト・ファイナルレポート
DOE	Department of Environment	（地方自治省）環境局
DOF	Department of Fisheries	（漁業省）漁業局
DOL	Department of Land	（国土鉱物資源省）土地局
DTCP	Department of Town and Country Planning	（地方自治省）市町計画局
DWS	Department of Water and Sewerage	（インフラ・気象サービス省）上下水道局
EIA	Environmental Impact Assessment	環境影響評価
EIB	European Investment Bank	欧州投資銀行
EIRR	Economic Internal Rate of Return	経済的内部収益率
ESC	Environmental and Social Considerations	環境社会配慮
FIRR	Financial Internal Rate of Return	財務的内部収益率
FOG	Fats, Oil, Grease	油脂類
FRA	Fiji Roads Authority	フィジー道路公社
F/S	Feasibility Study	事業実施調査
F/R	Final Report	ファイナルレポート
GCF	Green Climate Fund	緑の気候資金
GHG	Green House Gas	温室効果ガス
GIS	Geographic Information System	地理情報システム
HQ	Headquarters	本部
IC/R	Inception Report	インセプションレポート
IDEA	Intermittent Decant Extended Aeration	間欠排水長時間曝気
IEE	Initial Environmental Examination	初期環境調査
JCC	Joint Coordination Committee	合同調整会議
JET	JICA Expert Team	調査団
JICA	Japan International Cooperation Agency	国際協力機構
JPP	JICA Partnership Programs	草の根技術協力事業
KCCP	Knowledge Co-Creation Program (JICA)	課題別研修
LCC	Lautoka City Council	ラウトカ市
LEDS	Fiji Low Emission Development Strategy 2018-2050	フィジー低エミッション開発戦略計画 2018-2050
L&D	Lecture & Discussions	講義・討論

LMMA	Locally Managed Marine Area	地域主導型管理海域
MBBR	Moving Bed Biofilm Reactor	移動床式生物膜
ME	Mechanical/Electrical	機械電気
MHCD	Ministry of Housing and Community Development	住宅地域開発省
MHMS	Ministry of Health and Medical Services	保健・医療サービス省
MIMS	Ministry of Infrastructure and Meteorological Service	インフラ・気象サービス省（組織改変前、現公共事業・気象サービス・運輸省（MPW））
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)	国土交通省（日本）
MLMR	Ministry of Lands and Mineral Resources	国土鉱物資源省
MOA	Ministry of Agriculture	農業省
MOE	Ministry of Economy	経済省 （組織改編前、現財務省（MOF））
MOF	Ministry of Finance	財務省（組織改編後、旧経済省（MOE））
MoU	Memorandum of Understanding	基本合意書
MOWE	Ministry of Waterways and Environment	水路環境省（組織改変前）
M/P	Master Plan	マスタープラン
MRMD	Ministry of Rural and Maritime Development and Disaster Management	農村離島開発・防災省
MPW	Ministry of Public Works, Meteorological Services and Transport	公共事業・気象サービス・運輸省（組織改変後、旧インフラ・気象サービス省（MIMS））
MWCPA	Ministry of Women, Children and Poverty Alleviation	女性子供貧困軽減省
NFA	National Fire Authority	国家消防庁
NPO	Non-Profit Organization	非営利団体
NTC	Nadi Town Council	ナンディ町
OD	Oxidation Ditch	オキシデーションディッチ
ODA	Official Development Assistance	政府開発援助
OJT	On the Job Training	オン・ザ・ジョブ・トレーニング
O&M	Operation and Maintenance	運転維持管理
PDWF	Peak Dry Weather Flow	晴天時日最大水量
PG/R	Progress Report	プログレスレポート
PI/R	Project Implementation Report	業務計画書
Pre-F/S	Pre-Feasibility Studies	事業実施事前調査
R/D	Record of Discussion	討議議事録
SCF	Standard Conversion Factor	標準変換係数
SDGs	Sustainable Development Goals	持続可能な開発目標
SEA	Strategic Environmental Assessment	戦略的環境アセスメント
SEZ	Significant Ecological Zone	重要生態系ゾーン
SOP	Standard Operation Procedure	標準作業手順書
SP	Stabilization Pond	安定化池
SPD	South Pacific Distilleries Ltd.	サウスパシフィック蒸留所
SS	Suspended Solids	浮遊物質量
TC	Technical Committee	技術委員会
TF	Trickling Filter	散水ろ床法
TLFC	iTaukei Land and Fisheries Commission	伝統的土地及び漁業委員会
TLTB	iTaukei Land Trust Board	伝統的土地信託委員会
TN	Total Nitrogen	全窒素

TOR	Terms of Reference	委託事項
T-P	Total phosphorus	全リン
TSS	Total Suspended Solids	全浮遊物質量
UNDP	United Nation Development Program	国連開発計画
WAF	Water Authority of Fiji	フィジー水道公社
WWTP	Wastewater Treatment Plant	下水処理場

第1章 序章

1-1　背景

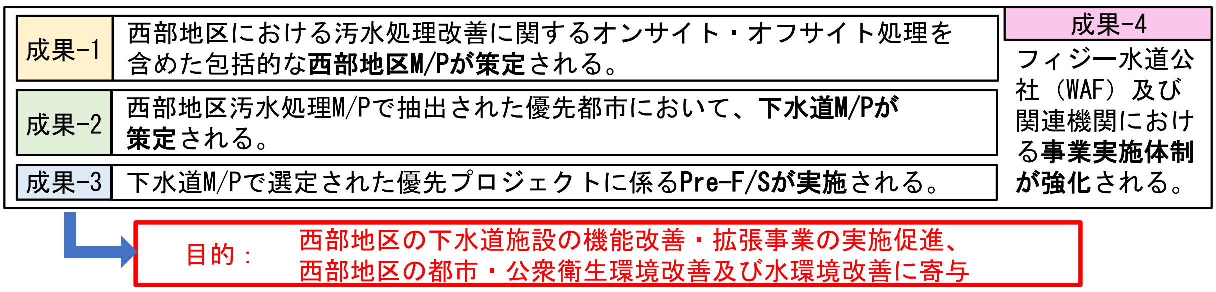
フィジー国 Viti Levu 島西部地区では、4 市町で下水処理場が整備されているものの、下水処理場への流入水量の増加等による過負荷運転、適切でない運転維持管理、機器の故障や施設の老朽化等により、処理が不十分なまま汚水が排出され、水質汚染が懸念されていた。かかる背景から、西部地域における分散型汚水処理を含めた汚水処理マスタープランの策定、および下水道施設の維持管理能力改善のための研修実施等を含む「フィジー国西部地区汚水処理マスタープラン策定プロジェクト」業務が 2021 年 10 月より実施された。

1 年目の成果 1「西部地区汚水処理マスタープラン」において、国家開発目標である「集合処理システムへのアクセスを 70%とする」ための集合処理区域を、西部地区の 6 市町（Lautoka、Nadi、Ba、Tavua、Rakiraki、Sigatoka）を対象に設定した。

2 年目の成果 2「都市下水道マスタープラン」では、対象都市を Lautoka 市・Nadi 町として、下水道全体計画を策定した。WAF より要望のあった複数処理区化の検討などを踏まえ、Lautoka 市は Vitogo 処理区、Natabua 処理区に分割し、Nadi 町は Sabeto 処理区、Navakai 処理区、Moala 処理区に分割した。下水処理方式も DOE との協議を踏まえ、Navakai 処理区は SEZ 排水基準対応のオキシデーションディッチ法（以下、「OD 法」という。）、その他 4 処理区は海洋放流管を併用する事を条件に General 排水基準対応の散水ろ床法（以下、「TF 法」という。）を採用する事となった。整備優先順位は既に発展している Natabua 処理区、Navakai 処理区の優先順位が高いものと考え、3 年目の成果 3「優先プロジェクトに係る Pre-F/S」にて優先事業を選定し Pre-F/S を実施する。

1-2　業務の成果と目的

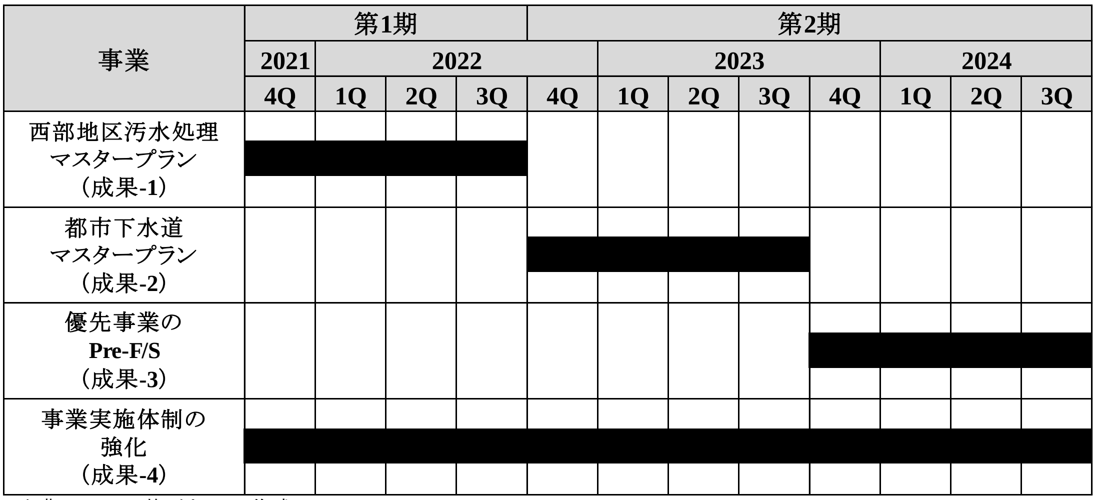
3 年次の業務では、成果 1、成果 2 の基づき優先事業に係る Pre-F/S の策定を行う。これらの成果の達成を通して、西部地区の下水道施設の機能改善・拡張事業の実施が促進され、西部地区の都市・公衆衛生環境改善及び水環境改善に寄与することを目的とする。



出典：R/D に基づき JET 作成

図 1-2.1　業務の成果と目的

全体を 3 年間で実施する本プロジェクトは、成果 1〜3 に並行して、成果 4 の下水道維持管理能力強化を行う。これまでの 2 年間で、①関係組織の能力評価や要望調査を実施し、②その結果に基づいて能力強化計画を策定し、③福岡市の協力を得て、能力強化のための研修を計画的に実施した。第 2 期には計画に基づいてオンライン研修、OJT 研修および本邦研修を実施する。



出典：R/D に基づき JET 作成

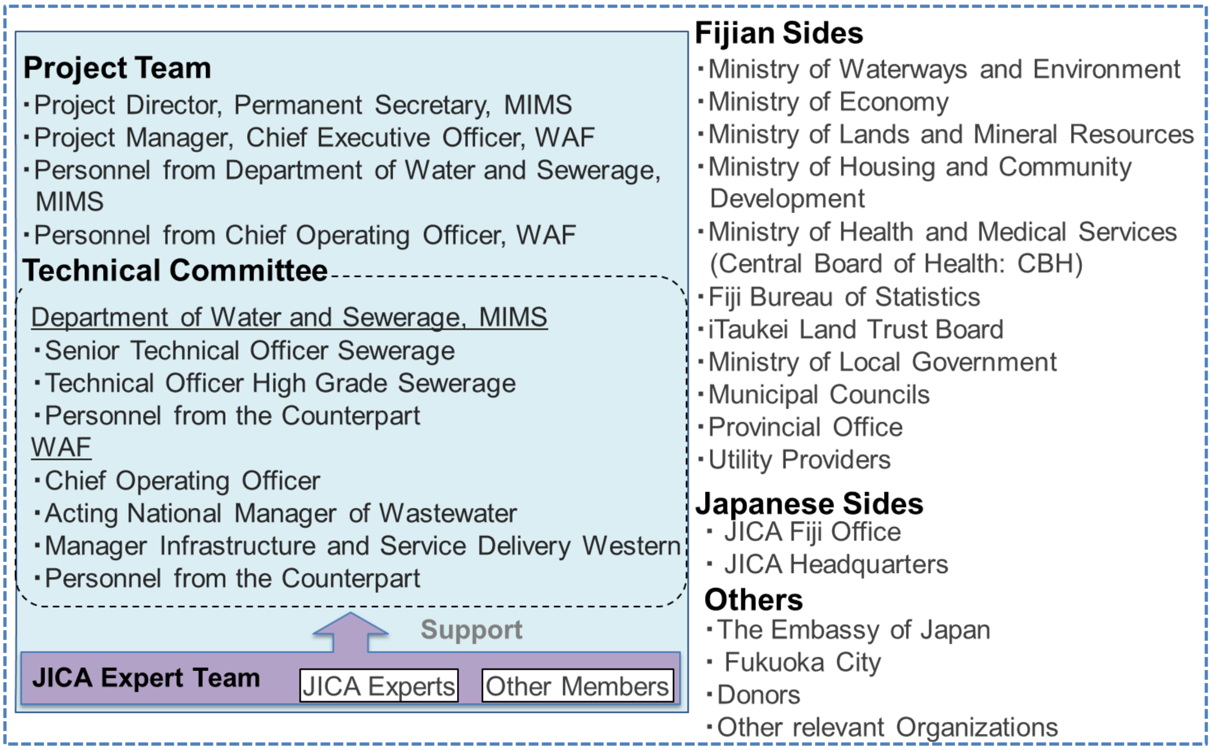
図 1-2.2　事業のフェーズ分けと内容

1-3　プロジェクトの実施体制

(1)　合同調整委員会：Joint Coordination Committee

本プロジェクトは**図 1-3.1** に示す合同調整委員会：Joint Coordination Committee（以下、「JCC」という。）を実施体制の中核とし、この JCC を用いて JET とフィジー国側の双方向の情報発信や意思疎通により、策定した計画の速やかな承認を働きかける。JCC の主な役割は以下のとおりである。

- ✓ 第 1 期の西部地区汚水処理 M/P、第 2 期の都市下水道 M/P 及び Pre-F/S の進捗確認や承認
- ✓ プロジェクトの全体の方向性の議論及び各機関との合意形成



*1 MIMS：現公共事業・気象サービス・運輸省（Ministry of Public Works, Meteorological Services and Transport（MPW））
*2 MOE：現財務省（Ministry of Finance（MOF））
出典：R/D に基づき JET 作成

図 1-3.1　本業務の実施体制

(2)　アドバイザー

本業務はマスタープランの策定と研修を含む技術移転に係る部分において、福岡市道路下水道局よりアドバイザーとして協力を得ている。福岡市は長年フィジーにおいて上下水道事業に係る協力を実施しており、WAF とのネットワークを有し、事業体制に係る知見を有している。

(3)　JICA 専門家チーム（JET）

本プロジェクトの日本側の関係者は以下のとおりである（**表 1-3.1** 参照）。また、JICA より福岡市道路下水道局に対してアドバイザーとして参画を依頼しており、福岡市道路下水道局はプロジェクトの活動や計画の内容について適宜助言を行っている。

表 1-3.1　調査メンバー

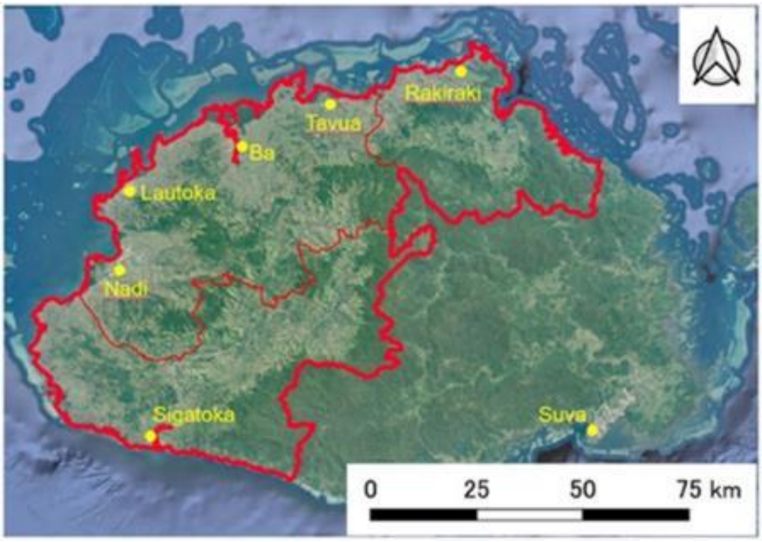
JICA	
氏名	所属
松岡 秀明	JICA 本部　地球環境部環境管理グループ　課長
吉田 健太郎	JICA 本部　地球環境部環境管理グループ　課長
保坂 幸也	JICA 本部　地球環境部環境管理グループ　技術主任
和田 真一	JICA 本部　地球環境部環境管理グループ　所員
大庭 隆	JICA フィジー事務所　所員
難波 茂基	JICA フィジー事務所　企画調査員
岩瀬 英明	JICA フィジー事務所　企画調査員（広域インフラ）
（アドバイザー:福岡市）	
氏名	所属
八島 弘倫	道路下水道局総務部 政策調整課　課長
森川 真伍	道路下水道局総務部 政策調整課　主査
橋爪 将治郎	道路下水道局総務部 政策調整課　主任
小野真由美	道路下水道局総務部 政策調整課　所員
太田 誠	道路下水道局 下水道施設部 中部水処理センター　操作第 1 係長

コンサルタントチーム		
氏名	担当	所属
中嶋 宜信	業務主任者/総合的汚水処理計画	株式会社日水コン
林 潔彦	副業務主任者/組織経営分析・強化	株式会社日水コン
和田 徹雄	下水道計画	株式会社日水コン
川嶋 幸徳	分散処理計画	株式会社日水コン
佐々木 伸一/小手川 陽子	下水処理場計画・設計	株式会社日水コン
五十嵐 英幸	下水管路計画/既存排水路調査	八千代エンジニヤリング株式会社
松本 恭明	機械設備	株式会社日水コン
若本 丈二	電気設備	株式会社日水コン
今野 雄一郎	積算/施工計画	株式会社日水コン
長曽 善之	経済財務分析	株式会社日水コン
工藤 ゆり子	環境社会配慮/住民啓発	八千代エンジニヤリング株式会社
飯島 康夫	自然状況調査	八千代エンジニヤリング株式会社
岡崎 浩一	上水道計画アドバイザー	株式会社日水コン
Divesh SAMI	下水道計画	NRW Macallan (Fiji) Ltd
Daiana BOLA	下水道計画	NRW Macallan (Fiji) Ltd
Andrew BANNER	土木エンジニア	NRW Macallan (Fiji) Ltd
Aneshwar AMIT	経済財務分析	NRW Macallan (Fiji) Ltd
Ashika SINGH	秘書	NRW Macallan (Fiji) Ltd

出典：JET

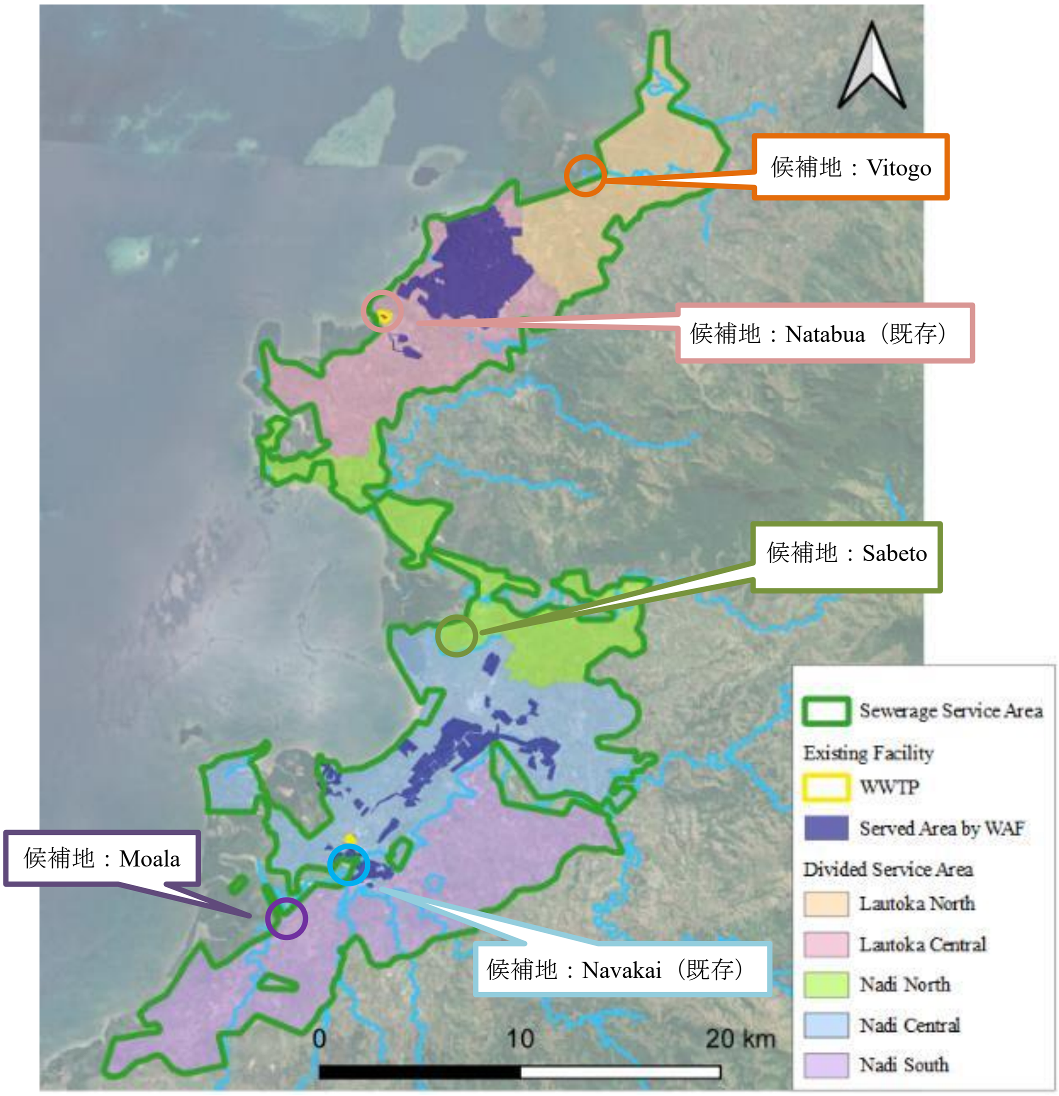
1-4　対象地域

本業務の対象地域は**図 1-4.1** に示すフィジー国西部地区であり、都市下水道 M/P で設定した Lautoka 市・Nadi 町の処理区は**図 1-4.2** の通りである。



出典：JET

図 1-4.1　本業務の対象区域



出典：JET

図 1-4.2　Lautoka 市・Nadi 町の下水処理区と下水処理場候補地

1-5　現況の問題点

両下水処理場は供用開始より既に 40～50 年が経過しており、Navakai 下水処理場では途中 IDEA 法への改築工事が実施されたものの、現状の処理水量が処理能力を大きく超過していると考えられる。この他にも維持管理の不足、エアレ―タをはじめとした機械設備の長期にわたる故障等の要因により下水が十分に処理されず、放流基準を満足できていない状況が続いている。WAF は放流水質が排水基準を達成できていないことから、新規の接続を積極的に増やすことが出来ず下水処理場の能力増強や法的遵守が最大の課題となっている。

また、汚泥についても適切な処理と最終処分が実施されていない状態にあるなど、複数の問題点が挙げられる。**表 1-5.1** に両下水処理場の全般的な問題点を示す。

表 1-5.1　Natabua、Navakai 下水処理場の問題点

名称	Natabua 下水処理場	Navakai 下水処理場
下水処理	・放流基準を満足しない処理水質 ・処理能力の不足 ・浚渫実施不足による池容量（処理能力）の低減	・放流基準を満足しない処理水質 ・処理能力の不足 ・エアレ―タの不足（計画台数：8 台、実稼働台数：4 台） ・IDEA 池活性汚泥の状態悪化（余剰汚泥の引き抜き不足）
汚泥処理	・浚渫実施不足（供用開始以来 40 年間で一度のみ実施） ・適切な最終処分場の欠如（下水処理場付近での積み上げ投棄） →風雨による近隣水域への流出	・余剰汚泥の引き抜き不足 ・好気消化池のエアレ―タの故障（計画台数：2 台、実稼働台数：1 台） ・汚泥脱水機の故障 ・最終処分場の欠如（場内積み上げ投棄） →風雨による近隣水域への流出
その他	・適切な維持管理の不足 ・素掘りピットへのセプテージ投棄 →適切に処理されないままの放流	・適切な維持管理の不足

出典：JET

表 1-5.2 に Natabua 下水処理場の放流水質を、**表 1-5.3** に Navakai 下水処理場の放流水質を排水基準とともに示す。Natabua 下水処理場、Navakai 下水処理場からの処理放流水質はフィジー国の排水基準を遵守できていないことが多く、BOD の遵守率（基準を満たす放流水サンプル数／放流水サンプル全数）はそれぞれ、Natabua で約 50%、Navakai で約 60%である。

表 1-5.2　Natabua 下水処理場の水質試験結果

年	流入水							放流水						
	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml
Gen Std.								60	40	－	25	5	5	400
2014	530	320	590	8.4	4.6	240	－	82	**64**	170	4.4	3.4	38	－
2015	480	300	580	11	3.7	150	－	44	**65**	130	4.9	2.2	33	－
2016	440	390	830	－	0.6	22	－	52	**44**	120	－	0.8	4.2	－
2017	850	330	600	51	3.6	24	54,000,000	110	**69**	190	26	2.3	7.3	1,200,000
2018	300	210	520	41	2.3	71	260,000,000	55	**51**	140	22	1.2	32	22,000
2019	370	220	410	28	5.8	86	300,000,000	53	39	110	20	4.0	15	210,000
2020	870	220	530	20	8.1	170	96,000,000	58	36	120	15	5.7	40	98,000
2021	430	170	480	22	7.0	130	360,000,000	57	**83**	210	1.9	3.9	49	770,000
2022	260	220	390	18	11.0	120	420,000,000	78	**84**	170	18	7.0	51	46,000
2023	480	260	370	23	15.0	87	9,400,000	27	35	90	14	7.0	23	10,000
平均	520	310	620	28	3.0	100	210,000,000	69	**59**	150	14	2.0	23	330,000

出典：WAF データより JET 作成

表 1-5.3　Navakai 下水処理場の水質試験結果

年	流入水							放流水						
	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms	T-SS	BOD	COD	T-N	T-P	FOG	Faecal Coliforms
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Col./100ml
Gen. Std.								60	40	－	25	5	5	400
2014	970	500	930	9.2	3.5	260	－	80	**55**	140	5.4	2.8	52	－
2015	930	360	880	9.2	2.8	190	－	44	**41**	91	5.6	2.3	55	－
2016	590	450	1300	13.0	2.3	24	－	54	**49**	120	11	1.6	11	－
2017	510	320	650	58.0	3.3	17	370,000,000	160	**85**	230	32	1.5	10	7,700,000
2018	450	240	590	47.0	3.2	57	300,000,000	120	**68**	180	29	2.4	23	8,900,000
2019	250	190	440	33.0	6.5	140	330,000,000	43	29	77	27	5.9	60	560,000
2020	200	140	430	20.0	7.6	130	98,000,000	24	20	100	15	2.8	36	3,200,000
2021	200	130	290	21.0	9.0	150	170,000,000	29	31	54	20	4.3	54	1,900,000
2022	260	220	390	18.0	11.0	120	160,000,000	78	**83**	190	17	8.0	55	6,400,000
2023	400	210	330	25.0	13.0	150	9,500,000	60	**45**	77	21	10.0	43	9,000
平均	690	370	870	27.0	3.0	110	210,000,000	91	**60**	150	17	2.1	30	4,100,000

出典：WAF データより JET 作成

第2章 設計条件

2-1 Pre-F/S の優先事業の選定

(1) 対象処理区

都市下水道 MP での検討にて、Lautoka・Nadi は 5 処理区（Vitogo、Natabua、Sabeto、Navakai、Moala）に処理区を分割して整備することが経済的に有利と判断された。その 5 処理区のうち、都市化が進展しており既に既存の下水処理場がある Natabua 処理区と Navakai 処理区の整備優先度が高いと判断された。よって、Pre-F/S の対象プロジェクトは Natabua 処理区・Navakai 処理区のコンポーネントから選択する。

(2) 都市下水道 MP で抽出されたプロジェクト群

都市下水道 MP では段階整備を目的として、Natabua 処理区、Navakai 処理区とも 2 フェーズで整備する事が推奨されている。フェーズ分けされたプロジェクトコンポーネントは**表 2-1.1** の通り。この表のリストから Pre-F/S の優先プロジェクトを選定する。

表 2-1.1　都市下水道 M/P にて抽出された 2 処理区の整備コンポーネント

処理区	種別	概要	施設概要
Natabua	下水処理場	全体計画の 1/2 分	TF 法：Q=22,000 m^3/日
	下水処理場	全体計画の 2/2 分	TF 法：Q=22,000 m^3/日
	腐敗槽汚泥処理場	Natabua 下水処理場用地への腐敗槽汚泥処理場設置	Q=65 m^3/日
	管渠	Urban 周辺（Natabua 処理区半分）の幹線整備	幹線・準幹線：Dia.100-750mm L=32 km
	管渠	Natabua 処理区半分の幹線、その他枝線整備	幹線・準幹線：Dia.100-750mm L=32 km 枝線：Dia.100-600 mm L=72 km
	管渠	その他枝線整備	枝線：Dia.100-600 mm L=72 km
Navakai	下水処理場	全体計画の 1/2 分	OD 法：Q=15,000 m^3/日
	下水処理場	全体計画の 2/2 分	OD 法：Q=15,000 m^3/日
	管渠	Urban 周辺（Navakai 処理区半分）の幹線整備	幹線・準幹線：Dia.100-900 mm L=29 km
	管渠	Navakai 処理区半分の幹線、その他枝線整備	幹線・準幹線：Dia.100-900mm L=29 km 枝線：Dia.100-310 mm L=102 km
	管渠	その他枝線整備	枝線：Dia.100-310 mm L=102 km

出典：JET

(3) Pre-F/S の優先事業の選定

Pre-F/S の優先事業の選定にあたり、WAF は既存下水処理場からの放流水質の法的遵守を重要視していることから、処理規模の大きい Navakai・Natabua 下水処理場の増設を優先事業として位置付ける。優先事業の比較選定は**表 2-1.2** のとおりである。

表 2-1.2　優先事業のケース別比較

項目	ケース 1: Nadi 管路&下水処理場	ケース 2: Lautoka 管路&下水処理場	ケース 3: Nadi & Lautoka 下水処理場
下水道接続者数	Lautoka: 29,000 Nadi: 21,100	Lautoka: 40,500 Nadi: 15,800	Lautoka: 29,000 Nadi: 15,800
処理水 BOD (mg/L)	Natabua: 56 Navakai: 20	Natabua: 40 Navakai: 47	Natabua: 40 Navakai: 20
処理水 BOD 負荷 (BOD-t/年)	304	331	237
除去 BOD 負荷 (BOD-t/年)	94	67	161
建設費 (mil. FJD)	413	356	399
建設費/除去 BOD 負荷 (mil. FJD/t/年)	4.4	5.3	2.5

出典：JET

- Natabua・Navakai 両下水処理場を含むケース 3 が、放流水質の遵守に直接関連する単位負荷削減量あたりの整備効果が高い。
- 既存下水処理場からの放流水質の法的遵守は WAF にとって高い優先順位を有する。
- 両処理区の管渠・ポンプ場の拡張整備は WAF にて実行可能である。但し、下水処理場の能力が改善されることが前提である。

2-2　事業の必要性

本事業は、Lautoka 市 Natabua、Nadi 町 Navakai において下水及び汚泥処理施設を増設することにより、同地域の水環境及び周辺の衛生環境の改善に貢献するものである。本事業は対象地域のニーズ及びフィジーの開発政策とも合致していることから、実施を支援する必要性及び妥当性は高い。具体的なポイントは下記の通りである。

1. Lautoka 市 Natabua、Nadi 町 Navakai は、Viti Levu 島西部地区において最も人口増加が続いている地区であり、かつ、今後の人口増加も見込まれる。同地区の処理区域内人口は 2043 年には 2023 年時点の約 1.3 倍まで増加すると見込まれている。

2. 現状における同地区の上水道施設の直近の増設予定は無いものの、日本の技術協力プロジェクト「フィジー国ナンディ・ラウトカ地区における無収水対策能力向上プロジェクト」にて無収水削減の対策が取られており、生活系、商業・観光系の使用水量増加も見込まれる。

3. 上記より、Lautoka 市 Natabua、Nadi 町 Navakai の発生下水量は、2043 年にかけて着実な増加が見込まれる。

4. また、フィジー国の国内総生産（GDP）の約 25%は観光収入であり、フィジー国への観光客数のおよそ 40%は Lautoka・Nadi に、10%は Nadi 近辺の諸島に滞在している。海洋資源がリゾートの根幹をなすことから、観光資源としての保全として公共用水域の保全の必要性は高い。

5. しかしながら、2023年時点のNatabua・Navakai両下水処理場からの放流水質の遵守率は60%程度であり、不十分な処理下水が両下水処理場より放流されていると推察される。未処理下水を含む放流水が、公共水域の水質悪化を引き起こしている。

6. 本事業は、Natabua、Navakai 下水処理場の下水・汚泥処理施設を増設することで、同下水処理場に流入する下水の処理を可能とするものである。これにより処理放流水のすべてが排水基準を満たすことで、下流域の水質改善が期待されると共に、放流水質の法的遵守かつ観光資源ともいえる海洋水環境の確保につながることからも、事業実施の意義は高い。

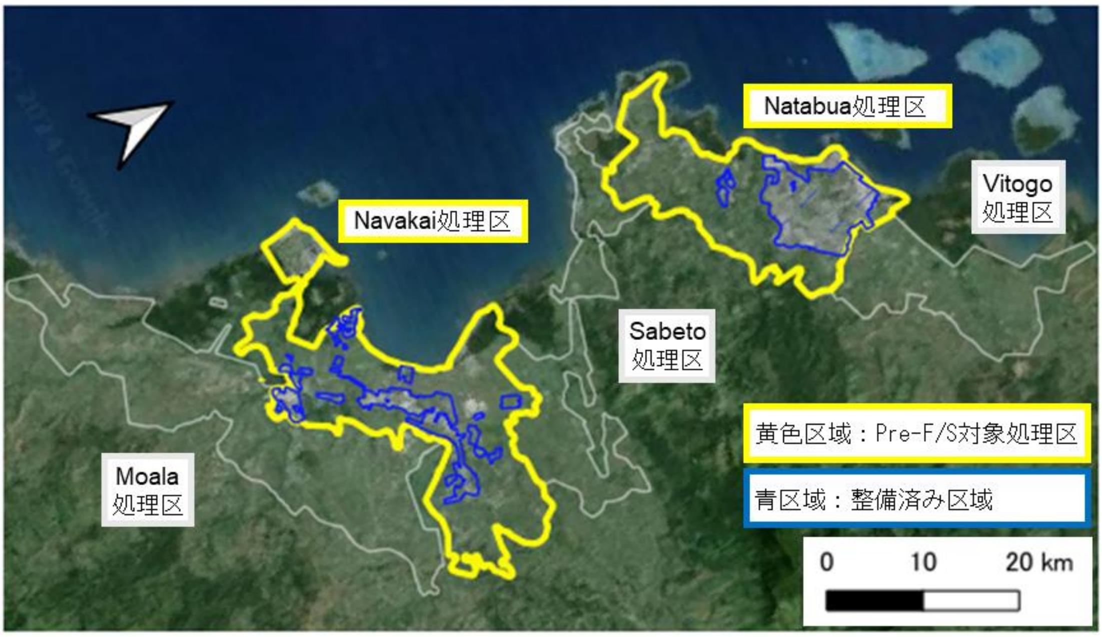
7. 国家開発計画であるNDP2036では、「2036年までに人口の70%が下水システムへのアクセスが可能となるよう、下水処理システムの整備と拡張を全ての都市部で進める」としている。また、MPW[1]とWAFにて2024年4月に公表したWater Sector Strategy 2050においても、都市下水道M/Pに基づき、Natabua と Navakai 下水処理場の増設計画が2040年までに達成する事業として挙げられている。本事業はこれらの政策と合致するものであり、事業実施の妥当性は高い。また、既存施設の機能回復や維持管理のソフト対策を並行して講ずることも重要である。

2-3　計画目標年次

都市下水道M/Pに基づいて全体計画の目標年次は2043年とする。

2-4　下水道計画区域

下水道計画区域は都市下水道M/Pと同様であり、**図 2-4.1** に示す区域となる。国家開発目標である「70%の人口が下水道にアクセスできるようにする」ための区域設定である事から下水道計画区域の変更はない。



[1] MPW：旧インフラ・気象サービス省 Ministry of Infrastructure and Meteorological Service（MIMS）

出典：JET

図 2-4.1　下水道計画区域（Natabua・Navakai 処理区）

2-5　計画下水量

(1)　下水道計画人口・その他計画フレーム

計画人口や汚水量原単位等の基本的な計画フレームは都市下水道 M/P に準じる。

都市下水道 M/P にて設定した 5 処理区の全体計画下水量は**表 2-5.1** の通りである。このうちの Natabua、Navakai 処理区は 2 つにフェーズを分けて下水処理場と管渠網を整備することから、現況水量と全体計画水量および整備ステップを考慮して、第 1 期の整備規模を設定する。

表 2-5.1　分割した処理区別の計画下水量（2043 年ベース）

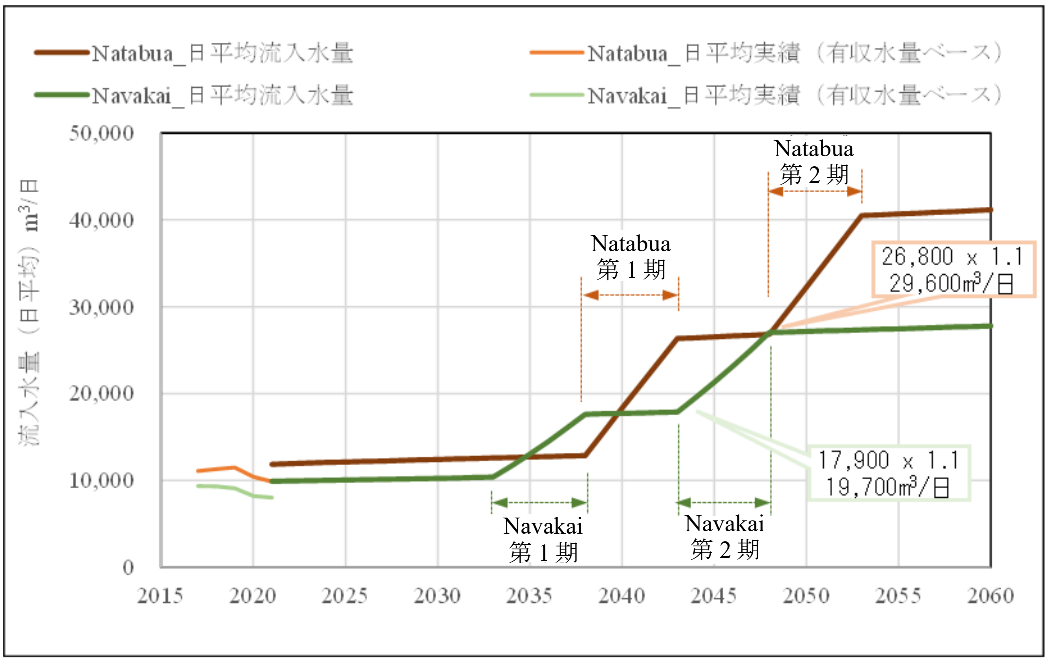
No	項目	単位	Lautoka		Nadi			合計
			Vitogo	Natabua	Sabeto	Navakai	Moala	
1	人口	人	15,130	105,590	13,510	52,740	35,420	222,390
2	使用水量原単位	m^3/日/人	0.220	0.220	0.220	0.220	0.220	
3	回収率	%	90	90	90	90	90	
4	汚水量原単位	m^3/日/人	0.200	0.200	0.200	0.200	0.200	
5	生活系汚水量	m^3/日	3,026	21,118	2,702	10,548	7,084	44,478
6	営業系汚水量	m^3/日	2,760	15,640	3,110	14,000	8,810	44,320
7	発生汚水量	m^3/日	5,786	36,758	5,812	24,548	15,894	88,798
8	浸入水率	%	10	10	10	10	10	
9	浸入水量	m^3/日	579	3,676	581	2,455	1,589	8,880
10	計画汚水量（日平均）	m^3/日	6,365	40,434	6,393	27,003	17,483	97,678
11	計画汚水量（日最大）	m^3/日	7,001	44,477	7,033	29,703	19,232	107,446

出典：JET

(2)　Pre-F/S の対象処理水量

本 Pre-F/S での Natabua 下水処理場の対象処理水量は 29,600 m^3/日（日最大）、Navakai 下水処理場の対象処理水量は 19,700 m^3/日（日最大）とした。

検討の過程として、両下水処理場の現況流入水量と全体計画水量、および整備ステップを**図 2-5.1** に示す。いずれの処理区も 2 段階での整備を想定しており、管渠の面整備を大きく二分して、1 段階目の管渠整備を終えた場合に想定される流入水量は約 29,600 m^3/日（日最大）、19,70 0m^3/日（日最大）となる。Pre-F/S にて整備する下水処理施設の系統数は、対象処理水量に加え、メンテナンスなどによる 1 系統休止時でも過負荷運転での処理対応を考慮して設定する。詳細は第 3 章、第 4 章に示す。



出典：JET

図 2-5.1　Natabua・Navakai 下水処理場の流入水量予測

2-6　計画下水水質

(1)　Natabua 下水処理場

本 Pre-F/S では、各下水処理場に流入水質と放流水質を設定する。Natabua 下水処理場の汚水処理系は「生下水（下水管路から流入する下水）」「腐敗槽汚泥脱離液」「醸造廃水前処理水」を処理対象と設定し、検討を行った。

Natabua 下水処理場の最終的な流入水質を**表 2-6.1** に示す。

表 2-6.1　Natabua 下水処理場の流入水質*

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)	水温 (℃)
398	500	45	11	20

*生汚水、腐敗槽汚泥脱離液、醸造廃水前処理水の混合
出典：JET

1)　生下水

流入水質は、コロナ禍の影響を受けた期間を除く 2014-2019 年、並びに 2023 年における Natabua 下水処理場の流入水質実測データより、**表 2-6.2** のとおり設定した。検討の詳細については **APPENDIX 3-3** を参照。

表 2-6.2　Natabua 下水処理場の生下水水質

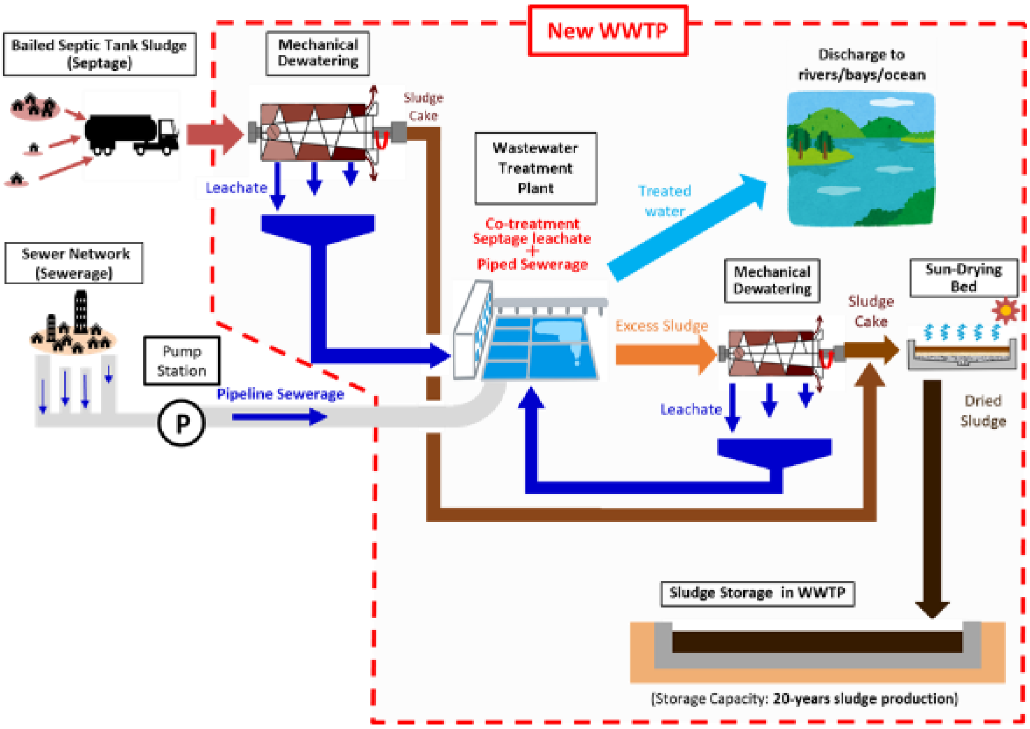
日最大水量 (m^3/日)	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
44,477	373	486	37	9

出典：JET

2)　腐敗槽汚泥

Nadi 及び Lautoka の現状では、Natabua 下水処理場が腐敗槽汚泥（セプテージ）を受け入れており、バキュームカー（現地では Bailing Truck と呼称）によって搬入された腐敗槽汚泥を自然湿地に投入している。このため、Natabua 下水処理場では腐敗槽汚泥の受け入れ継続を想定する。処理方式としてはバキュームカーから排出された腐敗槽汚泥を腐敗槽汚泥受槽に受けたのち直接脱水を行い、脱水ろ液を水処理系列にて処理する。脱水汚泥は天日乾燥後、場内にて埋め立て処分とする（**図 2-6.1**）。

腐敗槽汚泥の脱離液の水質を**表 2-6.3** に示す。搬入される腐敗槽汚泥量の将来予測値（2017~2036）は日平均で最大 65m^3/日程度になると想定され、うち 59 m^3/日が脱離液として Natabua 下水処理場の汚水処理系に流入する（詳細については **APPENDIX 3-3** を参照）。



出典：JET

図 2-6.1　下水処理場のフロー（腐敗槽汚泥受け入れを想定）

表 2-6.3　腐敗槽汚泥脱離液の水質

流量 (m^3/日)	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
59	250	620	37	9

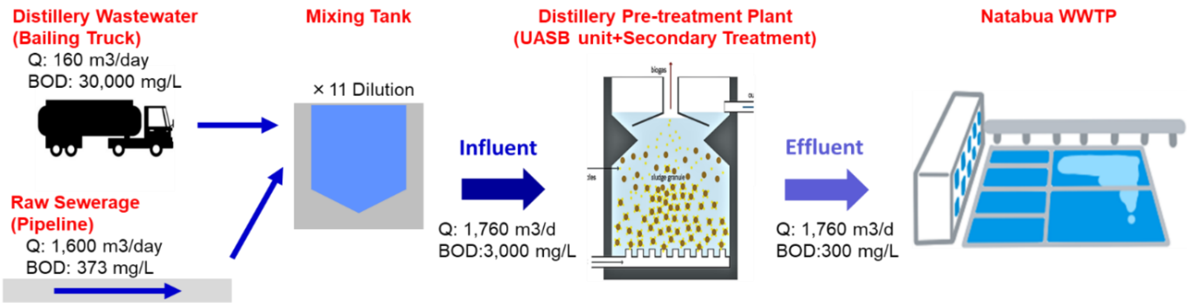
出典: "Adoption/Demonstration Experiment Project of Johkaso Sludge Dewatering Machines in Cebu City (Philippines)" (AMCON INC.) (2016) より JET 作成

3) 醸造廃水前処理水

本 Pre-F/S では、Natabua 下水処理場の検討において醸造廃水前処理水（以降、「前処理水」と記す）の受け入れを考慮することが WAF より要望された。

現状未処理で海洋放流されている South Pacific Distilleries Ltd.の醸造廃水を受け入れる前処理施設を Natabua 下水処理場に併設し、バキュームカーで搬入される廃水を生下水の一部で希釈、UASB ユニット等によって処理した前処理水を Natabua 下水処理場に受け入れる。処理フローの概要を**図 2-6.2** に示す。

施設自体は本 Pre-F/S の優先事業対象外とするものの、Natabua 下水処理場の流入水質検討においては、前処理水の受け入れを想定した。醸造廃水前処理施設についての詳細は **APPENDIX 3-1** を参照。前処理水の水質を**表 2-6.4** に示す。



出展：JET

図 2-6.2　醸造廃水前処理のフロー（Natabua 下水処理場での前処理水受入れを想定）

表 2-6.4　醸造廃水前処理水の想定水質

流量 (m³/日)	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
1,760*	600	600	100	20

*希釈に使用される生汚水量を含む。詳細については **APPENDIX 3-1** を参照
出典：WAF, NSW Department of Planning Industry and Environment より JET 作成

(2) Navakai 下水処理場

Navakai 下水処理場では、「生下水（下水管路から流入する下水）」のみが処理対象となる。生汚水の流入水質はコロナ禍の影響を受けた期間を除く 2014-2019 年、並びに 2023 年における Navakai 下水処理場の流入水質実測データより、**表 2-6.5** のとおり設定した。検討の詳細については **APPENDIX 4-1** を参照。

表 2-6.5　Navakai 下水処理場の流入水質

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)	水温 (℃)
367	544	37	6	20

出典：JET

2-7　放流水質

フィジー国の放流水質基準には**表 2-7.1** の通り、一般基準の General と、より厳しい基準である Significant Ecological Zone（以降、「SEZ」と記す）の 2 種類が制定されている。

表 2-7.1　放流水質基準

項目	単位	基準	
		General	Significant Ecological Zone
pH	pH	7-9	7-9
BOD5	mg/L	40	20
SS	mg/L	60	30
Fecal coliforms	CFU/100mL	400	200
T-N	mg/L	25	10
Ammonia	mg/L	10	5
T-P	mg/L	5	2

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

DOE によれば、SEZ 基準の適用は「デリケートな環境特性を持つ沿岸部、河川部に適用される」と示されたが、明確な適用区域が示される資料等は無い。他方、WAF は Suva の Kinoya 下水処理場の増改築事業（詳細設計中）において、General 基準に適合した処理水を海洋放流管により沿岸から 1km 沖合に放流する事で事業を進めている。これは処理に係る維持管理費の低減を主目的とした提案となっている。本 Pre-F/S においても Kinoya 下水処理場と同様の考え方を適用できるものとして「General 基準＋海洋放流管」の選択肢を残すことを DOE との協議で確認した。

本 Pre-F/S では上記のとおり海洋放流を行う Natabua 下水処理場にて General 基準を、ナンディ川に放流する Navakai 下水処理場にて SEZ 基準を放流水質として設定する。

「General 基準＋海洋放流管」の採用にあたっては、F/S 段階で下記を含む環境影響評価を DOE に提出・協議する事を DOE は条件として付している。

- 下水処理場の放流水量及び放流水質
- 放流予定水域における放流水の希釈度合・環境収容力
- 放流予定水域の環境的/生物的評価、等

2-8　施設計画・設計諸元

都市下水道 M/P に基づき、本 Pre-F/S では Natabua 下水処理場に二段式の TF 法（以下、「TF 法」という）を、Navakai 下水処理場はオキシデーションディッチ法（以下、「OD 法」という。）を処理方式として採用した。以降に各処理方式の設計諸元を整理する。

(1) TF 法

表 2-8.1　TF 法の設計諸元

処理池	諸元	設計値	出典
最初沈殿池	Surface Loading Rate	35~70 m^3/m^2・day	JSWA[※1], Ed.2019, p.103
	Water Depth	2.5~4.0 m	JSWA[※1], Ed.2019, p.103
	Weir Loading Rate	250 m^3/m・day	JSWA[※1], Ed.2019, p.103
散水ろ床： 共通諸元	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
	N-removal rate of double TF System	33%	Pearce[※5], p.47-52
散水ろ床 （一段目）	BOD loading (BOD Removal)	1.20 kg-BOD/(m^3・day)	JSWA, Ed.1984, p.379
散水ろ床 （二段目）	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
凝集水路	Fe:P Ratio of coaggulant	1:1	JWWA[※6], p.185-190
	Rapid Mixing Canal HRT	1~5 min	JWWA[※6], p.185-190
	Flocculation Canal HRT	20~30 min	JWWA[※6], p.185-190
最終沈殿池	Settling Time	6~12 hrs	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^2・day 125~250 m^3/m^2・day	JSWA, Ed.2019, p.108 Metcalf & Eddy[※7], p.620
塩素混和地	Chlorine contact time	15 min	JSWA, Ed.2019, p.238

※１：“下水道施設計画・設計指針と解説（後編）2019 年版”,公益社団法人日本下水道協会 , 2019
※２： “下水道施設計画・設計指針と解説 1984 年版”,公益社団法人日本下水道協会 , 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 Sewerage Treatment: Second Edition,” Central Public Health and Environmental Engineering Organization, 1993
※５：”Trickling filters for upgrading low technology wastewater plants for nitrogen removal,” P. Pearce, 2004
※６：”水道施設設計指針”公営社団法人日本水道協会,2012
※７：”Wastewater Engineering 4th Edition,” MetCalf & Eddy, 2004
出典：JET

(2) OD 法

表 2-8.2　OD 法の設計諸元

処理池	諸元	設計値	出典
オキシデーションディッチ	HRT	24~36 hrs	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・day	JSWA, Ed.2019, p.103
	Return Sludge Ratio	100~200 %	JSWA, Ed.2019, p.103
最終沈殿池	Settling Time	6~12 hrs	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^2・day 125~250 m^3/m^2・day	JSWA, Ed.2019, p.108 Metcalf & Eddy※2, p.620
塩素混和地	Chlorine Contact Time	15 min	JSWA, Ed.2019, p.238

※１：”下水道施設計画・設計指針と解説（後編）2019 年版”,公益社団法人日本下水道協会 , 2019
※２：”Wastewater Engineering 4th Edition,” MetCalf & Eddy, 2004
出典：JET

第3章 Natabua 下水処理場

3-1 整備概要一覧

Natabua 下水処理場は現況の『安定化池法』から『TF 法（二段式）＋凝集沈殿』に処理方式を変更するとともに、第 1 期工事にて処理能力を日最大 29,800 m^3/日、第 2 期工事にて日最大 44,800 m^3/日まで増強する。なお、WAF の要望により汚水処理施設は機器のメンテナンス等で一系列休止状態（第 1 期：5 系列運転、第 2 期：7 系列運転）となった場合でも適切な処理を継続できるよう、容量に余裕を持たせた設計とした。（**表 3-1.1**）

また、Natabua 下水処理場は下水・汚泥処理施設以外にも、以下の施設を下水処理場内ないし隣接地に併設する（**表 3-1.3**。醸造廃水前処理施設についての詳細は **APPENDIX 3-1**、他下水処理場汚泥受泥槽・汚泥消化施設・バイオガス発電施設については **APPENDIX 3-2** を参照）。これらに伴い、Natabua 下水処理場の処理フローは 2 期より変更となる（**図 3-1.1**、**図 3-1.2**）。

表 3-1.1 Natabua 下水処理場の整備概要

項目		第 1 期	第 1 期＋第 2 期
処理対象		【Wastewater】 ・Raw Sewerage ・Pretreated distillery wastewater 【Sludge】 ・Septic Sludge ・Pretreatment Plant Sludge	【Wastewater】 ・Raw Sewerage ・Pretreated distillery wastewater 【Sludge】 ・Septic Sludge ・Pretreatment Plant Sludge ・Thickened raw sludge from other WWTPs
処理方式		Two-stage Trickling Filter with post-coagulation	
	一系列の構成施設	1 Primary Clarifier 2 Stage-one Trickling Filter 2 Stage-two Trickling Filter 1 Coagulation/Flocculation Canal 1 Final Clarifier	
日最大水量		29,800 m^3/日	44,800 m^3/日
系列数		6 lines	8 lines total
一系列の設計処理能力		5,600 m^3/日 (6,100 m^3/日 per line including all return flows)	
一系列の最大処理能力*1		6,600 m^3/日 (including all return flows)	
用地面積	合計	24.51 ha*2*3	46.5 ha*2*3
	下水処理施設	16.36 ha	24.51 ha
	汚泥天日乾燥床*4	3.68 ha	4.93 ha
	汚泥保管場*4	4.48 ha	13.99 ha
	嫌気性消化槽＋バイオガス発電施設	0.00 ha	3.05 ha

*1 最大処理能力は各施設の最小 HRT/最大負荷に基づき算定。十分な処理水質を担保するためには処理能力のマージン確保が必須であることに留意する
*2 醸造廃水前処理施設を含まない（推定用地面積: 2.88 ha）
*3 Natabua 下水処理場の現用地を含む
*4 場内道路やバッファーゾーンを含む
出典：JET

表 3-1.2　Natabua 下水処理場の流入水質・目標処理水質

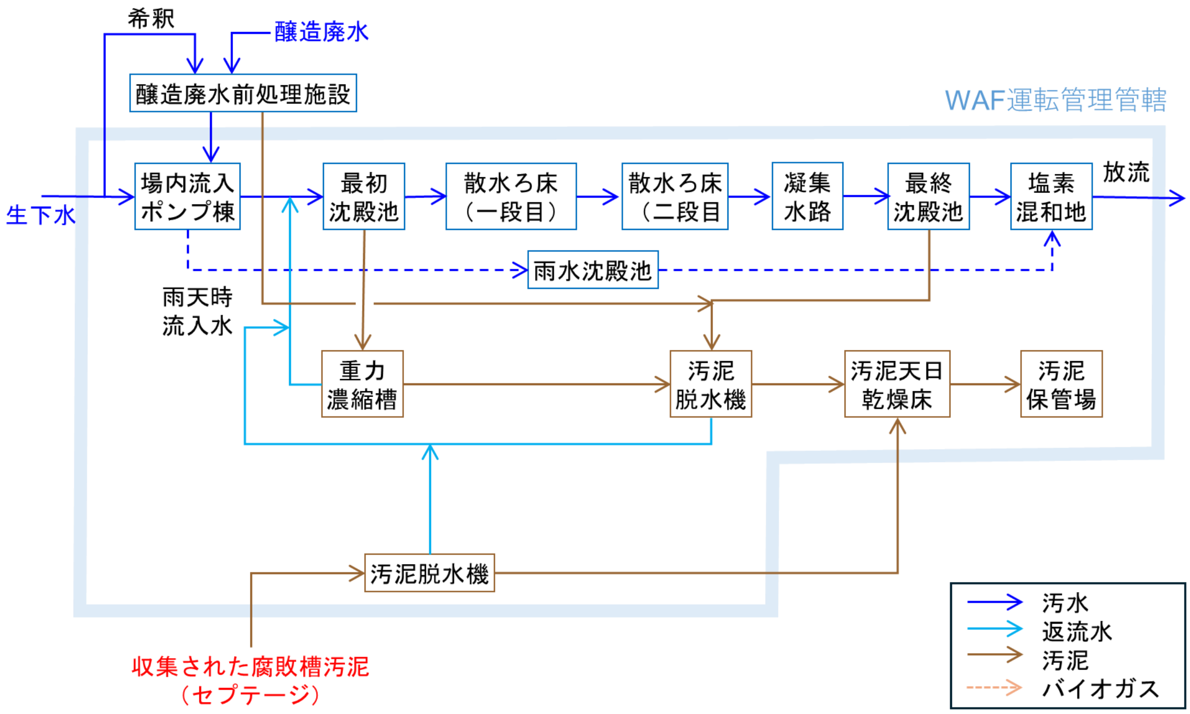
項目	流入水質*	目標処理水質 (General Standards)
BOD (mg/L)	398	40
SS (mg/L)	500	60
T-N (mg/L)	45	25
T-P (mg/L)	11	5

*: 前処理後の醸造廃水、及びセプテージ脱離液を含む
出典：JET

表 3-1.3　Natabua 下水処理場の併設施設

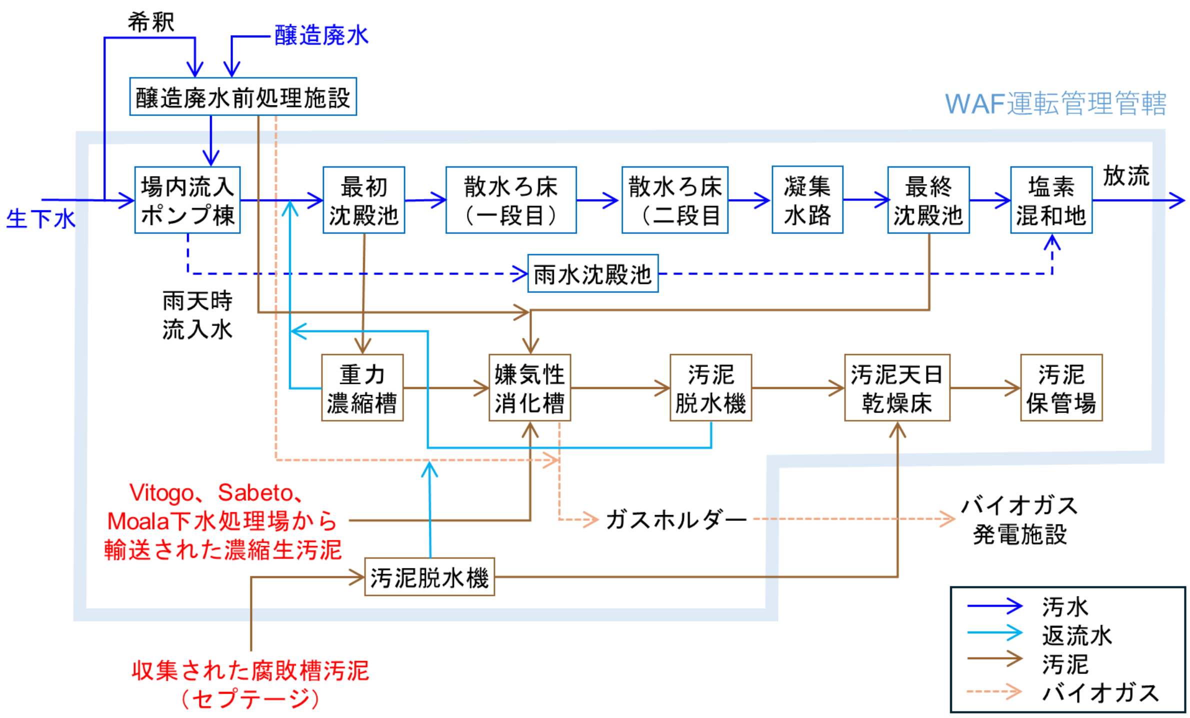
施設名	概要	Natabua 下水処理場との関わり	建設予定時期	Pre-F/S 検討対象
腐敗槽汚泥処理施設	Bailing Truck 搬入される腐敗槽汚泥（セプテージ）の処理施設	・場内にてセプテージの脱水処理→天日乾燥→場内保管 ・脱離液を汚水処理系に受け入れ	第 1 期以前	○
醸造廃水前処理施設	South Pacific Distillery から Bailing Truck 搬入される醸造廃水の処理施設	・管路からの流入汚水で醸造廃水を希釈し汚水処理を行う ・前処理水を汚水処理系に受け入れ	第 1 期	×
他下水処理場汚泥受泥槽*	将来新設予定の Vitogo、Sabeto、Moala 下水処理場から濃縮生汚泥を搬入	・下記の汚泥消化施設にて、Natabua で発生する下水汚泥とともに嫌気性消化を行う	第 2 期	○
汚泥消化施設*	Natabua、Vitogo、Sabeto、Moala 下水処理場の下水汚泥を嫌気性消化し、発生したバイオガスを下記発電施設に送る	・場内発生汚泥を嫌気性消化 ・消化汚泥を脱水処理→天日乾燥→場内保管 ・脱離液を汚水処理系に受け入れ	第 2 期以降	○
バイオガス発電施設*	上記汚泥消化施設で発生したバイオガスを精錬し、メタンガスを発電に利用	・汚泥消化施設で発生したバイオガスを送る	第 2 期以降	×

*: **APPENDIX 3-1、3-2-参照**
出典：JET



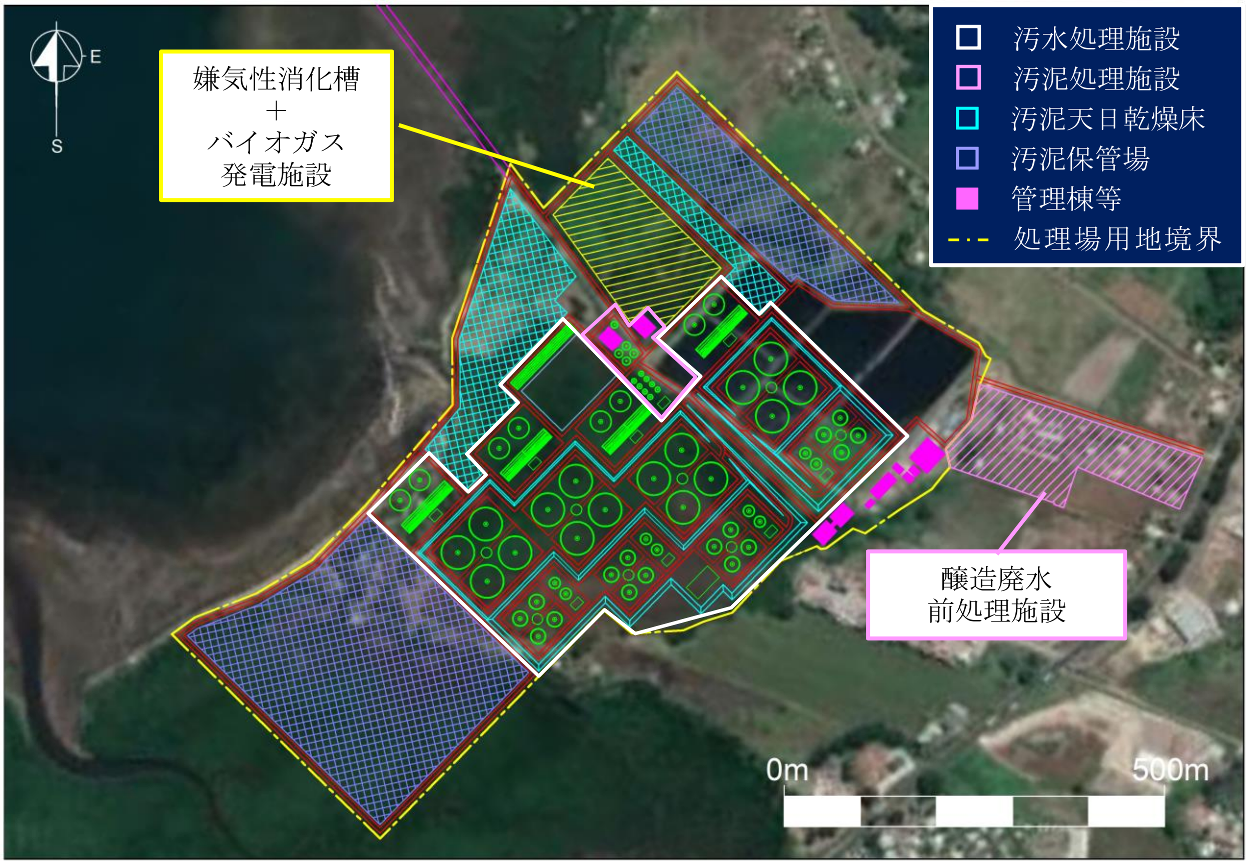
出典：JET

図 3-1.1　**Natabua** 下水処理場の処理フロー図（第 **1** 期）



出典：JET

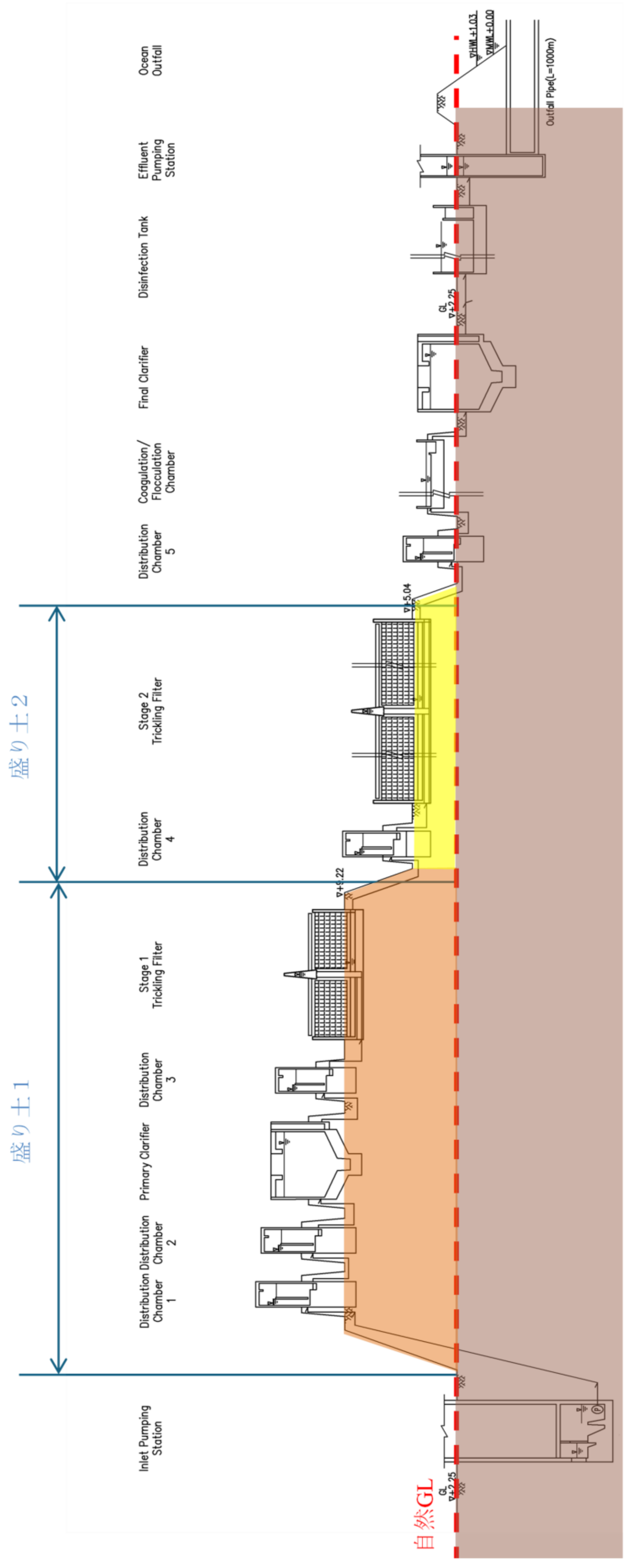
図 3-1.2　**Natabua** 下水処理場の処理フロー図（第 **2** 期）



出典：JET

図 3-1.3　Natabua 下水処理場の施設配置図

なお、機械設備を極力減らしたい WAF の要望を取り入れ、Natabua 下水処理場は造成した二段の盛り土上に建設し、流入ポンプ棟以降は自然流下で汚水を各施設に送水するものとする（**図 3-1.4** 参照）。



出典：JET

図 3-1.4　Natabua 下水処理場の断面図

3-2 下水処理場サイト周辺状況・土地状況

2024 年 3 月時点における Natabua 下水処理場周辺の土地利用状況を**図 3-2.1** に示す。

Natabua 下水処理場は北側から東側にわたってリース契約中の State Land と隣接しており、一部では開発が進んでいる（図中②～⑧)。既存施設としては、いくらかの距離を挟んで住居や工場、倉庫などが点在しているほかは未開発の野原が広がっている。下水処理場の西南にかけては、Department of Land に正式な所有者登録がされていない Foreshore Land（⑨）が広がっており、マングローブ林を挟んで小規模な Informal Settlement（⑩）が海岸沿いに一箇所確認されている。

出典：JET

図 3-2.1 Natabua 下水処理場周辺の土地利用状況（2024 年 3 月時点）

3-3　処理プロセス・土木施設

(1)　処理方式

1)　下水処理方式

下水処理方式は都市下水道 M/P に準じて、下記を考慮して TF 法を採用する。

- ✓ General の放流基準を満足する
- ✓ フィジー国ですでに採用され、Suva の Kinoya 下水処理場でも維持管理・運転されている
- ✓ 経済性及び維持管理が容易である

2)　汚泥処理方式

第 1 期の施設における汚泥処理フローは下記の通りとする。

- ✓ 生汚泥：重力濃縮→機械脱水→天日乾燥
- ✓ 余剰汚泥：機械脱水→天日乾燥
- ✓ 腐敗槽汚泥：機械脱水（別系統）→天日乾燥

処理水量・汚泥量が増加する第 2 期からは汚泥の嫌気性消化を追加する。Vitogo、Sabeto、Moala 下水処理場からの生汚泥を収集できる段階で、汚泥消化や消化ガス発電施設（WAF 管轄外を予定）を開始する計画である。（**APPENDIX 3-2** 参照）。

3)　汚泥処分方法

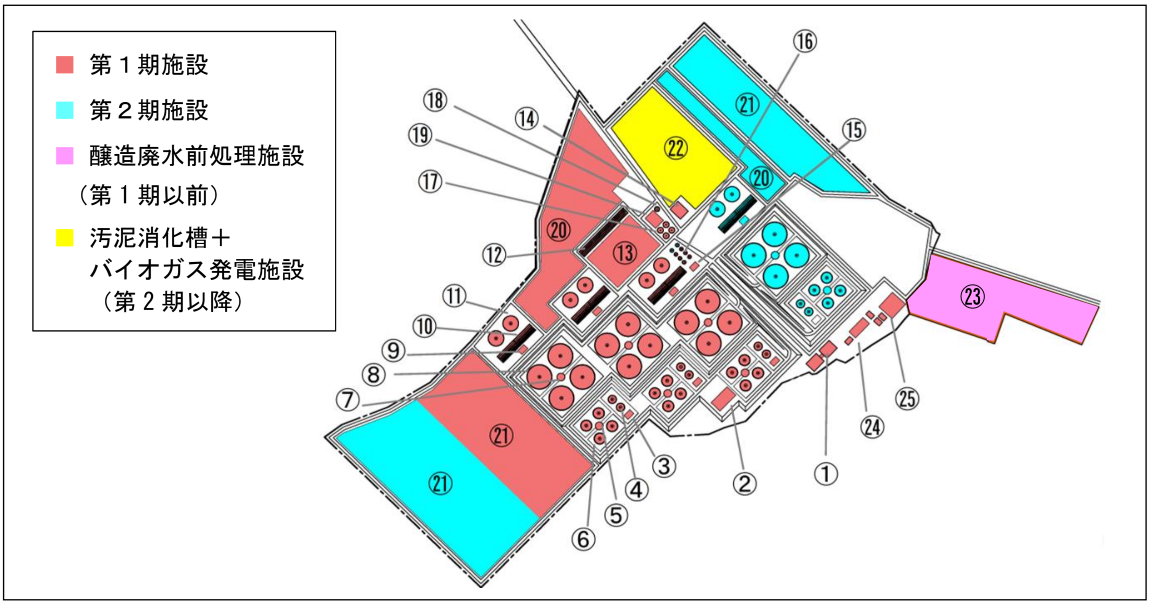
現状、下水処理場外での最終処分場にて下水汚泥の受け入れは行っていない。本 Pre-F/S では都市下水道 M/P に準じて、下水処理場内に乾燥汚泥の保管場所を配置する。

(2)　配置計画

Natabua 下水処理の土木施設を**図 3-3.1**、**表 3-3.1** に示す。第 1 期施設の施工期間中も現施設の運転を継続する必要があるため、1 期施設（図中赤塗り）は現敷地外、あるいは現在運転している施設と干渉しない位置に配置した。1 期施設の竣工並びに現施設の運転終了後、現敷地内に 2 期施設（図中青塗り）を建設する。

3-1 で前述した醸造廃水前処理施設については、本 Pre-F/S の対象外となるものの、WAF 側の要望により第 1 期施設と同時期に建設するものとして位置づける。汚泥消化槽並びにバイオガス発電設備（WAF 管轄外施設）については 2 期以降に建設する。

なお、汚泥天日乾燥床と汚泥保管場については汚泥の利活用や場外に下水汚泥最終処分場が確保された場合、敷地面積が縮小あるいは不要となる。



出典：JET

図 3-3.1　Natabua 下水処理場の土木施設

表 3-3.1　Natabua 下水処理場施設

図 No.	施設	概要
1	流入ポンプ棟	Includes Sewage and Stormwater pumps
2	分配槽①	Influent from: Inlet Pump Station, Distribution to: Distribution Chambers②, Stormwater Sedimentation Pond
3	分配槽②	Influent from: Distribution Chamber①, Distribution to: Primary Clarifiers
4	最初沈殿池	8 basins, Diameter: 14m
5	分配槽③	Influent from: Primary Clarifiers, Distribution to: Stage 1 TF
6	散水ろ床（一段目）	16 towers, Diameter: 19m (BOD removal)
7	分配槽④	Influent from: Stage 1 TFs, Distribution to: Stage 2 TFs
8	散水ろ床（二段目）	16 towers, Diameter: 43m (BOD + N removal)
9	分配槽⑤	Influent from: Stage 2 TFs, Distribution to: Coag./Floc. Canals
10	凝集水路	8 canals (P removal)
11	最終沈殿池	8 basins, Diameter: 27m
12	塩素混和池	Minimum contact time: 15 min
13	雨水沈殿池	
14	放流ポンプ棟	Pump to ocean outfall
15	汚泥分配槽	
16	重力濃縮槽	8 tanks, Diameter: 6 m
17	受泥槽	Phase 1: Thickened raw sludge + excess sludge Phase 2: Thickened raw sludge from other WWTPs 4 tanks, Diameter: 10 m
18	セプテージ受泥槽	Diameter: 6 m, Included in project scope
19	汚泥脱水機棟	Includes dewatering machine for septage treatment
20	汚泥天日乾燥床	3.76 ha (Includes space for septage)
21	汚泥保管場	11.48 ha (Includes space for septage)
22	嫌気性消化槽 ＋バイオガス発電施設	Biogas Power Generation Plant not included in project scope
23	醸造廃水前処理施設	Not included in project scope
24	管理棟	Includes emergency power generator
25	機械電気チーム作業場	Currently stationed at Natabua WWTP

出典：JET

(3) 概略施設計画

水処理および汚泥処理における主要な施設の規模及び機器の仕様を**表 3-3.2**、**表 3-3.3** に示す。施設容量計算は **APPENDIX 3-9** に添付する。

表 3-3.2　水処理施設の概略仕様（第 1 期分抜粋）

主要施設	設計負荷	池数及び形状
汚水沈砂池	水面積負荷 1,800m³/m²・日	4 池 矩形池　3 m × 4 m
雨水沈砂池	水面積負荷 1,800m³/m²・日	4 池 矩形池　3 m × 6 m
最初沈殿池	水面積負荷 35m³/m²・日	6 池 円形池 φ 14 m
一段目散水ろ床	散水負荷 9.5 m³/m²・日	12 池 円形池 φ 19 m
二段目散水ろ床	散水負荷 2.5 m³/m²・日	12 池 円形池 φ 43 m
凝集水路	流速 混和池 1.5m/s フロック形成池 0.16m/s～0.30m/s	6 池 矩形池 混和池 0.3m × 193 m × 0.3 m フロック形成池 1.3m/2.0m/2.5m × 80 m × 0.3 m
最終沈殿池	水面積負荷 10m³/m²・日	6 池 円形池 φ 27 m
塩素混和地	接触時間 15 分	1 池 矩形池 2m × 470 m × 2 m
雨水沈殿池	沈殿時間 2.5 時間	1 池 オープンカット池 75m × 105 m × 3.0 m

出典：JET

表 3-3.3　汚泥処理施設の概略仕様（第 1 期分抜粋）

主要施設	設計負荷	池数及び形状
重力濃縮	固形物負荷 75kg-DS/m2・日	8 池 円形池 φ 6m
機械脱水	処理能力 400 kg-DS/hr・台	2 台 多重板型スクリュープレス脱水機
汚泥乾燥床	乾燥期間 3 ヶ月	2.9 ha
汚泥保管場	20 年分の保管を想定	3.9 ha

出典：JET

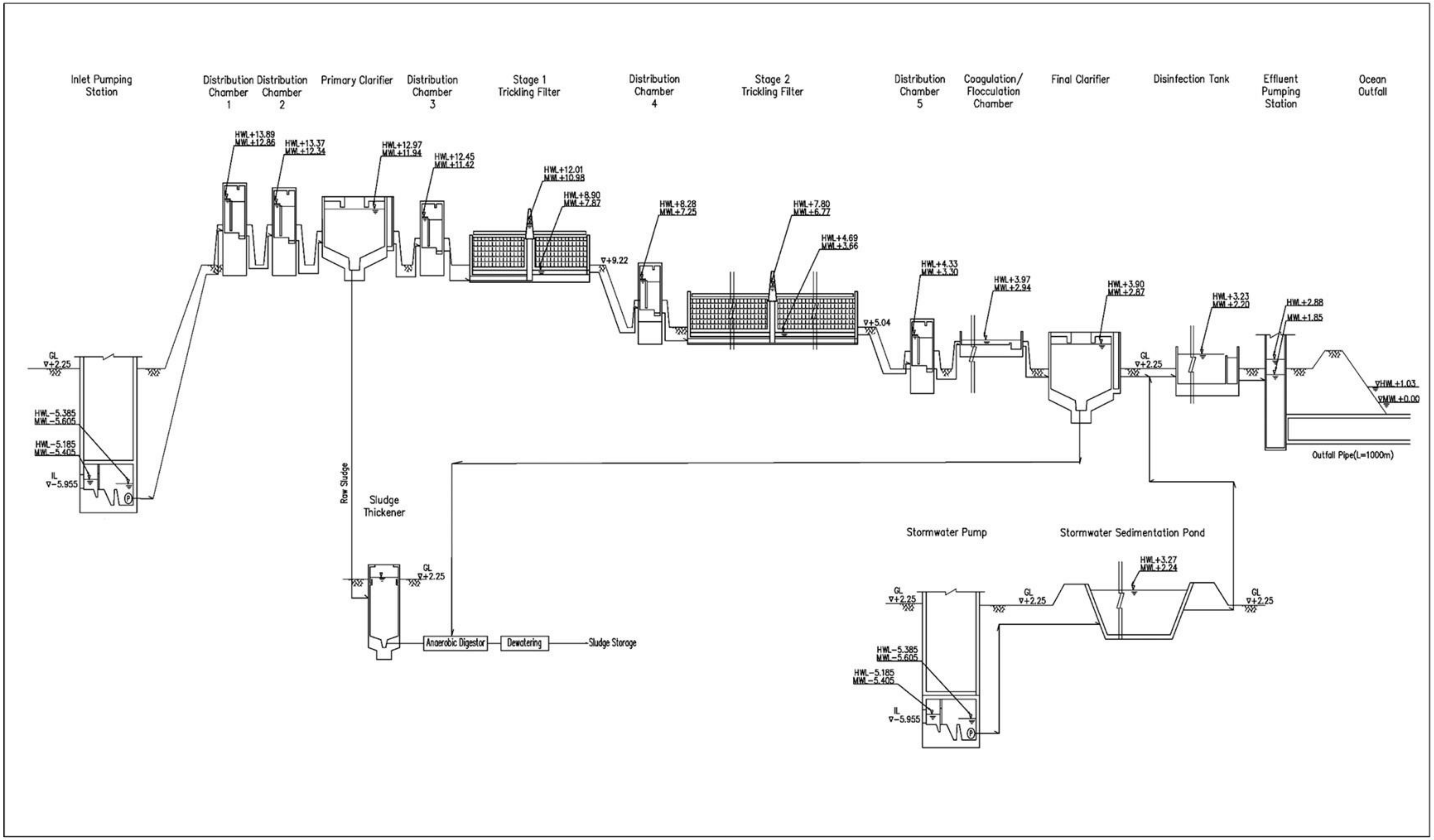
(4) 水位高低

想定する計画流入渠の流入水位と放流先の水位の差をもとに、汚水処理施設の導入に伴う水位高低を計画する。水位的条件を**表 3-3.4** に、水位高低図は**図 3-3.2** に示す。

表 3-3.4　水位的条件

項目	水位	場所
流入水位	-5.19 M	Inflow channel
放流水位（海洋）	+1.03 M	1km from offshore

出典：JET



出典：JET

図 3-3.2　Natabua 下水処理場の水位高低図

(5) 土質調査・基礎形式

1) 支持層の選定

Natabua 下水処理場で実施されたボーリング試験結果（**APPENDIX 3-6**）を元に、施設を支える土木基礎の支持層を選定した。一般的に、支持層として適しているのは N≧30 の砂礫層、あるいは N≧20 の粘性土層である。

ボーリング試験結果より、上記条件に当てはまる砂性シルト層（N=50+、深度 GL-21.5m～24.5 m）が支持層として選定された。なお、今回実施されたボーリング調査は現下水処理場敷地内のみで実施されているため、将来的な設計段階では建設予定地の範囲にて追加のボーリング調査を実施し、追加データの確認が推奨される。

2) 基礎形式の検討

ケーソン基礎等の特殊な形式を除けば、基礎構造物は大きく分けて直接基礎と杭基礎の二種類にカテゴライズされる。直接基礎は支持層が浅い位置（0～5m）に存在する場合に採用され、それより深い位置に存在する場合は杭基礎が採用される。

Natabua 下水処理場は支持層が GL-21.5m と深層に位置しており、更には主分配槽～二段目散水ろ床までの施設が盛り土上に建設されるため、杭基礎を採用する。杭長は最短（自然 GL に配置される施設）で 21～22.5m 程度となり、既設杭の上限（杭長 20m）を超過するため、場所打ち杭が採用された。

3-4 機械設備

Natabua 下水処理場における各種機械設備を以降のとおり選定した。検討の詳細については **APPENDIX 3-7**、各種図面については **APPENDIX 3-8** を参照。

(1) 流入ゲート設備

下水処理場に汚水が流入してくる流入渠に主流入ゲート設置する。流入後、汚水、雨水沈砂池にゲートを池毎に設置して池の機器点検、清掃を個別に行えるようにした。ゲートは耐久性が高く点検が容易な「外ネジ式角形鋳鉄製ゲート」を選定した。

表 3-4.1 流入ゲート設備計画

名称	仕様
主流入ゲート（電動式）	有効開口 1.5m 角×1 門
汚水流入ゲート（手動式）	有効開口 0.5m 角×4 門
雨水流入ゲート（手動式）	有効開口 0.6m 角×4 門

出典：JET

(2) スクリーン設備

沈砂池に設置するスクリーンは、後段の汚水、雨水ポンプの保護のために設置する。大きなごみの除去は手動の目巾 50mm の粗目スクリーンで除去し、小さなごみの除去については、目巾 25mm の細目自動除塵機を設置してごみの除去を行う。

1)　細目スクリーン目巾

細目スクリーンの目幅の選定は「除塵機設備設計指針(水門鉄管協会)」のポンプ口径による選定表により 25mm とした。

2)　自動除塵機

細目自動除塵機は、建設費、維持管理費の総合評価において優れている「ベルト走行式 自動除塵機＋二軸スクリュー式」を選定した。

表 3-4.2　し渣装置

沈砂池数	汚水 4 池、雨水 4 池
し渣装置	汚水：粗目スクリーン＋細目自動除塵機：4 組 雨水：粗目スクリーン＋細目自動除塵機：4 組

出典：JET

(3)　沈砂池設備

沈砂池に流入した汚水に混入している沈砂は、汚水ポンプインペラーを摩耗させるので、沈砂ピットで沈砂を沈殿させ沈砂ピットよりサンドポンプにより砂と汚水を一緒に揚水し、サイクロン式沈砂分離機により砂と汚水を分離させ砂の除去を行う。また汚水は沈砂池にもどして処理を行う。沈砂装置はシステムが簡単で経済性、維持管理性において優れている「サンドポンプ＋サイクロン式沈砂分離機」を選定した。

表 3-4.3　沈砂装置

沈砂池数	汚水 4 池、雨水 4 池
沈砂装置	サンドポンプ（8 台）＋沈砂分離機（サイクロン）／沈砂コンテナ 2 組

出典：JET

(4)　主ポンプ設備

流入汚水を水処理施設へ送水する施設で、ポンプ井はポンプの更新及び清掃を考慮してポンプ井は 2 槽とし、槽間には連絡ゲートを設け一体使用を行う。ポンプ容量・台数は計画水量により同一容量 2 台以上で予備機 1 台を設けた。ポンプ機種は安価で入手でき維持管理の容易な「水中汚水ポンプ」を選定した。ポンプ台数・吐出量計画を**表 3-4.4**、ポンプ仕様を**表 3-4.5** に示す。

表 3-4.4　ポンプ台数・吐出量計画

項目	計画水量 (m^3/分)	ポンプ台数(台)	ポンプ吐出量 (m^3/分・台)	
日平均汚水量	28.26	2	14.14	14.5
日最大汚水量	31.11		15.56	29.0
時間最大汚水量	56.32	2（1 台予備）	28.16	29.0
雨天時最大汚水量	84.24	3(1 台予備）	42.12	42.5

出典：JET　＊赤数字：定格吐出量

表 3-4.5 主ポンプ仕様

名称	ポンプ仕様・台数
1期：汚水ポンプ	口径 400Φ × 吐出量 14.5 m^3/分 × 揚程 20m × 出力 75kW × 2台
2期：汚水ポンプ	口径 600Φ × 吐出量 29.0 m^3/分 × 揚程 20m × 出力 132kW × 2台（1台予備）
雨水ポンプ	口径 700Φ × 吐出量 42.5 m^3/分 × 揚程 9.5m × 出力 90kW × 3台（1台予備）

出典：JET

(5) 分配槽設備

下水処理場施設の各系列に流入汚水を均等分配するための分配槽を設置する。分配を行うために分配各槽に手動の可動堰を設置する。可動堰は、耐久性が高く維持管理の容易な「外ネジ式鋳鉄製可動堰」を設置して流量調整を出来るように計画する。

(6) 最初沈殿池設備

1) 汚泥掻き寄せ機

汚泥掻き寄せ機は、中央駆動式、周辺駆動式の 2 方式があるが槽の径が小さく回転トルクも小さいので、中心駆動装置によりアームを回転させる機器費の安価な「中心駆動懸垂式」を選定した。

表 3-4.6 最初沈殿池汚泥掻き寄せ機仕様

名称	仕様
1期：汚泥掻寄機	径 14m × 水深 2.5m × 出力 0.4kW × 6台
2期：汚泥掻寄機	径 14m × 水深 2.5m × 出力 0.4kW × 2台

出典：JET

2) 生汚泥引抜きポンプ

生汚泥ポンプは、2 系列に対して 2 台（1 台予備）として計画を行った。ポンプ形式は、沈殿池ピットより汚泥を引き抜くので維持管理性考慮して「陸上型吸込みスクリュー式ポンプ」を選定した。

表 3-4.7 生汚泥引抜きポンプ仕様

名称	ポンプ仕様・台数
1期：生汚泥ポンプ	口径 100 mm × 吐出量 0.5 m^3/分 × 揚程 8m × 出力 1.5kW × 6台（3台予備）
2期：生汚泥ポンプ	口径 100 mm × 吐出量 0.5 m^3/分 × 揚程 8m × 出力 1.5kW × 2台（1台予備）

出典：JET

(7) 散水ろ床設備

1) 散水装置

1 段、2 段の散水ろ床は省エネルギ—を考慮して水頭差により回転動力を得る無動力散水装置とした。散水ろ床層は、価格が安価で重量も軽く工事の据付が容易なプラスチック製のハニカム形状のろ床を選定した。

2) ブロワー

フィジーは年間の平均気温が高く流入汚水の水温との温度差が 2℃前後である。TF 法においては温度差が 4℃以上なければ散水ろ床層に必要な空気量を自然換気で得ることができないので、散水ろ床層への強制換気を行うための送風機を設置する計画とした。

散気ろ床層に空気を供給する送風機は、鋼板製多段ターボブロワ、ロータリブロワ、スクリュー式ブロワの 3 機種の比較検討を行い設備費、維持管理費、設置スペース、重量の総合評価に優れる「スクリュー式ブロワ」を選定した。送風機台数は、1、2 系列毎に送風機 3 台（1 台予備）構成とした。以下に送風機仕様を示す。

表 3-4.8　散水ろ床ブロワー

工期	名称	風量 (m^3/分)	圧力ロス (kPa/m)	出力 (kW)	台数 (台)
第 1 期	1 段目　スクリュー式ブロワ	4.8 - 17	35	18.5	9 台（3 台予備）
	2 段目　スクリュー式ブロワ	5.5 - 22	35	26	9 台（3 台予備）
第 2 期	1 段目　スクリュー式ブロワ	4.8 - 17	35	18.5	3 台（1 台予備）
	2 段目　スクリュー式ブロワ	5.5 - 22	35	26	3 台（1 台予備）

出典：JET

(8)　最終沈殿池設備

1)　汚泥掻き寄せ機

汚泥掻寄機は、中央駆動式、周辺駆動式の 2 方式がある。周辺駆動式は沈殿池の周壁上を走行する台車が旋回アームを牽引することで、旋回アームを回転させるのでより少ない駆動力で大きなトルクを発生させることができ、動力が小さい「周辺駆動支柱式」を選定した。

表 3-4.9　最終沈殿池汚泥掻き寄せ機仕様

5	仕様
1 期：汚泥掻寄機	径 27m　×　水深 3.0m　×　出力 0.7kW　×　6 台
2 期：汚泥掻寄機	径 27m　×　水深 3.0m　×　出力 0.7kW　×　2 台

出典：JET

2)　余剰汚泥ポンプ

余剰汚泥ポンプは、2 系列に対して 2 台（1 台予備）として計画を行った。ポンプ形式は、沈殿池ピットより汚泥を引き抜くので維持管理性考慮して「陸上型吸込みスクリュー式ポンプ」を選定した。

表 3-4.10　余剰汚泥ポンプ仕様

名称	ポンプ仕様・台数
1 期：生汚泥ポンプ	口径 150mm × 吐出量 1.25 m^3/分 × 揚程 10m × 出力 3.7kW × 6 台（3 台予備）
2 期：生汚泥ポンプ	口径 150mm× 吐出量 1.25 m^3/分 × 揚程 10m × 出力 3.7kW× 2 台（1 台予備）

出典：JET

(9)　滅菌池設備

1)　次亜塩素酸ソーダ貯留量

次亜塩酸ソーダは、紫外線、温度により分解が促進されるので、次亜塩素酸ソーダ貯留量は雨天時最大水量に対し注入率 3 mg/L の使用量に対して 1 週間分の貯留能力の貯留槽を計画した。

2)　次亜塩素酸ソーダ注入ポンプ

次亜塩素酸ソーダ注入ポンプは、価格が安価で実績の多いダイヤフラムポンプで回転数制御装置

により放流量に対して比率注入制御を行うシステムを選定した。

表 3-4.11　次亜塩素酸ソーダ注入ポンプ仕様

名称	吐出口径	吐出量制御範囲	最高吐出圧力	電動機出力	台数
次亜塩注入ポンプ	25 mm	0.704～1.757 L/分	0.7 MPa	0.4 kW	3 台（予備 1 台）

出典：JET

(10) 放流ポンプ設備

放流先海域の潮位が MWL0.00m 以上に上昇すると Natabua 下水処理場から自然流下で放流できなくなるので、放流ポンプにより圧送放流を行う。ポンプ機種は安価で入手でき、維持管理の容易な「水中汚水ポンプ」を選定した。ポンプ台数・吐出量計画を**表 3-4.12**、ポンプ仕様を**表 3-4.13** に示す。

表 3-4.12　放流ポンプ台数・吐出量計画

名称	計画水量 (m^3/分)	ポンプ台数 (台)	ポンプ吐出量 (m^3/分・台)	
放流ポンプ	84.24	3 台（1 台予備）	70.28	71.0

出典：JET　＊赤数字：定格吐出量

表 3-4.13　放流ポンプ仕様

名称	ポンプ仕様・台数
放流ポンプ	口径 800 mm×吐出量 71（m^3/分）×揚程 5m×出力 90kW×3 台（1 台予備）

出典：JET

(11) 雨水沈殿池設備

雨水沈殿池は計画日最大汚水量の 4 倍水量を 2.5 時間滞留させたのち、滅菌池に排水して滅菌処理を行い放流する。

(12) 処理水再利用設備

下水処理場内の各装置の洗浄水や、次亜塩注入ポンプ薬品の溶解水等に使用するために設置する。形式は建設費が安価で維持管理の容易なパッケージ型で制御盤を含めて一体構成となっている「圧力式砂ろ過装置」を選定した。

(13) 脱水機設備

1) 汚泥貯留槽撹拌機

汚泥貯留槽容量は、脱水機運転が週 5 日運転なので土曜、日曜日の 2 日間貯留可能な容量で計画され、貯留タンクは 8 系列に対して 2 系列毎に 4 槽計画で撹拌機の設置計画を行った。

拌機形式は建設費が安価で、維持管理性の良い「水中ミキサー型撹拌機」を選定した。撹拌機台数は撹拌能力により、1 槽 3 台 4m 間隔で設置する計画とした。

2) 脱水機

汚泥貯留槽から汚泥供給ポンプにより引き抜いた汚泥を脱水機により脱水して汚泥の減量化を行

う。脱水機形式は、建設費、維持管理費が安価で、脱水効率の良い「多重板型スクリュープレス脱水機」を選定した。脱水機容量、台数は日処理汚泥量を 9 時間運転で処理できる容量、台数とした。

表 3-4.14　脱水機仕様

汚泥固形物量(t/日)	17.81
処理汚泥(kg/日)	1,979
脱水機形式	多重板型スクリュープレス脱水機
処理能力	400(kg-DS/時)×8.3kW×5 台
運転時間	週 7 回　9 時間運転
脱水汚泥量(m^3/日)	68

出典：JET

(14) 脱臭設備

下水・汚泥から発生する悪臭が周辺に悪影響を及ぼすのを防止するため、脱臭設備を設置する。脱臭形式は維持管理が比較的容易で脱臭効率が高く、また調達が比較的容易な「活性炭吸着法」と「充てん塔式生物脱臭法」を選定した。その他の形式は、以下の理由より採用しなかった。

- 直接燃焼法：建設費・維持管理費共に比較的高額。また O&M に比較的高度な技術を必要とする。
- 薬剤洗浄法：酸・アルカリ剤等の薬剤を使用するため維持管理費が比較的高額。また、廃液処理用の施設を別途追加する必要がある。
- 土壌脱臭法：建設費と維持管理費は比較的安価である一方、おおよそ 5 年毎の交換時に大量のメディアを輸入しなければならないため、調達の観点から実現性は低いと考えられる。

上記より Natabua の下水処理系には「活性炭吸着法」を、より強い臭気が発生する汚泥処理系には「充てん塔式生物脱臭法＋活性炭吸着法」の組み合わせを適用する。

表 3-4.15　脱臭設備

処理系	下水処理系	汚泥処理系
対象施設	・流入ポンプ棟 （着水井、沈砂池、ポンプ井）	・受泥槽 ・汚泥脱水機棟
脱臭形式	活性炭吸着法	充てん塔式生物脱臭法 ＋活性炭吸着法

出典：JET

3-5　電気設備

Natabua 下水処理場における各種電気設備を以降のとおり選定した。各種図面については **APPENDIX 3-8** を参照。

(1) 受電設備

1) 受電方式、配電電圧

フィジー電力公社（EFL）との協議により、フィジーの送電電圧は 3 相 3 線 11 kV、周波数 50Hz で、EFL が下水処理場敷地内に 11KV から 415 V の降圧する変圧器を設置する。WAF 側では、EFL か

ら変圧器 2 次側電圧 3 相 4 線 415V の配電電圧を、下水処理場主配電盤に受電して、各施設のモーターコントロールセンターに配電を行い各負荷に電源を供給する。

表 3-5.1　受電・配電電圧

項目	受電・配電電圧
受電電圧・動力負荷電圧	3 相 4 線 50Hz　415V
建築動力・照明負荷電圧	動力配電電圧 3 相 4 線 50Hz415V 照明配電電圧単相 2 線 50Hz240V

出典：JET

2)　負荷容量

本計画における各設備の負荷を**表 3-5.2** に示す。

表 3-5.2　負荷表

設備名	1 期負荷（kW）	2 期負荷（kW）
沈殿池設備	25.2	
主ポンプ設備	414	
雨水ポンプ設備	180	
最初沈殿池設備	8.1	2.7
一段目散水ろ床設備	166.5	55.5
二段目散水ろ床設備	234	78
最終沈殿池設備	38.2	11.5
滅菌・揚水設備	18.75	
放流ポンプ設備	183.7	
汚泥濃縮設備	8.1	2.7
脱水機設備	138.95	73.55
建築設備動力	329.00	
建築設備照明	165.00	
計（kW）	1,909.5	223.95
	合計（kW）	2,133.45

出典：JET

3)　変圧器容量・契約電力

契約電力（最大需要電力）の算出は、AS/NZS 3000:2018 ELECTRICAL INSUTALLATIONS STANDARD の算出基準に基づき工事請負業者が算出し、工事着工前に受電申請時に EFL と協議を行い送電線容量の可否、工事スケジュールの確認調整を行う。EFL との協議において Natabua 下水処理場変圧器容量 2000KVA と想定されるので、EFL 側の配電変圧器は 1000KVA×2 台で計画を行う。工事着工前に再確認を行う。計画時の変圧器容量・契約電力を**表 3-5.3** に示す。

表 3-5.3　変圧器容量・契約電力

工期	負荷合計 (kW)	契約電力 (kW)	電力量 (kWh/day)	年間電力量 (kWh/yr)
第 1 期	1907.5	810	13,608	4,966,920
第 2 期	223.9	905	15,204	5,549,460

出典：JET

(2) 非常用発電機設備

1) 停電実績

今回、下水処理場の予定地の Lautoka 地域の過去 6 年間（2018～2023 年）の停電実績調査を行った結果を**表 3-5.4** に示す。停電実績表より、年平均停電回数が多いので商用電源のバックアップが必要である。

表 3-5.4　停電実績

項目	突発的停電	計画停電
件数（2018-2023）	192	1
最大停電時間(hr)	12	8
平均停電時間(hr)	3	―
最小停電時間(hr)	0.02	―
年間平均停電数	32	1
月平均停電数	2.7	
12 時間以上の停電回数	―	―
12 時間以上の平均停電時間	―	―

出典：JET

2) 非常用発電機の設置

停電実績調査において Lautoka 地域は停電が多く下水処理場の機能保全のために非常用発電機の設置を行う。非常用発電機主要な対象負荷を**表 3-5.5** に示す。

表 3-5.5　非常用発電機対象負荷

非常用発電機対象負荷	台数
主流入ゲート	1 台
汚水ポンプ	予備除く全台数
雨水ポンプ	予備除く全台数
送風機	2 系列 1 台
滅菌注入装置	全台数
放流ポンプ	予備除く全台数
生活に必要な用水装置	
非常用発電機補機	全台数
維持管理用建築動力・照明	必要最小限

出典：JET

3) 非常用発電機エンジン形式

非常用発電機エンジン形式は、建設費が安価で車両整備士が維持管理を行うことができる空冷式の「ディーゼルエンジンラジエター搭載パッケージ式」とする。設置台数は 1 台とする。

(3) 計装設備

沈砂池・ポンプ設備関連、水処理設備関連、および汚泥脱水設備関連の適正な運転制御を行うために必要な計装項目を**表 3-5.6** の通り計画する。

表 3-5.6 計測項目一覧表

施設	計測項目	形式	採用理由
沈砂池・ポンプ設備	ポンプ井水位計	投込式水位計	ポンプ台数制御運転のために設置
	流入汚水流量計	電磁式	流入水量把握のために設置
水処理設備	TF タンク風量計	オリフィス式	送風機の運転を制御するために設置
	余剰汚泥量計	電磁式	余剰引抜汚泥量の制御のために設置
	次亜塩貯留槽水位計	圧力式	次亜塩素酸ソーダの維持管理のために設置
	次亜塩注入量計	電磁式	放流流量に比例した注入量制御のために設置
	放流流量計	堰式	次亜塩注入量制御のために設置
	放流ポンプ井水位計	投込式水位計	ポンプ台数制御運転のために設置
汚泥脱水設備	濃縮槽引抜汚泥流量	電磁式	濃縮槽引抜汚泥ポンプの汚泥量運転制御に利用
	薬品タンク液位	圧力式	薬品の維持管理のために設置
	汚泥貯留タンク液位	圧力式	余剰汚泥引抜制御のために設置
	薬品注入流量	電磁式	汚泥量比例注入制御のために設置
	供給汚泥流量	電磁式	薬品量比例注入制御のために設置
	供給汚泥濃度	マイクロ波式	固形物量制御のために設置
	ケーキホッパ重量	ロードセル式	脱水汚泥量管理のために設置

出典：JET

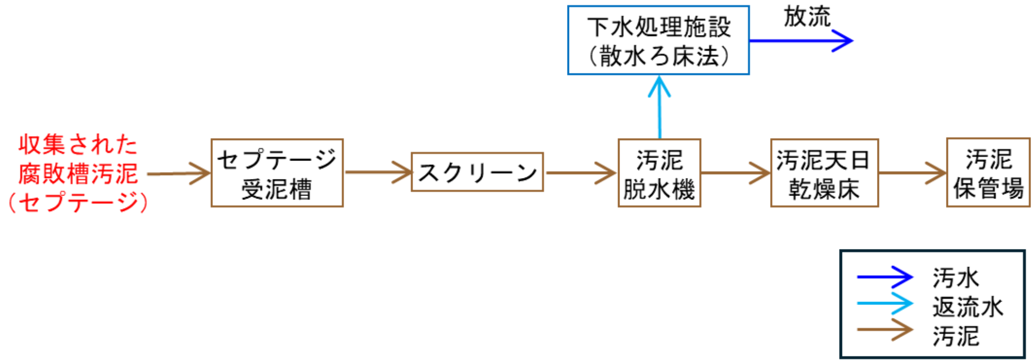
(4) 監視制御設備

監視制御設備は、分散している下水処理場の設備を維持管理者が監視室で監視、操作を行い、効率的な下水処理場設備の運転操作を行い、維持管理費の低減、省力化、労働環境の改善及び作業性の向上等の目的で設置する。

施設の情報を把握する重要な機器であり、施設情報の一元管理をはかり、帳票管理、設備運転管理における協調的な利用が重要であり、コンピュータネットワーク技術を利用した汎用性の高い「監視装置 SCADA システム」により監視制御システムを構築する。

3-6 腐敗槽汚泥処理場

腐敗槽汚泥処理のフロー図を**図 3-6.1** に示す。腐敗槽汚泥（セプテージ）は民間業者が各家庭や商業施設等から定期的に回収し、Ba 州及び Ra 州のセプテージを Natabua 下水処理場に搬入すると想定する。搬入される腐敗槽汚泥量の将来予測値（2017~2036）は日平均で最大 65m^3/日と計算され、下水道普及率が上昇するにつれ搬入量は減少していく。建設時期は Natabua 下水処理場の 1 期工事以前とする。



出典：JET

図 3-6.1　腐敗槽汚泥処理場の処理フロー図

表 3-6.1　腐敗槽汚泥設備仕様

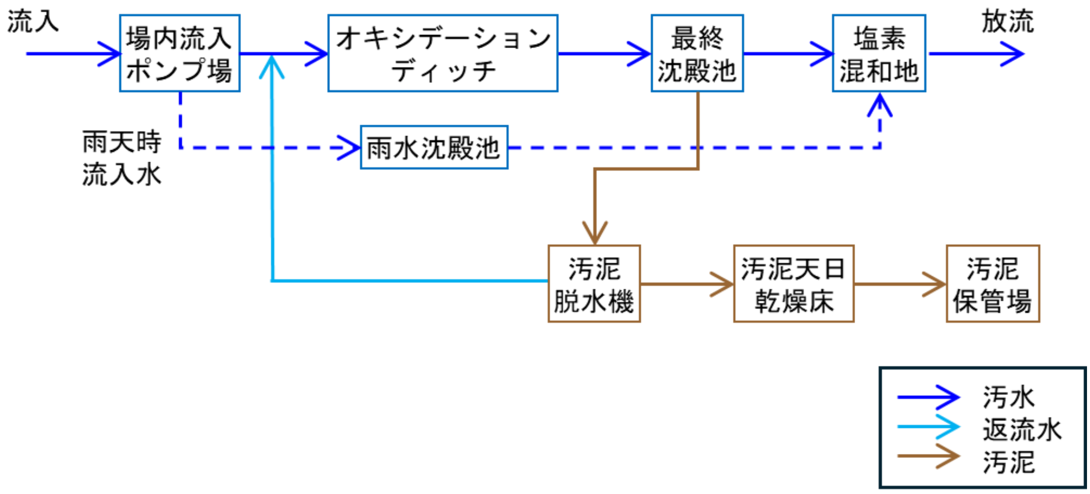
対象	仕様	
セプテージ受泥槽	直径 (m)	6
	容量 (m^3)	113m^3×1 槽
スクリーン	形式	ドラムスクリーン（洗浄ユニット、制御盤付き）
	処理能力(m^3/時)	32(m^3/hr) ×0.2kW×1 台
	目巾(mm)	1.0
汚泥脱水機	汚泥固形物量 (t/日)	1.56
	処理汚泥 (m^3/日)	65
	処理汚泥 (kg/日)	173.3
	脱水機形式	多重板型スクリュープレス脱水機
	処理能力	14(kg-DS/h)×3.3kW×2 台
	運転時間	週 7 回　9 時間運転
	脱水汚泥量 (m^3/日)	6

出典：JET

第4章 Navakai 下水処理場

4-1 整備概要一覧

Navakai 下水処理場は現況の『IDEA 法』から『OD 法』(**図 4-1.1**)に処理方式を変更するとともに、第 1 期工事にて処理能力を日最大 19,700 m³/日、第 2 期工事にて日最大 29,900 m³/日まで増強する。なお、WAF の要望により汚水処理施設は機器のメンテナンス等で一系列休止状態(第 1 期:3 系列運転、第 2 期:5 系列運転)となった場合でも適切な処理を継続できるよう、容量に余裕を持たせた設計とした。(**表 4-1.1**)



出典:JET

図 4-1.1 Navakai 下水処理場の処理フロー図

表 4-1.1 Navakai 下水処理場の整備概要

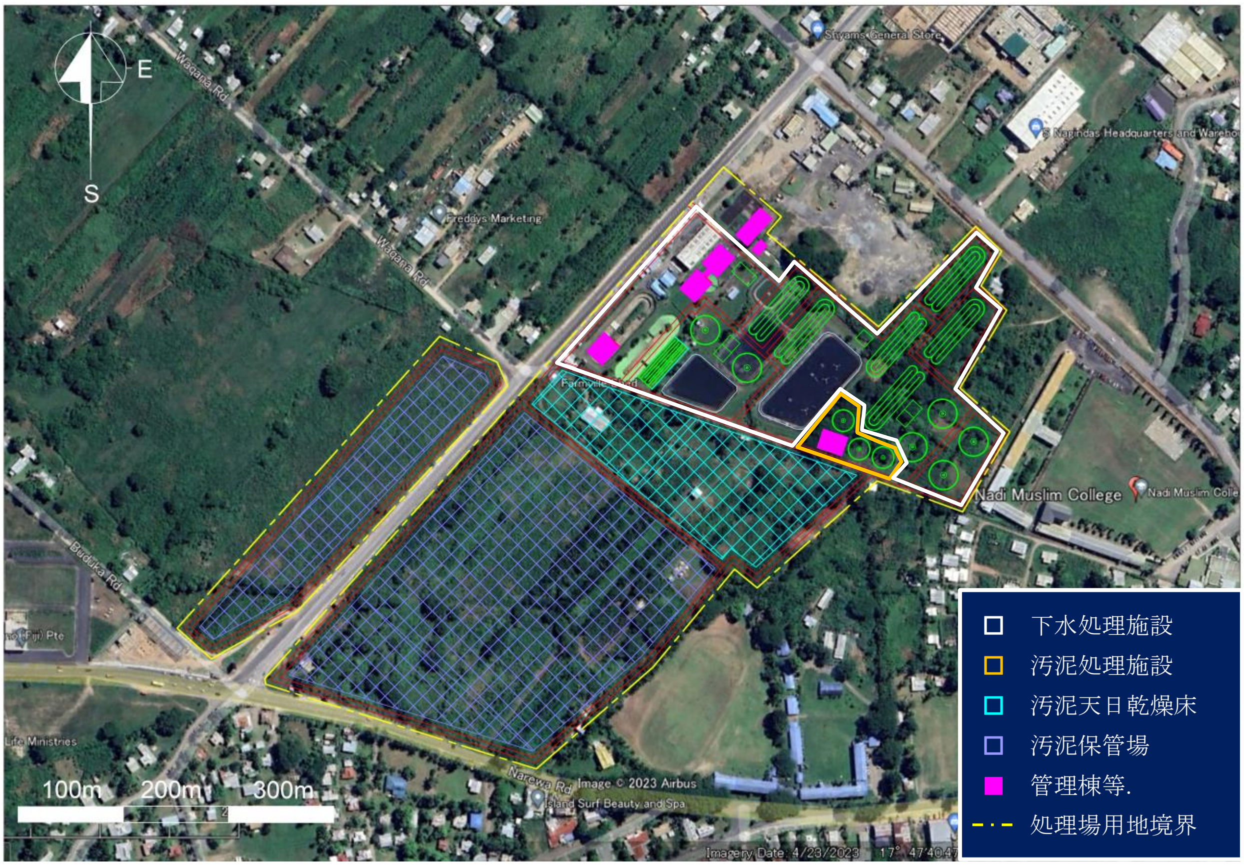
項目		第 1 期	第 1 期＋第 2 期
処理対象		Raw Sewerage	
処理方式		Oxidation Ditch Method	
日最大水量		19,700 m³/日	29,900 m³/日
系列数		4 lines	6 lines (total)
一系列の設計処理能力		4,900 m³/日	4,900 m³/日
一系列の最大処理能力*1		6,800 m³/日	6,800 m³/日
用地面積	合計	12.16 ha	20.86 ha
	汚水処理施設*2	7.08 ha	7.08 ha
	汚泥天日乾燥床	1.99 ha	3.02 ha
	汚泥保管場	3.10 ha	10.77 ha

*1 最大処理能力は各施設の最小 HRT/最大負荷に基づき算定。十分な処理水質を担保するためには処理能力のマージン確保が必須であることに留意する
*2 Navakai 下水処理場の現用地を含む
出典:JET

表 4-1.2　Navakai 下水処理場の流入水質・目標処理水質

項目	流入水質	目標処理水質 (SEZ Standards*)
BOD (mg/L)	340	20
SS (mg/L)	500	30
T-N (mg/L)	37	10
T-P (mg/L)	6	2

*: SEZ = Significant Ecological Zone
出典：JET



出典：JET

図 4-1.2　Navakai 下水処理場の施設配置図

4-2　下水処理場サイト周辺状況・土地状況

2024 年 3 月時点における Navakai 下水処理場周辺の土地利用状況を図 4-2.1 に示す。

Land Type and Facilities

① Current Navakai WWTP
② WAF Nadi Depot
③ FRA Nadi Depot
④ Government Land (unused)
⑤ FRA Training Facility (planned)
⑥ State Land with Active Lease (household)
⑦ Nadi Muslim College
⑧ Nadi District School
⑨ Ratu Navu College
⑩ iTaukei Land (households)
⑪ iTaukei Land (agricultural land+ households)
⑫ iTaukei Land (agricultural land + households)

出典：JET

図 4-2.1　Navakai 下水処理場周辺の土地利用状況（2024 年 3 月時点）

Navakai 下水処理場は下記の既存政府関連施設（図中②③）、Government Land（④）、並びに農地・住居利用されている iTaukei Land（⑪）と隣接している。

- WAF 上水道部 Nadi デポ（事務所、倉庫）
- FRA（フィジー道路公社）Nadi デポ（事務所、倉庫、作業場、従業員住居）

このうち Government Land は WAF 等の政府関連施設のために保持された未使用の土地であり、下水処理場拡張にあたって取得が最も容易と考えられる。一方、2024 年に入って National Fire Authority（消防局）が訓練施設新設のために一部を取得（⑤）するなど、他政府関連組織による開発が進められており、残存する土地の確保が急がれる。下水処理場西側の iTaukei Land は主に農地として利用されているものの、取得に当たって土地を所有する一族の 60%から同意を得る必要があることに留意する。

Navakai 下水処理場は拡張後南側の学校施設（⑦⑧⑨）と住宅地（⑥⑩）と隣接することになるため、脱臭設備の設置や臭気源となり得る汚泥処理施設を敷地内側に配置する等の配慮を行った。

また、図中②③に示す WAF 上水道部並びに FRA の施設については、WAF が交渉を行い図中⑫の位置に移転し、現敷地を Navakai 下水処理場の拡張用地として利用する余地があると示唆した。参考として移転が叶った場合の Navakai 下水処理場平面図別案を **APPENDIX 4-3** に示す。

4-3　処理プロセス・土木施設

(1)　処理方式

1)　下水処理方式

下水処理方式は都市下水道 M/P に準じて、下記を考慮して OD 法を採用する。

- ✓ Significant Ecological Zone の放流基準を満足する
- ✓ 求められる放流基準を満足できる処理法の中で経済性及び維持管理性で有利である

2)　汚泥処理方式

第 1 期の施設における汚泥処理フローは下記の通りとする。

- ✓ 余剰汚泥：機械脱水→天日乾燥

3)　汚泥処分方法

現状、下水処理場外での最終処分場にて下水汚泥の受け入れは行っていない。本 Pre-F/S では都市下水道 M/P に準じて、下水処理場内に乾燥汚泥の保管場所を配置する。

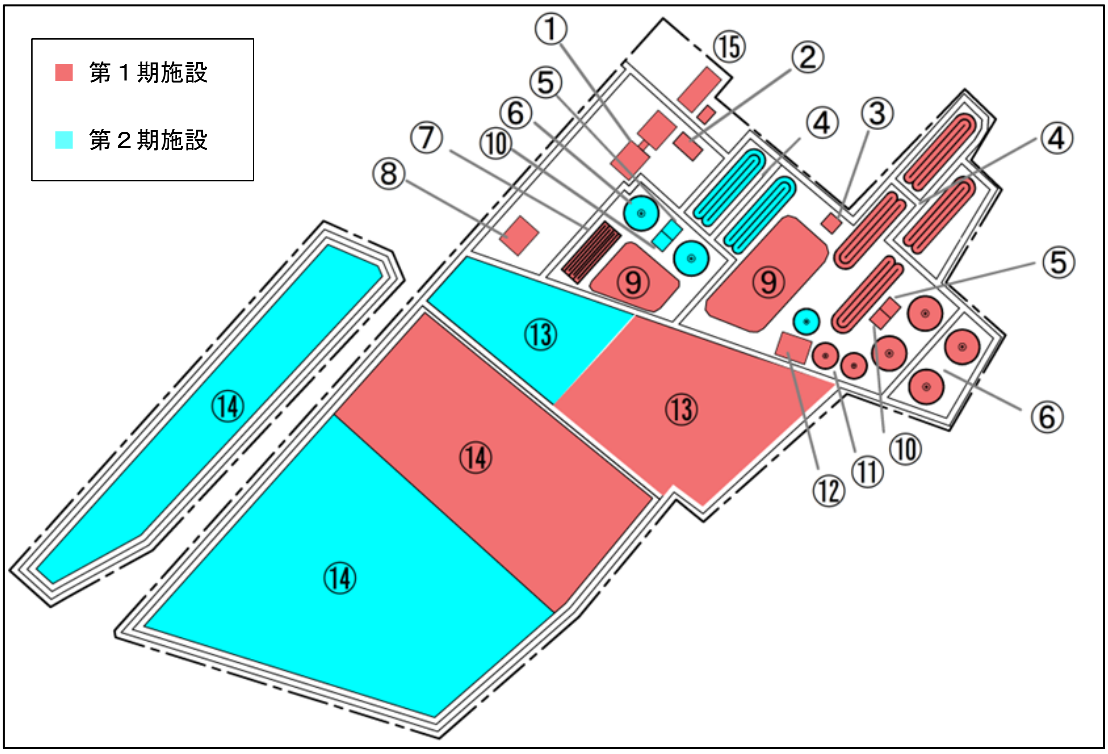
(2)　配置計画

Navakai 下水処理場の土木施設を**図 4-3.1**、**表 4-3.1** に示す。

第 1 期施設の施工期間中も現施設の運転を継続する必要があるため、1 期施設は現敷地外、あるいは現在運転している施設と干渉しない位置に配置した。

第 1 期施設の運転開始後、現施設（IDEA 法）は運転を終了するため、既存の IDEA 池と仕上池（図中⑨）を雨水沈殿池として活用し、2 期工事の水処理施設は現下水処理場用地内に建設する。

なお、汚泥天日乾燥床と汚泥保管場については、乾燥汚泥の利活用や場外の処分場が確保された場合、敷地面積が縮小あるいは不要となる。



出典：JET

図 4-3.1　Navakai 下水処理場の土木施設

表 4-3.1　Navakai 下水処理場施設

図 No.	施設	概要
1	流入ポンプ棟	Includes Sewage and Stormwater pumps
2	分配槽①	Influent from: Inlet Pump Station Distribution to: Distribution Chamber②, Phase 2 OD tanks, Stormwater Sedimentation Ponds
3	分配槽②	Influent from: Distribution Chamber① Distribution to Phase 1 OD tanks
4	オキシデーションディッチ	HRT: 21.4 hr
5	分配槽③	Influent from: OD tanks Distribution to: Final Clarifiers
6	最終沈殿池	Diameter: 27 m
7	塩素混和池	Minimum contact time: 15 min.
8	放流ポンプ棟	Pump to Nadi River
9	雨水沈殿池	Utilize existing IDEA pond
10	返送汚泥ポンプ棟	
11	受泥槽	Diameter: 20m
12	汚泥脱水機棟	
13	汚泥天日乾燥床	3.02 ha
14	汚泥保管場	10.77 ha
15	管理棟	Includes emergency power generator and electricity room

出典：JET

(3) 概略施設計画

水処理および汚泥処理における主要な施設の数量及び形状を**表 4-3.2**、**表 4-3.3** に示す。施設容量計算は **APPENDIX 4-7** に添付する。

表 4-3.2 水処理施設の概略仕様（第 1 期分抜粋）

主要施設	実負荷	池数及び形状
汚水沈砂池	水面積負荷 1,800m^3/m^2・日	3 池 矩形池 3 m × 3.5 m
雨水沈砂池	水面積負荷 1,800m^3/m^2・日	3 池 矩形池 3 m × 5 m
オキシデーションディッチ	HRT 21.4 時間	4 池 馬蹄型 4.5m × 282.5 m × 3.5m
最終沈殿池	水面積負荷 9 m^3/m^2・日	4 池 円形池 φ 27 m
塩素混和池	接触時間 15 分	1 池 矩形池 2m × 360 m × 2 m
雨水沈殿池	沈殿時間 2.5 時間	2 池* 法切りオープン 43m × 91 m × 3.0 m 法切りオープン 35m × 54 m × 3.0 m

*既存 IDEA 池及び仕上池を活用
出典：JET

表 4-3.3 汚泥処理施設の概略仕様（第 1 期分抜粋）

主要施設	実負荷	池数及び形状
機械脱水	処理能力 400 kg-DS/hr・台	2 台 多重板型スクリュープレス脱水機
汚泥乾燥床	乾燥期間 3 ヶ月	1.8 ha
汚泥保管場	20 年分の保管を想定	2.7 ha

出典：JET

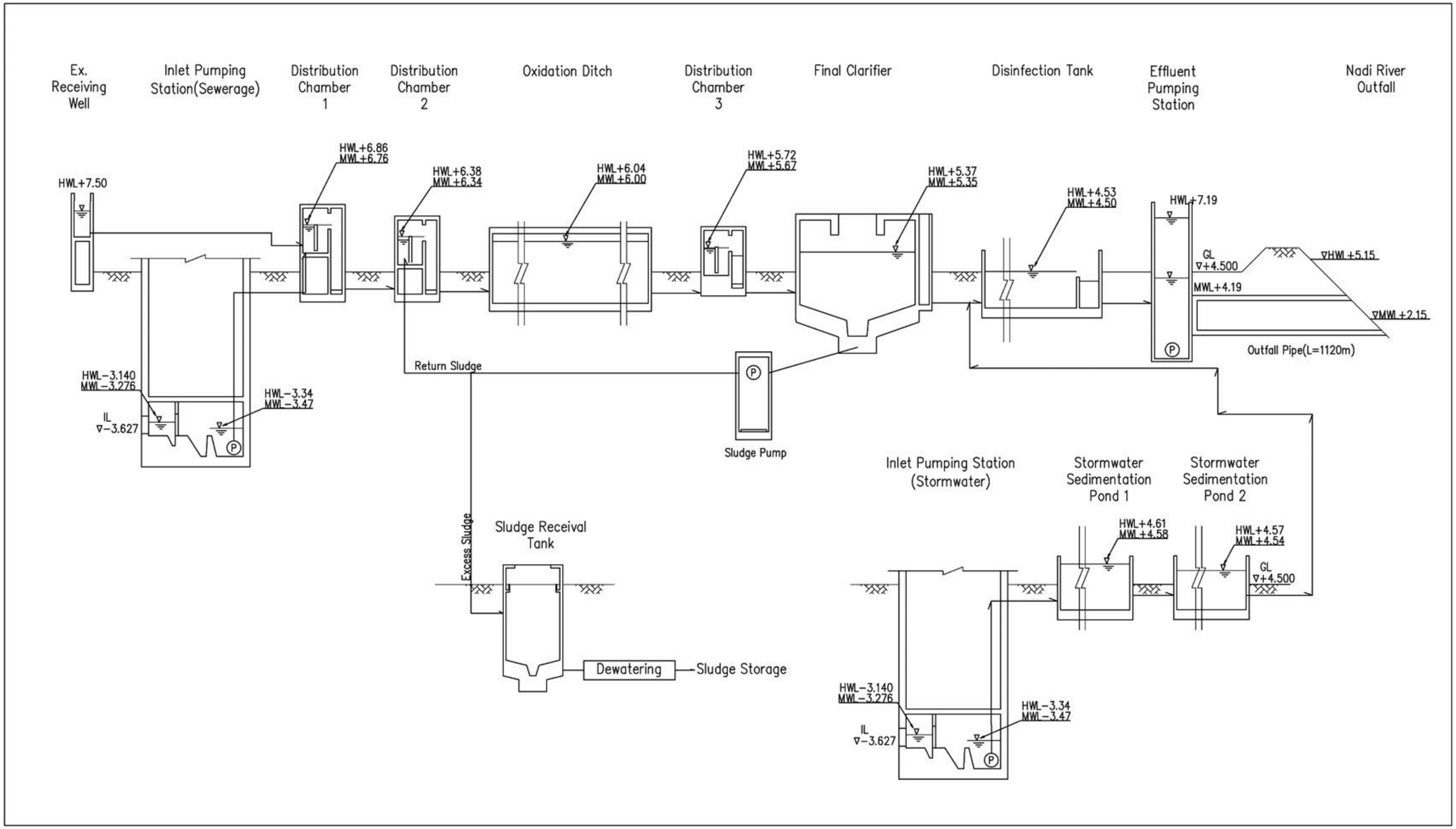
(4) 水位高低

想定する計画流入渠の流入水位と放流先の水位の差をもとに、汚水処理施設の導入に伴う水位高低を計画する。水位的条件を**表 4-3.4** に、水位高低図を**図 4-3.2** に示す。

表 4-3.4 水位的条件

項目	水位*	場所
流入水位	-3.14 M	Inflow channel
放流水位（河川）	+5.15 M	Nadi River

*HWL
出典：JET



出典：JET

図 4-3.2　Navakai 下水処理場の水位高低図

(5) 土質調査・基礎形式

1) 支持層の選定

Navakai 下水処理場で実施されたボーリング試験結果（**APPENDIX 4-5**）を元に、施設を支える土木基礎の支持層を選定した。一般的に、支持層として適しているのは N≧30 の砂礫層、あるいは N≧20 の粘性土層である

ボーリング試験結果より、上記条件に当てはまる砂礫層（N=50+、深度 GL-14.0m～17.0m）が支持層として選定された。なお、今回実施されたボーリング調査は現下水処理場敷地内のみで実施されているため、将来的な設計段階では建設予定地の範囲にて追加のボーリング調査を実施し、追加データの確認が推奨される。

2) 基礎形式の検討

ケーソン基礎等の特殊な形式を除けば、基礎構造物は大きく分けて直接基礎と杭基礎の二種類にカテゴライズされる。直接基礎は支持層が浅い位置（0～5m）に存在する場合に採用され、それより深い位置に存在する場合は杭基礎が採用される。

Navakai 下水処理場は支持層が GL-14.0m と深層に位置しているため、杭基礎を採用する。杭長は 13.5～15m 程度となるため、既設杭（最大杭長 20m）と場所打杭の両方が適用可能となる。このため Navakai 下水処理場の土木施設は適用可能な既製杭もしくは場所打ち杭の経済比較を行い、より経済的に優位な杭を構造物ごとに選定した。

4-4 機械設備

Navakai 下水処理場における各種機械設備を以降のとおり選定した。検討の詳細については **APPENDIX 4-6**、各種図面については **APPENDIX 4-7** を参照。

(1) 流入ゲート設備

下水処理場に汚水が流入してくる流入渠に主流入ゲート設置する。流入後、汚水、雨水沈砂池にゲートを池毎に設置して池の機器点検、清掃を個別に行えるようにした。ゲートは耐久性が高く点検が容易な「外ネジ式角形鋳鉄製ゲート」を選定した。

表 4-4.1 設備計画

名称	仕様
主流入ゲート（電動式）	有効開口 1.20m 角×1 門
汚水流入ゲート（手動式）	有効開口 0.45m 角×3 門
雨水流入ゲート（手動式）	有効開口 1.00m 角×3 門

出典：JET

(2) スクリーン設備

沈砂池に設置するスクリーンは、後段の汚水、雨水ポンプの保護のために設置する。大きなごみの除去は手動の目巾 50mm の粗目スクリーンで除去し、小さなごみの除去については、目巾 25mm の細目自動除塵機を設置してごみの除去を行う。

1) 細目スクリーン目巾

細目スクリーンの目幅の選定は「除塵機設備設計指針（水門鉄管協会)」のポンプ口径による選定表により 25mm とした。

2) 自動除塵機

細目自動除塵機は、建設費、維持管理費の総合評価において優れている「ベルト走行式 自動除塵機＋二軸スクリュー式」を選定した。

表 4-4.2　し渣装置

沈砂池数	汚水 3 池、雨水 3 池
し渣装置	汚水：粗目スクリーン＋細目自動除塵機：3 組

出典：JET

(3) 沈砂池設備

沈砂池に流入した汚水に混入している沈砂は、汚水ポンプインペラを摩耗させるので、沈砂ピットで沈砂を沈殿させ沈砂ピットよりサンドポンプにより砂と汚水を一緒に揚水し、サイクロン式沈砂分離機により砂と汚水を分離させ砂の除去を行う。また汚水は沈砂池にもどして処理を行う。沈砂装置はシステムが簡単で経済性、維持管理性において優れている「サンドポンプ＋サイクロン式沈砂分離機」を選定した。

表 4-4.3　沈砂装置

沈砂池数	汚水 3 池、雨水 3 池
沈砂装置	サンドポンプ（6 台）＋沈砂分離機（サイクロン）／沈砂コンテナ 2 組

出典：JET

(4) 主ポンプ設備

ポンプ井はポンプの更新及び清掃を考慮してポンプ井は 2 槽とし、槽間には連絡ゲートを設け一体使用を行う。ポンプ容量・台数は計画水量により同一容量 2 台以上で予備機 1 台を設けた。ポンプ機種は安価で入手でき維持管理の容易な「水中汚水ポンプ」を選定した。ポンプ台数・吐出量計画を**表 4-4.4**、ポンプ仕様を**表 4-4.5** に示す。

表 4-4.4　ポンプ台数・吐出量計画

項目	計画水量 (m^3/分)	ポンプ台数 (台)	ポンプ吐出量 (m^3/分・台)	
日平均汚水量	18.82	2	9.41	9.5
日最大汚水量	20.76		10.39	9.5
時間最大汚水量	37.64	2（1 台予備）	12.55	19.0
雨天時最大汚水量	56.32	3（1 台予備）	28.16	29.0

＊赤数字：定格吐出量
出典：JET

表 4-4.5　ポンプ仕様

名称	ポンプ仕様・台数
1 期：汚水ポンプ	口径 300mm × 吐出量 9.5 m^3/分 × 揚程 11m × 出力 30kW×2 台
2 期：汚水ポンプ	口径 450mm × 吐出量 19 m^3/分 × 揚程 11m × 出力 55kW×2 台（1 台予備）
雨水ポンプ	口径 600mm × 吐出量 29 m^3/分 × 揚程 8.5m × 出力 55kW×3 台（1 台予備）

出典：JET

(5) オキシデーションディッチ設備

オキシデッションディッチは分配槽から分配された汚水を撹拌機、散気装置により空気を供給して生物処理を行う。

1) 撹拌方式

今回、OD 槽用撹拌方式の縦軸型、横軸型、縦軸水流型＋散気装置、斜軸型、水中プロペラ＋散気装置の 5 撹拌方式の比較検討を行い建設費、維持管理費、処理能力により比較検討を行い、総合評価において「縦軸水流発生装置＋散気装置」または「水中プロペラ＋散気装置」が同等に、最も高く評価された。本業務では「水中プロペラ＋散気装置」を選定し、後段の検討を進める。

2) 送風機

散気装置に空気を供給する送風機は、鋼板製多段ターボブロワ、ロータリブロワ、スクリュー式ブロワの 3 機種の比較検討を行い設備費、維持管理費、設置スペース、重量の総合評価に優れる「スクリュー式ブロワ」を選定した。

送風機台数は、施設配置で 6 系列の内、第一期で建設する 1～4 系列と、第二期で建設する 5・6 系列(既設撤去跡地設置)の距離が離れているため、下記のとおりとする。

表 4-4.6　送風機仕様

名称	風量範囲 (m^3/分)	圧力 (kPa/m)	電動機出力 (kW)	台数 （台）
1 期：スクリュー送風機	5～17	30	18.5	3（予備 1 台）
2 期：スクリュー送風機	5～17	30	18.5	2（予備 1 台）

出典：JET

3) 散気装置

OD 槽の汚水の循環を行う水流撹拌機と、送風機から送付された空気を OD 槽底部に設置した散気装置に取込み超微細気泡を汚水中に放出して汚水の生物処理を効率よく行う。散気装置は酸素移動効率の高い高効率散気装置を選定した。

表 4-4.7　送風機仕様

名称	池数 (池)	SOR (kg-O2/日)	水流撹拌機 (台数)	散気装置 (台数)
1 期：水流撹拌機＋散気装置	4	9035	8	4
2 期：水流撹拌機＋散気装置	2	4518	4	2

出典：JET

(6) 最終沈殿池設備

オキシデーションディッチで処理した汚水を取込み静置して上澄水と汚泥に分離し、上澄水は自然流下により滅菌池に送水、沈殿汚泥は余剰ポンプにより汚泥貯留槽に送泥する。

1) 汚泥掻寄機

汚泥掻寄機は、中央駆動式、周辺駆動式の 2 方式があるが周辺駆動式は沈殿池の周壁上を走行する台車が旋回アームを牽引することで、旋回アームを回転させるのでより少ない駆動力で大きなトルクを発生させることができ動力が小さい「周辺駆動支柱式」を選定した。

表 4-4.8　最終沈殿池汚泥掻き寄せ機仕様

名称	仕様
1 期：汚泥掻寄機	径 25m　×　水深 4m　×　出力 0.75kW　×　4 台
2 期：汚泥掻寄機	径 25m　×　水深 4m　×　出力 0.75kW　×　2 台

出典：JET

2) 余剰汚泥ポンプ

余剰汚泥ポンプは、2 系列に対して 2 台（1 台予備）として計画を行った。ポンプ形式は、沈殿池ピットより汚泥を引き抜くので維持管理性考慮して「陸上型吸込みスクリュー式ポンプ」を選定した。ポンプ台数は 2 系列：2 台（1 台予備）とした。

表 4-4.9　余剰汚泥ポンプ仕様

名称	ポンプ仕様・台数
1 期　余剰汚泥ポンプ	口径 150 mm × 吐出量 1.25 m^3/分 × 揚程 10m × 出力 3.7kW × 4 台（2 台予備）
2 期　余剰汚泥ポンプ	口径 150 mm × 吐出量 1.25 m^3/分 × 揚程 10m × 出力 3.7kW × 2 台（1 台予備）

出典：JET

(7) 滅菌池設備

1) 次亜塩素酸ソーダ貯留量

次亜塩素酸ソーダは、紫外線、温度により分解が促進されるので、次亜塩素酸ソーダ貯留量は雨天時最大水量に対し注入率 3mg/L の使用量に対して 1 週間分の貯留能力の貯留槽を計画した。

2) 次亜塩素酸ソーダ注入装置

次亜塩素酸ソーダ注入ポンプは、価格が安価で実績の多い「ダイヤフラム定量ポンプ」で回転数制御装置により放流量に対して比率注入制御を行うシステムを選定した。

表 4-4.10　次亜塩素酸ソーダ注入ポンプ仕様

名称	吐出口径	吐出量制御範囲	最高吐出圧力	電動機出力	台数
次亜塩注入ポンプ	25mm	0.0637～1.2L/分	0.7MPa	0.4kW	3 台（予備 1 台）

出典：JET

(8) 放流ポンプ設備

放流ポンプは、ナンディ川の河川水位が MWL 4.19 m に上昇すると自然流下で放流できなくなるので、放流ポンプにより圧送放流を行う。ポンプ機種は安価で入手でき、維持管理の容易な「水中

汚水ポンプ」を選定した。ポンプ台数・吐出量計画を**表 4-4.11**、ポンプ仕様を**表 4-4.12** に示す。

表 4-4.11　ポンプ台数・吐出量計画

名称	計画水量 (m^3/分)	ポンプ台数 (台)	ポンプ吐出量 (m^3/分・台)	
放流ポンプ	93.89	3 台（1 台予備）	46.95	47.0

＊赤数字：定格吐出量
出典：JET

表 4-4.12　ポンプ仕様

名称	ポンプ仕様・台数
放流ポンプ	口径 600mm × 吐出量 47m^3/分 × 揚程 10m × 出力 110kW× 3 台（1 台予備）

出典：JET

(9)　雨水沈殿池設備

雨水沈殿池は計画日最大汚水量の 4 倍水量を 2.5 時間滞留させたのち、滅菌池に排水して滅菌を行い放流する。雨水沈殿池は既設の IDEA 槽と沈殿池を使用する。

(10) 処理水再利用設備

下水処理場内の各装置の洗浄水や、次亜塩注入ポンプ薬品の溶解水に使用するために設置する。形式は建設費が安価で維持管理の容易なパッケージ型で制御盤を含めて一体構成となっている「圧力式砂ろ過装置」を選定した。

(11) 脱水機設備

1)　汚泥貯留槽撹拌機

汚泥貯留槽容量は、脱水機運転が週 5 日運転なので土曜、日曜日の 2 日間貯留できる容量で計画され、貯留タンクは 6 系列に対して 2 系列毎に 3 槽計画で撹拌機の設置計画を行った。

撹拌機形式は建設費が安価で、維持管理性の良い「水中ミキサー型撹拌機」を選定した。撹拌機台数は撹拌能力により、1 槽 3 台 5m 間隔で設置する計画とした。

2)　脱水機

汚泥貯留槽から汚泥供給ポンプにより引き抜いた汚泥を脱水機により脱水して汚泥の減量化を行う。脱水機形式は、建設費、維持管理費が安価で、脱水効率の良い「多重板型スクリュープレス脱水機」を選定した。

表 4-4.13　脱水機仕様

汚泥固形物量 (t/日)	10.8
処理汚泥 (kg/日)	1,200
脱水機形式	多重板型スクリュープレス脱水機
処理能力	400(kg-DS/h)×8.3kW×3 台
運転時間	週 7 回　9 時間運転
脱水汚泥量 (m^3/日)	46

出典：JET

(12) 脱臭設備

下水・汚泥から発生する悪臭が周辺に悪影響を及ぼすのを防止するため、脱臭設備を設置する。脱臭形式は維持管理が比較的容易で脱臭効率が高く、また調達が比較的容易な「活性炭吸着法」と「充てん塔式生物脱臭法」を選定した。その他の形式は、以下の理由より採用しなかった。

- 直接燃焼法：建設費・維持管理費共に比較的高額。また O&M に比較的高度な技術を必要とする。
- 薬剤洗浄法：酸・アルカリ剤等の薬剤を使用するため維持管理費が比較的高額。また、廃液処理用の施設を別途追加する必要がある。
- 土壌脱臭法：建設費と維持管理費は比較的安価である一方、おおよそ 5 年毎の交換時に大量のメディアを輸入しなければならないため、調達の観点から実現性は低いと考えられる。

上記より Navakai の下水処理系には「活性炭吸着法」を、より強い臭気が発生する汚泥処理系には「充てん塔式生物脱臭法＋活性炭吸着法」の組み合わせを適用する。

表 4-4.14　脱臭設備

処理系	下水処理系	汚泥処理系
対象施設	・流入ポンプ棟 （着水井、沈砂池、ポンプ井）	・受泥槽 ・汚泥脱水機棟
脱臭形式	活性炭吸着法	充てん塔式生物脱臭法 ＋活性炭吸着法

出典：JET

4-5　電気設備

Navakai 下水処理場における各種電気設備を以降のとおり選定した。各種図面については **APPENDIX 4-7** を参照。

(1)　受電設備

1)　受電方式、配電電圧

フィジー電力公社（以降：EFL）との協議により、フィジーの送電電圧は 3 相 3 線 11kV、周波数 50Hz で、EFL が下水処理場敷地内に 11KV から 415Ｖの降圧する変圧器を設置する。

WAF 側では、EFL から変圧器 2 次側電圧 3 相 4 線 415V の配電電圧を、下水処理場主配電盤に受電して、各施設のモーターコントロールセンターに配電を行い各負荷に電源を供給する。

表 4-5.1　受電・配電電圧

項目	受電・配電電圧
受電電圧・動力負荷電圧	3 相 4 線 50Hz　415V
建築動力・照明負荷電圧	動力配電電圧 3 相 4 線 50Hz415V 照明配電電圧単相 2 線 50Hz240V

出典：JET

2) 負荷容量

本計画における各設備の負荷を**表 4-5.2** に示す。

表 4-5.2　負荷表

設備名	1期負荷（kW）	2期負荷（kW）
沈殿池設備	47.3	
主ポンプ設備	118.7	
雨水ポンプ設備	110	
オキシデーションディッチ設備	207	126
最終沈殿池設備	31.75	16.25
滅菌・揚水設備	24.4	
放流ポンプ設備	220	
脱水機設備	123.32	26.77
建築設備動力	201.00	
建築設備照明	106.00	
計（kW）	1189.47	179.02
合計（kW）		1368.5

出典：JET

3) 契約電力

契約電力（最大需要電力）の算出は、AS/NZS 3000:2018 ELECTRICAL INSUTALLATIONS STANDARD の算出基準に基づき工事請負業者が算出し、工事着工前に EFL と協議を行い送電線容量の可否、工事スケジュールの確認調整を行う。

4) 変圧器容量

EFL との協議において下水処理場変圧器容量は 1500KVA と想定している旨を説明した。EFL 側配電変圧器は 1500KVA で問題が無いことを確認した。EFL から工事着工前に再確認を行うように要望された。

(2) 非常用発電機設備

1) 停電実績

今回、下水処理場の予定地の Nadi 地域の過去 6 年間（2018～2023 年）の停電実績調査を行った結果を**表 4-5.3** に示す。停電実績表より、年平均停電回数が多く 12 時間以上の平均停電時間が 15.8 時間と長いので、商用電源のバックアップが必要である。

表 4-5.3　停電実績

項目	突発的停電	計画停電
件数（2018-2023）	354	0
最大停電時間(hr)	24	—
平均停電時間(hr)	3.4	—
最小停電時間(hr)	0.1	—
年間平均停電数	59	—
月平均停電数	5	—
12 時間以上の停電回数	6	—
12 時間以上の平均停電時間	15.8	—

出典：JET

2)　非常用発電機の設置

停電実績調査において Nadi 地域は停電が多く下水処理場の機能保全のために非常用発電機の設置を行う。非常用発電機主要な対象負荷を**表 4-5.4** に示す。

表 4-5.4　非常用発電機対象負荷

非常用発電機対象負荷	台数
主流入ゲート	1 台
汚水ポンプ	予備除く全台数
雨水ポンプ	予備除く全台数
OD 槽散気装置用送風機	2 系列 1 台
滅菌注入装置	全台数
放流ポンプ	予備除く全台数
生活に必要な用水装置	
非常用発電機補機	全台数
維持管理用建築動力・照明	必要最小限

出展：JET

3)　非常用発電機エンジン形式

非常用発電機エンジン形式は、建設費が安価で車両整備士が維持管理を行うことができる空冷式の「ディーゼルエンジンラジエター搭載パッケージ式」とする。設置台数は 1 台とする。

(3)　計装設備

下水処理場の運転監視制御、維持管理に必要な計装計器を**表 4-5.5** に示す。

表 4-5.5　計測項目一覧表（Navakai 下水処理場）

対象施設	計測項目	形式	採用理由
沈砂池・	ポンプ井水位計	投込式水位計	ポンプ台数制御運転のために設置
ポンプ設備	流入汚水流量計	電磁式	流入水量把握のために設置
水処理設備	DO 槽 DO 計	光学式	返送汚泥ポンプの運転制御のために設置
	DO 槽 MLSS 計	光学式	返送汚泥ポンプの運転制御のために設置
	余剰汚泥量計	電磁式	余剰引抜汚泥量の制御のために設置
	次亜塩貯留槽水位計	圧力式	次亜塩素酸ソーダの維持管理のために設置
	次亜塩注入量計	電磁式	放流流量に比例した注入量制御のために設置
	放流流量計	堰式	次亜塩注入量制御のために設置
	放流ポンプ井水位計	投込式水位計	ポンプ台数制御運転のために設置
汚泥脱水	薬品タンク液位	圧力式	薬品の維持管理のために設置
設備	汚泥貯留タンク液位	圧力式	余剰汚泥引抜制御のために設置
	薬品注入流量	電磁式	汚泥量比例注入制御のために設置
	供給汚泥流量	電磁式	薬品量比例注入制御のために設置
	供給汚泥濃度	マイクロ波式	固形物量制御のために設置
	ケーキホッパ重量	ロードセル式	脱水汚泥量管理のために設置

出展：JET

(4) 監視制御設備

監視制御設備は、分散している下水処理場の設備を維持管理者が監視室で監視、操作を行い、効率的な下水処理場設備の運転操作を行い、維持管理費の低減、省力化、労働環境の改善及び作業性の向上等の目的で設置する。

施設の情報を把握する重要な機器であり、施設情報の一元管理をはかり、帳票管理、設備運転管理における協調的な利用が重要であり、コンピュータネットワーク技術を利用した汎用性の高い「監視装置 SCADA システム」により監視制御システムを構築する。

第5章 維持管理体制（O&M）

5-1 提案する業務の内容と実施方法

5-1-1 下水処理場運転計画

下水処理施設は多岐の施設、設備とそれに付随する装置や機器で構成されているので、このうちどれか一つでも不調があれば、全体に悪影響を及ぼす。

また、下水の処理は一般に生物処理であるため、ひとたび異常が発生し、その原因を排除しても、再度、良好な処理水質を得るまでには多大な時間を要するので、異常が起きないように適正に管理することが最も大切なことである。下水道施設は重要な社会資本であり、現在の社会的背景として、限りある資源を有効に活用し「持続可能な社会」を実現することが求められている。計画的に施設管理を行い、施設をできるだけ長期間有効活用（長寿命化）し、コストの縮減を図ることが重要である。さらに、管理記録の継続性、記録の分析と管理業務の継続的な見直しが必要である。（下水道維持管理指針：日本下水道協会 2014 年）

下水処理施設の計画的な運転・維持管理については、先ず以下の計画策定が必要で、そのうえで計画に従った運転管理を実施する。

表 5-1.1　下水処理施設の計画的な運転・維持管理に策定が必要な計画

1	**運転**	
	運転計画策定	処理に係るコスト削減、異常時の対応を考慮し、放流水質基準を遵守するための施設運転計画の策定
	水質管理計画策定	放流基準の遵守のため、及び流入水量・水質、活性汚泥性状に対する最適運転条件把握のための水質管理計画策定
	危機管理計画策定	停電、火災、断水、浸水、薬品漏洩、機器故障等に対する管理体制、対策を示した危機管理計画の策定
	安全衛生計画策定	労働災害防止のための管理体制、管理方法を定めた安全衛生計画の策定
2	**日常点検**	
	日常点検計画策定	点検項目、点検ルート、点検方法（目視、数値等）、点検頻度（1 回／日、2 回／週等）、点検基準（適正な数値の範囲等）を定めた日常点検計画の策定
3	**定期点検・修繕管理**	
	設備の重要度ランクの設定	設備台帳を用いて、処理機能への影響、安全性への影響、予備機の有無、修繕費用、設置後の経過年数等に基づいて重要度の設定
	管理方法の選定	設備の重要度による予防保全、事後保全の選定
	管理基準の設定	異常の範囲を示した点検基準の設定 修繕の必要な状態を示した修繕基準の設定
	管理計画・実績表作成	設備毎に定期点検の実施計画年、月と実施実績を具体的に示した表の作成

出典：下水道施設維持管理指針 2014 年に基づいて JET が作成

(1) 運転管理

策定した運転計画に従って、処理コストの削減を図りながら常時放流水質基準を遵守できように処理施設の運転管理を行う。

JICA が提案する OD 法や WAF が保有する IDEA 法などの活性汚泥法、また Lautoka の Natabua 下水処理場で提案している TF 法では、以下について注意を払いながら運転を行う。

表 5-1.2 下水処理施設の運転管理における注意点

<table>
<tr><th colspan="3">施設</th><th>注意点</th></tr>
<tr><td rowspan="8">1</td><td rowspan="3">下水処理（OD 法、IDEA 法）</td><td>スクリーン</td><td>➢ し渣は（できれば洗浄後）速やかに処分地に搬出する。</td></tr>
<tr><td>反応槽</td><td>➢ 処理に必要な空気量（酸素量）を槽に供給する。
➢ 処理に必要な活性汚泥濃度を維持する
➢ 適切な活性汚泥濃度となるよう余剰汚泥の引き抜きを行う。
➢ 適切な返送汚泥比で運転する。（OD 法）
➢ 活性汚泥が十分に沈殿する時間を確保する。（IDEA 法）</td></tr>
<tr><td>消毒</td><td>➢ 大腸菌数が基準値以下となるよう薬品の注入率を調整する。</td></tr>
<tr><td rowspan="4">下水処理（TF 法）</td><td>スクリーン</td><td>➢ し渣は（できれば洗浄後）速やかに処分地に搬出する。</td></tr>
<tr><td>最初沈殿池</td><td>➢ 生汚泥濃度は 1%程度となるようにポンプで引き抜く
➢ 定期的に池内の汚泥界面を測定して、池内に汚泥が長時間堆積しないように注意する。</td></tr>
<tr><td>散水ろ床</td><td>➢ 散水ノズルが閉塞すると散水軸の回転が停止して処理が悪化するため、ノズルは定期的に洗浄する。</td></tr>
<tr><td>消毒</td><td>➢ 大腸菌数が基準値以下となるよう薬品の注入率を調整する。</td></tr>
<tr><td rowspan="5">2</td><td rowspan="5">汚泥処理</td><td>重力濃縮槽</td><td>➢ 適切な濃縮汚泥濃度を確保し、汚泥が腐敗しないように汚泥投入量を決める。</td></tr>
<tr><td>嫌気性消化槽</td><td>➢ メタン発酵が十分に進行するように汚泥投入量を決める。
➢ 槽内で汚泥の攪拌装置が十分に機能するよう注意する。</td></tr>
<tr><td>好気性消化槽（Navakai 下水処理場）</td><td>➢ 十分に消化が進行するように汚泥の投入量を決める。</td></tr>
<tr><td>機械脱水機</td><td>➢ 適切な汚泥含水率となるよう凝集剤を選定し、添加する。
➢ 脱水機の能力に適した汚泥量を供給する。</td></tr>
<tr><td>汚泥乾燥床（Navakai 下水処理場）</td><td>➢ 気象状況に合わせた運転を行う。</td></tr>
</table>

出典：下水道施設維持管理指針 2014 年、TF 法や好気性消化槽については WAF 施設 O&M 状況に基づいて JET が作成

(2) 水質管理

下水処理場の水質検査には、①放流基準の遵守のための検査、②流入下水の水量・水質や活性汚泥性状に対して処理施設を最適な運転条件で処理するための検査がある。

水質試験結果に基づいて、空気の供給量、活性汚泥濃度を変化させて、効率的かつ経済的な処理を行う。

水質検査は通常、水質管理計画に基づいて決められた検査試料、検査項目、頻度で実施されるが、下水処理場の現場では処理状況を簡易な方法を用いてリアルタイムに把握することは一般的に実施されている。最も一般的な方法は透視度と活性汚泥の SV 測定である。

透視度は浮遊物質（SS）濃度や BOD 濃度の目安となり、SV は活性汚泥濃度、活性汚泥の沈降性の目安となるため極めて有用な検査である。

(3) 危機管理計画

下水道施設では各種工場と同様に、十分に維持管理を実施しても事故等の緊急事態が発生する場合がある。下水道施設における緊急事態としては**表 5-1.3** がある。緊急事態発生による周辺住民を含む人的被害、下水道施設の機能への被害を最低限に抑えるよう、関係者、関係機関などとの連絡体制の整備、緊急事態の管理体制、対応方法等を定めた危機管理計画を策定しておく必要がある。計画には緊急事態を想定した職員への訓練の実施について実施方法、実施頻度等を明記し、実際に定期的に訓練を実施する必要がある。

表 5-1.3　下水道施設における緊急事態

緊急事態	下水道施設への影響
停電	各種機器類の運転停止（自家発がない場合）
火災	火災発生施設における機器類損傷による長期の運転停止 安全衛生上の問題
断水	機器の洗浄水の確保不能 安全衛生上の問題
浸水	機器類の水没による損傷 安全衛生上の問題
薬品等漏洩	機器類の損傷 周辺の住民、環境を含めた安全衛生上の問題
機器故障	施設の機能への長期の影響（迅速な修理が行われない場合）
配管の損傷	施設の機能への長期の影響（迅速な修理が行われない場合）

出典：下水道施設維持管理指針 2014 年に基づいて JET が作成

(4) 安全衛生計画

職場において労働災害が発生していないとしても、それは必ずしも「労働災害の危険性がない職場」であることを意味するものではなく、労働災害の危険性は常に内在していることを認識しなければならない。（下水道施設維持管理指針 2014 年）

職場において安全衛生を管理するための「労働安全衛生委員会」を設置し、委員会の中で安全衛生の管理体制、管理方法を示した安全衛生計画を策定する必要がある。

1) 管理体制

各職場では、例えば足場組立、酸欠作業、クレーン作業等の危険を伴う作業について作業責任者を選定し、また電気工事やガス溶接、ボイラ取り扱い等について資格保持者を充てるなどの管理体制を確立する必要がある。

2) 管理方法

i) 安全衛生教育

職員が職務遂行上生じる安全衛生に必要な知識を得るためには教育が重要である。教育は新しく職員を雇用した際、作業内容を変更した際、職員に危険・有害な作業をさせる際に必要となる。**表 5-1.4** は教育の具体例を示している。表の事項以外に、例えばアーク溶接、電気工事、クレーン、酸欠危険個所作業が必要な場合には、それらの安全な業務実施のための教育を行う必要がある。

表 5-1.4　安全衛生教育事項例

1	機械類、原材料等の危険性、有害性、取り扱い方法
2	安全装置、有害物抑制装置、保護具の性能と取り扱い方法
3	作業手順
4	作業開始時の点検
5	業務に関して発生する可能性のある疾病の原因と予防方法
6	整理、整頓、清潔、清掃、しつけ
7	事故等における応急措置、待避

出典：下水道施設維持管理指針 2014 年に基づいて JET が作成

ii)　職場における危険

各職場の安全衛生委員会において、職場に潜む様々な危険（例えば落下、酸欠、有毒ガス、回転機器、高電圧等）を把握し、業務を安全に実施するために必要な取り組み（例えば正しい服装、整理整頓、安全点検、作業標準（SOP）の励行、災害時の避難訓練等）を行う。

iii)　作業環境確保

国の定める安全基準や作業基準に基づいて、空気環境（臭気、有害ガス、酸素等）、温熱環境（温度、湿度）、照度環境（作業に適した明るさ）、作業空間（通路幅、床面の保全）等の作業環境を確保する。

iv)　応急措置

労働災害発生時における連絡体制、救急搬送先等に加えて、現場における救急措置について検討しておく必要がある。下水道の現場では下水を取り扱っており、また酸欠等の危険が潜在するため、傷の手当、止血法、人口呼吸法等について専門家を講師とする研修を定期的に実施する必要がある。

v)　安全器具・保護具

作業現場ではヘルメット、安全靴を使用し、高所作業では安全帯、閉所作業では換気装置、空気呼吸器、酸素濃度計、ガス検知器、その他防塵マスク、耳栓等を必要数用意し、使用方法について定期的に研修を実施する必要がある。

5-1-2 日常点検

日常点検管理は設備を適正に維持するための基本的な管理であり、運転管理および定期点検・修繕管理との相互補完関係をなす重要な業務である。

日常点検業務は点検者の五感、各種計器の指示値、簡易な工具・計測器などを用いて巡回点検し、運転状態の日常的傾向や異常の有無などを把握し、故障や機能低下を未然に防止することを目的としており、設備の運転状況に関わる簡易診断に相当する管理である。

また、計画的設備管理を適正に行うために、日常点検結果を継続的に記録することが重要である。（下水道施設維持管理指針 2014 年）

そのため、点検項目、点検ルート、点検方法（目視、数値等）、点検頻度、点検基準（適正な数値の範囲等）を定めた日常点検計画を策定し、それに基づいて日常点検を実施し、点検記録を作成する。**表 5-1.5** には日常点検項目の例を示す。

表 5-1.5　日常点検項目の例

点検項目	詳細
官能点検	異音、異臭、振動、発熱等のチェック
計器指示値	電流値、圧力等の計器指示値が正常範囲かどうかの確認
潤滑状態	油温、油面レベル、油漏れ等のチェック
設備締結部	緩み等のチェック
劣化状況	錆、腐食、変形、亀裂、損傷等の劣化状況の確認
環境状態	点検ルートにおける異音、異臭、汚れ等のチェック

出典：下水道施設維持管理指針 2014 年、排水処理施設維持管理（東京都）に基づいて JET が作成

5-1-3 定期点検・修繕管理

定期点検・修繕管理については、①設備の重要度ランクの設定、②管理方式の選定、③管理基準の設定、④管理計画・実績表の作成の順に実施する。

i)　設備の重要度ランクの設定

設備の重要度ランクの設定は**表 5-1.6** に示した評価項目に基づいて実施する。

表 5-1.6　設備の重要度ランク評価項目

1	処理機能への影響度
2	安全性（人災、公害、二次災害）への影響度
3	予備機（予備能力）の有無
4	修繕交換費用、修繕交換期間への影響度
5	機器等の経過年数
6	運転負荷（日常運転、緊急時運転）への影響度
7	法的規制の有無

出典：下水道施設維持管理指針 2014 年に基づいて JET が作成

ii)　管理方式の選定

重要度ランク分けにより重要度が高いと判定された設備については、故障停止が発生しないように「予防保全」を選択する。一方、重要度が低い、予備機が備わっている設備については「事後保全」を選択する。

iii)　管理基準の設定

設備の修繕や部品交換を計画的に実施するためには、劣化状況を数値で確認する必要がある。そのため、各設備について摩耗等の劣化状況を判断する管理基準を設定し、基準に応じて修繕や部品交換を実施する。

iv)　管理計画表、実績表の作成

長期的展望にたって設備の信頼性を保証し、経済的・効率的な設備管理を展開するために、具体的な管理計画表を作成する。表は単年度の計画を立てるだけでなく、数年にわたるマクロ的視野のもとで長期計画表を作成する必要がある。

表 5-1.7 は水中ポンプの長期管理計画表の事例であり、本体、軸受、水中モータ、保護装置について点検頻度と点検内容、及び部品交換とメーカーによる補修の頻度を示している。

表 5-1.7　長期管理計画表（事例）

<table>
<tr><th rowspan="2">水中ポンプ</th><th colspan="8">点検頻度</th><th rowspan="2">点検内容</th><th rowspan="2">部品交換
メーカー補修</th></tr>
<tr><th>1日</th><th>7日</th><th>1ヵ月</th><th>3ヵ月</th><th>6ヵ月</th><th>1年</th><th>2年</th><th>3年</th></tr>
<tr><td>本体</td><td>＊</td><td></td><td></td><td></td><td></td><td>✔</td><td></td><td></td><td>＊：異音、振動、圧力
✔：摩耗、腐食</td><td rowspan="4">部品交換：
2~5年
メーカー補修：
5~8年</td></tr>
<tr><td>軸受</td><td></td><td></td><td></td><td></td><td></td><td></td><td>✔</td><td></td><td>✔：給油、交換</td></tr>
<tr><td>水中モータ</td><td></td><td></td><td></td><td></td><td>✔</td><td></td><td></td><td></td><td>✔：絶縁抵抗</td></tr>
<tr><td>保護装置</td><td></td><td></td><td></td><td></td><td></td><td>✔</td><td></td><td></td><td>✔：導通、作動チェック</td></tr>
</table>

出典：下水道施設維持管理指針 2014 年に基づいて JET が作成

5-2　下水道施設 O&M 体制

本プロジェクトで提案する下水道区域の下水管路施設、ポンプ場、下水処理場の適切な O&M のための組織体制、業務分担について以下に示す。

5-2-1 予算と実施体制

下水道施設の適切な O&M には、O&M 体制の確立と同時に予算の確保や各種実施体制の確立が重要である。

(1)　O&M に係る予算

現在のところ WAF では人員不足、予算不足により、機械・電気設備はオイル交換のような基本的な整備すらほとんど実施されておらず、下水処理場やポンプ場に設置された様々な機械・電気設備は劣化が著しい。設備は重要度の判定、劣化状況の診断に基づいた優先度を考慮した保全による長寿命化を図り、通常の耐用年数を超えて使用することにより、トータルコストの削減が可能となることを認識し、予防保全のための交換部品や消耗品類等の予算を確保する必要がある。

また、適切な保全を実施していても設備は故障停止することがある。このような故障に対しては、設備の重要度に応じて速やかに修繕を実施するための予算は常に確保しておく必要がある。また、将来的にはコンセッション契約等の PPP による下水道施設の O&M による下水道事業の効率化を検討する必要がある。

(2)　職員の待遇改善

下水道施設の O&M には現場職員の経験と知識が極めて重要である。WAF によれば、職員給与は国内の一般企業に比較して低くないが、経験豊富な現場職員が離職してオーストラリア等の給与の高い国に移住する事例が頻出しており、下水道施設の現場でナレッジの継承が難しい状況にある。

このような状況の改善のためには、職員の給与体系の見直しが必要である。もし、給与に改善が困難な場合は、O&M の質を確保するために、業務を大幅に民間委託することを検討する必要がある。

(3)　委託業務実施のための手続きの簡素化

機械電気設備については、適切な保全を行っていても故障停止が発生する場合がある。各設備はその重要性、予備機の有無等により優先度を予め定めて、それに従い故障時に緊急修理できるようにメーカーや修理業者との修理契約を迅速に結ぶことが必要である。

(4) 複雑な処理施設の O&M における業務委託化

消化ガス発電等の施設を導入する際には、運転操作や機械電気設備の整備が極めて複雑になるため、運転操作と点検整備のメーカー等への委託による実施を検討する必要がある。そのため、必要な予算の確保と共に、メーカー等と円滑に契約を締結する必要がある。

(5) 提案する下水処理場 O&M 業務の内容と実施方法

下水処理場の O&M 体制は下水処理方式により変わる。Nadi の Navakai 下水処理場で提案されている OD 法や既存の IDEA 法、Natabua 下水処理場で提案されている TF 法等では設置された様々な機器類の適切な運転操作と、最適な処理水質を得るための活性汚泥濃度等の運転条件を変更するため、運転操作職員が巡視・点検、簡易な水質試験を行い、運転状況を常時把握する必要がある。

表 5-2.1 には機械式の下水処理場における日常的な巡視・点検業務を示した。O&M 担当職員が処理現場で、表に示した項目について点検して記録する。

表 5-2.1 機械式下水処理場における巡視・点検業務

項目	業務の詳細
処理状況の目視点検	➢ 異臭：例えば、スクリーン設備、し渣集積場所、反応槽、沈殿槽、側溝等における腐敗臭 ➢ 異常な色：例えば活性汚泥や処理水の腐敗による黒色化
機械・電気設備の稼働状況	➢ 故障停止、異音、異常振動等 ➢ 機械設備の稼働状況 ➢ 温度、電流、電圧と等指示値のチェックと記録

出典：下水道維持管理指針 2014 年に基づいて JET が作成

日本において、職員が常駐する下水処理場では毎日、定時に気温、水温、透視度、pH、活性汚泥沈降率（SV）等の簡易な水質項目の試験をするように示されている。（下水道維持管理指針 2014 年）

一方、西部地区 4 下水処理場の水質は月に 1 回の頻度で WAF 中央の水質試験室が実施する試験以外には水質試験は実施されていない。これは、現場職員に水質測定の重要性や測定方法についての知識がなく、また測定に必要な資器材が備わっていないためである。日常的水質試験は O&M の状況を判断する重要な業務であり、WAF においては改善が必要である。

表 5-2.2 には機械式下水処理場において推奨される日常的水質試験項目、試験の目的、及び実施方法を示した。表中の活性汚泥溶存酸素濃度（MLDO）の測定には計器が必要であり、WAF で調達できるまでの間は、透視度と活性汚泥沈降率（SV）の測定が推奨される。

表 5-2.2　機械式下水処理場における日常的水質試験業務

項目	試験の目的	実施方法
透視度	✧シリンダーだけで測定が可能である。 ✧処理水の透視度は浮遊物資濃度（SS）やBODとの相関があり、処理水質の目安となる。	✧定時に処理水の透視度測定し、記録に残す ✧定期的に透視度のデータをグラフ化（横軸：月日、縦軸：透視度）し、月間、年間の変化を観察 ✧透視度とSVのデータをグラフ化（横軸：透視度、縦軸：SV）し、反応槽内の活性汚泥濃度が高すぎる、低すぎる場合の処理水質に与える影響を解析
活性汚泥沈降率(SV)	✧シリンダーだけで測定が可能である。 ✧活性汚泥濃度の目安となる。 ✧IDEA 法では、汚泥の沈降性により、IDEA槽における必要な沈殿時間を推計できる。	✧定時に反応槽活性汚泥のSVを測定し、記録に残す。 ✧定期的にSVのデータをグラフ化（横軸：月日、縦軸：SV）し、反応槽からの汚泥の引き抜き時期の目安とする。
活性汚泥溶存酸素(MLDO)	✧送気量を制御する基準となる。 ✧活性汚泥微生物が活発に活動できるかどうか監視できる。 ✓　測定機器の調達が必要である。	✧定時に反応槽の溶存酸素濃度（MLDO）を測定し、記録を残す。 ✧MLDOが低すぎると活性汚泥微生物の活動が低下し、処理性能が低下する。

出典：下水道維持管理指針 2014 年に基づいて JET が作成

Navakai 下水処理場の IDEA 槽では現在のところ定期的な汚泥の引き抜きは行われておらず、汚泥濃度が高くなりすぎて処理水質が悪化するという現象が見られる。そこで、表に示したように、処理水の透視度と SV の測定を継続的に実施してデータを蓄積し、データに基づいて両者の関係を図示することにより、どの程度 SV が高くなる（活性汚泥濃度が高くなる）と処理水の透視度が低下するか（処理水質が悪化するか）を把握して、適切な汚泥引き抜きを実施する必要がある。透視度と活性汚泥沈降率（SV）については、測定機材を用意し、既に Navakai 下水処理場で OJT による測定方法の指導が行われ、現場で測定が継続されている。

巡視・点検、水質試験の結果は所定の記録用紙に記入して、適切に保管する。異常が発見された際には、**表 5-2.3** に示した項目を含む報告書を作成して上申する。報告を受けた上司は対応方法を報告書に記して指示する。報告書は O&M 上の貴重な情報となるため、適切に保存する。

表 5-2.3　異常に関する報告書の記載項目

報告項目	発見者の名前：
	発見した日時：
	異常のある施設、設備：
	異常の具体的な状況：
	考えられる原因：
	考えられる対応策：
上司の指示	上司の名前
	報告に対する対応方法の指示
指示に対する対応	対応者の名前
	対応した日時
	対応の結果の状況
	更なる対応の必要性

出典：JET

下水処理場では巡視・点検、日常的水質試験の実施にあたり、担当する職員に実施の意義、実施方法、記録・報告方法について研修を行って周知徹底を図る必要がある。

(6) 提案する組織

下水処理場の O&M を実施する組織体制は下水と汚泥の処理方式により異なる。Natabua と Navakai 下水処理場の処理方式と処理能力、及び提案する O&M 方式は**表 5-2.4** に示したとおりである。

表 5-2.4　2 下水処理場の処理方式と処理能力

都市	下水処理場	下水処理		汚泥処理方式	O&M 体制
		処理方式	処理能力 (m^3/日)		
Lautoka	Natabua	散水ろ床法	44,400	生汚泥：濃縮⇒消化⇒脱水⇒天日乾燥 余剰汚泥：消化⇒脱水⇒天日乾燥 腐敗槽汚泥：脱水⇒天日乾燥 * 他下水処理場から生汚泥を消化槽に受け入れ * 6 都市から腐敗槽汚泥を受け入れ	体制-1
Nadi	Navakai	OD 法	29,800	余剰汚泥：脱水⇒天日乾燥	体制-1

出典：JET

表の O&M 方式に示した体制-1 の具体的な O&M 実施方法は**表 5-2.5** に示すとおりである。

表 5-2.5　O&M 実施方法

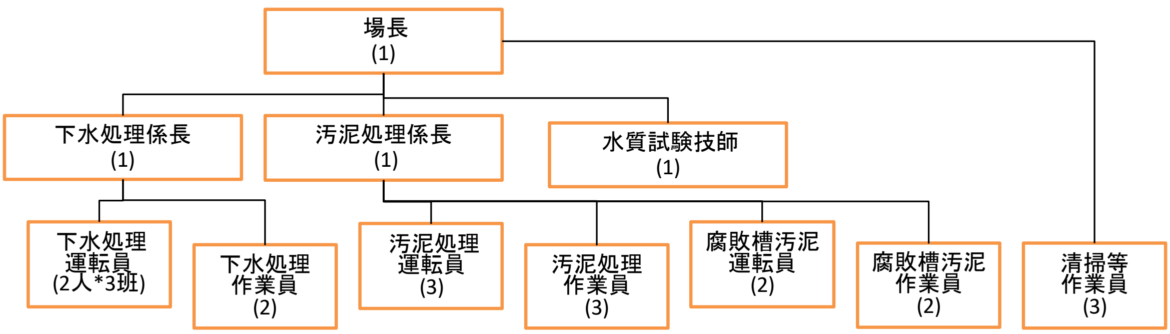
体制-1	運　　転	3 交代で下水処理、汚泥処理施設の運転
	維持管理	昼間に施設の巡視、点検整備作業
	水質試験	pH、透視度、SV（OD 法の場合）溶存酸素等の簡易水質試験

出典：JET

5-2-2 全体計画に対する人員体制

(1) Natabua 下水処理場

Lautoka の Natabua 下水処理場では下水処理に二段式の TF 法、汚泥処理に濃縮・嫌気性消化・脱水・天日乾燥を提案している。Natabua 下水処理場では Navakai 下水処理場を除く他の 3 下水処理場からの濃縮汚泥、及び Ba 州と Ra 州の腐敗槽汚泥を嫌気性消化槽に受け入れる計画である。なお、下水処理場に建設予定のバイオガスの有効利用施設は運営を民間に委託する予定のため、消化槽及びバイオガス有効利用施設の O&M は提案する組織には含まれない。提案する組織は**図 5-2.1** に、図中の各担当の提案する職務は**表 5-2.6** に示したとおりである。



出典：JET

図 5-2.1　Natabua 下水処理場の組織図（提案）

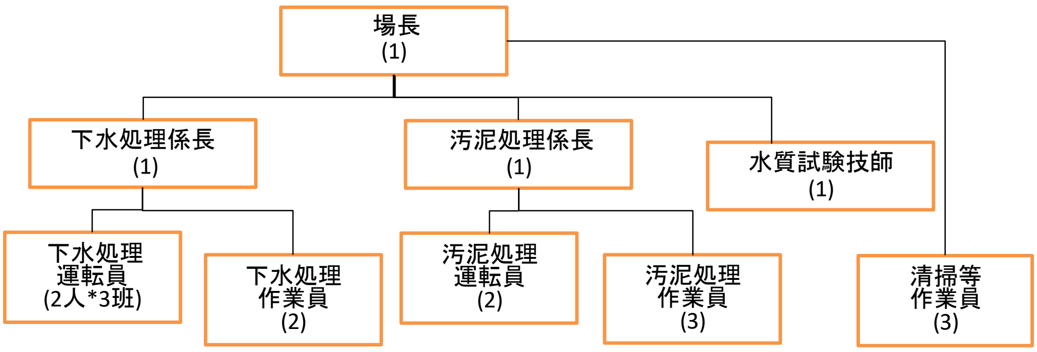
表 5-2.6　Natabua 下水処理場各担当の職務（提案）

職位		主な職務
場長		下水処理場の運営管理
下水処理	下水処理係長	下水処理施設の運転管理／運転日報、月報の管理
	下水処理運転員	3 交代シフト 下水処理施設の運転操作／処理状況の目視点検／機械電気設備の稼働状況点検／運転日報の作成
	下水処理作業員	目視点検、稼働状況点検の補助／スクリーンし渣、スカム除去作業
汚泥処理	汚泥処理係長	汚泥処理施設、腐敗槽汚泥処理施設の運転管理／腐敗槽汚泥受け入れ、処理施設の運転管理／汚泥処理、腐敗槽汚泥処理日報の管理
	汚泥処理運転員	汚泥処理施設の運転操作／凝集液の調整／汚泥含水率の測定／汚泥処理日報の作成
	汚泥処理作業員	凝集液の調整補助／汚泥処理施設の清掃
腐敗槽汚泥処理	腐敗槽汚泥運転員	腐敗槽汚泥の受け入れ業務／腐敗槽汚泥処理施設の運転／受け入れ日報、処理日報の作成
	腐敗槽汚泥作業員	腐敗槽汚泥受け入れ補助作業／腐敗槽汚泥処理施設の運転補助／施設の清掃
水質試験技師		日常水質試験の実施／試験日報の作成／他下水処理場の水質データの管理
清掃等作業員		下水処理場内の整理整頓、清掃／その他雑務

出典：JET

(2)　Navakai 下水処理場

Nadi の Navakai 下水処理場では下水処理には OD 法を、汚泥処理には脱水・天日乾燥を提案している。施設の規模は大きく、また放流水が SEZ を遵守する必要があるため、他下水処理場に比較して運転管理に注意を払う必要がある。提案する組織は**図 5-2.2** に、また図中の各担当の提案する職務は**表 5-2.7** に示したとおりである。



出典：JET

図 5-2.2　Navakai 下水処理場の組織図（提案）

表 5-2.7 Navakai 下水処理場各担当の職務（提案）

職位		主な職務
場長		下水処理場の運営管理
下水処理	下水処理係長	下水処理施設の運転管理／運転日報、月報の管理
	下水処理運転員	3 交代シフト 下水処理施設の運転操作／処理状況の目視点検／機械電気設備の稼働状況点検／運転日報の作成
	下水処理作業員	目視点検、稼働状況点検の補助／スクリーンし渣、スカム除去作業
汚泥処理	汚泥処理係長	汚泥処理施設の運転管理／汚泥処理日報の管理
	汚泥処理運転員	汚泥処理施設の運転操作／凝集液の調整／汚泥含水率の測定／汚泥処理日報の作成
	汚泥処理作業員	凝集液の調整補助／汚泥処理施設の清掃
水質試験技師		日常水質試験の実施／試験日報の作成／他下水処理場の水質データの管理
清掃等作業員		下水処理場内の整理整頓、清掃／その他雑務

出典：JET

5-2-3 第 1 期整備時の人員体制

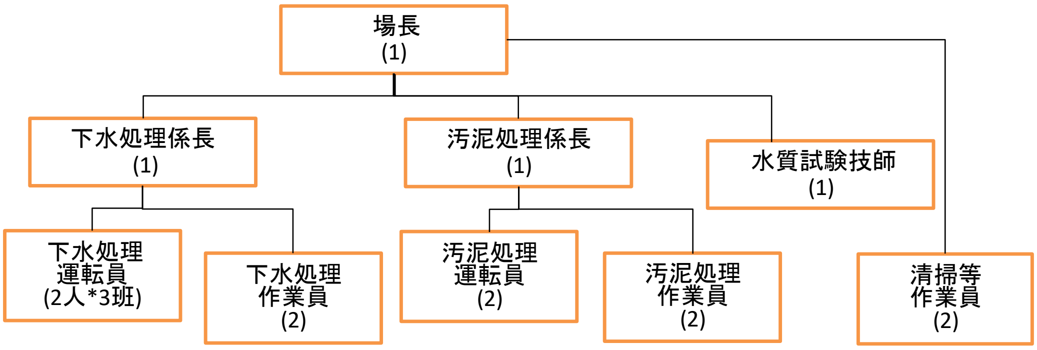
(1) 全体計画時と第 1 期の人員体制の差異

第 1 期の下水道プロジェクトでは Lautoka の Natabua 下水処理場に全体計画の 3/4 にあたる処理能力 30,000 m^3/日の TF 法施設が、Nadi の Navakai 下水処理場に全体計画の 2/3 にあたる 20,000 m^3/日の OD 法施設が建設される予定である。下水処理場 O&M は自動化が進んでいるため、下水・汚泥処理施設の必要な運転員数は施設規模の多少の増減には影響されない。一方で、現場の機器洗浄、清掃等の作業は機器点数の増減で必要人数が増減する。

そのため、Natabua 下水処理場、Navakai 下水処理場ともに、下水処理・汚泥処理運転員数は**図 5-2.1**、**図 5-2.2** に示した提案組織図と変更はない。

一方、作業員数について Natabua 下水処理場で**図 5-2.1** のとおり汚泥処理作業員 3 人、腐敗槽汚泥処理作業員 2 人、下水処理場全般作業員 2 人を提案しているが、第 1 期に 3/4 施設が稼働した場合に必要な人数は 3 人×3/4＝2.25 人、2 人×3/4＝1.5 人となり、切り上げて 3 人と 2 人と**図 5-2.1** の提案と同数となる。そのため、**図 5-2.1** の提案図のとおり、全体計画より変更はない。

Navakai 下水処理場では**図 5-2.2** のとおり汚泥処理作業員 3 人、下水処理場全般作業員 2 人を提案しているが、第 1 期に 2/3 施設が稼働した場合に必要な人数は 3 人×2/3＝2 人、2 人×2/3＝1.3 人となり、汚泥処理作業員が**図 5-2.2** の提案より 1 人少なくなる。そのため、第 1 期における Navakai 下水処理場の組織体制は**図 5-2.3** のとおりとなる。



出典：JET

図 5-2.3　第 1 期 Navakai 下水処理場の組織図（提案）

両下水処理場で新規の下水処理施設が建設された段階で、適切な O&M を実施するためには、先ず既存の Navakai 下水処理場において必要な O&M 予算を確保し、故障機器の修繕を行ったうえで、運転職員の能力強化を図り、将来的な両下水処理場の運転職員を育成して O&M を実施できることが重要となる。

このような職員の育成は現在の WAF では実施が困難であり、例えば JICA の技術協力プロジェクトの中で能力強化を図ることにより、新たに建設される下水処理場の適切な O&M 実施体制を作るのが効果的である。

(2)　水質試験室

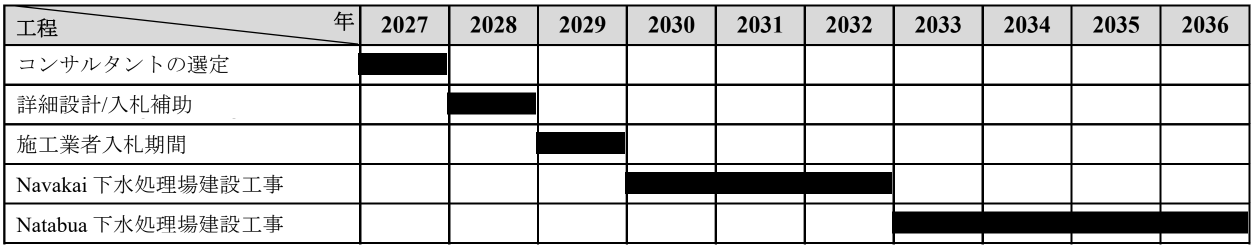
フィジーでは BOD や SS 等の一般項目に加えて重金属類、シアン等の有害物質について排水基準が設けられている。しかしながら、分析器材の整備が進んでいないため、WAF の水質試験室でも全ての規制項目を適切に分析できるわけではなく、また発生する汚泥中の重金属類については全く分析ができない状況にある。そのため、下水処理場の水質管理、下水汚泥の管理、事業所排水の規制のために、水質試験室の分析器材の整備、試験員の能力強化が必須である。また、下水処理場で OD 法等の機械式処理方式が導入されると、最適な処理条件の設定のために現場における日々の水質チェックが重要となり、各下水処理場に溶存酸素や活性汚泥濃度等の簡易な項目の測定できる水質試験室を設ける必要がある。Natabua 下水処理場と Navakai 下水処理場では**図 5-2.1**、**図 5-2.2** のとおり水質試験員 1 人を置くように提案している。

このような提案の実現のためには下水処理場 O&M に関して経験の乏しい WAF の努力だけでは困難であり、そのためには、JICA の技術協力プロジェクトの中で必要な資器材を整備し、それを用いた水質試験員の能力強化を図るのが効果的である。

第6章 事業実施計画

6-1 事業実施スケジュール

本 Pre-F/S にて設定した Natabua 処理区、Navakai 処理区の整備スケジュールを踏襲し、事業実施スケジュールは図 **6-1.1** の通りとした。2 下水処理場の整備を前倒しで実施する可能性を残すとの WAF からの意見を踏まえ Water Sector Strategy 2050 のスケジュールは適用しない。なお、施設建設終了は、Natabua 下水処理場で 2036 年頃、Navakai 下水処理場で 2032 年頃と想定される。



出典：JET

図 6-1.1　第 1 期実施工程

実施スケジュールの想定にあたって**表 6-1.1** に示す必要期間を見込んでいる。

表 6-1.1　各フェーズの必要期間

項目	期間
F/S調査	1年
コンサルタント選定	1年
詳細設計	1年
施工業者入札期間	1年
建設期間（Natabua下水処理場）	4年
建設期間（Navakai下水処理場）	3年

出典：JET

6-2 建設費・維持管理費の積算

(1) 建設費算定の前提条件

Pre-F/S にて各施設の概略設計を行った。土木関連の概略数量に単価を乗じる事で概略建設費を積算する。建設費算定の前提条件を挙げれば下記のとおりである。

- 基本的な土木工種は概略数量×概略単価による建設費算定とする。
- 土木工種の主要項目についてはフィジーの単価を参照とし、入手が困難な単価は日本や第 3 国の事例を参照した単価を採用する。
- 主要な機械設備費はフィジー国での見積もりに準拠し、主要な電気設備費は日本の見積もりに準拠して積算する。その他小規模な設備は日本の単価を元に算定する。

- 下水処理場における用地取得費は MOF[2]の要望に準じ含めている。ただし、実際の下水処理場用地の土地種別等により用地単価も大きく異なるため、ここで試算した用地取得費は今後の変更が予定される。
- 土木工種の主要な概略単価はコロナ禍およびロシアのウクライナ進行以前のものである。事業費の積算にて価格予備費を適切に見込む方針とする。

以下に各施設の積算結果を示す。

(2) 下水処理場建設費

土木工種の概略数量を施設規模より想定し、機械電気費も見積額を基に積算した。第 1 期における各下水処理場の建設費を**表 6-2.1** に示す。土地取得費は建設費には含めていない。Natabua 下水処理場で 136 億円、Navakai 下水処理場で 90 億円程度の建設費が見込まれる。

表 6-2.1　各下水処理場（第 1 期）の概略建設費

下水処理場名	処理方式	概略建設費（百万円）				FJD 換算
		土木建築	機械	電気	合計	（million FJD）
Natabua	TF 法	8,646	2,972	1,959	13,578	201
Navakai	OD 法	4,796	2,905	1,283	8,984	133

注記：1 FJD ＝ 67.55 JPY（2024 年 4 月）
出典：JET

(3) 下水処理場維持管理費

維持管理費は電力費・修繕維持費・人件費の積み上げとし、**表 6-2.2** の通り算定した。

表 6-2.2　各下水処理場（第 1 期）の概略維持管理費

下水処理場名	処理方式	概略建設費（百万円）				FJD 換算
		電力費	修繕/維持費	人件費	合計	（1000 FJD/年）
Natabua	TF 法	105	121	24	250	3,700
Navakai	OD 法	137	80	18	235	3,478

注記：1 FJD ＝ 67.55 JPY（2024 年 4 月）
出典：JET

6-3　事業費

(1) 前提条件

事業費算出の条件を**表 6-3.1** に示す。両下水処理場増設の事業費規模はローンプロジェクトの規模ではあるものの、ドナーは決まっていないため参考としての設定値である。

[2] MOF：旧経済省（Ministry of Economy（MOE））

表 6-3.1　事業費算定の設定条件

番号	項目	数値	根拠
1	Exchange Rate	1 USD = 151.37 JPY 1 USD = 2.2409 FJD 1 FJD = 67.5498 JPY	JICA Rate April 2024
2	Price Escalation Rate (Foreign Currency)	2.70 %/year	総務省 2020 年基準消費者物価指数 2024 年 4 月時点
	Price Escalation Rate (Local Currency)	3.60 %/year	Consumer Price Index by Fiji Bureau of Statistics の 4 月時点
3	Physical Contingency Rate	5 %	コスト積算支援ツール実用マニュアル
4	Value Added Tax (VAT)	15 %	フィジー政府 HP より
5	Import Tax	15 %	フィジー政府 HP より
6	Administration Cost	5 %	コスト積算支援ツール実用マニュアル
7	Interest rate (Construction)	2.00 %	円借款供与条件表
	Interest rate (Consulting Service)	0.20 %	円借款供与条件表
8	Front End Fee	0.2 %	コスト積算支援ツール実用マニュアル

出典: JICA

(2)　コンサルティング・サービス費

コンサルティング・サービスとして建設費（Price Escalation、Physical Contingency は含まない）の 10%を計上する。

(3)　用地取得費

用地取得費の計上項目は**表 6-3.2** に示す通りとし、約 25 億円を見込む。乾燥汚泥の保管用地を含む面積であることから、汚泥の有効利用法が決まれば必要な用地費は削減される。

表 6-3.2　用地取得費

下水処理場	新規取得面積 (ha)	用地取得費 (million FJD)	備考
Natabua 下水処理場	42.1	27.4	
Navakai 下水処理場	14.5	9.4	
合計	56.6	36.8	(2,488 million JPY)

出典: JET

(4)　事業費

第 1 期事業費の算出結果を**表 6-3.3** に示す。事業費は 552 億円、借款金額は 370 億円と算出される。土地収用費、VAT、事務管理費および、輸入税からなるフィジー国側の負担は約 182 億円となる。

表 6-3.3　第 1 期事業費及び借款額

項目	外貨 (百万円)	内貨 (百万 FJD)	計 (百万円)
A. FOREIGN PORTION	**29,128**	**116**	**36,944**
I) Procurement / Construction	26,668	106	33,849
ICB1:WWTP1_Const	7,202	27	8,995
ICB2:WWTP2_Const	12,633	46	15,763
Base cost	19,835	73	24,758
Price escalation	5,564	28	7,479
Physical contingency	1,270	5	1,612
II) Consulting services	2,460	9	3,095
Base cost	1,983	7	2,476
Price escalation	253	1	338
Physical contingency	224	1	281
B. BORROWER PORTION	**-**	**229**	**15,949**
I) Procurement / Construction	-	-	-
a. Land Acquisition	-	46	3,118
b. Administration cost	-	30	2,003
c. VAT	-	89	6,009
d. Import Tax	-	65	4,369
TOTAL (A+B)	**29,128**	**345**	**52,444**
C. Interest during Construction	2,626	-	2,626
For Construction	2,573	-	2,573
For Consultant	53	-	53
D. Front End Fee	**79**	-	**79**
GRAND TOTAL (A+B+C+D)	**31,834**	**345**	**55,150**

出典: JET

第7章 環境社会配慮

7-1 Pre-F/S における環境社会配慮

Pre-F/S 段階の環境社会配慮では、優先プロジェクトにおけるスコーピングの検討に加え、今後実施される現地法制度に基づく環境アセスメント（以下、「EIA」という。）報告書の作成及び許認可取得の支援として、公共水域の水質、対象地の土地利用状況についても確認し、Initial Environmental Examination（以下、「IEE」という。）レベルでの調査を実施した。

7-2 環境社会配慮制度・組織

7-2-1 環境社会配慮に係る政策・計画等

APPENDIX 7-1 に下水道セクター開発及び環境社会配慮に係る政策・計画等を示す。

7-2-2 環境許認可手続き

環境管理法の附表 2 Part 1 によれば、DOE による EIA 許認可が必要な事業（Part 1 事業）リストとして「(q) 処分場、コンポストプラント、海洋排水または排水処理施設の建設に関する提案」があり、優先プロジェクトである Navakai 下水処理場及び Natabua 下水処理場の拡張は、これらの事業に該当する。なお、処理水の排水及び汚泥処理については、DOE Pollution Control Unit より排水・廃棄許可を取得することになる（通常は環境許認可の付帯条件として含まれる）。**APPENDIX 7-2** に Part 1 事業における環境許認可手続きの概要を示す。

7-2-3 用地取得手続き

フィジー国の土地所有は先住民保有地（iTaukei land）、自由保有地（Freehold land）、国有地（State/Crown land）の 3 種類に分類されている。フィジー憲法では土地の強制収用を認めておらず、先住民保有地については、公的利用を除いて譲渡不可である。政府による用地取得の場合、いずれの土地形態であっても全ての土地と権利について補償することが定められており、State Acquisition of Lands Act にて具体的な規定がなされている。優先プロジェクトにおいて想定される用地取得手続き（所有権取得、リース、地役権設定）の概要を **APPENDIX 7-3** に示す。

7-3 Natabua 下水処理場

7-3-1 事業概要

第 3 章参照。

7-3-2 環境及び社会の現状

(1) 水質

1) WAF による水質調査

WAF の水質試験ラボでは、Natabua 下水処理場からの排水先である海域において、水質分析を定期的に実施している。**APPENDIX 7-4** に過去 2 年の分析結果を示す。2022 年調査では、排出地点において Faecal Coliforms が 100,000 個/100mL 以上、300m～500m 離れた地点であっても 50,000 個/100mL 以上の検出であった。一方、2023 年調査では排出地点で 6,000～10,000 個/100mL、排出地点以外では 1,000 個/100mL を下回るなど大きく改善されている。これは、2021 年度に実施された池の浚渫による影響が考えられる。なお、日本の環境基準では Fecal Coliforms（糞便性大腸菌群数）は設定されていないが、水浴場水質判定基準[3]と比較すると、2023 年においては排出地点以外では水浴場「可」（判定基準値 1,000 個/100mL 以下）に相当する。

2) プロジェクトによる水質調査

F/S 段階にて実施される環境影響評価に向けたデータ収集の一環として、周辺の公共用水域における水質調査（雨季・乾季）を実施した。この調査では表流水に加えて下層水（2～5m）の調査も行った。調査結果を **APPENDIX 7-5** に示す。調査地点は異なるものの、表流水については、いずれの地点でも前述の 2023 年の WAF 調査結果と概ね類似した水質であり、下層水についても表流水と類似した水質であった。

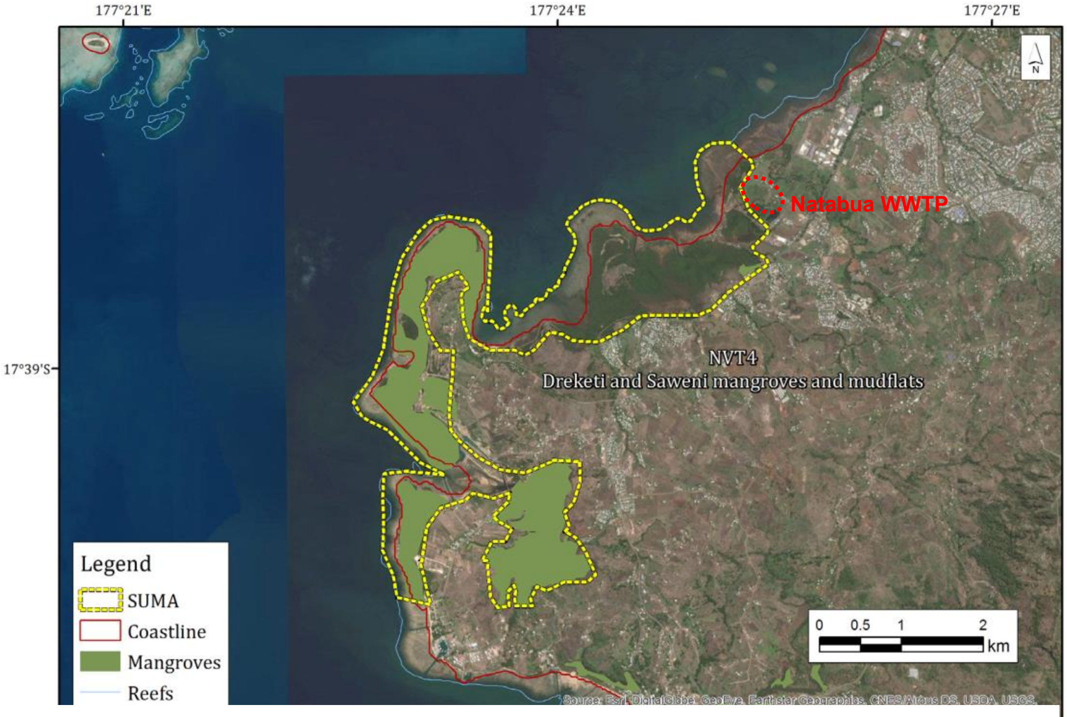
3) SPD による水質等調査

Natabua 下水処理場では、Lautoka にある South Pacific Distilleries（SPD）から持ち込まれる蒸留酒製造工程で発生する廃水を海洋放流管に直接接続し、下水処理場の処理水と一緒に海洋放流している。SPD では、海洋放流口付近の水質や底質、生物のモニタリング調査を毎年実施しており、その調査報告書を WAF に提出している。ここでは 2018～2022 年の過去 5 年間に実施された調査報告書のレビューを行った（**APPENDIX 7-8**）。ただし、SPD のモニタリング項目に大腸菌関連の指標は含まれていない。

(2) 自然環境[4]

対象地周辺には自然保護・文化遺産保護の指定地域は存在しない。ただし、Natabua 下水処理場は沿岸湿地に位置しており、DOE 及び Ministry of Fisheries が海洋保護区の追加指定に向けて特定した、重要な海洋生態系を有する地域（Special Unique Marine Areas（SUMAS））が隣接している（**図 7-3.1**）。

[3] 環境省, 水浴場水質判定基準 https://www.env.go.jp/content/000141595.pdf (Japanese)
[4] National Biodiversity Strategy and Action Plan for Fiji 2020-2025 及び Biophysically Special, Unique Marine Areas of Fiji



Biophysical Justification of NVT4: Coastal and inland mangrove connectivity, mud crabs, mud lobsters, juvenile reef fish, shorebirds.

出典：Biophysically Special, Unique Marine Areas of Fiji

図 7-3.1　対象地周辺の SUMA（NVT4: Dreketi and Saweni mangroves and mudflats）

(3) 社会環境

1) 社会経済状況

Natabua 下水処理場の位置する Lautoka における主な社会経済指標を **APPENDIX 7-6** に示す。

2) 土地利用

Natabua 下水処理場は Lautoka 郊外、海岸沿いのマングローブ林や湿地と住宅地に挟まれた平坦な場所にある。対象地周辺の土地及び水域の利用について以下に示す。

東：	対象地に隣接して Queens Road 沿いは民間企業の利用地であり、Queens Road を挟んで住宅地（Natabua settlement）となっている。南東約 1km 付近に学校（Natabua Primary School、St. Thomas High School 及び Fiji National University）と病院（Natabua Health Center）が位置している。
西：	隣接して海岸沿いにマングローブ林及び湿地がある。
南：	隣接してマングローブ林及び湿地が広がっている。拡張エリア予定地内にはマングローブ林と湿地の他、南側に Informal settlement が位置している。
北：	既存下水処理場北側に小さなコミュニティ（Saru 及び Taiperia）が立地している。最も近い住居は北側敷地境界から 50m 程である。
水域：	周辺住民によるマングローブ林内でのカニ等の採取活動が時々行われている。排水先は海岸から 2km 以上離れているが、この周辺での漁業活動については不明である。

3) 用地取得

本事業では、既存施設に隣接する土地の取得が必要である。そこで、地籍図及び現地踏査など現時点で入手可能な情報を基に、土地目録を作成した。**APPENDIX 6-7** に土地利用目録を示す。

4) 非自発的住民移転

既存下水処理場の南側には非正規居住者（Informal Settlement）の集落 Naqiroso Settlement があり、18 軒の住居が大規模ではないものの非自発的住民移転の対象となる。なお、MHCD では非正規集落の公認化（Formalization）を進めており、西部地区長官へのヒアリングでも MHCD や各自治体、TLTB などの関連機関が連携して非正規集落の公認や、必要に応じた移転を実施しているとのことであった。

7-3-3 スコーピング

表 **7-3.1** にスコーピングを示す。

表 7-3.1　スコーピング（Natabua 下水処理場）

項目			スコーピング		根拠
			建設	運用	
汚染対策	1	大気汚染	X		建設：建設機械により粉塵や排気ガスが一定期間発生する。 運用：大気汚染などの影響は想定されない。
	2	水質汚濁	X	X	建設：建設工事により濁水が下流域で一時事的に影響を及ぼす可能性がある。 運用：下水処理は一般的に周囲の水質改善に貢献する。一方、処理パフォーマンスが低下した場合は周辺環境の水質に悪影響を与える可能性がある.
	3	廃棄物	X	X	建設：廃土・廃材が発生する。 運用：作業員が排出する固形廃棄物やゴミの清掃以外にも、下水処理によって発生する汚泥を適切に処理・処分する必要がある。
	4	土壌・地下水汚染	X	X	建設：油漏れ等により土壌汚染が発生する可能性がある。 運用：油漏れ等の他に、生下水の溢水によって汚染が発生する可能性がある。
	5	騒音・振動	X	X	建設：建設工事や機械より騒音・振動が発生する。 運用：処理場内のポンプやモーター等より騒音・振動が発生する。
	6	地盤沈下			用地は平坦な地形のため、地盤沈下は発生しないと見込まれる。
	7	臭気	X	X	工事：建設工事が稼働中の既存施設の処理に悪影響や支障をきたした場合、臭気が発生する可能性がある。 運用：適切な脱臭設備の設置・運用により、臭気問題は改善すると考えられる。一方で処理パフォーマンスが低下した場合、臭気が発生すると考えられる。
	8	底質	X	X	建設：放流管の設置工事中に沿岸地域の底質が一時的に乱される可能性が考えられる。 運用：処理水質の改善に伴い水域の底質も改善される可能性がある。 一方で処理パフォーマンスが低下した場合、底質が悪化する可能性も考えられる。
自	9	保護区			Lautoka 市内及びその近辺に保護区は確認されていない。

項目			スコーピング		根拠
			建設	運用	
	10	生物多様性	X	X	建設：隣接する海岸線にある重要な海洋生態系を有する地域（SUMA）NVT4 の環境が建設工事により一時的に乱される可能性が考えられる。 運用：維持管理が適切に行われない場合、SUMA の環境劣化を引き起こす可能性が考えられる。
	11	水象	X		当該地域はサイクロンやモンスーンによる洪水、暴風、高潮などの影響を受けやすいため、施設設計でこれらの影響を考慮する必要がある。
	12	地形・地理的特徴	X		当該用地はマングローブ林や干潟が存在する海岸線の近辺に位置しているため地形が変化する可能性がある。
社会環境	13	非自発的住民移転および土地取得	X		建設：Natabua 下水処理場の拡張・新施設建設には土地の取得と、小規模な非自発的移住が必要となる。
	14	貧困	X	X	処理場の南西には非正規居住地があり、建設にあたって移転が必要となる。これらの非正規居住地については地方自治体と協議を行い、慎重に対応を検討する必要がある。
	15	少数民族および 先住民族			世界銀行セーフガードポリシーに定義される先住民族は確認されていない。 iTaukei はフィジーの先住民族として法的に認められており、伝統文化と習慣はフィジーの法律の下で尊重・保護されている
	16	地域経済（雇用、生活など）	X	X	建設：土地取得と非自発的住民移転が非影響住民の生活に負の影響を及ぼす可能性がある。 一方で、建設工事が地元住民に雇用の機会を提供することも考えられる。
	17	土地利用および 地域資源	X	X	マングローブ林や干潟を食材採取の場として利用している地元住民が土地開発の影響を受ける可能性がある。
	18	水利用	X		建設：建設工事が一時的に周辺海域の水環境に影響を及ぼす可能性がある。 運用：運転開始後に放流水質が改善されることによって、水環境が改善されると考えられる。
	19	既存の社会インフラ・サービス	X		建設：建設工事によって工事車両の出入りが増加し、交通に支障が生じる可能性がある（迂回や一時的な通行止めなど）。 また、電気、ガス、水道管が工事の影響を受ける可能性がある。
	20	社会制度 （地方の意思決定機関など）			フィジーでは iTaukei 制度が法的に制度化されているため、意思決定プロセスや社会制度への影響はないと考えられる。
	21	利益と損害の不公平な分配 / 地域的な利益相反		X	用地取得プロセスが不十分である場合、利益の不当な分配や、地域住民間の利害対立が生じる可能性がある
	22	文化遺産			サイト内に伝統的または文化的遺跡は確認されていない
	23	景観			西部地区は観光地であるため、施設設計や建設工事期間中の外観に配慮が必要となる。
	24	ジェンダー / 子どもの権利			ジェンダーや子どもの権利への影響はないと考えられる。 ただし、サイトから 1km ほど南に学校があることから、配慮が必要になる可能性がある。
	25	衛生と感染症 （HIV/AIDS）			下水処理場の処理システム改善により衛生環境が向上し、感染症のリスクが軽減されることが期待される。
	26	労働環境（労働安全を含む）/事故	X	X	建設：建設作業員の労働環境を考慮しなければならない。 運用：維持管理作業中にガス中毒や酸欠が発生する可能性

項目			スコーピング		根拠
			建設	運用	
					があるため、作業員の労働環境を考慮しなければならない。
その他	30	気候変動	X	X	建設：建設工事用の重機からの CO_2 の排出が見込まれる。 運用：下水・汚泥処理により GHG（CH_4 および CO）が発生する。

Const.: Before/during construction
Ope.: During operation
出典：JET

7-4 Navakai 下水処理場

7-4-1 事業概要

第 3 章参照。

7-4-2 環境及び社会の現状

(1) 汚染対策

1) WAF による水質調査

WAF の水質試験ラボでは、Navakai 下水処理場からの排水先であるナンディ川にて水質分析を定期的に実施している。**APPENDIX 7-4** に過去 2 年の分析結果を示す。排出地点とその上下流の地点（かなり離れた Denarau Bridge 地点を除く）の Faecal Coliforms を比較すると、排出地点で最も高く、下流が最も低い値となっている。なお、日本の環境基準では Faecal Coliforms（糞便性大腸菌群数）は設定されていないが、水浴場水質判定基準[5]と比較した場合、いずれの地点でも基準値である 1,000 個/100mL を大きく超えており、これは水浴場「不適」に相当する。

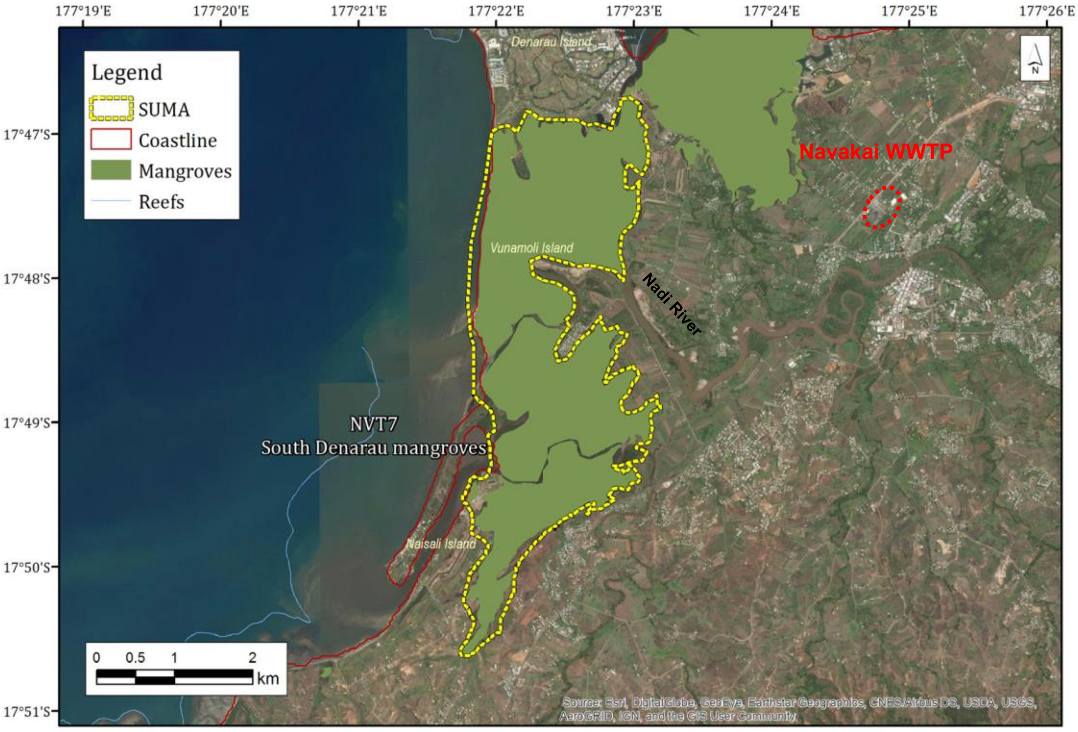
2) プロジェクトによる水質調査

EIA 作成に向けたデータ収集の一環として、周辺の公共用水域における水質調査（雨季・乾季）を実施した。調査結果を **APPENDIX 7-5** に示す。いずれの地点でも前述の WAF 調査結果と概ね類似した水質であった。

(2) 自然環境[6]

対象地周辺には自然保護・文化遺産保護の指定地域は存在しない。ただし、Navakai 下水処理場からの排水先であるナンディ川河口には、DOE 及び Ministry of Fisheries が海洋保護区の追加指定に向けて特定した、重要な海洋生態系を有する地域（Special Unique Marine Areas。以下、「SUMA」という。）が位置している（**図 7-4.1**）。

[5] 環境省, 水浴場水質判定基準 https://www.env.go.jp/content/000141595.pdf
[6] National Biodiversity Strategy and Action Plan for Fiji 2020-2025 及び Biophysically Special, Unique Marine Areas of Fiji



Biophysical Justification of NVT7: Coastal mangroves and mudflats, river estuaries, seagrass beds, juvenile tiger, hammerhead and blacktip reef sharks and endemic fish.

出典：Biophysically Special, Unique Marine Areas of Fiji

図 7-4.1　対象地周辺の SUMA（NVT7: South Denarau Mangroves）

(3)　社会環境

1)　社会経済状況

Navakai 下水処理場の位置する Nadi における主な社会経済指標を **APPENDIX 7-6** に示す。

2)　土地利用

Navakai 下水処理場は平たんな Nadi 市街地に位置し、周辺は住居地域や商業地域として既に開発の進んだ地域である。対象地周辺の土地及び水域の利用について以下に示す。

東：　近隣に学校（隣接して Nadi Muslim Collage 及び Natu Navula College、約 200m 離れて Nadi District School）が位置している他、Namotomo village の住宅地や畑がある。最も近い病院は 500m 程度離れた Nadi 中心部に集まっている。

西：　Wailoaloa Road を挟んで西側は主に畑である他、住宅が点在している。

南：　拡張エリア予定地内には畑が広がり、住居や建物も数軒確認できる。Narewa Road を挟んで南側にはコミュニティ（Narewa）があり、Nadi River までの排水管はこのコミュニティを通過する。

北：　FRA の資材置き場と宿舎及び NFA 施設予定地が隣接している。Navakai Road を挟んで北側は住宅地や商業施設、倉庫などがある。

水域：　排水先となるナンディ川では、排水口周辺では漁業活動は行われていないものの、海に近い下流のコミュニティでは小規模ながら漁業が行われている。また、定常時には住民や子供が水遊びをする姿も見られる。

3)　用地取得

本事業では、既存施設に隣接する土地の取得が必要である。そこで、地籍図及び現地踏査など現時点で入手可能な情報を基に、土地目録を作成した。**APPENDIX 7-7** に土地利用目録を示す。

4)　非自発的住民移転

拡張予定地は殆どが空き地や畑であるが 7 軒の住居が存在し、大規模ではないものの非自発的住民移転の対象となる。これらの住居及び居住者に係る法的位置づけについては、今後の調査にて確認する必要がある。

7-4-3 スコーピング

表 7-4.1 にスコーピングを示す。

表 7-4.1　スコーピング（Navakai 下水処理場）

項目			スコーピング		根拠
			建設	運用	
汚染対策	1	大気汚染	X		建設：建設機械により粉塵や排気ガスが一定期間発生する。 運用：大気汚染などの影響は想定されない。
	2	水質汚濁	X	X	建設：建設工事により濁水が下流域で一時事的に影響を及ぼす可能性がある。 運用：下水処理は一般的に周囲の水質改善に貢献する。一方、処理パフォーマンスが低下した場合は周辺環境の水質に悪影響を与える可能性がある。
	3	廃棄物	X	X	建設：廃土・廃材が発生する。 運用：作業員が排出する固形廃棄物やゴミの清掃以外にも、下水処理によって発生する汚泥を適切に処理・処分する必要がある。
	4	土壌・地下水汚染	X	X	建設：油漏れ等により土壌汚染が発生する可能性がある。 運用：油漏れ等の他に、生下水の溢水によって汚染が発生する可能性がある。
	5	騒音・振動	X	X	建設：建設工事や機械より騒音・振動が発生する。 運用：処理場内のポンプやモーター等より騒音・振動が発生する。
	6	地盤沈下			用地は平坦な地形のため、地盤沈下は発生しないと見込まれる。
	7	臭気	X	X	工事：建設工事が稼働中の既存施設の処理に悪影響や支障をきたした場合、臭気が発生する可能性がある。 運用：適切な脱臭設備の設置・運用により、臭気問題は改善すると考えられる。一方で処理パフォーマンスが低下した場合、臭気が発生すると考えられる。
	8	底質	X	X	建設：放流管の設置工事中に沿岸地域の底質が一時的に乱される可能性が考えられる。 運用：処理水質の改善に伴い水域の底質も改善される可能性がある。 一方で処理パフォーマンスが低下した場合、底質が悪化する可能性も考えられる。
自	9	保護区			Nadi 町内及びその近辺に保護区は確認されていない。

項目			スコーピング 建設	運用	根拠
	10	生物多様性	X	X	建設：処理場下流にある重要な海洋生態系を有する地域（SUMA）NVT7の環境が建設工事により一時的に乱される可能性が考えられる。 運用：維持管理が適切に行われない場合、SUMAの環境劣化を引き起こす可能性が考えられる。
	11	水象	X		当該地域はサイクロンやモンスーンによる洪水、暴風、高潮などの影響を受けやすいため、施設設計でこれらの影響を考慮する必要がある。
	12	地形・地理的特徴			予定用地は現在農地等として開発・利用されている。既存用地に隣接し内陸部にあるため、地形的変化は発生しないと考えられる。
社会環境	13	非自発的住民移転および用地取得	X		建設：Navakai下水処理場の拡張・新施設建設に必要な土地の取得にあたって小規模な非自発的移住が発生する。
	14	貧困	X	X	周辺に非正規居住地はないものの、用地取得によって貧困層が影響を受ける可能性は考えられる。
	15	少数民族および先住民族			世界銀行セーフガードポリシーに定義される先住民族は確認されていない。 iTaukeiはフィジーの先住民族として法的に認められており、伝統文化と習慣はフィジーの法律の下で尊重・保護されている。
	16	地域経済（雇用、生活など）	X		建設：農地の土地取得が市民の生活に影響を及ぼす可能性がある。 一方で、建設工事が地元住民に雇用の機会を提供することも考えられる。
	17	土地利用および地域資源			土地利用及び地域資源の土地利用への負の影響はないと見込まれる。
	18	水利用	X		建設：周辺の市民が生活に利用するナンディ川の水環境が建設工事によって一時的に影響を受ける可能性がある。 運用：運転開始後に放流水質が改善されることによって、水環境が改善されると考えられる。
	19	既存の社会インフラ・サービス	X		建設：建設工事によって迂回や一時的な通行止めなど交通に支障が生じる可能性がある（道路下に設置される放流管の建設工事の影響が特に大きいと考えられる）。 また、電気、ガス、水道管が工事の影響を受ける可能性がある。
	20	社会制度（地方の意思決定機関など）			フィジーではiTaukei制度が法的に制度化されているため、意思決定プロセスや社会制度への影響はないと考えられる。
	21	利益と損害の不公平な分配 / 地域的な利益相反		X	用地取得プロセスが不十分である場合、利益の不当な分配や、地域住民間の利害対立が生じる可能性がある。
	22	文化遺産			予定用地内に伝統的または文化的遺跡は確認されていない。
	23	景観	X		西部地区は観光地であるため、施設設計や建設工事期間中の外観に配慮が必要となる。
	24	ジェンダー / 子どもの権利			ジェンダーや子どもの権利への影響はないと考えられる。ただし、サイトの南東に学校があることから、配慮が必要になる可能性がある。
	25	衛生と感染症（HIV/AIDS）			下水処理場の処理システム改善により衛生環境が向上し、感染症のリスクが軽減されることが期待される。

項目			スコーピング		根拠
			建設	運用	
	26	労働環境（労働安全を含む）/事故	X	X	建設：建設作業員の労働環境を考慮しなければならない。 運用：維持管理作業中にガス中毒や酸欠が発生する可能性があるため、作業員の労働環境を考慮しなければならない。
その他	30	気候変動	X	X	建設：建設重機からの CO_2 の排出が見込まれる。 運用：下水・汚泥処理により温室効果ガス（CH_4 および CO）が発生する。

Const.: Before/during construction
Ope.: During operation
出典：JET

7-5　ステークホルダー協議

7-5-1 スコーピング段階

Pre-F/S 実施に当たって WAF と協議した結果、事業実施に向けてのより具体的な情報共有や懸念点の把握を行うため、対象地域を管轄する行政機関や自治体などの主要ステークホルダーとして個別コンサルテーションを WAF 同席のもと実施した。協議は主に各処理場の拡張計画、隣接地の用地取得について議論が行われ、管轄自治体や官庁、住民代表より様々な意見が出された。特に Navakai 処理場では、拡張エリアを所有する村も村域拡大のために同エリアの利用を検討していることから、NTC や関連省庁も交えて協議が行われた。議事録を **APPENDIX 7-9** に示す。

表 7-5.1　ステークホルダー協議（スコーピング段階）の概要

協議日時	内容	参加ステークホルダー
2024 年 4 月 24 日	農村離島開発・防災省（西部地区開発に係る行政機関）の関係者を対象とした説明・協議	・Commissioner Western, Ministry of Rural and Maritime Development and Disaster Management (MRMD) ・Divisional Planning Officer, MRMD ・Provincial Office Lautoka, MRMD ・District Office Lautoka/Yasawa, MRMD ・District Office Nadi, MRMD
2024 年 4 月 24 日	Lautoka 市（以下、「LCC」という。）の関係者を対象とした説明・協議	・Chief Executive Officer, LCC ・Acting Manager Building/Engineering Services, LCC ・Team Leader Assets, LCC ・Acting Head of Services, LCC ・Acting Director Building/Engineering Services, LCC ・Health Department Officer, LCC
2024 年 4 月 24 日	Nadi 町（以下、「NTC」という。）の関係者を対象とした説明・協議	・Estate Assistant (Operation), TLTB ・Principal Town Planner, DTCP Lautoka ・Acting CEO, NTC ・Building Inspector, NTC ・Manager Com. Service, NTC ・Planning & Engineering Officer, NTC ・Special Administrator, NTC
2024 年 5 月 27 日	Department of Land（以下、「DOL」という。）を対象とした説明・協議	・Assistant Director, DOL ・Officers, Land Use Planning & Development Team, DOL
2024 年 5 月 27 日	National Fire Authority（以下、「NFA」という。）を対象とした説明・協議	・Manager, NFA
2024 年 7 月 22 日	ナンディ空港関係者を対象とした説明・協議	・Representatives from Airport Fiji Limited (AFL) ・Representatives from Civil Aviation Authority of Fiji (CAAF)
2024 年 7 月 22 日	Navakai 下水処理場に係る住民協議	・Representatives, NTC ・Representative, District Office Nadi ・Representative, Ba Provincial Office ・Representative, DTCP ・Senior Estate Officer, TLTB ・Estate Assistant, TLTB ・Representatives of Navoci Village

出典：JET

7-5-2 ドラフト・ファイナルレポート段階

優先プロジェクトに関わる主なステークホルダーを対象として、Pre-F/S 調査結果を周知し意見徴取するためのワークショップを 2024 年 8 月 1 日に開催した。協議には省庁や自治体関係者の他、処理場周辺の村民、関連するインフラ事業者、ホテル・リゾート開発関連団体など 60 名が参加し、用地代替案や用地取得に係る協議実施状況に加えて、不法接続防止、悪臭対策、省エネ対策、環境水質などについて質問や意見があった。参加者は、用地問題はあるものの、各処理場拡張の必要性について理解を示しており、WAF も引き続き関係者との協議・調整を続けていく意向である。議事録を **APPENDIX 7-10** に示す。

7-6　F/S 段階にて検討すべき事項

各事業の F/S 段階では、環境許認可取得のための EIA 策定（社会影響評価を含む）が実施されることとなる。その際に、本 Pre-F/S で明らかにした環境・社会面での特徴を鑑みて、特に実施すべき調査や活動等について以下にまとめる。

<u>環境面</u>

- 排水先及び周辺におけるマングローブへの影響評価
- 排水の拡散モデル解析及び評価

<u>社会面</u>

- 土地所有者や周辺住民を含むステークホルダーを対象としたパブリックコンサルテーション
- 影響住民を対象とした社会経済影響評価
- 排水先及び排出先下流における漁業権設定の有無（DOL、DOF、iTLFC より確認）
- 伝統的漁業エリア（Qoliqoli area）への補償設定に係る漁業影響評価
- 用地取得、リース、地役権設定が必要となる全ての土地における資産評価
- 住民移転に係るコンサルテーション及び移転計画及び生計回復支援プログラムの策定

第8章 事業効果

8-1 定量的効果

8-1-1 運用・効果指標

効果指標としては、下水道人口普及率や水質改善状況を用いることが一般的である。本事業では、下水道人口普及率を指標とする。運用指標は処理施設の処理水量及び処理人口とする。

各運用・効果指標の測定・算出は下記の通りである。

- 下水処理場からの放流水質状況（BOD_5、TSS）：放流渠で測定
- 処理水量：下水処理場内流量計測器により測定
- 処理人口：下水処理水量と換算汚水量原単位を用いて算出

(1) 指標の目標値

指標の目標値は増設した下水処理場が運転を開始してから 2 年後に達成されるものとして、Natabua 下水処理場は 2037 年に、Navakai 下水処理場は 2040 年に設定する。指標及びその目標を**表 8-1.1** に示す。

表 8-1.1 運用・効果指標及び目標値

下水処理場	指標	現在（2024 年）	目標
Natabua	放流水質（mg/L）	BOD_5：35、TSS：27	BOD_5≦40、TSS≦60
	放流水質遵守率（%）	BOD_5：62.5%、TSS：87.5%	BOD_5：100%、TSS：100%
	日平均処理水量（m^3/日）	10,800 （有収水量による推計値）	26,800
	処理換算人口（人）	54,000	134,000
Navakai	放流水質（mg/L）	BOD_5：60、TSS：91	BOD_5≦20、TSS≦30
	放流水質遵守率（%）	BOD_5：40%、TSS：62.5%	BOD_5：100%、TSS：100%
	日平均処理水量（m^3/日）	8,800 （有収水量による推計値）	17,900
	処理換算人口（人）	44,000	89,000

出典：JET

(2) 指標の測定方法

放流水質は塩素混和地流出地点での採水により把握する。日平均処理水量は日々下水処理場内の流量計で自動的に測定される。処理換算人口は、処理水 1 m^3/日あたり 5 人として処理水量から算出する。

8-2　財務分析

経済財務分析にて内部収益率（以下、「IRR」という。）を算定し分析する。財務分析では実施機関におけるプロジェクトの財務的収益性を測定する。一方で経済分析では、国民経済における資源配分上の効率性の程度を測定する。

8-2-1 経済財務分析の前提

(1) With Project と Without Project

- With Project ケース

プロジェクトを実施する。下水処理能力と接続数が増大する。下水処理システムの整備と拡張を実施する。

- Without Project ケース

プロジェクトを実施しない。下水処理能力と接続数は現状のままとする。

(2) 増分分析

プロジェクトを実施しない（Without Project）基準から、実施（With Project）を比較する。財務的評価は、実施に係る支出と収入、そして経済的評価は、実施に係る費用と便益の増分にて費用便益の増分で IRR を計測する。[7]

(3) 分析期間

2028 年から 2053 年の 26 年間とする。

(4) 平均処理水量、下水処理場、管渠、ポンプ場の建設期間及び接続準備期間

Lautoka と Nadi に建設する下水処理場の平均処理水量、建設期間を**表 8-2.1** に示す。

表 8-2.1　Lautoka・Nadi に建設する下水処理場の平均処理水量、建設期間

市町	下水処理場	平均処理水量 (m^3/日)	下水処理場、管渠、ポンプ場の建設期間（年）
Lautoka	Natabua	30,325	2033-2036
Nadi	Navakai	18,011	2028-2032

出典：JET

(5) 一般家庭、ビジネス顧客の接続者、未接続者の推移

一般家庭、ビジネス顧客の接続者数と未接続者数を以下の**表 8-2.2** に示す。

[7] 評価に用いたキャッシュフロー表は **APPENDIX8-1** に示す。

表 8-2.2　一般家庭、ビジネス顧客の接続者数と未接続者数

年	接続者数（一般家庭）	接続者数（ビジネス顧客）	未接続者数（一般家庭）	未接続者数（ビジネス顧客）
2028	11,111	2,678	43,220	10,417
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	11,889	2,937	40,960	10,119
2034	12,889	3,269	39,631	10,052
2035	14,706	3,873	39,625	10,436
2036	14,706	3,873	39,625	10,436
2037	14,706	3,873	39,625	10,436
2038	17,817	4,449	35,192	8,787
2039	21,817	5,189	32,514	7,733
2040	25,416	5,855	28,916	6,661
2041	25,416	5,855	28,916	6,661
2042	25,416	5,855	28,916	6,661
2043	25,416	5,855	28,916	6,661
2044	25,416	5,855	28,916	6,661
2045	25,416	5,855	28,916	6,661
2046	25,416	5,855	28,916	6,661
2047	25,416	5,855	28,916	6,661
2048	25,416	14,304	28,916	6,661
2049	25,416	14,304	28,916	6,661
2050	25,416	14,304	28,916	6,661
2051	25,416	14,304	28,916	6,661
2052	25,416	14,304	28,916	6,661
2053	25,416	14,304	28,916	6,661

出典：JET

8-2-2 支出

(1) 下水処理場事業費

事業費を**表 8-2.3** に示す。支出には建設費、コンサルタント費、土地取得費のほか、物理的予備費、管理費、諸税を含む。価格予備費、及び建中金利は含めない。

表 8-2.3　事業費

（1000FJD）

年	2028	2029	2030	2031	2032	2033	2034	2035	2036
建設費	0	0	45,604	45,604	45,604	65,214	65,214	65,214	65,214
コンサルタント費	22,460	22,460	0	0	0	0	0	0	0
土地取得費	0	38,681	0	0	0	0	0	0	0
管理費	1,123	3,057	2,280	2,280	2,280	3,261	3,261	3,261	3,261
諸税	6,738	12,540	12,318	12,318	12,318	17,612	17,612	17,612	17,612
総事業費	30,320	76,737	60,202	60,202	60,202	86,087	86,087	86,087	86,087

出典：JET

(2) 下水管渠、ポンプ場の事業費

Pre-F/S では下水管渠、ポンプ場のコスト積算は実施していない。都市下水道 MP で算定した事業費[8]を**表 8-2.4** に示す。

表 8-2.4　下水管渠、ポンプ場の事業費

(1000FJD)

市町	下水管渠	ポンプ場
Lautoka	225,475	30,871
Nadi	265,300	34,377

出典：JET

(3) 維持管理費

各施設の維持管理費（O&M 費）[9] を**表 8-2.5** に示す。

表 8-2.5　各施設の維持管理費

（単位：1000FJD）

市町	下水処理場	下水管渠	ポンプ場
Lautoka	3,698	155	2,387
Nadi	3,486	174	2,735

出典：JET

(4) 残余価値

最終年以降も継続して利用可能、又は他への転用可能な資本財の残存価値は、分析最終年にマイナスの支出として計上する。その価値は定額法（スクラップ価値＝初期投資の 10%を仮定）を適用して次式により計測する。事業用地の減価はないとする。

・ 残存価値＝資産・施設の投資費×（1.0-0.9×使用年数（年）÷法定耐用年数[10] などによる償却期間（年））

処理施設、管渠、そして機材に係る残余価値を以下の**表 8-2.6** に示す。

表 8-2.6　残余価値

下水処理場	設備投資カテゴリー	設備投資費（1000 FJD）	運営期間（年）	残余価値（1000 FJD）
Natabua	土木建築（処理場、管渠、ポンプ場）	466,818	16	332,374
	機械電気	132,161	15	13,216
	土地	1,716	-	1,716
	合計	600,695		347,307
Navakai	土木建築（処理場、管渠、ポンプ場）	470,136	20	300,887
	機械電気	115,238	15	11,524
	土地	21,307	-	21,307
	合計	606,681		333,718

出典：JET

[8] 都市下水道 MP での Navakai × 0.667,　Natabua × 0.75 の費用比率にて算定した。
[9] 日本国内の費用関数及び都道府県汚水構想策定マニュアルを参照した。
[10] 国交省の指針により土木建築施設と管渠は 50 年、機械電気機材は 15 年とした。

8-2-3 収入

(1) 下水道料金収入

増分の下水処理量の収入を算定する。

年間の下水道収入の増分 = (Pre-F/S 実施による処理数量－プロジェクト実施前の処理水量) x 下水道料金（FJD/m^3）

- プロジェクト実施前の 1 日あたり地域処理水量[11]：15,600 m^3
- 下水道料金：現行の設定料金である 0.20 FJD/m^3

(2) 新規接続料

新規接続料の収入を算定する。

- 新規接続収入 = 新規接続者数の増分 x 申請料金
- 新規接続の申請料金：一般家計 22 FJD/戸、事業者 101 FJD/戸

(3) 汚泥受け入れ料

下水未接続の家計および事業者からの汚泥受け入れ処理料の収入を算定する。

- 汚泥受け入れ収入＝年間の汚泥受け入れ回数 x 汚泥受け入れ料金
- 汚泥受け入れに係る料金[12]：一般家計 12 FJD（/5 年毎）、事業者 12 FJD（/毎年）

8-2-4 財務分析の結果

(1) 財務的内部収益率（Financial Internal Rate of Return : FIRR）

算定した FIRR はマイナス 2.8%のネガティブリターンとなる。基本シナリオによる FIRR がネガティブリターンの為、感度分析は行わない。

(2) 財務的妥当性

プロジェクト実施は事業実施主体の財務的収益性からは妥当でない。

[11] WAF 内部資料を参照した。
[12] 1 戸当たりの投棄料金は西部地域マスタープラン記載の腐敗槽汚泥の収集料金を使用した。

8-3 経済分析

8-3-1 費用

(1) 事業費

国富の増減に直接的に影響しない租税等の移転支出は、経済的費用として計上しない。経済分析の事業費は財務分析に示した費用から、土地取得費と諸税を差し引く。

(2) 維持管理費

財務分析で算出した O&M 費は非貿易財とみなし、標準変換係数（以下、「SCF」という。）[13] である 0.96 を掛けて費用とする。

(3) 残余価値

財務分析にて算定した残余価値をマイナスの費用とする。

8-3-2 便益

便益のデータは Lautoka と Nadi で実施した聞き取り調査を利用した。聞き取り調査の詳細は **APPENDIX 8-2** に示す。

(1) 下水道利用者の便益

増分の下水使用量と支払い意思額（以下、「WTP」という。）[14]により、利用者便益を算定する。

- 年間の下水利用者便益=（Pre-F/S 実施による処理水量- プロジェクト実施前の処理水量）x WTP/m^3
- WTP： 0.69 FJD/m^3

(2) 腐敗層設置・管理費の軽減の便益

下水管接続により不必要となる腐敗槽設置費、汲み取り費、および腐敗層スペース費の削減[15] を利用者便益として算定する。

- 便益 ＝接続者数の増分 x （腐敗槽設置費＋汲み取り費+腐敗層設置スペース費）
- 腐敗槽設置費：一般家庭あたり 8,800 FJD/槽 ÷ 使用年数 20 年＝440 FJD /年
- その他事業者あたり 8,800 FJD/槽 x 2 槽÷ 使用年数 20 年＝880 FJD /年
- 汲み取り費：= 一般家庭あたり 300 FJD /5 年毎汲み取り ＝60 FJD /年
- その他事業者 600 FJD /毎年汲み取り＝600 FJD /年
- 設置スペース費：一般家庭あたり 1,400 FJD /年、 自業者あたり 2,800 FJD /年

[13] 標準変換係数（SCF）は MP にて算定した。
[14] WTP は聞き取り調査の平均 WTP/月と家計あたり平均下水使用料により算定した。
[15] MP 記載の腐敗槽の関連費用を使用した。

(3) 医療費軽減の便益

下水整備による水質環境改善は下痢症状による通院・治療費の軽減をもたらす。医療費削減額[16]を利用者便益として算定する。

- 便益 ＝接続者数の増分 x 下痢関連の治療費
- 治療費： 一般家計あたり 11 FJD /年

(4) 水質環境保護の便益

水質改善による環境保護への支払い意思額（以下、「WTP」という）[17]を便益として算定する。

- 便益 ＝接続者数の増分 x 環境保護 WTP
- 環境保護 WTP： 一般家計あたり 65 FJD /年

(5) 新規接続に係る事業者の便益

財務分析で算定した新規接続収入と汚泥受け入れ収入を事業者便益とする。

(6) 観光収入の保持による便益

プロジェクト実施は環境水質の悪化を防止し、環境悪化による観光収入の減益を阻止する効果を持つ。実施対象地域となる Nadi、Lautoka での 2023 年観光収入を基準として便益を算定する（**表 8-3.1**）。積み上げ便益は毎年 0.5%ずつ増加し、最大で 10%/年を上限とする。

表 8-3.1 観光収入の減益阻止による便益

観光からの便益	(1000FJD)	比率
フィジー観光収入 2023	2,367,700	
Nadi の収入	828,695	35%
Lautoka の収入	71,031	3%
Lautoka と Nadi の観光収入	899,726	
年間あたり積み上げ累計する観光減益阻止の便益	**4,499**	**0.50%**

出典：JET

8-3-3 経済分析の結果

(1) 経済的内部収益率（Economic Internal Rate of Return : EIRR）

プロジェクト実施による EIRR はプラス 9.0%である。

環境汚染の防止、地方の貧困削減、そして自然被害対策などのプロジェクト実施基準[18]は 6.0%とされる。本プロジェクト実施による EIRR はこの基準を上回る。

(2) EIRR の感度分析

費用変化に係る便益の感度分析を以下の**表 8-3.2** に示す。便益は一定として、費用がベースシナリ

[16] 聞き取り調査による医療費の一家計当たり年間平均額を使用した。
[17] 聞き取り調査による環境保護への一家計当たり年間 WTP 平均額を使用した。
[18] アジア開発銀行の費用便益マニュアル(2017)による。

オより20%高騰時のケースでもEIRRは7%超であり、実施目標を上回る。

表 8-3.2　費用変化に係るEIRR感度分析

費用	マイナス20%	マイナス10%	変化なし	プラス10%	プラス20%
EIRR	11.5%	10.1%	9.0%	8.1%	7.2%

出典：JET

(3)　経済的妥当性

プロジェクト実施は妥当である。フィジー国民経済における資源配分上の効率性は高い。

8-3-4 プロジェクト資金調達・返済

(1)　資金調達

小島嶼開発途上国（Small Island Developing State。以下、「SIDS」という。）であるフィジーにはアジア開発銀行の譲許的融資[19]、また、その他援助期間による環境分野を対象とした低利での長期融資の活用が検討できる。

プロジェクト実施には当然ながら資金が必要であり、必要な設備投資金はおおよそ12億フィジードルである。年間の歳出予算の3割相当を占める資金は、税収のみで手当するには巨額である。プロジェクト費用には国内外からの出資や融資借入れが必要となるが、政府、もしくは民間を含む出資のみで十分な金額を調達するのは困難であろう。従って、融資借入れが必須であり、フィジー政府に有利な条件である国際援助機関からの譲許的融資の活用を優先すべきである。

(2)　資金返済

事業費の調達を融資借入金[20]とした場合、その返済に十分な収入を得るための料金水準が必要となる。借入比率ごとに必要となる料金水準を以下の**表 8-3.3**に示す。

借入れ比率100%のケースでの必要料金は4.0 FJD/m^{3}であり、現行料金、またWTPと比較しても現実的でない。借入れ比率が50%のケースでは1.5 FJD/m^{3}であるが、この水準でも現行料金を大幅に上回る。いずれにせよ債務返済には借入れ比率を抑え、下水道供給の原価を反映した料金設定が必要となる。

表 8-3.3　借入金返済に要する料金水準

借入比率	100%	80%	50%
借入金返済に要する料金水準（FJD/m^3）	4.0	3.0	1.5

出典：JET

8-3-5 その他定性的評価・提言

(1)　下水道料金の値上げ

住民への聞き取り調査による下水道料金の支払い意思額（以下、「WTP」という。）は、現行料金

[19] Ordinary Capital Resources : OCR blend lending 等
[20] 譲許的融資による金利は1%と仮定する。

よりはるかに高い。政府・WAF は利用者の理解を得て、料金値上げを実施すべきである。

下水道サービスは生活衛生の向上に欠かせない公益性の高い事業であり、事業主体者にとって事業の収益性が全てではない。しかしながら、本プロジェクト事業継続には少なくとも O&M 費をカバーできる収入が必要である為、下水道料金 0.72 FJD/m^3 以上の値上げによる収入増が必須である。また、事業費借入金の返済も考慮するとさらなる値上げも必要となる。

(2) 独立した事業運営

下水道サービスは受益者負担と原価主義の適用、つまり、事業運営に必要な経費を料金収入で賄うことが基本である。

WAF の事業資金は料金収入では十分でなく、政府予算と補助金の受領を前提に事業運営されている。WAF は原価主義に基づき、財政的に政府から独立した事業経営を目指すべきである。

8-4 その他定性的効果

前節で定量的効果について述べたが、本節では本事業の実施により発生する主な定性的効果を以下にまとめる。

- 疫病による欠勤の減少
- 農業及び水産業生産性の増加
- 土地価格上昇効果

(1) 疫病による欠勤の減少

下水処理場の下流地域に適切に処理された処理水が提供されることにより、下痢、感染性胃腸炎、消化不良、赤痢等の水系感染症患者数が減少することが予想される。この公衆衛生の向上に伴い、疫病よる欠勤減少は本事業の効果の一つであると考えられるが、事業の実施とその発生率の現象との相関関係を定量的に推定することは困難であるため、定性的な効果の一つとなる。

(2) 水産業生産性の増加

下水処理場下流の沿岸の漁民は適切に処理された処理水を利用することができ、最終的には水産業の生産増加は本事業の効果ということができる。ただし、漁獲高に関連した生産性増加を示す情報を入手し、分析することは困難であるため、本事業においては定性的効果とする。

(3) 土地価格上昇効果

下流地域に適切に処理された処理水が提供され、衛生環境が改善される地域においては、土地価格が上昇する効果が期待され、下水道整備の重要な波及効果である。しかながら、事業の実施と波及効果の大きさの相関関係の想定は困難で、定量化して便益として計上することは難しいため、本事業においては定性的効果とする。

第9章 結論と提案

9-1 結論

2023 年時点で Viti Levu 島西部地区の人口の約 40%を有し、フィジー国有数の観光地を有する Lautoka・Nadi 地区にて、フィジー国で定められた排水基準を満たすことが出来ていない処理水が放流され、Viti Levu 島沿岸部に流出している。本事業によりこの未処理下水が適切に処理され、沿岸水域の水質が改善されると共に、観光資源が豊富なフィジー国にとって継続的な観光業の発展が可能となる。

本事業は公共用水域の水質汚濁低減と公衆衛生の向上が図れることから Lautoka・Nadi 地区の持続可能な経済発展に寄与するものであると判断される。また、本事業はフィジーの国家開発計画及び日本政府によるフィジーへの援助方針にも合致している。

9-2 持続可能性

プロジェクトの効果は、(i) Lautoka・Nadi 地区の状況に適した革新的な技術の使用、(ii) O&M の能力構築への取り組み、(iii) 適切な下水道使用料金体系、(iv) 適切な汚泥の処理処分計画の策定と実行、を通じて持続可能である。

(1) 事業の持続可能性

提案した Natabua・Navakai 下水処理場の維持管理は、増設した下水処理場の供用初期は WAF にて直営で実施を提案する。WAF は既に既存の下水道処理施設を運営維持管理していることから、下水処理場の維持管理人員の増加とその教育訓練を適切に実施すれば、技術的には問題ないと考えられる。また、維持管理業務を民間委託する事も選択肢としては有るものの、直営方式に比較して維持管理費が高額になることから、料金改定を含む財政的な検討を行ったうえで判断する必要がある。

この Pre-F/S にて計画した Navakai 下水処理場・Natabua 下水処理場には乾燥汚泥の保管施設も計画敷地面積に含めている。これにより当面は下水処理場から発生する汚泥の処分に窮する事は無いが、あくまで物理的な対応であり、本質的には有効利用や適切な処分方法の計画が必要である。

(2) 財務的持続可能性

財務省[21]等による債務返済負担等の公的財務支援により、WAF はフィジーにおける上下水道施設の建設に係る一連の事業をほぼ支障なく運営している。しかしながら、事業運営において WAF は赤字を計上している年が有り、これら営業差損は買掛金・未払い金等として次年度に繰越され、財務省等による借入金により次年度における支払い等で賄われている。これによると、WAF の手元流動性（短期の現預金等）についてはその脆弱性を否めない。この点を鑑み、中央政府が WAF の財務基盤強化のための資金フローの整備及び、下水道使用料金単価の改定や、年次の政府交付金制度の拡

[21] 財務省（MOF）：旧経済省（Ministry of Economy（MOE））

充を図ることが望ましいと考えられる。

9-3　提言

本 Pre-F/S で対象とした優先事業の実施に際しての提言は以下の通りである。

(1)　下水処理場用地の協議

WAF は下水道事業の重要性に関する啓発活動を実施し、本プロジェクト目的の理解を深め、用地取得に係る手続きを促進する必要がある。Natabua・Navakai 下水処理場用地として特定するために、潜在的な移転問題の評価や、既存住居の土地の交渉／取得プロセスの調査などを行ったうえで、関係者との十分な協議を実施する必要がある。

(2)　汚泥の有効利用・処分計画の策定

本 Pre-F/S の優先事業で計画した下水処理場には発生汚泥の保管場所を場内に設けている。当然、汚泥保管場には広大な敷地が必要であり、建設費がかさむ要因でもある。理想的には乾燥汚泥の有効利用方法が確立される、もしくは場外の最終処分場に処分できることが望ましく、有効利用計画・処分計画の策定が必要となる。日本の技術協力プロジェクト等のスキームを活用した汚泥の有効利用・処分計画の策定が望まれる。

なお、本 Pre-F/S では Natabua・Navakai 下水処理場の下水汚泥を採取し、その成分分析を実施した。分析結果を WHO、米国環境省（以下、「US EPA」という）、オーストラリア水道協会（以下、「AWA」という。）、EU、日本下水道協会等が設定した汚泥の処分／有効利用等の基準値と照らし合わせた結果、各基準値を参考とした場合、Natabua・Navakai 下水処理場で発生する下水汚泥について以下の点が判明した（**APPENDIX 9-1**）。

- 長期利用等の制限はありつつも、肥料や調整剤として緑地利用が可能
- いくつかの制限はありつつも、農産物・自然環境、人間の健康に悪影響を与えずに有効活用・リサイクルが可能
- ライニングや浸出水収集処理システムがない埋め立て地で処分可能

なお比較的高濃度で含まれる銅や亜鉛などについては、火山島であるフィジーの自然土壌に高い濃度で含まれるものが浸入水とともに流入した結果である可能性もある。このため今後フィジーでの汚泥処分、あるいは有効活用基準を定める場合、下水汚泥と共に周辺地域の土壌サンプルの成分分析を行い、結果を考慮することが推奨される。

(3)　本格 F/S 時における放流先水域の影響検討

環境影響評価に必要な基礎データについては、同様に海洋放流管の建設を計画している Suva の Kinoya 下水処理場における調査・検討結果も参考にしながら、F/S 実施において調査すべき項目を示す必要がある。海洋放流管を通した放流先水域への処理水放流に係る影響検討には、流入河川や放流先海域の水質調査、潮流調査、および実水質を再現できる海域のシミュレーションモデルの構築が必要となる。モデル構築後に下水処理場から放流される水量・水質が周辺海域にどの程度の水質影響を与えるかを定量的に推計する必要がある。

(4) 本格 F/S 時における追加の土質調査の実施

今回の Pre-F/S の概略設計では各下水処理場に 2 本のボーリング調査を実施した。Natabua は既存下水処理場敷地でボーリングを行っているが、第 1 期で建設する施設の大半は既存敷地外に建設される。本格的な F/S での設計時は拡張敷地にてボーリング調査を実施する必要がある。Navakai 下水処理場においても同様で、既存下水処理場の東側の拡張区域での追加ボーリング調査が必要である。

(5) 腐敗槽汚泥処理

本プロジェクトの実施に係らず下水道サービスを享受しない住民は対象処理区およびその周辺にて多く存在する。WAF は本プロジェクトにより下水道サービスの恩恵を対象処理区内にもたらすとともに、下水道サービス区域以外から腐敗槽汚泥を受け入れ、処理を Natabua 下水処理場で実施すべきである。

(6) 健全な下水道財政

本 Pre-F/S において、下水道施設の維持管理費を下水道料金で賄うためには、現行の 4 倍の料金が必要であることが明らかとなった。そのため、段階的な料金値上げ等の受益者による相応の負担増も考慮した対策の検討が必要である。一方で、下水道を含む公共料金は国の重要な政策課題となっているため、容易には料金改定ができない状況にある。WAF として国家予算から必要な維持管理費を確実に捻出するよう要求する必要がある。下水道料金としての収入のみならず、観光客から環境税の様な名目で徴収し、下水道事業の運営費を補填する案も一案として提案される。

(7) O&M に係る組織体制

1) 下水処理場

現在、西部地区の既存 4 下水処理場の中で唯一機械式下水処理方式を用いている Nadi の Navakai 下水処理場では、流入下水量に対する処理能力不足による放流基準の遵守不能に加えて、O&M に係る予算と資器材の不足により、設備の劣化が著しく、適切な O&M が実施できない状況にある。本プロジェクトでは今後 Nadi、Lautoka 地区で提案する 5 下水処理場全てで OD 法や TF 法等の機械式下水処理の導入を目指しており、O&M に係る予算と資器材の確保は必須である。

将来建設される下水処理場において適切な O&M を実施するためには、現在の Navakai 下水処理場において必要な O&M 予算を確保したうえで、運転職員の能力強化を図り、適切な O&M を実施できることが重要となる。このような能力強化は現在の WAF では実施が困難であり、例えば JICA の技術協力プロジェクトの中で能力強化を図るとともに、新たに建設される下水処理場の適切な O&M 実施体制を作るのが効果的である。

2) 水質試験室

フィジーでは BOD や SS 等の一般項目に加えて重金属類、シアン等の有害物質について排水基準が設けられている。しかしながら、分析器材の整備が進んでいないため、WAF の水質試験室でも全ての規制項目を適切に分析できるわけではなく、また発生する汚泥中の重金属類については全く分析ができない状況にある。そのため、下水処理場の水質管理、下水汚泥の管理、事業所排水の規制のために、水質試験室の分析器材の整備、試験員の能力強化が必須である。そのためには、JICA の

技術協力プロジェクトの中で必要な資器材を整備し、それを用いた水質試験員の能力強化を図るのが効果的である。

3) 機械電気設備

現在、西部地区の水道、下水道施設における機械電気設備保全は機械電気設備保全班（以下、「ME 班」という。）が担当しているが、実際にはポンプ類の目視点検と一部ポンプの修繕しか実施できておらず、設備の急速な老朽化が発生している。WAF 西部は、この原因を人員不足と予算不足によるとしている。ME によれば、以前（時期は確認できず）には班員が 16 人であったが、現在では 9 人に削減されており、適切な保全が実施できない。そして、保全ができないため設備の故障が相次いて発生し、その修繕のために予算を使うため、例え限られた人員で設備保全に取り組もうとしても、保全に必要な資器材、消耗品等の予算が確保できないという悪循環に陥っていると考えられる。

このような状況の改善のためには、先ず設備保全のための予算確保が最重要である。また、少ない人数で保全を実施できるように、設備の目視点検は管路維持管理班と下水処理場運転班が実施し、ME 班はグリース・オイル交換、スペアパーツ交換等の日常点検、定期点検を主に実施するような体制構築が必要である。また、設備の定期整備は故障防止、長寿命化に必須であり、また、設備故障に対する緊急修理対応は安定した下水処理に重要である。複雑な機器類の整備や修繕は直営では困難であり、メーカーや整備会社が委託するのが一般的であるため、整備や修繕に必要な予算の確保に加えて、WAF はそのような会社と契約を円滑に結べるようにする必要がある。

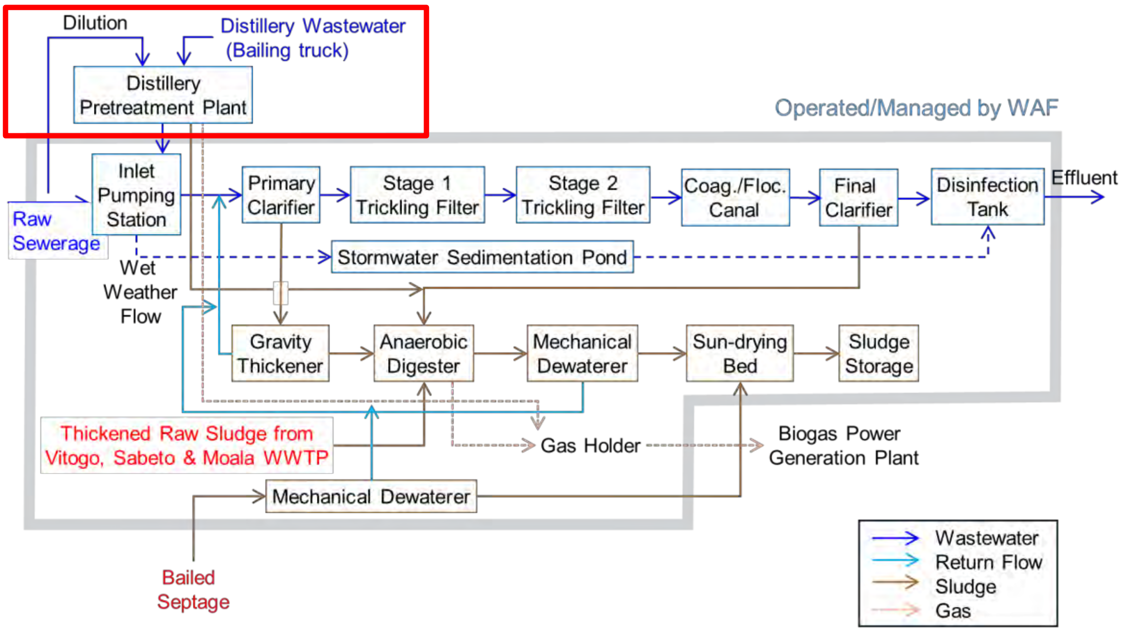
APPENDIX

APPENDIX 3-1 Examinations/Estimations of the Distillery Pretreatment Plant

(1) Overview

For the Pre-F/S, WAF requested to take into consideration a pretreatment plant treating liquid trade waste bailed in from South Pacific Distilleries Ltd., a local distillery brewing rum and other liquors. Currently the distillery's liquid waste is bailed to a receival pit located next to Natabua WWTP. The pit's waste merges with the treated effluent from Natabua WWTP through a pipeline, eventually discharged to the ocean through an ocean outfall pipe. Since the waste is released into the environment without any type of treatment, WAF recognized the proper pretreatment of distillery waste as an urgent issue to be dealt with, setting the construction of the Distillery Pretreatment Plant (hereinafter referred as "Pretreatment Plant") to be at the same time period as Natabua WWTP's Phase 1 Facilities.

Figure A3-1.1 shows the flow of the Pretreatment's influent and effluent. Since the plant's treatment target is trade waste, it was agreed that the Pretreatment Plant itself was not to be included in the scope of the project. However, since the plant's pretreated effluent and sludge was requested to be further treated by Natabua WWTP's treatment system, a simplified examination of the Pretreatment Plant was done to estimate the expected quality and quantity of wastewater/sludge to be received by Natabua WWTP.



Source: JET

Figure A3-1.1 Natabua WWTP Treatment Flow Diagram

(2) Influent Water Quality Parameters

Unfortunately, South Pacific Distilleries Ltd. did not respond to the data request for their distillery waste. As a substitute, multiple literature references were looked into to assume the water quality of wastewater to be bailed to the Pretreatment Plant (**Table A3-1.1**).

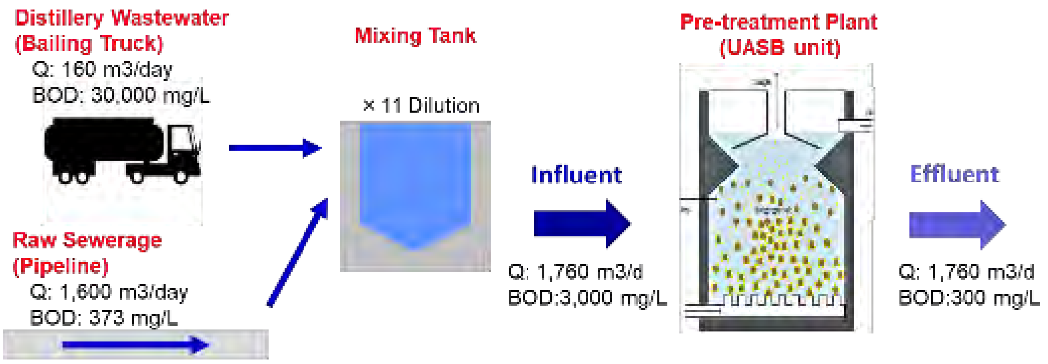
Table A3-1.1 Distillery Wastewater Quality*

Data Set	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
Data Range from References	24,652-50,000	2,400-5,000	1,148-4,200	225-308

Source: Created by JET based on below references

1. Mikucka, W., Zielińska, M. Distillery Stillage: Characteristics, Treatment, and Valorization. *Appl Biochem Biotechnol Vol.192*, 770–793 (2020). https://doi.org/10.1007/s12010-020-03343-5
2. Manyuchi M.M., Mbohwa C., Muzenda E.: Biological treatment of distillery wastewater by application of the vermifiltration technology. *South African Journal of Chemical Engineering Vol 25*, 74-78 (2018). https://www.sciencedirect.com/science/article/pii/S1026918517300707?ref=pdf_download&fr=RR-2&rr= 83be3dc6cfdaaf25
3. Patel, S.: Treatment of Distillery Waste Water: A Review. *International Journal of Theoretical & Applied Sciences Vol. 10*, 117-139 (2018). https://www.researchgate.net/publication/324551084_Treatment_of_Distillery_Waste_Water _A_ Review? enrichId=rgreqbfe7f600eeb85f550bf8b6240d96e74eXXX&enrichSource=Y292ZXJQYWdlOzMyNDU1MTA4NDtBUzo2MTYyMDA5MzM0OTQ3ODVAMTUyMzkyNTE1OTEyNA%3D%3D&el=1_x_2

WAF's original proposal was to dilute the distillery wastewater with raw sewerage, which enters a UASB (Upflow Anaerobic Sludge Blanket) unit, estimating an effluent BOD of 300 mg/L. Setting a hypothetical influent BOD of 30,000 mg/L, and assuming the UASB unit's BOD removal rate to be 90%, the distillery waste's dilution rate was set to x11.



Source: Created by JET

Figure A3-1.2 Distillery Wastewater Dilution and Pretreatment based on WAF Initial Proposal

Since these water quality and flowrate data are based off literature references and assumed values provided by WAF, it is strongly advised to collect past distillery wastewater data from South Pacific Distilleries Ltd. Sampling and analysis by WAF is also strongly recommended to verify the accuracy of the provided data. If no past data exists, sampling and analysis should be done monthly for at least three years to study seasonal variations and to eliminate possibilities of non-normal events.

(3) Treatment Method

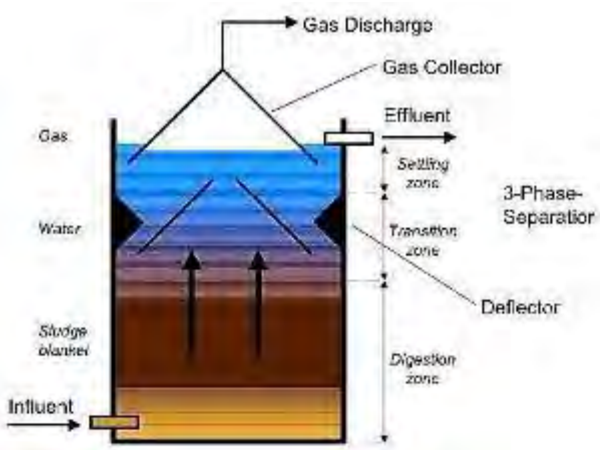
WAF's original proposal for the Pretreatment Plant's treatment method was the UASB (Upflow anaerobic sludge blanket) Method.

UASB is a type of anaerobic treatment, featured by its high reduction of BOD/TSS, small sludge production, small footprint requirement etc. A schematic diagram of the process is shown in **Figure A3-1.3**. Influent enters from the bottom of the reactor, flowing upward to a blanket of sludge granules. The blanket retains suspended solids, as well as breaks down organic matter through anaerobic digestion, partially converting it to biogas. These gas bubbles and upward flow naturally mixes the liquor, allowing mixing without mechanical equipment. Baffles/deflectors at the top of the reactor collects biogas, as well as retain the sludge blanket from flowing out.

Table A3-1.2 General Design Parameters of UASB units*

Parameter	General Range
HRT	6.3 - 7.85
Temperature	35 - 38℃
pH	2 - 20 hrs
Upflow Velocity	0.7 - 1 m/h
BOD Removal	60 - 90%
TSS Removal	60 - 85%
T-N Removal	Minimal
T-P Removal	Minimal

Source: Created by JET based on Source: Sustainable Sanitation and Water Management Toolbox, https://sswm.info/factsheet/uasb-reactor



Source: Sustainable Sanitation and Water Management Toolbox, https://sswm.info/factsheet/uasb-reactor

Figure A3-1.3 Schematics of UASB Reactor

WAF's original proposal was to pre-treat the diluted distillery wastewater singly by the UASB unit. However, as **Table A3-1.2** shows, nitrogen and phosphorus are minimally removed by the treatment, leading to industrial-levels nitrogen/phosphorus inflow to Natabua WWTP (**Table A3-1.1**). Even after being diluted by the remaining raw sewerage flowing into Natabua WWTP, its system cannot treat wastewater up to the required effluent quality (General Standards).

Therefore, the UASB method must be coupled with some kind of nitrogen/phosphorus removal procedure, or apply a completely different type of pre-treatment method that can treat distillery waste down to effluent qualities acceptable to Natabua WWTP. Detailed exploration of the treatment method is to be studied in future projects, since the Pretreatment Facility itself is not included in the Pre-F/S scope.

(4) Effluent Water Quality Parameters

Due to the lack of actual distillery wastewater data and undetermined pre-treatment methods, the plant's effluent quality cannot be estimated at the current state. For this reason, this study assumes that the Pretreatment Plant will treat its wastewater down to levels of "allowable liquid trade waste entering the sewerage system" set in Fiji's National Liquid Trade Waste Standards.

Since Fijian standards do not state the upper limit of T-N and T-P of allowable liquid trade waste, similar Australian standards with the same BOD/TSS limits were adopted as substitute values. **Table A3-1.3** shows assumed effluent water quality parameters of the Pre-treatment Plant.

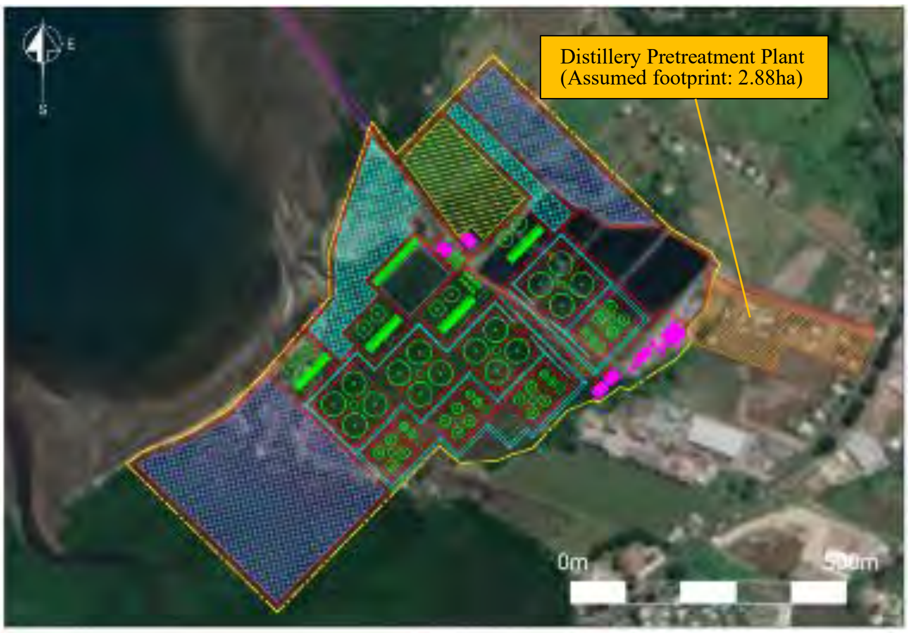
Table A3-1.3 Assumed Pretreatment Plant Effluent Water Quality

Data Set	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
Data Range from References	600	600	100	20

Source: Created by JET based on Fiji National Liquid Trade Waste Standards (2017),
New South Wales Liquid Trade Waste Policy (New South Wales Federation Council, 2018)

(5) Footprint Requirement (Reference)

Similar to effluent qualities, the Pretreatment Plant's footprint requirement cannot be precisely estimated due to lack of data and undetermined treatment methods. However as reference, the footprint requirement for a "UASB unit (TSS, BOD removal) + high-rate Oxidation Ditch (TSS, BOD, T-N removal) + Coagulation/Flocculation Channel (T-P removal)" system with the same flowrate was roughly estimated, summing up to be about 1.7 ha. Considering that the facility will need additional space for receival tanks and drive-throughs for bailing trucks etc., the 2.88ha lot just east of Natabua WWTP was proposed as a candidate site for the Pre-treatment Plant .



Source; Created by JET

Figure A3-1.4 Proposed Site for Distillery Pretreatment Plant

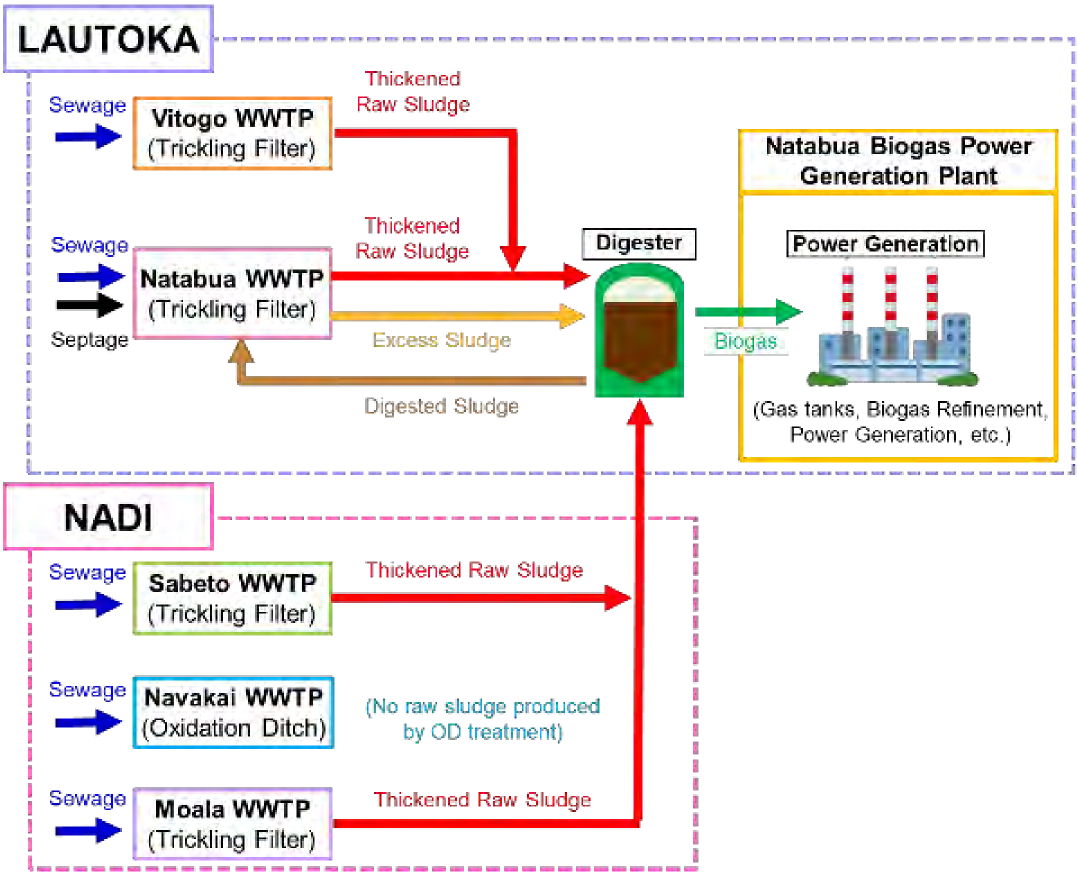
APPENDIX 3-2 Sludge Utilization(Biogas Power Generation) Flow of Lautoka/Nadi WWTPs

In the Regional Wastewater M/P, WAF request to incorporate the utilization of sewerage sludge, specifically energy recovery though biogas production. Considering economies of scales, it was determined that a single, large-scale anaerobic digester + biogas power generation plant was to be built.

Since excess sludge is low in calorific value, the digester's input target was set to be mainly raw sludge produced from primary clarifiers of WWTPs with Trickling Filter systems (Oxidation Ditch systems do not have primary clarifiers).

Out of the four WWTPs with TF systems (Vitogo, Natabua, Sabeto, Moala), Natabua WWTP has the largest treatment capacity, producing the largest amount of sewerage sludge. Thus, the anaerobic digester + biogas power generation plant was placed at Natabua WWTP. Raw sludge from the other three WWTPs are to be gravitationally thickened, then bailed to Natabua for receival.

Figure A3-2.1 shows the sludge utilization flows of the Lautoka/Nadi WWTPs.



Source: JET

Figure A3-2.1 Sludge Utilization (Biogas Power Generation) Flow of Lautoka/Nadi WWTPs

APPENDIX 3-3 Setting Natabua WWTP Influent Water Quality Parameters

In the previous Regional Wastewater M/P and Municipal Sewerage M/P, the influent water quality for all WWTPs were set at a uniform value, applying the maximum value taken from adjusted raw influent data (2014-2018 annual averages, all WWTPs) and values adopted in past donor projects.

For the Pre-F/S, WWTP-specific influent water quality values were adopted, taking into consideration of additional raw data (2019-2023) and the addition of pretreated distillery waste (refer to **APPENDIX 3-1** for details).

The influent water quality parameters for Natabua WWTP was set as shown in **Table A3-3.1**.

Table A3-3.1 Natabua WWTP Influent Water Quality*

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
398	500	45	11

*Including Raw sewerage, pretreated distillery waste, and dewatered septage leachate
Source: JET

(1) Raw Sewerage (Pipeline Sewerage)

1) Selection of Raw Data

Due to the COVID-19 pandemic, Fiji shut down its borders to all foreign nationals (March 2020-November 2021), leading to the sharp drop of tourist population visiting Fiji. It is believed that the influent flowrate and water quality of sewerage also was affected by this decrease, producing off-normal data.

Statistics show that visitor arrivals significantly decreased from 2020-2022, but recovered back to pre-COVID (2019) levels from 2023 (**Table A3-3.2, Figure A3-3.1**). Therefore, in this report the raw data from 2014-2019 and 2023 was adopted for examination.

Table A3-3.2 Annual Visitor Arrivals to Fiji

Year	Arrivals to Fiji
2017	842,884
2018	870,309
2019	894,389
2020	146,552
2021	31,618
2022	636,312
2023	Refer to graph

Source: Created by JET based on Tourism Fiji data

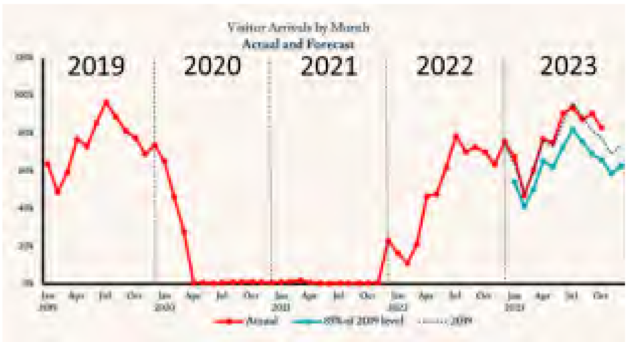
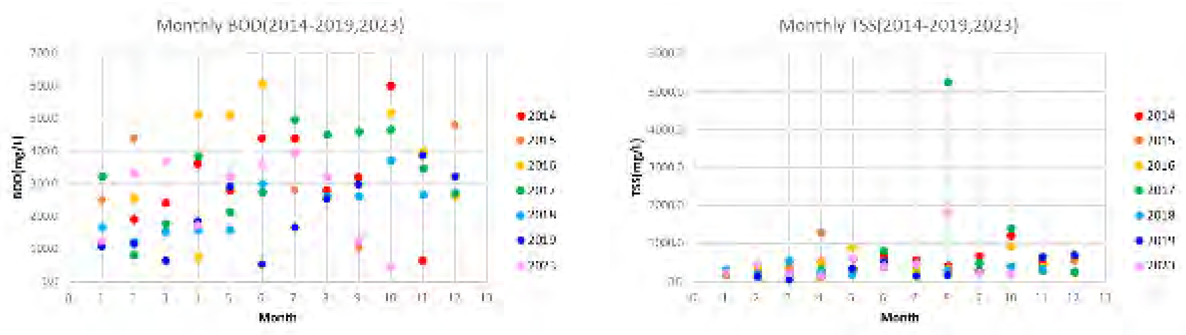


Figure A3-3.1 Visitor Arrivals to Fiji
Source: Tourism Fiji, "Statistics and Insights: Visitors Arrival"(https://corporate. fiji. travel/statistics-and-insights/visitors-arrival)

2) Removing Outlier Data

WAF collects/analyzes influent samples taken from their WWTPs once a month. Raw influent data for Natabua WWTP showed unusually extreme high/low results: BOD levels ranging from 47.4-607 mg/L, and TSS levels ranging from 108.3-5252 mg/L. The collected data was examined for possible seasonal/annual trends but showed no apparent patterns, several being abrupt one-time events (**Figure A3-3.2**).

It was inferred that these readings were possible due to sample contamination or mis-recording of data, and direct application of all raw data would lead to over/under-estimation of influent water quality. Before further examination, outlier data (top 10% and bottom 10%) was removed from each data group. From the remaining data sets, the 80%tile value was set as Natabua WWTP's raw sewerage influent water quality (**Table A3-3.3**).



Source: JET

Figure A3-3.2 Checking Seasonal Trends for Natabua WWTP Raw Influent Water Quality Data

Table A3-3.3 Natabua WWTP Raw Sewerage Water Quality

Max Daily Flowrate (m^3/day)	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
44,477	373	486	37	9

Source: JET

(2) Influent from other Facilities

1) Septage Treatment Facility

A septage treatment facility prior to Phase 1, and Natabua WWTP will receive dewatered leachate produced from dewatering to its sewerage treatment system. 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 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		
Flowrate (m^3/d)	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)	Sludge Volume (m^3/day)	Water Content	TSS (mg/L)
59 m^3/d	250 mg/L	620 mg/L	37	9	6 m^3/day	75%	20,000

Source: "Adoption/Demonstration Experiment Project of Johkaso Sludge Dewatering Machines in Cebu City (Philippines)" (AMCON INC.) (2016)

2) Distillery Waste Pretreatment Facility

As explained earlier in **APPENDIX 3-1**, Natabua WWTP is planned to receive pretreated distillery wastewater starting from Phase 1. Since the plant's specific treatment methods are out of this project's scope, this report sets the Pretreatment Plant's effluent (aka. Natabua WWTP's influent) based on Fijian and Australian Liquid Trade Waste Standards (**Table A3-3.5**).

Table A3-3.5 Expected Pretreated Distillery Wastewater Quality

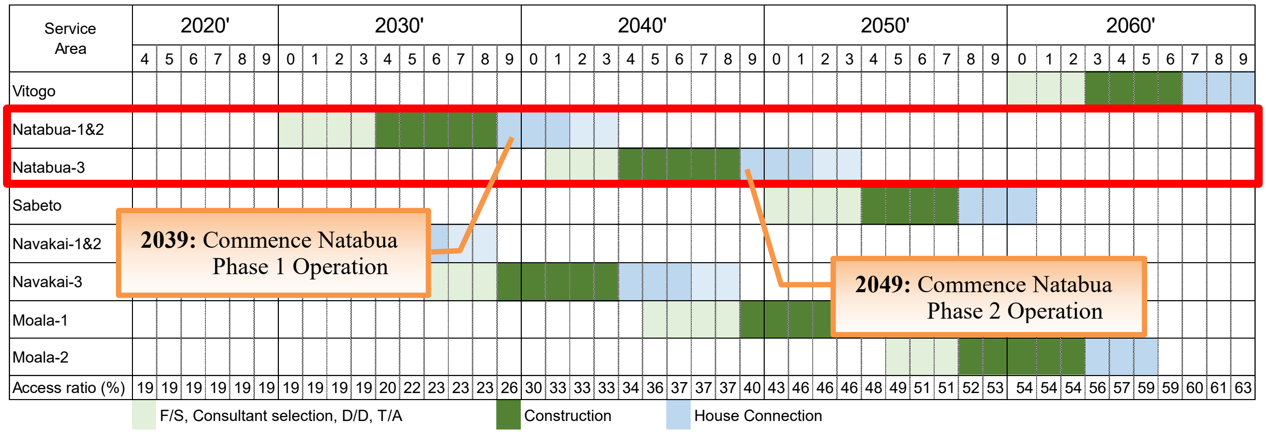
Max Daily Flowrate (m^3/day)	BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
1,760*	600	600	100	20

*Includes raw sewerage used for dilution. Refer to **APPENDIX 3-1** for details
Source: JET, WAF, NSW Department of Planning Industry and Environment

APPENDIX 3-4 Determining Number of Treatment Line in Natabua WWTP

(1) Setting Influent Flowrates for each Construction Phase

Due to its large requirement in treatment capacity, Navakai WWTP's facility will be constructed in two construction phases (**Figure A3-4.1**).

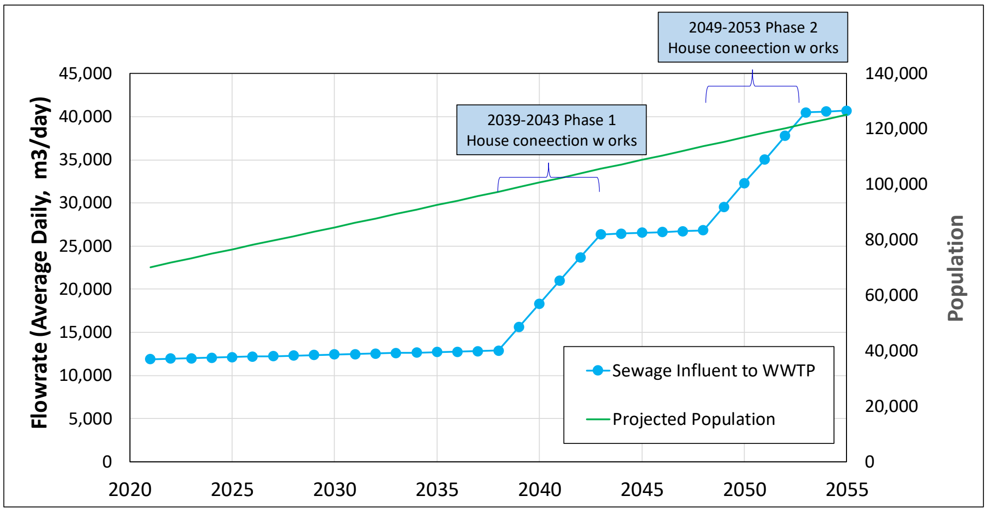


Source: Created by JET

Figure A3-4.1 Implementation Schedule for Natabua WWTP

Required treatment capacities of each phase was calculated based on their commencement schedule and the projected sewerage discharge (based on projected population growth of the sewerage service area) corresponding with that year. Namely, Natabua WWTP Phase 1 facilities must have the capacity to treat sewerage up until the commencement of Phase 2 facilities (2049), and Phase 2 facilities must be able to fulfill demands up until the completion of all house connection works (2053).

The projected population and sewerage flowrate to be treated by Natabua WWTP are shown in **Figure A3-4.2** and **Table A3-4.1**.



Source: Created by JET

Figure A3-4.2 Natabua WWTP Sewerage Discharge vs. WWTP Treatment Capacity

Table A3-4.1 Sewerage Discharge vs. Phase 1/Phase2 Treatment Capacity

Navakai WWTP Facilities	Year of Operation Commencement	Sewerage Influent to WWTP (Average Daily Flowrate) (m^3/day)
Phase 1	2039	26,820
Phase 2	2049	13,685
Total	2049 (Full Operation)	40,505

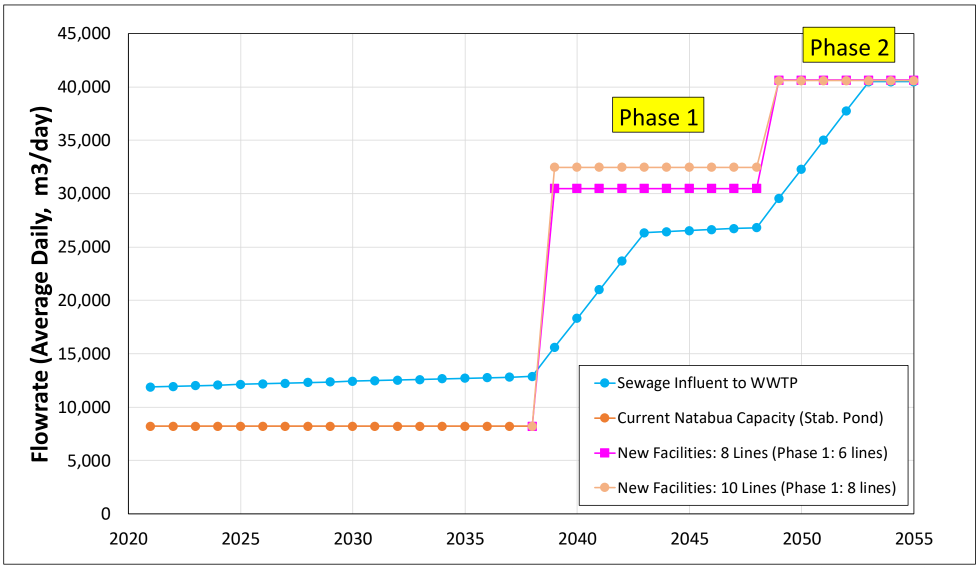
Source: Created by JET

(2) Determining Number of Treatment Lines

WWTPs often have even-number treatment lines, since this generally facilitates O&M and lessens required ME equipment units. Natabua WWTP's 4, 6,8, and 10-line scenarios were compared under the following conditions.

- Capacity of the operating treatment lines must fully cover the expected sewerage flowrate
- All treatment lines have same capacity throughout Phase 1 and Phase 2
- Even-number treatment lines in both Phase 1 and Phase 2 to facilitate O&M (ex. unified operation for all distribution chambers) and lessen required ME equipment units
- Treatment capacity of the treatment line does not exceed design constraints of treatment facilities (ex. maximum diameter of trickling filters)
- Capacity of the operating treatment lines do not overly exceed sewerage flowrate

Figure A3-4.2 and **Table A3-4.1** shows the result of each scenario. The 4-line and 6-line scenario's per-line flowrate would require trickling filters exceeding the design maximum (45 m diameter), and thus were excluded. The excess treatment capacity of the remaining 8-line and 10-line scenarios were compared, showing that the 8-line scenario was better in overall efficiency. Thus, the 8-line scenario was chosen for Natabua WWTP, constructing 6 lines in Phase 1, and 2 lines in Phase 2.



Source: Created by JET

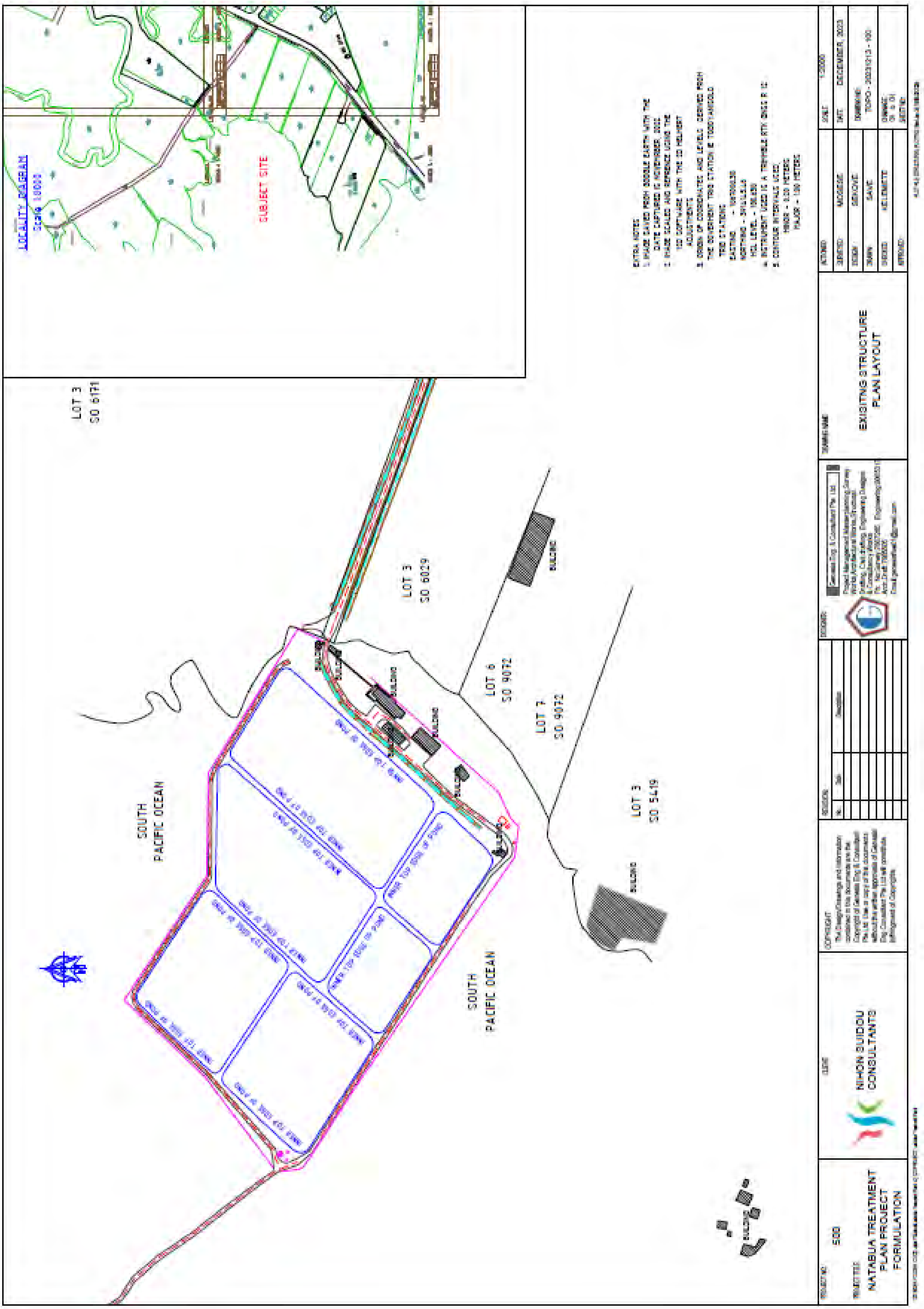
Figure A3-4.3 Natabua WWTP Multi-line System Scenario Comparison

Table A4-4.2 Natabua WWTP Multi-line System Scenario Comparison

Year	Event	Facility in Operation	4 Line Scenario 10150 m3/d per line					6 Line Scenario 6770 m3/d per line					8 Line Scenario 5080 m3/d per line					10 Line Scenario 4060 m3/d per line				
			Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)	Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)	Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)	Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)
2021	Current Plant Operation	Current	-	-	8,200	11,880	-	-	-	8,200	11,880	-	-	-	8,200	11,880	-	-	-	8,200	11,880	-
2022		Current	-	-	8,200	11,943	-	-	-	8,200	11,943	-	-	-	8,200	11,943	-	-	-	8,200	11,943	-
2023		Current	-	-	8,200	12,005	-	-	-	8,200	12,005	-	-	-	8,200	12,005	-	-	-	8,200	12,005	-
2024		Current	-	-	8,200	12,066	-	-	-	8,200	12,066	-	-	-	8,200	12,066	-	-	-	8,200	12,066	-
2025		Current	-	-	8,200	12,127	-	-	-	8,200	12,127	-	-	-	8,200	12,127	-	-	-	8,200	12,127	-
2026		Current	-	-	8,200	12,187	-	-	-	8,200	12,187	-	-	-	8,200	12,187	-	-	-	8,200	12,187	-
2027		Current	-	-	8,200	12,247	-	-	-	8,200	12,247	-	-	-	8,200	12,247	-	-	-	8,200	12,247	-
2028		Current	-	-	8,200	12,306	-	-	-	8,200	12,306	-	-	-	8,200	12,306	-	-	-	8,200	12,306	-
2029		Current	-	-	8,200	12,365	-	-	-	8,200	12,365	-	-	-	8,200	12,365	-	-	-	8,200	12,365	-
2030		Current	-	-	8,200	12,423	-	-	-	8,200	12,423	-	-	-	8,200	12,423	-	-	-	8,200	12,423	-
2031		Current	-	-	8,200	12,480	-	-	-	8,200	12,480	-	-	-	8,200	12,480	-	-	-	8,200	12,480	-
2032		Current	-	-	8,200	12,537	-	-	-	8,200	12,537	-	-	-	8,200	12,537	-	-	-	8,200	12,537	-
2033		Current	-	-	8,200	12,593	-	-	-	8,200	12,593	-	-	-	8,200	12,593	-	-	-	8,200	12,593	-
2034	Phase 1 WWTP Construction	Current	-	-	8,200	12,649	-	-	-	8,200	12,649	-	-	-	8,200	12,649	-	-	-	8,200	12,649	-
2035		Current	-	-	8,200	12,704	-	-	-	8,200	12,704	-	-	-	8,200	12,704	-	-	-	8,200	12,704	-
2036		Current	-	-	8,200	12,758	-	-	-	8,200	12,758	-	-	-	8,200	12,758	-	-	-	8,200	12,758	-
2037		Current	-	-	8,200	12,814	-	-	-	8,200	12,814	-	-	-	8,200	12,814	-	-	-	8,200	12,814	-
2038		Current	-	-	8,200	12,869	-	-	-	8,200	12,869	-	-	-	8,200	12,869	-	-	-	8,200	12,869	-
2039	Phase 1 House Connections	Phase 1	4	4	40,600	15,600	25,000	4	4	27,080	15,600	11,480	6	6	30,480	15,600	14,880	8	8	32,480	15,600	16,880
2040		Phase 1		4	40,600	18,314	22,286		4	27,080	18,314	8,766		6	30,480	18,314	12,166		8	32,480	18,314	14,166
2041		Phase 1		4	40,600	21,011	19,589		4	27,080	21,011	6,069		6	30,480	21,011	9,469		8	32,480	21,011	11,469
2042		Phase 1		4	40,600	23,690	16,910		4	27,080	23,690	3,390		6	30,480	23,690	6,790		8	32,480	23,690	8,790
2043		Phase 1		4	40,600	26,352	14,248		4	27,080	26,352	728		6	30,480	26,352	4,128		8	32,480	26,352	6,128
2044	Phase 2 WWTP Construction	Phase 1		4	40,600	26,446	14,154		4	27,080	26,446	634		6	30,480	26,446	4,034		8	32,480	26,446	6,034
2045		Phase 1		4	40,600	26,539	14,061		4	27,080	26,539	541		6	30,480	26,539	3,941		8	32,480	26,539	5,941
2046		Phase 1		4	40,600	26,633	13,967		4	27,080	26,633	447		6	30,480	26,633	3,847		8	32,480	26,633	5,847
2047		Phase 1		4	40,600	26,727	13,873		4	27,080	26,727	353		6	30,480	26,727	3,753		8	32,480	26,727	5,753
2048		Phase 1		4	40,600	26,820	13,780		4	27,080	26,820	260		6	30,480	26,820	3,660		8	32,480	26,820	5,660
2049	Phase 2 House Connections	Phase 1 + Phase 2		4	40,600	29,557	11,043	6	6	40,620	29,557	11,063	8	8	40,640	29,557	11,083	10	10	40,600	29,557	11,043
2050		Phase 1 + Phase 2		4	40,600	32,294	8,306		6	40,620	32,294	8,326		8	40,640	32,294	8,346		10	40,600	32,294	8,306
2051		Phase 1 + Phase 2		4	40,600	35,031	5,569		6	40,620	35,031	5,589		8	40,640	35,031	5,609		10	40,600	35,031	5,569
2052		Phase 1 + Phase 2		4	40,600	37,768	2,832		6	40,620	37,768	2,852		8	40,640	37,768	2,872		10	40,600	37,768	2,832
2053		Phase 1 + Phase 2		4	40,600	40,505	95		6	40,620	40,505	115		8	40,640	40,505	135		10	40,600	40,505	95
2054		Phase 1 + Phase 2		4	40,600	40,505	95		6	40,620	40,505	115		8	40,640	40,505	135		10	40,600	40,505	95
2055		Phase 1 + Phase 2		4	40,600	40,505	95		6	40,620	40,505	115		8	40,640	40,505	135		10	40,600	40,505	95
			Total Excess Capacity				195,900	Total Excess Capacity				60,840	Total Excess Capacity				94,980	Total Excess Capacity				114,700

Source: Created by JET

APPENDIX 3-5 Natabua WWTP Survey Results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SUBJECT SITE
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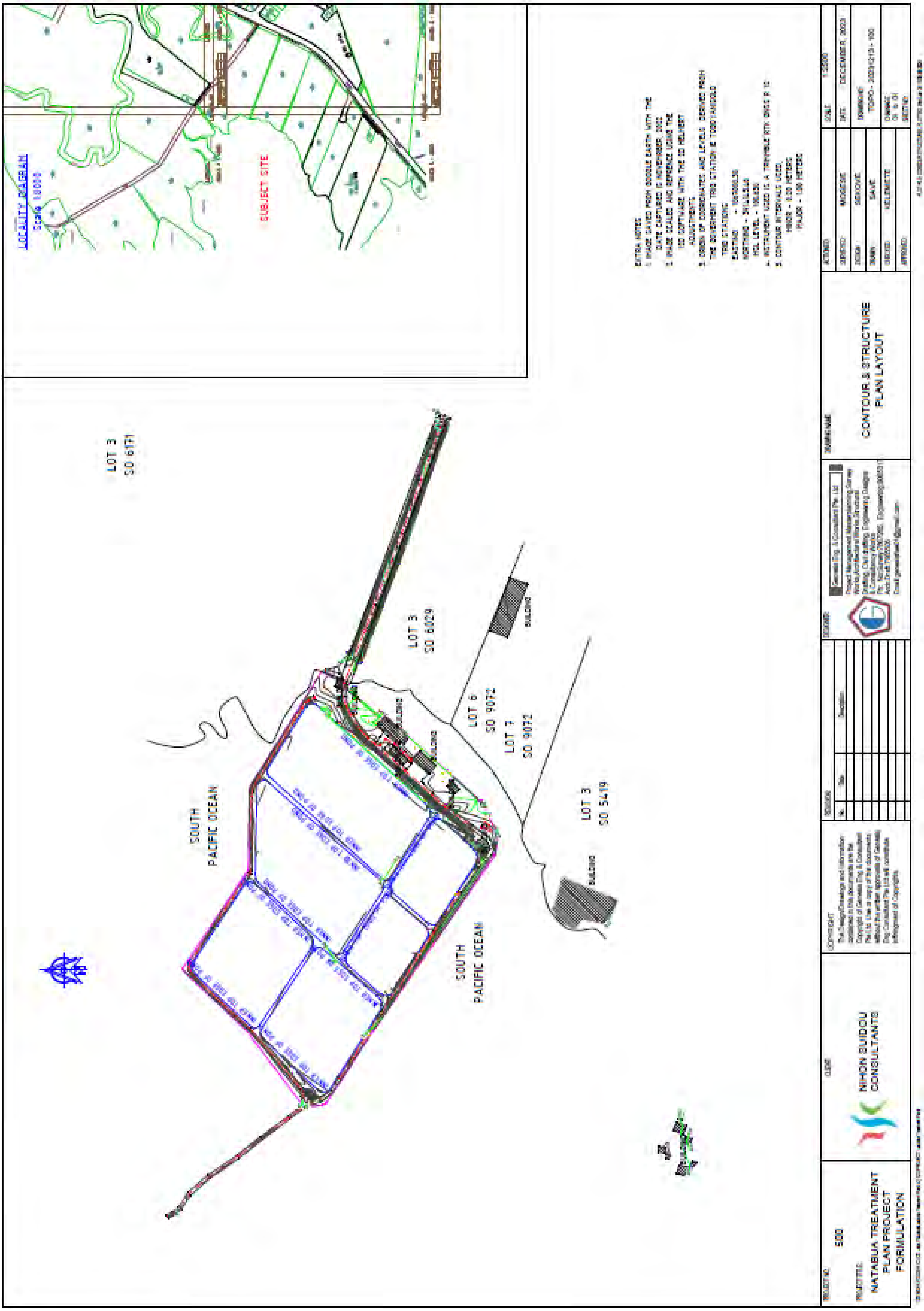
SO 6171
LOT 3
SO 6029
LOT 6
SO 9072
LOT 7
SO 9072
LOT 3
SO 5419
SOUTH
PACIFIC OCEAN
SOUTH
PACIFIC OCEAN
EXISITNG STRUCTURE
PLAN LAYOUT
NIHON SUIDOU
CONSULTANTS
NATABUA TREATMENT
PLAN PROJECT
FORMULATION
DECEMBER, 2023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LOT 3
SO 6029
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LOT 3
SO 5419
SOUTH
PACIFIC OCEAN
SOUTH
PACIFIC OCEAN
CONTOUR & STRUCTURE
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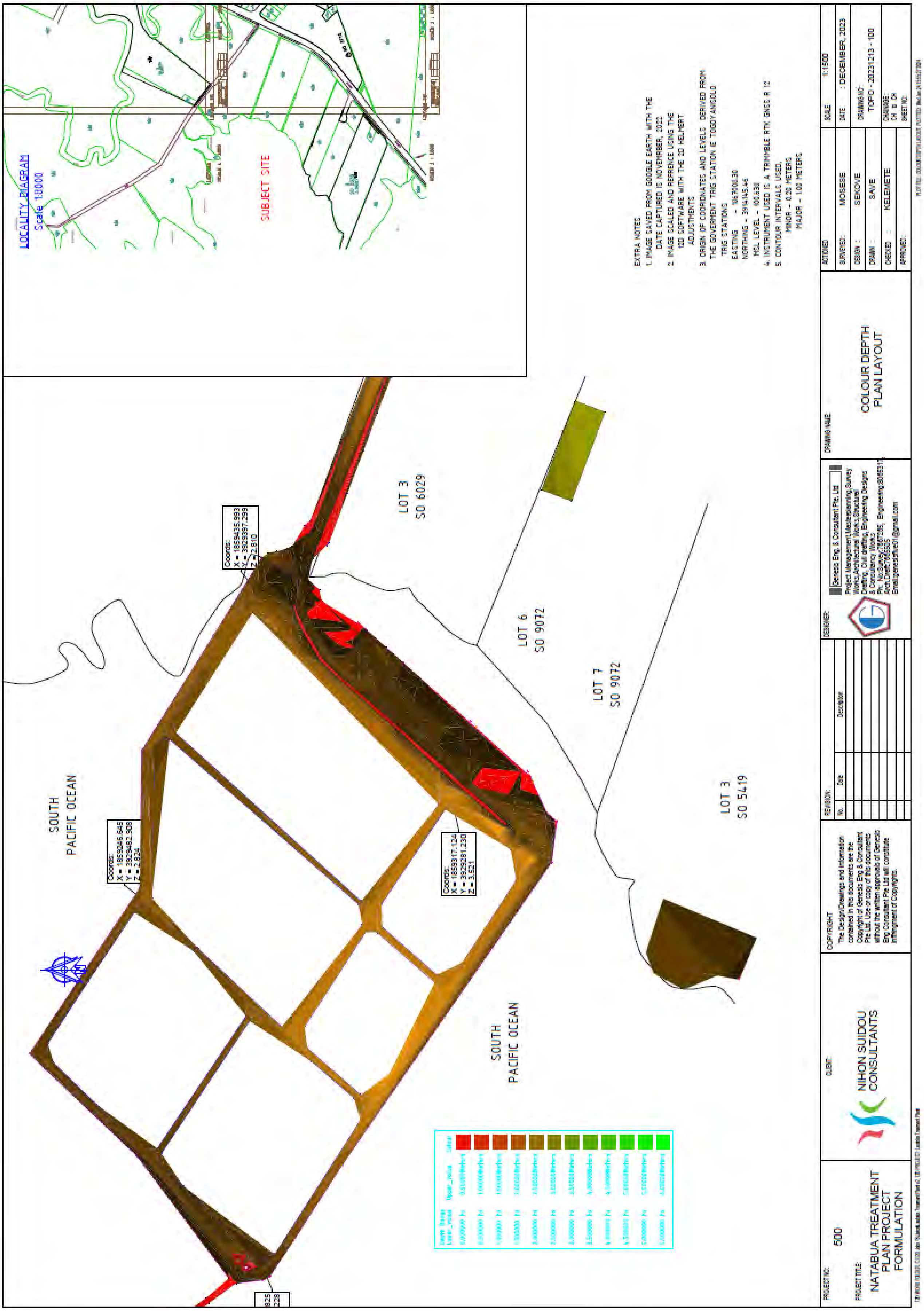
NATABUA TREATMENT
PLAN PROJECT
FORMULATION
NIHON SUIDOU
CONSULTANTS
DECEMBER, 2023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SOUTH
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SO 6029
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SO 9072
LOT 7
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MOISESE
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1:1500
DECEMBER, 2023
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APPENDIX 3-6 Natabua WWTP Soil Survey Results

Soil survey studies were conducted at Natabua WWTP to obtain geotechnical data of the area. Soil boring tests were performed at two locations, Boring HoleL1 and Boring Hole L2, within the current WWTP boundaries **(Figure 3-6.1**). The soil boring test results are shown in the following pages.

It should be noted that in future stages of facility designs, additional boring tests should be conducted for the planned construction area outside of the current WWTP boundaries.

Source: ENTEC PTE Ltd.

Figure 3-6.1 Navakai WWTP Soil Boring Test Locations

(1) Boring Hole L1

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L1**
Job No.: 1381123.B	Start Date: 23-3-2024 Finish Date: 25-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 545014.000 N: 8050138.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 29.00 m	Inclination: -90°	Sheet: 1 of 6

Column headings: Type; Run; Fluid & Water; Piezometer; Geological Description (Soil Description: subordinate, particle size, MAJOR, minor colour, structure, strength: moisture condition; grading; bedding; plasticity, sensitivity, major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour texture, fabric and orientation; NAME; strength; geologic unit.); Legend; Weathering; Field Strength; Elevation (m MSL); Depth (m); Geological Unit; Defect Spacing (mm); Defect Description; TCR (SCR) RQD (%); Samples; Tests

Fluid & Water: 28-03-24 09:08 Waterlevel @0.12mbgl

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
0.00	FILL: GC gravel with some clay and sand and minor organics; trace silt; dark grey mottled brown. Dense to loose, recovered as medium to coarse grained; angular to subangular; moist. CORE LOSS.		FILL	10		
1.00	CORE LOSS. FILL: GP gravel, trace clay, silt and sand; dark grey. Loose, recovered as medium to coarse grained; subangular to angular; moist. CORE LOSS.	1	FILL	10		SPT 1.00 m 5,1,3 N=4 REC=0
2.00	CH CLAY with traces fine sand and silt; dark brown. Very soft, wet. CORE LOSS.	2 3	QUATERNARY SURFICIAL DEPOSITS	18	SPT Sample 1 2.00	SPT 2.00 m 1 for 450mm N=1 REC=0.43
3.50	CH Sandy CLAY with some silt; greyish brown. Very soft, wet. CORE LOSS.	4	QUATERNARY SURFICIAL DEPOSITS	0		SPT 3.50 m 1,1 for 300 N=1 REC=0

Explanations:
Rock Mass Weathering - Fresh (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
Small Disturbed Sample
Large Disturbed Sample
SPT - blows/300mm
Permeability Test
U100 Undisturbed Sample
Insitu Vane Shear Strength (kPa)
UTP = Unable to penetrate

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
28/03/24, 9:08am WL @0.12mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L1**
Job No.: 1381123.B	Start Date: 23-3-2024 Finish Date: 25-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 545014.000 N: 8050138.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 29.00 m	Inclination: -90°	Sheet: 2 of 6

Column headings: Type; Run; Fluid & Water; Piezometer; Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure; strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications; weathering of clasts, subordinate qualifications, minor qualifications; additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit); Legend; Weathering; Field Strength; Elevation (m MSL); Depth (m); Geological Unit; Defect Spacing (mm); Defect Description (type, orientation, coating, roughness, persistence, aperture, infilling etc.); TCR (SCR) RQD (%); Samples; Tests

Run	Geological Description	Depth (m)	Geological Unit	TCR (%)	Samples	Tests
5.00	ML Sandy SILT with trace gravels and shell fragments; dark grey mottled white. Very soft, wet.		QUATERNARY SURFICIAL DEPOSITS	97	SPT Sample 3 5.00	SPT 5.00 m 1 for 300mm, 1 N=1 REC=0.45; WC= 53.8%
	ML Sandy SILT with trace gravels and shell fragments; dark grey mottled white. Very soft, wet.	6			Sample 1 6.10	
	CORE LOSS.					
6.50	ML Sandy SILT with trace gravels and shell fragments; dark grey mottled white. Very soft, wet.	7		67	PUSHTUBE 1 6.50	
	CORE LOSS.					
8.00	ML Sandy SILT: dark grey mottled white. Very soft, wet.	8		93	PUSHTUBE 2 8.00	
		9				
	CH CLAY: dark brown. Very soft, moist.				Sample 2 9.25	WC= 68% LL= 94% PL= 47% PI= 47%
	CORE LOSS.					
9.50	CH CLAY with trace silt and fine sand, dark brown. Very soft, moist.			100	SPT Sample 3 9.50	SPT 9.50 m 1 for 300mm, 1 N=1 REC=0.45

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
28/03/24, 9.58am WL @0.12mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2)		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: BH_L1
Job No.: 1381123.B	Start Date: 23-3-2024 Finish Date: 25-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 545014.000 N: 8050138.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 29.00 m	Inclination: -90°	Sheet: 3 of 6

Geological Description: Soil Description: subcomlasses, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit.
Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit.

Geological Unit: QUATERNARY SURFICIAL DEPOSITS

Run	Geological Description	Depth (m)	TCR (SCR) RQD (%)	Samples	Tests
9.50	CH CLAY with trace silt and fine sand, dark brown Very stiff, moist (continued)		100	PUSHTUBE 3 9.70	
11.00	ML SILT with clay, trace fine sand and gravel, dark brown mottled grey. Firm, moist to wet.	11	100	SPT Sample 4 11.00	SPT 11.00 m 3,2,3 N=5 REC=0.45; WC= 67.3% LL= 69% PL= 40% PI= 26%
12.50	GM Gravelly sandy SILT with minor clay, dark brown. Firm, low to medium plasticity, moist.	12, 13	97		SPT 12.50 m 2,3,4 N=7 REC=0
	CORE LOSS.				
14.00	ML Gravelly sandy SILT with minor clay, dark brown. Soft, moist.	14	93	SPT Sample 5 14.00	SPT 14.00 m 2,2,3 N=5 REC=0.40

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- insitu Vane Shear Strength (kPa)
- UTP - Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
26/03/24, 9:08am WL @0.12mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2)		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L1**
Job No.: 1381123.B	Start Date: 23-3-2024 Finish Date: 25-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 545014.000 N: 8050138.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 29.00 m	Inclination: -90°	Sheet: 4 of 6

Geological Description: Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of class, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit.

Defect Description: type, orientation, spacing, roughness, aperture, infilling etc.

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
14.00	ML Gravelly sandy SILT with minor clay, dark brown. Soft, moist. (continued)		QUATERNARY SURFICIAL DEPOSITS	93		UCS @ 15.1m-4m UCS= 31kPa E= 1MPa
	CORE LOSS					
15.50	ML Sandy SILT with gravel, brown mottled dark grey. Stiff, low to medium plasticity, moist.	15		100	SPT Sample 6 15.50 Sample 5 16.40	SPT 15.50 m 4,5,6 N=11 REC=0.45
17.00	SM Silty SAND with gravels, brown grey. Medium dense, recovered as coarse grained, moist to wet.	17			SPT Sample 7 17.00	SPT 17.00 m 4,6,9 N=15 REC=0.45
	ML Sandy SILT with gravels, brown mottled grey. Stiff, low plasticity, moist.	18		100		
18.50	ML Sandy SILT with gravels, brown mottled grey. Very stiff, low plasticity, moist.	19		93	SPT Sample 8 18.50	SPT 18.50 m 4,8,13 N=21 REC=0.45
	CORE LOSS					

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR = Total Core Recovery
SCR = Solid Core Recovery
RQD = Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
Small Disturbed Sample
Large Disturbed Sample
SPT - blows/300mm
Permeability Test
U100 Undisturbed Sample
Insitu Vane Shear Strength (kPa)
UTP = Unable to penetrate

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.5%

Water Level:
28/03/24, 9:08am WL @0.12mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwall Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L1**
Job No.: 1381123.B	Start Date: 23-3-2024 Finish Date: 25-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 545014.000 N: 8050136.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 29.00 m	Inclination: -90°	Sheet: 5 of 6

Columns: Type | Run | Fluid & Water | Piezometer | Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit.) | Legend | Weathering | Field Strength | Elevation (m MSL) | Depth (m) | Geological Unit | Defect Spacing (mm) | Defect Description | TCR (SCR) RQD (%) | Samples | Tests

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
20.00	Sandy SILT with gravels, brown mottled grey. Very stiff, low plasticity, moist.	21	QUATERNARY SURFICIAL DEPOSITS	93	SPT Sample 9 20.00	SPT 20.00 m 5,10,11 N=21 REC=0.45 WC= 45.7%
	CORE LOSS					
21.50	XW SILTSTONE (Sandy SILT with gravels, brown mottled grey. Hard, low plasticity, moist).		MIOCENE PLIOCENE UPPER VUDA BED		SPT Sample 10 21.50	SPT 21.50 m 7,11,9 N=50+ DS REC=0.45
	CORE LOSS	22		60		
	XW SILTSTONE (Sandy SILT with gravels, brown mottled grey. Hard, low plasticity, moist).				Sample 4 22.70	
23.00	XW SILTSTONE (Sandy SILT with gravels, brown mottled grey. Hard, low plasticity, moist).	23			SPT Sample 11 23.00	SPT 23.00 m 7,5,7 for 20mm N=50+ DS REC=0.3
	CORE LOSS	24		40		
	XW SILTSTONE (Sandy SILT with gravels, brown mottled grey. Hard, low plasticity, moist).					
24.50	CORE LOSS			40	SPT Sample 12 24.50	SPT 24.50 m 8,11 for 150mm N=50+ DS REC=0.2

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
28/03/24: 9:08am WL @0.12mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: BH_L1
Job No.: 1381123.B	Start Date: 23-3-2024 Finish Date: 25-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 545014.000 N: 8050138.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 29.00 m	Inclination: -90°	Sheet: 6 of 6

Column headings: Type; Run; Fluid & Water; Piezometer; Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit); Legend; Weathering; Field Strength; Elevation (m MSL); Depth (m); Geological Unit; Defect Spacing (mm); Defect Description; TCR (SCR) RQD (%); Samples; Tests

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
24.50	CORE LOSS. (continued)		MIOCENE PLIOCENE UPPER VUDA BED	40		
	XW SILTSTONE (Sandy SILT with gravels, brown mottled grey, hard, low plasticity, moist)					
26.00	HW dark grey SILTSTONE, very low strength, moist.	26			SPT Sample 13 26.00	SPT 26.00 m 9,11 for 130mm N=50+ DS REC=0.26
	CORE LOSS.			97		
	HW dark grey SILTSTONE, very low strength, moist.	27				
27.50					SPT Sample 14 27.50	SPT 27.50 m 3 for 80mm N=50+ DS REC=0.08
		28		35		
	CORE LOSS.					
	HW dark grey SILTSTONE, very low strength, moist.					
	Hole Terminated at 29.00 m	29			SPT Sample 15 29.00	SPT 29.00 m 8,12 for 40mm N=50+ DS REC=0.15

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Hand Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
- D - Dry
- M - Moist
- W - Wet

Remarks
-Hammer #01 efficiency: 72.6%

Water Level:
28/03/24: 9:08am WL @0.12mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

(2) Boring Hole L2

ENTEC PTE LIMITED
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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: BH_L2
Job No.: 1381123.B	Start Date: 25-3-2024 Finish Date: 27-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 544688.000 N: 8050330.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.50 m	Inclination: -90°	Sheet: 1 of 7

Columns: Type, Run, Fluid & Water, Piezometer, Geological Description (Soil Description: subordinate, particle size, MAJOR, minor; colour; structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit), Legend, Weathering, Field Strength, Elevation (m MSL), Depth (m), Geological Unit, Defect Spacing (mm), Defect Description, TCR (SCR) RQD (%), Samples, Tests

Fluid & Water: 28-03-24 10:30, Waterlevel @0.8mbgl

Run	Geological Description	Depth (m)	Geological Unit	TCR (%)	Samples	Tests
0.00	FILL: (GAP65) gravel: dark grey. Dense to loose, recovered as coarse grained, well graded, moist, (100mm). CORE LOSS.		FILL	16		
1.00	CH CLAY with sand and silt, trace gravel: dark brown. Firm, high plasticity, moist. CORE LOSS.	1	QUATERNARY SURFICIAL DEPOSITS	40	SPT Sample 1 1.00	SPT 1.00 m 7, 2, 3 N= 6 REC= 0.2
	CH CLAY with sand and silt, trace gravel: dark brown. Soft to firm, high plasticity, moist.				Sample I 1.80	WC= 46.1% LL= 78% PL= 38% PI= 38%
2.00	GW Gravelly SAND with silt, trace clay: dark grey. Medium dense to dense, gravel, recovered as coarse grained, well graded, moist to wet. CORE LOSS.	2		17	SPT Sample 2 2.00	SPT 2.00 m 10, 9, 4 N= 13 REC= 0.28
		3				
3.50	GW Gravelly SAND with silt, trace clay: dark grey. Very loose to loose, gravel, recovered as coarse grained, well graded, moist to wet. CORE LOSS.			17	SPT Sample 3 3.50	SPT 3.50 m 3, 3, 1 N= 4 REC= 0.05
		4				

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
Small Disturbed Sample
Large Disturbed Sample
SPT - blows/300mm
Permeability Test
U100 Undisturbed Sample
Insitu Vane Shear Strength (kPa)
UTP = Unable to penetrate

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%
Water Level:
-28/03/24: 10:30am @0.8mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED

ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L2**
Job No.: 1381123 B	Start Date: 25-3-2024 Finish Date: 27-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 544688.000 N: 8050330.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.50 m	Inclination: -90°	Sheet: 2 of 7

Type	Run	Fluid & Water	Piezometer	Geological Description (Soil Description: subordinate particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering, colour, texture, fabric and orientation; NAME, strength, geologic unit)	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description (type, inclination, spacing, roughness, persistence, aperture, infilling etc.)	TCR (SCR) RQD (%)	Samples	Tests
	5.00			GW Gravelly SAND with silt, trace clay: dark grey. Very loose; gravel recovered as coarse grained, well graded; moist to wet. (continued)						QUATERNARY SURFICIAL DEPOSITS				SPT 1 Sample 4 5.00	SPT 5.00 m 3, 1 for 300mm N= 1 REC= 0.05
				CORE LOSS.											
				GP Coral COBBLES and GRAVEL(GP): pale white mottled grey. Very loose; gravel, recovered as coarse grained, angular; moist.					6				17		
				CORE LOSS.											
	6.60			GP Coral GRAVEL : pale white mottled grey. Loose; moist.										SPT Sample 5 6.50	SPT 6.50 m 4, 4, 6 N= 10 REC= 0.5
				CORE LOSS.					7				17		
	8.00			CORE LOSS.					8						SPT 8.00 m 1, 1 for 300mm N= 1 REC= 0
									9				13		
				GP Coral GRAVEL with silt, trace sand and clay: grey mottled pale white, mottled grey. Very loose; moist.											
	9.50			CORE LOSS.									0		SPT 9.50 m 4, 2, 1 N= 3 REC= 0

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR = Total Core Recovery
SCR = Solid Core Recovery
RQD = Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
-28/03/24, 10:30am @0.6mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).

Location: Natabua WWTP. Off Queens Road, Lautoka

No.: **BH_L2**

Job No.: 1381123.B

Start Date: 25-3-2024
Finish Date: 27-3-2024

Ground Level (m MSL):

Co-Ordinates (FMG): E: 544688.000 N: 8050330.000

Client: Nihon Suido Consultants Co. Ltd

Hole Depth: 30.50 m

Inclination: -90°

Sheet: 3 of 7

Column headings: Type | Run | Fluid & Water | Piezometer | Geological Description (Soil Description: subordinate, particle size, MAJOR, minor; colour; structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit) | Legend | Weathering | Field Strength | Elevation (m MSL) | Depth (m) | Geological Unit | Defect Spacing (mm) | Defect Description | TCR (SCR) RQD (%) | Samples | Tests

Geological Unit: QUATERNARY SURFICIAL DEPOSITS

Run (m)	Geological Description	Depth (m)	TCR (%)	Samples	Tests
9.50	CORE LOSS. (continued)		0		
11.00	GP Coral GRAVEL with silt, trace sand and clay: grey mottled pale white, mottled grey. Very loose, moist.	11	60	SPT Sample 6 11.00	SPT 11.00 m 1, 1 for 300mm N= 1 REC= 0.10
	CORE LOSS.				
	ML SILT trace sand and gravel: dark brown. Soft to firm, moist.			Sample 2 11.45	WC= 35.3%
11.75	CORE LOSS.		33		
	CH CLAY with trace silt: dark brown mottled grey. Firm to stiff, moist.	12			
12.50	CH CLAY with trace silt: dark brown. Stiff, moist.		70	SPT Sample 7 12.50	SPT 12.50 m 5, 6, 8 N= 14 REC= 0.35; WC= 44.8% LL= 80.4% PL= 47% PI= 40%
	CORE LOSS.	13			
	MH SILT with clay: dark grey. Stiff, moist.			Sample 3 13.30	UCS= 0.13MPa E= 2MPa
14.00	MH SILT with clay: dark grey. Very stiff, moist.	14	70	SPT Sample 8 14.00	SPT 14.00 m 5, 8, 10 N= 18 REC= 0.45
	CORE LOSS.				
	XW SILTSTONE; (SILT with clay: dark grey. Stiff, moist.)				

Explanations:
Rock Mass Weathering - Fresh (FR)
Slightly Weathered (SW), Moderately Weathered (MW)
Highly Weathered (HW), Extremely Weathered (XW)
Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
-28/03/24, 10:30am @0.6mbgl.

All dimensions in metres
Scale 1:31

Contractor: Rockwell Pacific Pte Ltd

Rig/Plant Used: HANJIN

Logged by: IT

Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L2**
Job No.: 1381123.B	Start Date: 25-3-2024 Finish Date: 27-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 544688.000 N: 8050330.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.50 m	Inclination: -90°	Sheet: 4 of 7

Column headings: Type | Run | Fluid & Water | Piezometer | Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit) | Legend | Weathering | Field Strength | Elevation (m MSL) | Depth (m) | Geological Unit | Defect Spacing (mm) | Defect Description (type, orientation, spacing, roughness, persistence, aperture, infilling etc) | TCR (SCR) RQD (%) | Samples | Tests

Run	Geological Description	Depth (m)	TCR (SCR) RQD (%)	Samples	Tests
14.00	XW SILTSTONE. [SILT with clay, dark grey. Stiff, moist.] (continued)				
	XW to HW dark grey CONGLOMERATE; low strength, moist. (Recovered as dense gravel)		70		
15.50	CORE LOSS	16			SPT 15.50 m 0 for 00mm N= 50+ D0 REC= 0
	HW dark grey CONGLOMERATE very low to low strength, matrix supported, moist.		47		
17.00	HW dark grey CONGLOMERATE, low to medium strength, moist.	17		SPT Sample 3 17.00	SPT 17.00 m 5,8 for 75mm N=50+ D8 REC=0.23
	CORE LOSS	18	51		
	HW dark grey CONGLOMERATE, low to medium strength, moist.			Sample 4 19.00	
18.50	CORE LOSS	19	0		SPT 18.50 m 4 for 40mm N=50+ D8 REC=0

Geological Unit: MIOCENE PLIOCENE UPPER VUDA BED

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
Hammer #01 efficiency 72.9%

Water Level:
28/03/24, 10:30am @0.5mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: BH_L2
Job No.: 1381123.B	Start Date: 25-3-2024 Finish Date: 27-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 544688.000 N: 8050330.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.50 m	Inclination: -90°	Sheet: 5 of 7

Geological Description: Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit.

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
20.00	HW dark grey CONGLOMERATE medium strength, moist, (recovered as broken coarse gravel)		MIOCENE PLIOCENE UPPER VUDA BED		SPT Sample 15 20.00	SPT 20.00 m 10 for 80mm N=50+ DB REC=0.04
	CORE LOSS.					
	HW to MW dark grey, mottled white pale brown CONGLOMERATE medium strength, moist.	21		89		
21.50	CORE LOSS.					SPT 21.50 m 5 for 50mm N=50+ DB REC=0
	HW to MW dark grey, mottled white CONGLOMERATE medium strength, moist	22		97		
23.00	HW to MW dark grey, mottled white CONGLOMERATE medium strength, moist	23 24		100		SPT 23.00 m 3 for 30mm N=50+ DB REC=0
24.50	CORE LOSS.			63		SPT 24.50 m 11 for 40mm N=50+ DB REC=0
	HW to MW dark grey, mottled white CONGLOMERATE medium strength moist					

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
-28/03/24, 10:30am @0.6mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2)		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L2**
Job No.: 1391123.B	Start Date: 25-3-2024 Finish Date: 27-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 544688.000 N: 8050330.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.50 m	Inclination: -90°	Sheet: 6 of 7

Type	Run	Fluid & Water	Piezometer	Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit)	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description	TCR (SCR) RQD (%)	Samples	Tests
	24.50			HW to MW dark grey, mottled white CONGLOMERATE, medium strength, moist. (continued)						MIOCENE PLIOCENE UPPER VUDA BED			60		
	26.00			HW to MW dark grey, mottled white CONGLOMERATE, medium strength, moist.					26				100		SPT 26.00 m 3 for 40mm N=50+ DB RED=0
									27					Sample 6 27.30	
	27.50			CORE LOSS.					28				23		SPT 27.50 m 3 for 30mm N=50+ DB RED=0
				HW to MW dark grey, mottled white CONGLOMERATE, medium strength, moist.											
	29.00			CORE LOSS.					29				0		SPT 29.00 m 3 for 20mm N=50+ DB RED=0

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- ■ Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
- D - Dry
- M - Moist
- W - Wet

Remarks
-Hammer #01 efficiency: 72.5%

Water Level:
-28/03/24, 10:30am @0.6mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Natabua WWTP, Off Queens Road, Lautoka	No.: **BH_L2**
Job No.: 1381123.B	Start Date: 25-3-2024 Finish Date: 27-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 544688.000 N: 8050330.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.50 m	Inclination: -90°	Sheet: 7 of 7

Type	Run	Fluid & Water	Piezometer	Geological Description (Soil Description: subordinate, particle size; MAJOR; minor; colour; structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit.)	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description	TCR (SCR) RQD (%)	Samples	Tests
	29.00			CORE LOSS. (continued)									0		
				Hole Terminated at 30.50 m											SPT 30.50 m 2 N= 150 N=30+ OR REC=0
									31						
									32						
									33						
									34						

Explanations:
Rock Mass Weathering - Fresh(FR)
Slightly Weathered (SW), Moderately Weathered (MW)
Highly Weathered (HW), Extremely Weathered (XW),
Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
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- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

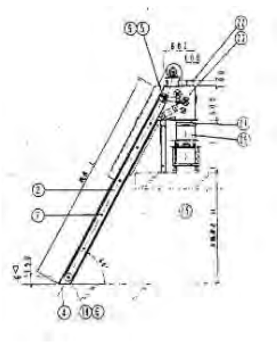
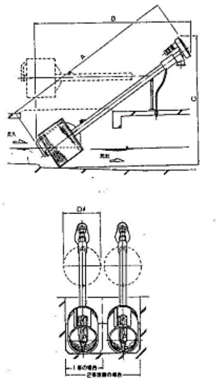
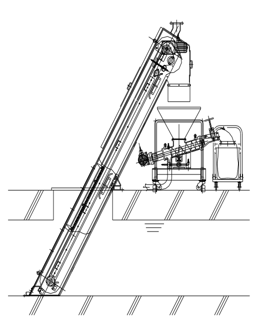
Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
-28/03/24, 10:30am @0.6mbgl

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

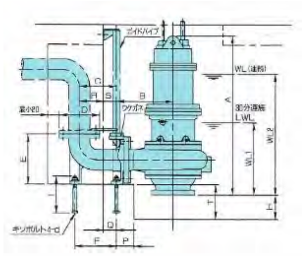
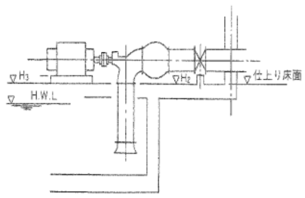
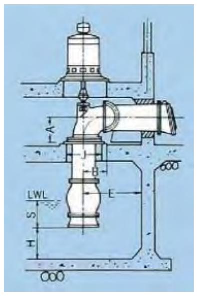
APPENDIX 3-7 Natabua WWTP Comparison/Selection of Mechanical Equipment

(1) Grit Removal Screen

	Automatic belt-running grit screen + Biaxal Screw Type	Drum type screen with dewatering mechanism	Continuous back-scraping type automatic grit screen + Residue dewaterer (Biaxial screw type)
Description	・Automatic screen and residue dewaterer integrated into a single unit. ・Automatic screen: rotating screen with V-shaped grooves that runs and scrapes up residue ・Residue Dewaterer: dewaters scraped residue using a biaxial screw 	・Residue supplemented by drum-type screen is conveyed by screw conveyor and dewatered in the press section ・Washing device can be installed in the drum-type screen section to wash the residue to some extent. 	・Residue trapped in front of the bar screen is scraped up by a comb-like rake attached to an endless chain at the back, scraped off when it returns at the top, and fed into a residue dewaterer connected to a chute 
Specifications	Screen width: 20-30mm Electric motor capacity: 0.4kW (600 width) Capacity of residue dewatering machine: 0.6m^3/h	Screen width: 15-25mm Electric motor capacity: 0.4kW (600 width) Capacity of residue dewatering machine: 0.1-0.5m^3/h	Screen width: 15-25mm Electric motor capacity: 0.4kW (600 width) Capacity of residue dewatering machine: 0.6m^3/h
Advantages	・Continuous scraping rakes allows large capacity ・Simple and reliable operation mechanism	・Continuously scraping rakes allows large capacity	・Continuous scraping rakes allows large capacity. ・Simple and reliable operation mechanism.
Disadvantages	・Necessary to cover the open machine to prevent odors	・The closed structure makes maintenance and management of the system less efficient ・Maintenance is performed by pulling it up to the top of the waterway	・A part of the screen needs to be cut off to allow the rake to pass through at the bottom of the channel ・An auxiliary screen must be installed to prevent residue from flowing downstream from the cut off part
Construction Cost	80	120	100
Maintenance Cost	100	110	100
Overall Cost Evaluation	90	110	100
8. Machine Performance	A	C	A
Overall Evaluation	A	C	B
	The "belt-run automatic grit screen+ residue dewaterer (two-axle screw type)" is highly efficient in combination with a dewaterer because of its high residue capturing performance and economic efficiency.		

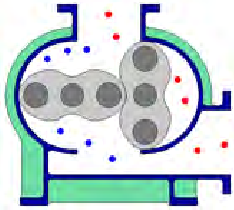
Source: Created by JET

(2) Main Pump

	Submersible sewerage pumps	Horizontal-shaft semi-axial flow pump	Vertical-shaft semi-axial flow pump
Description			
Pump efficiency	50 - 80% (φ100 -800)	70 - 85% (φ300 -3400)	75 - 80% (φ200 -1000)
Maintenance fee	・Detachable type is relatively easy to install/remove for maintenance and inspection. ・Regular mechanical seal maintenance is needed	・Pumps are set up external of the tank, allowing easy maintenance ・Installation of waterless shaft seal system requires maintenance of the mechanical seal.	・Pumps are set up external of the tank, allowing easy maintenance ・Installation of waterless shaft seal system requires maintenance of the mechanical seal.
	90%	100%	100%
Size and space	・Pump is placed inside the tank → smaller footprint ・Pumps and motors are submerged underwater, so only the machine hatch is on the dry floor.	・Requires largest vertical and horizontal installation footprint, (horizontal setup type external of the tank)	・The upper drawer installation footprint is larger due to the setup external of the tank
Construction cost	40 ～ 50 %	100 %	100 %
Auxiliary equipment	No shaft-sealed water pump required.	Requires a shaft-sealed water pump	No shaft-sealed water pump required.
Measures to be taken in case of flooding	If a waterless shaft seal is installed, no vacuum pump or shaft water supply is required.	Requires a shaft-sealed water pump.	If a waterless shaft seal is installed, no vacuum pump or shaft water supply is required.
Evaluation	A	B	B
	In this plan, 'submersible sewerage pumps' will be adopted, considering flood prevention measures, maintainability, and economic efficiency and installment track record		

Source: Created by JET

(3) Blowers

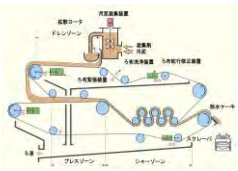
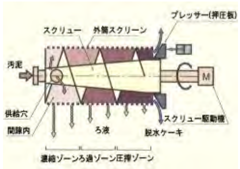
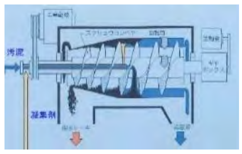
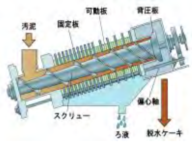
		Steel plate multi-stage turbo blowers	Rotary (Roots-type) blowers	Screw-Type Blower
Description		 	 	
	caliber	Suction side: φ200 Output side: φ150	Suction side: φ200 Output side: φ150	Suction side: φ200 Output side: φ150
	air volume	30 m³/min	30 m³/min	30 m³/min
	pressure	Suction pressure: 2kPa Discharge pressure: 60kPa	Suction pressure: 2kPa Discharge pressure: 60kPa	Suction pressure: 2kPa Discharge pressure: 60kPa
Advantages		・No refueling equipment or cooling water equipment is required. ・Air flow analysis and other technologies have improved efficiency. ・Smooth operation with low rotational vibration.	・Equipment costs are low. ・Experienced in small-scale or initial response.	・Packaged and compact. ・High efficiency due to continuous internal compression by screw. ・Auxiliary equipment is built into the package. ・High blower total thermal efficiency. ・No surging due to the volumetric system.
Disadvantages		・Surging occurs in some areas, so a surging limiter setting is required in the air flow control.	・Silencers required for noise control as they are not packaged. ・Inverter controllers use electronic equipment, so it is necessary to secure unit replacement parts for version upgrades and to take renewal measures corresponding to the service life of the equipment.	・Matrix converter control units use electronic equipment, so it is necessary to secure unit replacement parts for version upgrades and to take renewal measures corresponding to the service life of the unit.
Total thermal efficiency		57%	57%	70%
Pressure loss		・Silencers are not required, resulting in low pressure losses in the piping system.	・Silencers are required and pressure losses are high.	・Silencers are not required, resulting in low pressure losses in the piping system.
Airflow Control		・Inlet guide vane ・Controlled by adjusting the opening of the inlet guide vane, rather than by adjusting the speed of rotation ・Smooth operation with low rotational vibration.	・Inverter device ・Controlled by rotational speed. ・There is no surging area, but the noise level increases as the RPM increases.	・Matrix converter devices ・It is controlled by the speed of rotation, but unlike inverters, it does not require harmonic countermeasures. ・No surging area and it is quiet due to the integrated cover, even when the speed increases.
Size		5,000×2,200×1,600	5,000×2,200×1,600	5,000×2,200×1,600
Weight		6.2 t	1.87 t	1.87 t

Source: Created by JET

	Steel plate multi-stage turbo blowers	Rotary (Roots-type) blowers	Screw-Type Blower
Maintenance	・Protective instrument panels and individual forced lubrication devices are included and installed on the machine side for easy inspection. ・The centrifugal force of the cylindrically arranged runners (forward facing blades) draws in air and creates a swirling flow in a direction almost perpendicular to the axis of rotation. ・The swirling flow generated is rectified in one direction by the scroll and the required pressure is generated and supplied according to the number of runner stages, resulting in less pulsation and vibration and fewer failures.	・Protective devices are not attached but installed separately. ・Pressure pulsation due to 2- and 3-leaf rotors, requiring vibration countermeasures for piping, etc. ・Equipment body, rotor and inverter inspections are required.	・The operating panel, auxiliary equipment and protective devices are installed in a package that is easy to inspect, safe and reliable. ・The operating panel, auxiliary equipment and protective devices are installed in a package that is easy to inspect, safe and reliable. ・Since the air is compressed and blown by the screw, pulsation is smaller than with rotary blowers and smooth operation is possible.
Equipment Cost	100%	95%	90%
Maintenance cost	100%	97%	79%
Overall Evaluation	・High equipment and maintenance costs ・Low thermal efficiency. ・Building costs are high due to the large volume and heavy weight	・Resonance measures should be taken for piping where resonance occurs. ・Resonance measures should be taken for piping where resonance occurs. ・Low thermal efficiency.	・The control panel is installed on the surface of the package and allows for full operation and monitoring, making it easy to manage operations. ・No concern about surging caused by airflow control. ・Many have been introduced in other countries.
	Screw-type blowers are adopted in this project because they are superior in terms of thermal efficiency, equipment cost, maintenance cost, installation space and weight.		

Source: Created by JET

(4) Sludge Dewatering Machine

	Belt-press Dewaterer	Press-in screw press Dewaterer	Centrifugal Dewaterer	Multi-plate screw press Dewaterer
Description	The sludge is fed onto a filter cloth, gravity dewatered, then clipped between two filter cloths and pressed against rollers using the tension of the filter cloth to dewater it. 	Flocculated sludge is pressurized and fed at a constant pressure into the gap between the screen and the screw shaft, and the sludge is continuously dewatered through thickening, filtration and pressing by volume changes while moving from the inlet to the outlet due to the low-speed rotation of the screw. 	Sludge is fed into a rotating cylinder rotating at high speed, where centrifugal force separates solids of different specific gravity from water, and sludge cake is discharged by a screw-shaped discharger (conveyor) that is slightly differentiated from the rotating cylinder. 	Flocculated sludge flocculated in the service tank and mixing tank in the front section of the machine is gravity dewatered and separated into sludge and filter liquid. The screws are progressively thicker and narrower in pitch. Dewatering is carried out by the internal pressure created by this and the pressure applied from the back pressure plate. 
Target Sludge	・Mixed raw sludge ・Digested sludge. ・OD excess sludge, thickened sludge	・Mixed raw sludge ・Digested sludge. ・OD excess sludge, thickened sludge	・Mixed raw sludge ・Digested sludge. ・OD excess sludge, thickened sludge	・Mixed raw sludge ・OD excess sludge, thickened sludge
Auxiliary equipment	・Sludge supply system ・Chemical dosing system (polymer coagulant) ・Wash water pumps, ・Air compressors	・Sludge supply system ・Chemical dosing system (polymer coagulant) ・Wash water pumps, ・Air compressors	・Sludge supply system ・Chemical dosing system (polymer coagulant) ・Wash water pumps, ・Air compressors	・Sludge supply system ・wash water pumps. ・Chemical injection system (polymeric and inorganic coagulants)
Pre-treatment	Thickener tank required	Thickener tank required	Thickener tank required	No need for a thickener tank
Maintenance and management	・Sludge flocculation equipment, diffusion rotor, filter cloth tensioning device, filtration cloth meander corrector, filtration filter cleaning equipment, driving unit. ・One type of chemical	・Screws, outer casing screen, Screw driving unit ・One type of chemical .	・High-speed rotating equipment to be taken back to the factory for overhaul. ・One type of chemical	・Screws, fixed plate, movable plate, dorsal pressure plate, eccentric axis, driving device ・Two types of chemicals
	Difficult due to number of required parts	Easy due to small number of required parts	Needs to be taken back to the factory for overhaul/ minor repairs	Easy due to small number of required parts
Equipment cost	100%	82%	86%	35%
	Includes gravity thickener, dewatering/ conditioning equipment	Includes gravity thickener, dewatering/ conditioning equipment	Includes gravity thickener, dewatering/ conditioning equipment	Includes dewatering/ conditioning equipment
Maintenance costs	100%	68%	89%	89%
Overall Evaluation	In this project, the multiple plate screw press dewaterer will be adopted due to the following reasons ・Does not require a thickening process (thickening tank). ・Lowest sludge cake water content and excellent dewatering performance. ・Low equipment and maintenance costs			

Source: Created by JET

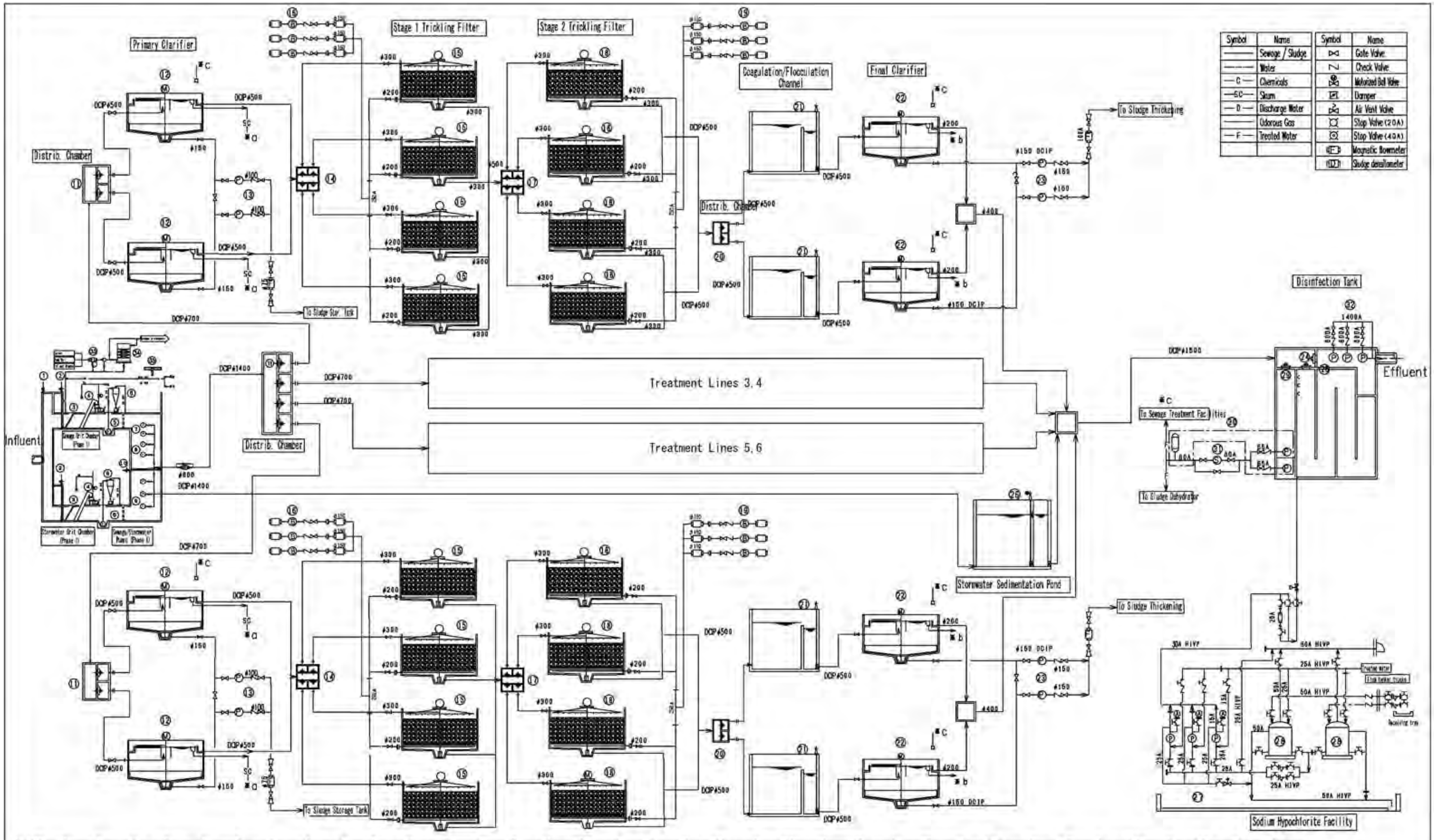
(5) Emergency Generator

	Diesel Engine Generator	Gas Turbine Generator
Description		
	The thermal energy of the intermittently exploding combustion gas is once converted into the reciprocating motion of the piston, which is then converted into the rotational motion of the crankshaft.	The thermal energy of the continuously burning combustion gas is directly converted into rotational motion by the turbine.
Generator Speed	Diesel, generator: 1,500rpm	Turbine: 22,000rpm, Generator: 1,500rpm
Fuel	Heavy oil, diesel oil	Heavy oil, kerosene, diesel oil
Fuel consumption	Small: 0.23-0.31 kg/kW・h	Large: 0.52-0.68 kg/kW・h
Grease consumption	Large: 1.36-2.72 g/kW・h	Small: 0.05-0.27 g/kW・h
Size/ Weight	Large and heavy	Small and light
Fuel air ratio	less	2.5-3 times more than the diesel
Maintenance Cost	Overhaul possible locally. Maintenance and inspection available by car mechanic.	Maintenance/overhaul must be conducted at factory
	50%	100%
Equipment Cost	100%	140%
Overall Evaluation	Diesel generators, which are advantageous in terms of equipment and maintenance costs, will be adopted in this project.	

Source: Created by JET

APPENDIX 3-8 Natabua WWTP Mechanical/Electrical Drawings

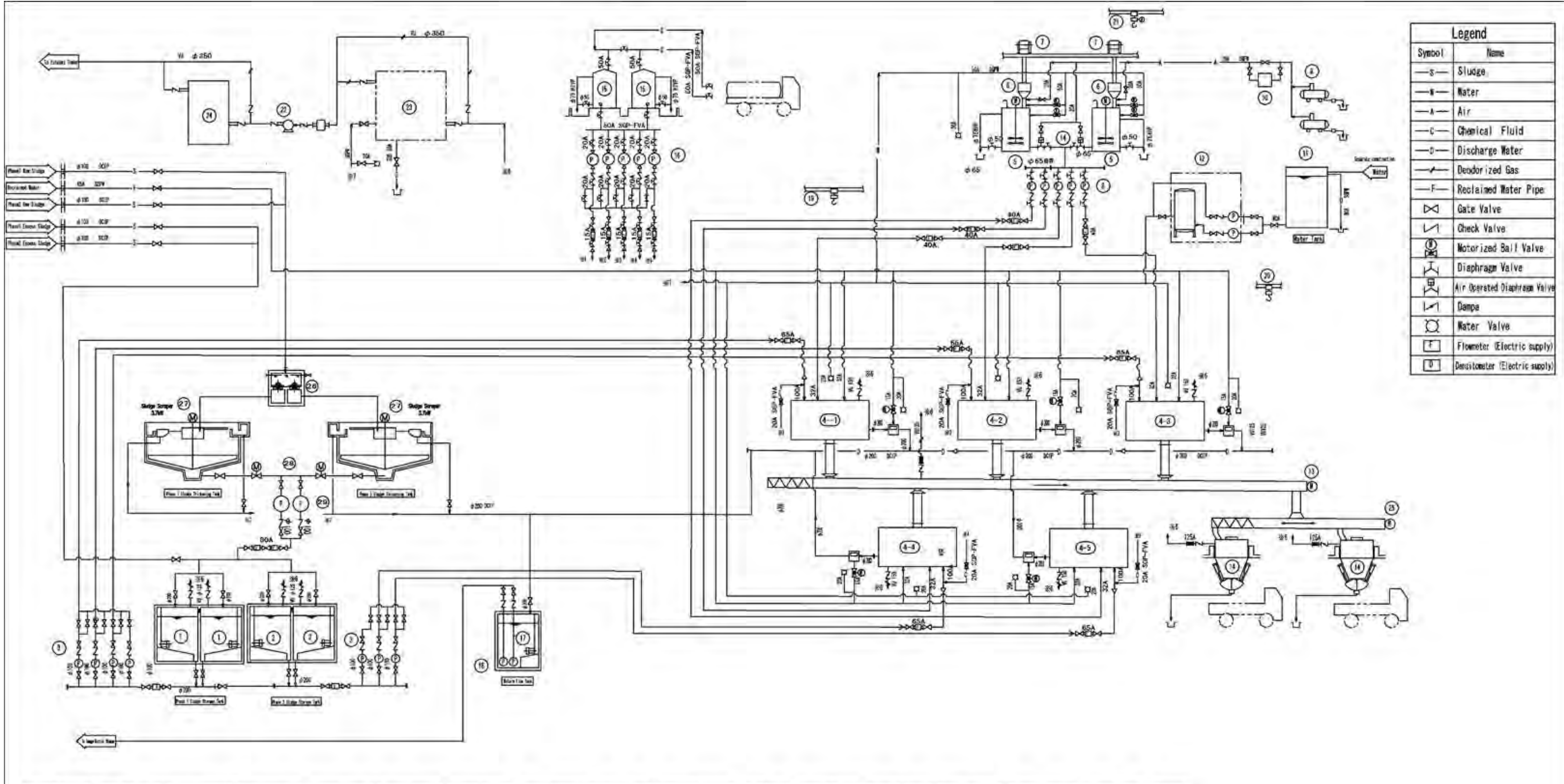
(1) Mechanical Equipment



NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Name	Main Inlet gate	Grit Chamber Inlet Gate (Sewage/Stormwater)	Coarse Screen (Sewage/Stormwater)	Automatic Fine Screen (Sewage/Stormwater)	Sand Pump (Sewage/Stormwater)	Sand Separator (Sewage/Stormwater)	Phase 1 Sewage Pump	Phase 2 Sewage Pump	Stormwater Pump	Pump Well Connection Gate	[illegible]	Primary Clarifier Sludge Scraper	Raw Sludge Pump	Stage 1 Trickling Filter Movable Weir	Stage 1 Trickling Filter Distributor	Stage 1 Trickling Filter Blower	Stage 2 Trickling Filter Movable Weir	Stage 2 Trickling Filter Distributor
Type	Type: Outside Screw Material: Cast Iron	Type: Outside Screw Material: Cast Iron	Material: Steel Plate	Material: Stainless steel	Suction screw type submersible pump	Cyclone type sand separator	Suction screw type submersible pump	Suction screw type submersible pump	Non-clogging submersible pump	Type: Outside Screw Material: Cast Iron	Type: Outside Screw Material: Cast Iron	Central-drive suspended type	Suction screw type	Type: Outside Screw Material: Cast Iron	Head Difference-driven Rotation	Screw-type blower	Type: Outside Screw Material: Cast Iron	Head Difference-driven Rotation
Specification	1500W×1500H	[illegible]	Opening size 50mm X Width 0.5m	Opening Size 25mm X Width 0.5m	80A×0.5m³/min×13m	80A×30m³/h×13m	φ400×14.5m³/min×20m	φ600×29m³/min×20m	φ700×42.5m³/min×9.5m	500W×500H	500W×500H	Dia:14m×water depth2.5m	φ100×0.5m³/min×8m	400W×300H	Diameter:19m	[illegible]	400W×300H	Diameter:43m
	Motorized	Manual type	Manual type	[illegible]	-	-	-	-	-	Manual		-	-	Movable Range: 300mm	-	-	Movable Range: 300mm	-
Motor Capacity	2.2KW	-	-	0.4KW	5.5KW		75	132KW	90KW	-	-	0, 4KW	1.5KW	-	-	18.5KW	-	-
Units Ph1 / Ph2	1 / -	8 / -	8 / -	8 / -	8 / -	2 / -	2 / -	2 (1) / -	3 (1) / -	1 / -	4 / -	6 / 2	6 (3) / 2 (1)	12 / 4	12 / 4	9 / 3	12 / 4	12 / 4
Remarks							Detachable type	Detachable type	Detachable type									

NO	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Name	Stage 2 Trickling Filter Blower	Coagulation/Flocculation Channel Inlet Weir	Coagulation/Flocculation Pool Outlet Gate	Final Clarifier Sludge Scraper	Excess Sludge Pump	Disinfection Tank Inlet Gate	Disinfection Tank Bypass Gate	Stormwater Sedimentation Pool Outlet Gate	Hypochlorite Injection Pump	Hypochlorite Storage Tank	Inlet Gate for Treated Water	Treated water Pressure tank unit	Automatic Strainer	Effluent Pump	Deodorizer Fan	Activated Carbon Adsorption Tower	Chain Hoist
Type	Screw type	Type: Outside Screw Material: Cast Iron	Type: Outside Screw Material: Cast Iron	Peripheral-drive Column-supported type	Suction Screw type	Type: Outside Screw Material: Cast Iron	Type: Outside Screw Material: Cast Iron	Type: Outside Screw Material: Cast Iron	Diaphragm metering type	FRP cylindrical tank	Type: Outside Screw Material: Cast Iron	Pressure tank unit	Automatic washing type	Non-clogging submersible pump	Single-suction turbo fan	Vertical activated carbon adsorption tower	Manual chain hoist
Specification	[illegible]	400W×300H	400W×400H	Dia:27m×water depth3m	φ150×1.0m³/min×10m	1500W×1500H	1500W×1500H	400W×400H	[illegible]	8m³	400W×400H	80A×2.5m³/min×28m	φ80×2.5m³/min	φ800×71m³/min×5m	50m³/min×200mmAq	50m³/min	2t×10mH
	-	Movable Range: 300mm	Movable Range: 400mm	-	-	-	-	-	With VVVF speed control	-	-	Made of FRP Tanks 3m³	-	-	-	Activated carbon cartridge type	-
Motor Capacity	26KW	-	-	0.75KW	3.7KW	-	-	-	0.4KW	-	-	7.5KW×2	0.75KW	90KW	3.7KW		-
Units Ph1 / Ph2	9 (3) / 3 (1)	6 / 2	6 / 2	6 / 2	6 (3) / 2 (1)	1 / -	1 / -	1 / -	3 (1) / -	2 / -	1 / -	1 / -	1 / -	3 (1) / -	1 / -	1 / -	1 / -
Remarks									With control panel			With control panel	With control panel				

Natabua WWTP (Lautoka)
Sewage Treatment Equipment Flowsheet

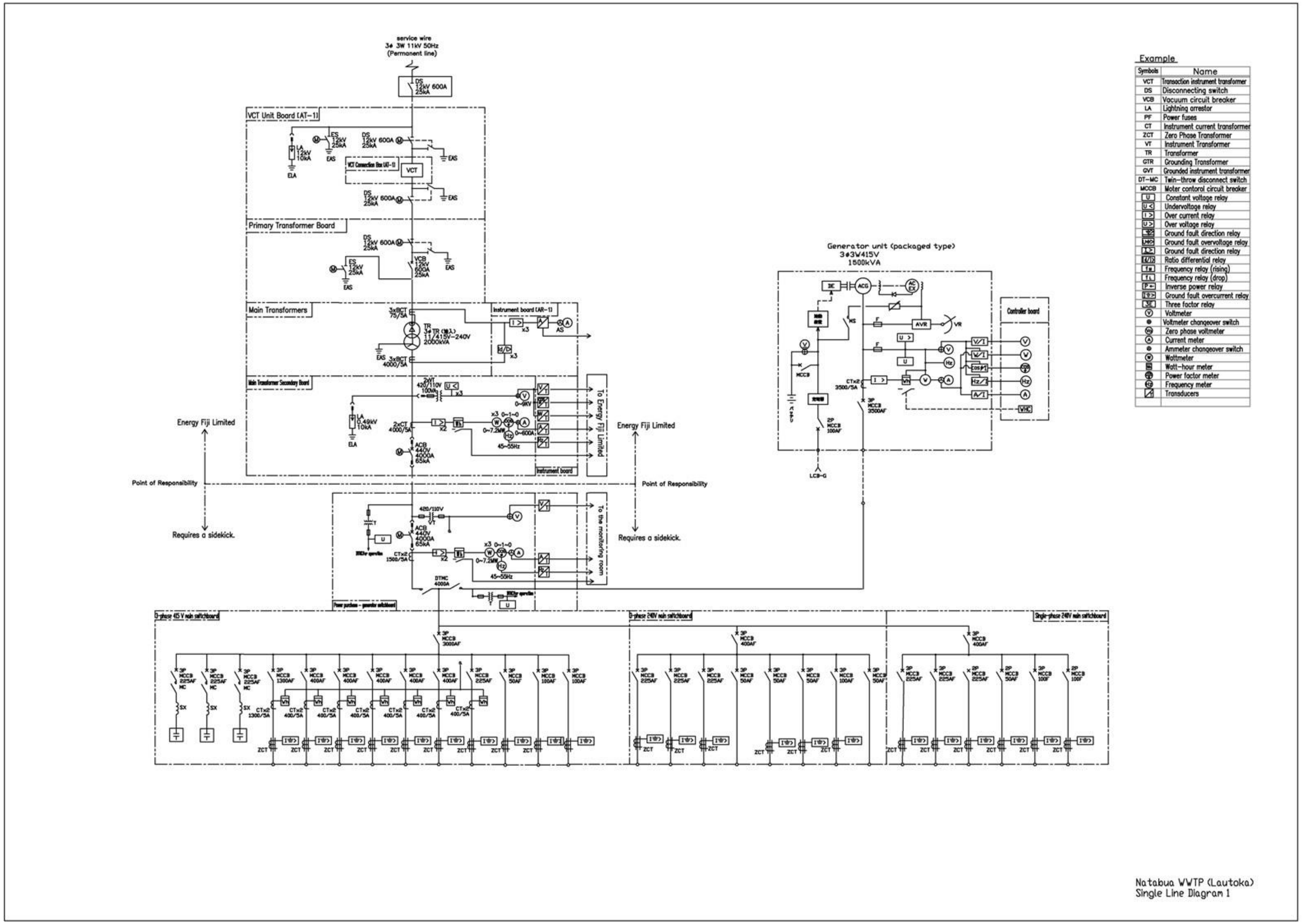


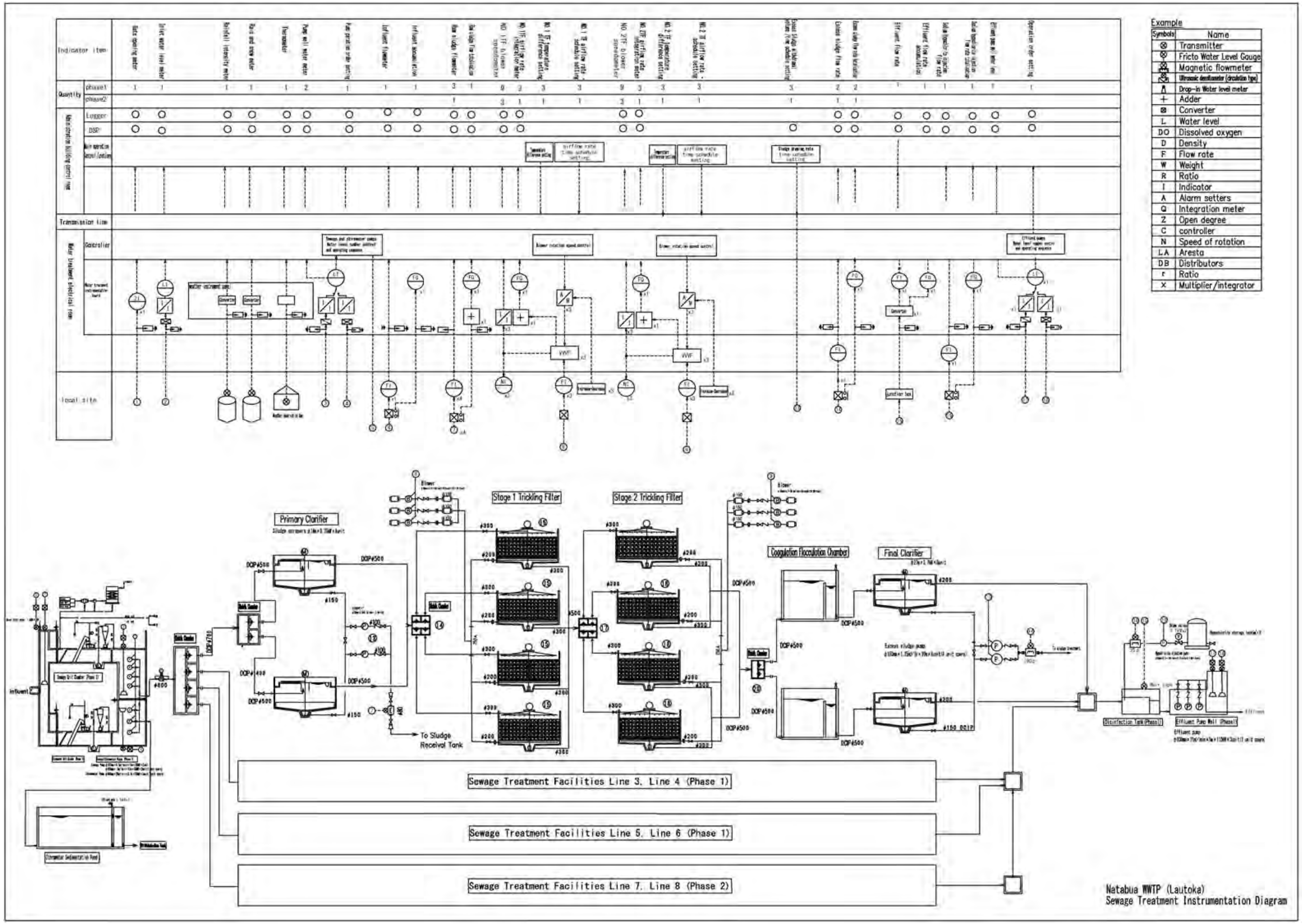
Equipment No.	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
Name	Phase 1 Sludge Storage Tank Mixer	Phase 2 Sludge Storage Tank Mixer	Sludge Supply Pump	Sludge Dewaterer	Chemical Storage Tank	Chemical Dosing Device	Chemical Container	Chemical Supply Pump	Air Compressor	Dehumidifying Device	Water Tank	Water Supply Unit	Sludge Cake Conveyor	Sludge Cake Storage Hopper	Inorganic Flocculant Storage Tank	Inorganic Flocculant Supply Pump
Type	Submerged Mixer	Submerged Mixer	Single Screw Type	Multi-plate Screw Press Dewaterer	Vertical Mixing Tank	Adjustable Continuous Feeder	Inverted Type	Single Screw Type Pump	Portable Type	Freezer Type	Rectangular Tank	Pressurized Tank Type Water Supply Pump Unit	Flight Conveyors	Material:Steel Plate Type:Square Cut Gate	Vertical Mixing Tank	Diaphragm Type Electromagnetic metering pump
Specification	φ580 mm	φ580 mm	φ200×13.0~32.0m³/h ×196Kpa	400kg-DS/day	8 m³	MAX 18,000L/h Hopper 200L	0.5 m³	φ32×4000~6000L/h ×196Kpa	0.1m³/min ×0.73Mpa	0.1m³/min	8 m³	0.5m³/min ×343Kpa(35m)	600mm×32m	10 m³	8 m³	φ13×10~100L/h ×98Kpa
Motor Capacity (kW)	5.5	5.5	5.5	8.3 or Lower	3.7	0.4	–	2.2	1.5	0.075(Single phase)	[illegible]	7.5×2	7.5	2.2×2	FRP Type	2.2
Unit (All / Ph1 / Ph2)	9 / 9 / -	3 / - / 3	7 / 4(1) / 3(1)	5 / 3 / 2	2 / 2 / -	2 / 2 / -	2 / 2 / -	5 / 3 / 2	2(1) / 2(1) / 0	1 / 1 / 0	1 / 1 / 0	1 / 1 / 0	1 / 1 / 0	2 / 2 / 0	2 / 2 / -	5 / 3 / 2
Remarks			VVVF Control Equipment	With Control Panel	FRP Type			VVVF Control Equipment	With Control Panel	With Control Panel		With Control Panel		With Control Panel		

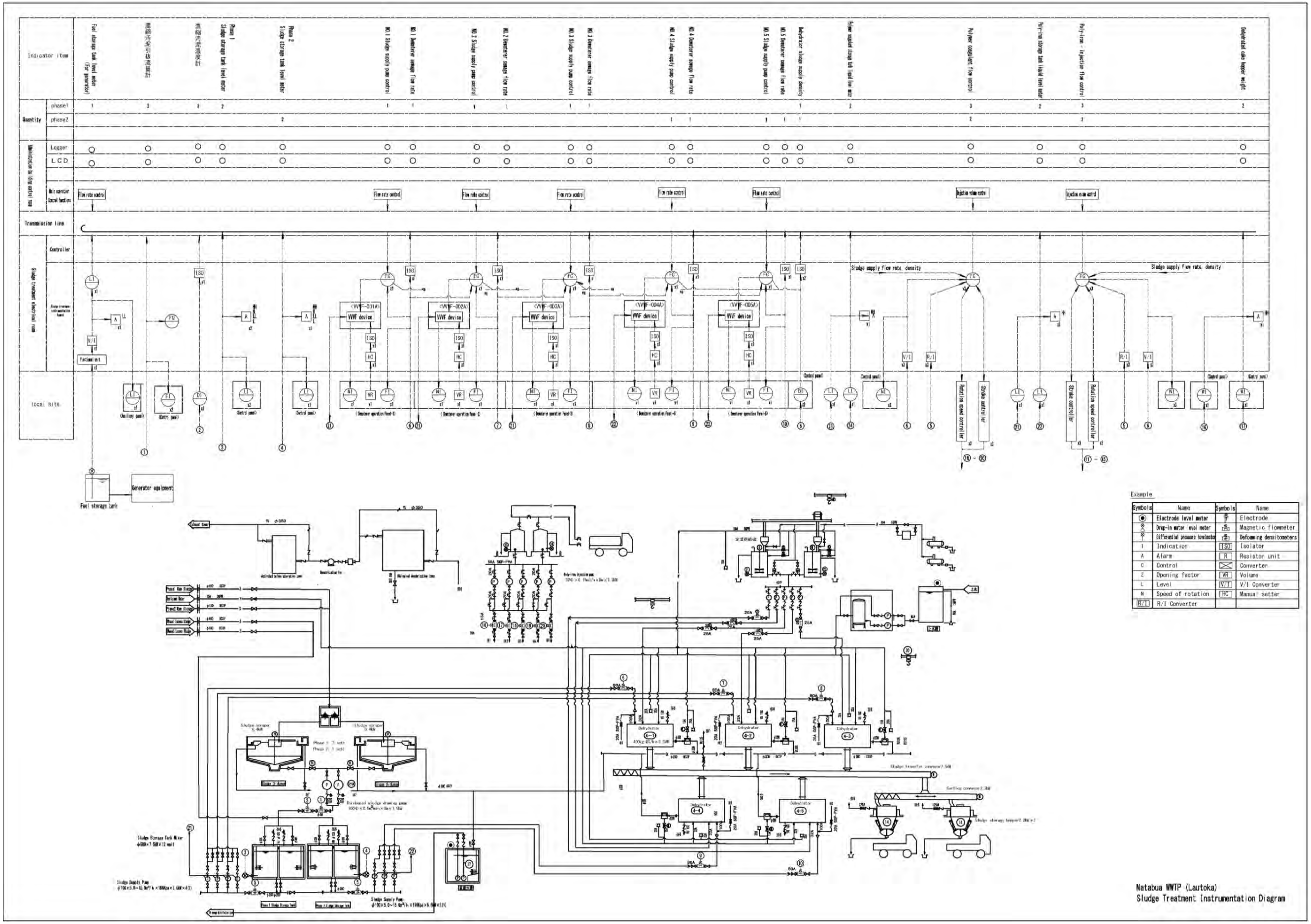
Equipment No.	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔	㉕	㉖	㉗	㉘	㉙			
Name	Return Flow Tank Mixer	Return-flow Pump	Lifting Machine for Dewaterer Inspection	Lifting Machine for Loading/Unloading Machinery	Lifting Machine for Loading/Unloading Chemicals	Deodorizing Fan	Biological Deodorization Tower	Activated Carbon Adsorption Tower	Sludge Cake Distribution Conveyor to Hopper	Sludge Thickener Distribution Chamber Movable Weir	Thickening Tank Sludge Scraper	Thickened Sludge Withdrawal Valve	Thickened Sludge Withdrawal Pump			
Type	Submerged Mixer	Screw Type Submersible Pump Detachable Type	Manual-type Chain Block	Manual-type Chain Block	Motorized Chain Block	Single Suction Turbo Fan	Packed Column Tower	Vertical Type Tower	Flight Conveyor	Type: Outside Screw Material:Cast Iron	Center-drive Suspension type	Type: Outside Screw Material:Cast Iron	Suction Screw Type Sludge Pump			
Specification	φ580 mm	100φ×0.5m³/min×10m	2t×8m"	2t×10m"	1t×4m"	50 m³/min	50 m³/min	50 m³/min	600mm×10m	Width 400mm x Height 300mm	φ5.5 m×water depth 4m	φ100mm	φ100mm×0.5m³/min×8m			
Motor Capacity (kW)	7.4 or higher	0.2			Hoist 0.8 + Traverse 0.4	3.7	–	Activated Carbon Cartridge Type	1.5	–	0.4	0.2	1.5			
Units (All / Ph1 / Ph2)	1 / 1 / -	2(1) / 2(1) / 0	2 / 2 / 0	1 / 1 / 0	1 / 1 / 0	2 / 1 / 0	1 / 0 / 1	1 / 1 / 0	1 / 1 / 0	8 / 6 / 2	8 / 6 / 2	8 / 6 / 2	8(4) / 6(3) / 2(1)			
Remarks																

Natabua WWTP (Lautoka)
Sludge Treatment Equipment Flowsheet

(2) Electrical Equipment


service wire
3φ 3W 11kV 50Hz
(Permanent line)
VCT Unit Board (AT-1)
VCT Connection Box (AT-1)
Primary Transformer Board
Main Transformers
Instrument board (AR-1)
Main Transformer Secondary Board
Instrument board
To Energy Fiji Limited
Energy Fiji Limited
Point of Responsibility
Requires a sidekick.
To the monitoring room
Generator unit (packaged type)
3φ3W415V
1500kVA
Controller board
Example
Symbols
Name
VCT
Transaction instrument transformer
DS
Disconnecting switch
VCB
Vacuum circuit breaker
LA
Lightning arrestor
PF
Power fuses
CT
Instrument current transformer
ZCT
Zero Phase Transformer
VT
Instrument Transformer
TR
Transformer
GTR
Grounding Transformer
GVT
Grounded instrument transformer
DT-MC
Twin-throw disconnect switch
MCCB
Moter contorol circuit breaker
Constant voltage relay
Undervoltage relay
Over current relay
Over voltage relay
Ground fault direction relay
Ground fault overvoltage relay
Ground fault direction relay
Ratio differential relay
Frequency relay (rising)
Frequency relay (drop)
Inverse power relay
Ground fault overcurrent relay
Three factor relay
Voltmeter
Voltmeter changeover switch
Zero phase voltmeter
Current meter
Ammeter changeover switch
Wattmeter
Watt-hour meter
Power factor meter
Frequency meter
Transducers
Natabua WWTP (Lautoka)
Single Line Diagram 1


Indicator item
Quantity
phase1
phase2
Logger
DSP
Transmission line
Controller
Local site
Example
Symbols
Name
Transmitter
Fricto Water Level Gauge
Magnetic flowmeter
Drop-in Water level meter
Adder
Converter
L Water level
DO Dissolved oxygen
D Density
F Flow rate
W Weight
R Ratio
I Indicator
A Alarm setters
Q Integration meter
Z Open degree
C controller
N Speed of rotation
LA Aresta
DB Distributors
r Ratio
X Multiplier/integrator
Primary Clarifier
Stage 1 Trickling Filter
Stage 2 Trickling Filter
Coagulation Flocculation Chamber
Final Clarifier
Influent
To Sludge Receival Tank
Sewage Treatment Facilities Line 3, Line 4 (Phase 1)
Sewage Treatment Facilities Line 5, Line 6 (Phase 1)
Sewage Treatment Facilities Line 7, Line 8 (Phase 2)
Natabua WWTP (Lautoka)
Sewage Treatment Instrumentation Diagram


Natabua WWTP (Lautoka)
Sludge Treatment Instrumentation Diagram

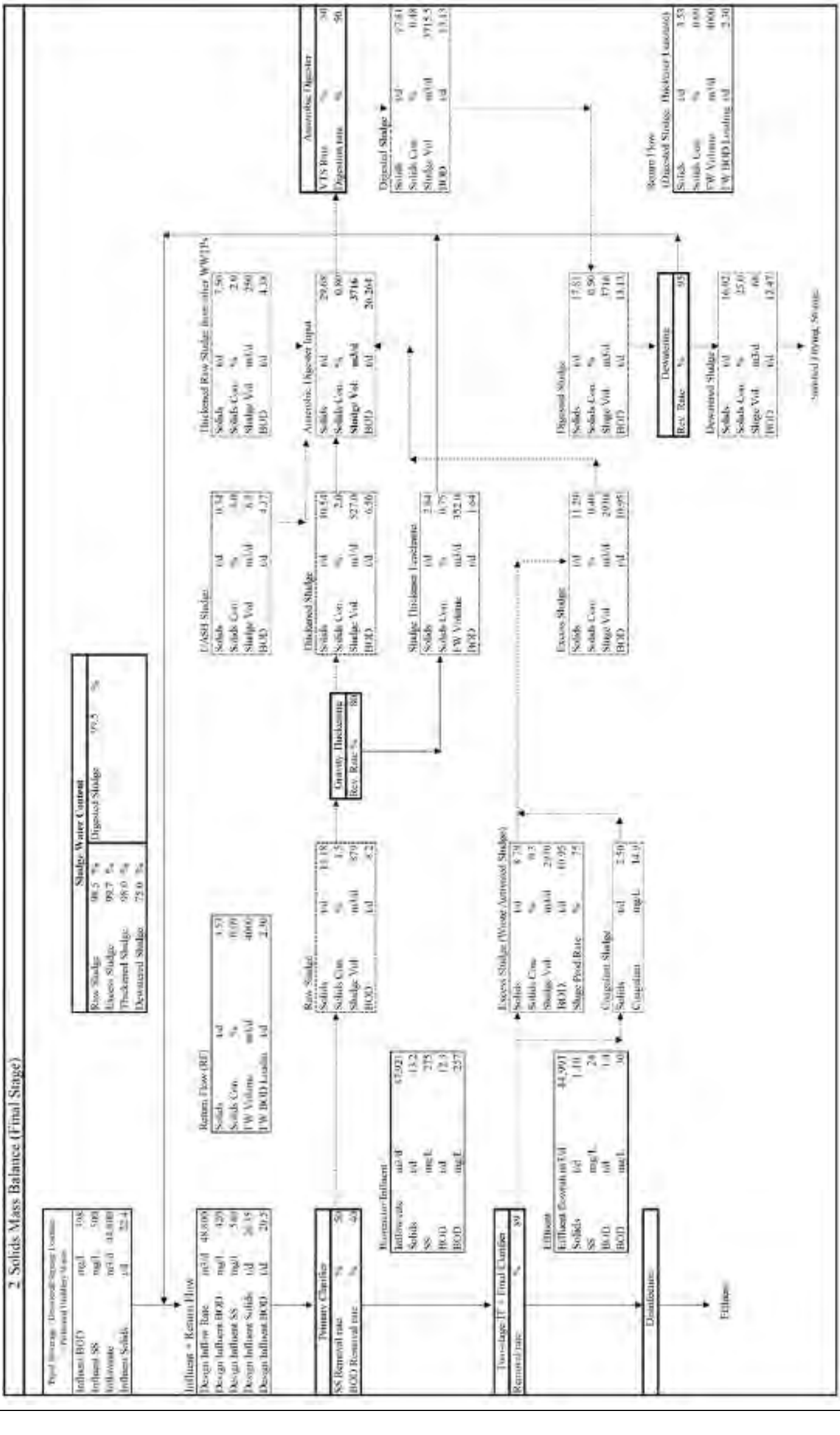
APPENDIX 3-9 Natabua WWTP Capacity Calculations

(1) Natabua WWTP

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
【Pretreated Distillery Waste】	
(1) Bailed-in Distillery Waste	160 m^3/d
(2) Pretreatment Influent	1760 m^3/d
(Diluted using pipeline sewerage)	1600
【Total Influent Flowrate】	
(1) Average Daily Flowrate	40,700 m^3/d
(2) Maximum Daily Flowrate	44,800 m^3/d
(3) Maximum Hourly Flowrate	81,100 m^3/d
(4) Peak Wet Weather Flowrate	202,400 m^3/d
1-3 Influent Wastewater Quality	
【Pipeline Sewerage】	
(1) BOD	373 mg/L
(2) SS	486 mg/L
【Bailed Domestic Septage Dewatered Leachate】	
(1) BOD	250 mg/L
(2) SS	620 mg/L
【Pretreated Distillery Waste】	
(1) BOD	600 mg/L
(2) SS	600 mg/L
【Total Influent Flowrate*】	
(1) BOD	398 mg/L
(2) SS	500 mg/L
(3) T-N	45 mg/L
(4) T-P	11 mg/L
*: Based on pipeline sewerage/ pretreated distillery waste after comissioning of Season 1	

Item	Calculation
1-4 Design Influent Wastewater (Including Return Flow)	
(1) BOD	420 mg/L
(2) SS	540 mg/L
1-5 Removal Efficency (Primary Clarifier)	
(1) BOD	40 %
(2) SS	50 %
(Primary TF)	
(1) BOD	40%
(2) SS	40%
(Secondary TF + Final Clarifier)	
(1) BOD	80%
(2) SS	80%
Total	
(1) BOD	93 %
(2) SS	94 %
(3) T-N	45 %
(4) T-P	60 %
1-6 Effluent Wastewater Quality	General
(1) BOD	30.4 mg/L 40 mg/L →OK
(2) SS	32.5 mg/L 60 mg/L →OK
(3) T-N	24.7 mg/L 25 mg/L →OK
(4) T-P	4.4 mg/L 5 mg/L →OK
Sludge Production (Maximum Daily Flowrate)	
1-7 Excess Sludge	Solids＝ Maximum Daily Flowrate × Influent SS × 0.95×0.75×10^{-6} Solids＝ 44,800 m3/d × 540 mg/L × 94 %×0.75× 10^-6 ＝ 17.1 ds-t/d Solid Concentration ＝ 0.3 % Sludge ＝ Solids ÷ Solids Concentration×10^2 Sludge ＝ 17.10 t/d ÷ 0.3 % × 10^2 Sludge(OUT) ＝ 5,700 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) ＝ 17.1 ds-t/d Solids(OUT) ＝ WAS × Recovery Rate×10^{-2} Solids (OUT) ＝ 17.10 t/d × 85 % × 10^-2 Ricovery Rate ＝ 85 % ＝ 14.6 ds-t/d Sludge(OUT) ＝ Solids ÷ Solids Concentration×10^2 Sludge(OUT) ＝ 14.60 t/d ÷ 2 % × 10^2 Solid Concentratio ＝ 2 % Sludge(OUT) ＝ 730 m^3/d

Item	Calculation
I-10 Trucked-in Thickened Raw Sludge (from other WWTPs)	Solids (IN) = 7.5 ds-t/d Sludge(IN) = 250 m^3/d
I-11 Anaerobic Digestion	Solids (Excess) = 17.1 ds-t/d Solids (Raw) = 14.6 ds-t/d Solids (Raw from other WWTP) = 7.5 ds-t/d Solids (IN) = 39.2 ds-t/d Solids(OUT) = Input Sludge×VTS rate×Digestion Rate×10^{-2} Solids (OUT) = 39.20 t/d × 95 % × 10^-2 VTS Rate = 95 % Digestion Rate Solids(OUT) = Input Sludge × Recovery Rate×10^{-2} Solids (OUT) = 39.20 t/d × 95 % × 10^-2 Recovery Rate = 95 % = 37.3 ds-t/d Sludge(OUT) = Solids ÷ Solids Concentration×10^2 Sludge(OUT) = 37.30 t/d ÷ 25 % × 10^2 Solid Concentratio = 25 % Sludge(OUT) = 150 m^3/d
I-12 Dewatering	Solids (Excess) = 17.1 ds-t/d Solids (Raw) 2.3 ds-t/d Solids (IN) = 19.4 ds-t/d Solids(OUT) = WAS × Recovery Rate×10^{-2} Solids (OUT) = 19.37 t/d × 95 % × 10^-2 Recovery Rate = 95 % = 18.5 ds-t/d Sludge(OUT) = Solids ÷ Solids Concentration×10^2 Sludge(OUT) = 18.50 t/d ÷ 25 % × 10^2 Solid Concentratio = 25 % Sludge(OUT) = 74 m^3/d


2 Solids Mass Balance (Final Stage)
Influent BOD mg/L 398
Influent SS mg/L 500
Inflowrate m3/d 44,800
Influent Solids t/d 22.4
Sludge Water Content
Raw Sludge 98.5 %
Excess Sludge 99.7 %
Thickened Sludge 98.0 %
Dewatered Sludge 75.0 %
Digested Sludge 99.5 %
Influent + Return Flow
Design Inflow Rate m3/d 48,800
Design Influent BOD mg/L 420
Design Influent SS mg/L 540
Design Influent Solids t/d 26.35
Design Influent BOD t/d 20.5
Return Flow (RF)
Solids t/d 3.53
Solids Con. % 0.09
FW Volume m3/d 4000
FW BOD Loading t/d 2.30
UASB Sludge
Solids t/d 0.34
Solids Con. % 4.0
Sludge Vol m3/d 8.5
BOD t/d 4.37
Thickened Raw Sludge from other WWTPs
Solids t/d 7.50
Solids Con. % 2.9
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 13.18
Solids Con. % 1.5
Sludge Vol m3/d 879
BOD t/d 8.2
Gravity Thickening
Rev. Rate % 80
Thickened Sludge
Solids t/d 10.54
Solids Con. % 2.0
Sludge Vol m3/d 527.0
BOD t/d 6.56
Anaerobic Digester Input
Solids t/d 29.68
Solids Con. % 0.80
Sludge Vol m3/d 3716
BOD t/d 20.264
Anaerobic Digester
VTS Rate % 30
Digestion rate % 50
Bioreactor Influent
Inflow rate m3/d 47,921
Solids t/d 13.2
SS mg/L 275
BOD t/d 12.3
BOD mg/L 257
Sludge Thickener Leachate
Solids t/d 2.64
Solids Con. % 0.75
FW Volume m3/d 352.0
BOD t/d 1.64
Digested Sludge
Solids t/d 17.81
Solids Con. % 0.48
Sludge Vol m3/d 3715.5
BOD t/d 13.13
Two-stage TF + Final Clarifier
Removal rate % 89
Excess Sludge (Waste Activated Sludge)
Solids t/d 8.79
Solids Con. % 0.3
Sludge Vol m3/d 2930
BOD t/d 10.95
Sluge Prod.Rate % 75
Effluent
Effluent flowrate m3/d 44,991
Solids t/d 1.10
SS mg/L 24
BOD t/d 1.4
BOD mg/L 30
Coagulant Sludge
Solids t/d 2.50
Coagulant mg/L 14.9
Excess Sludge
Solids t/d 11.29
Solids Con. % 0.40
Sluge Vol m3/d 2936
BOD t/d 10.95
Digested Sludge
Solids t/d 17.81
Solids Con. % 0.50
Sluge Vol m3/d 3716
BOD t/d 13.13
Disinfection
Effluent
Dewatering
Rev. Rate % 95
Return Flow
(Digested Sludge Thickener Leachate)
Solids t/d 3.53
Solids Con. % 0.09
FW Volume m3/d 4000
FW BOD Loading t/d 2.30
Dewatered Sludge
Solids t/d 16.92
Solids Con. % 25.0
Sluge Vol m3/d 68
BOD t/d 12.47

Item	Calculation
3. Sewerage Pump	
3-1 Grit Removal Chamber	
Design Flowrate	
Maximum Daily Flowrate	= 44,800 m^3/d
Maximum hourly Flowrate	= 81,300 m^3/d
Number of Chambers	= 4
Flowrate per Chamber	= 81,300 m3/d ÷ 4 = 20,325 m3/d
Width	W = 3.0 m
Target Grit	Specific Weigh = 2.65 Diameter = 0.2 mm and larger Settling Velocit = 21 mm/sec
Average Velocity	= 0.3 m/s
Retention Time (T)	= 60 sec Range: 30~60 sec
Hydraulic Load	= 1800 m3/m2/d
Chamber Length(L)	$= \frac{Q}{Ls \times W}$ $= \frac{20,325}{1800 \times 3.0}$ = 3.8 m → 4.0 m
Water Depth	$= \frac{T \times Q}{W \times L}$ $= \frac{60 \times 20,325 /(60\times60\times24)}{3.0 \times 3.8}$ = 1.3 m
Sand pit Depth	= 0.2 × 1.3 m = 0.3 m →Minimun 0.3 m → OK
Expected Grit Removal	0.05 m3-removed Grit/ 1000m3-sewerage = 0.05 × 81300.0 ÷ 1,000 = 4.065 m3/d
3-2 Screen	
Average Velocity	= 0.45 m/s
Water Depth	= 1.3 m
Width	$= \frac{Q}{V \times H}$ $= \frac{20,325 /(60\times60\times24)}{0.45 \times 1.3}$ = 0.5 m
Expected Screen Waste	0.05 m3-removed screen waste/ 1000m3-sewerage = 0.05 × 81300.0 ÷ 1,000 = 4.065 m3/d

Item	Calculation
4. Stormwater Pump	
4-1 Grit Removal Chamber	
Design Flowrate	
Maximum hourly Flowrate	= 133,667 m^3/d
Number of Chambers	= 4
Flowrate per Chamber	= 133,667 m3/d ÷ 4
	= 33,417 m3/d
Width	W = 3.0 m
Target Grit	Specific Weigh = 2.65
	Diameter = 0.2 mm and larger
	Settling Velocit = 21 mm/sec
Average Velocity	= 0.3 m/s
Retention Time (T)	= 60 sec Range: 30~60 sec
Hydraulic Load	= 1,800 m3/m2/d
Chamber Length(L)	$= \frac{Q}{Ls \times W}$
	$= \frac{33,417}{1800 \times 3.0}$
	= 6.2 m → 6.5 m
Water Depth	$= \frac{T \times Q}{W \times L}$
	$= \frac{60 \times 33,417 /(60 \times 60 \times 24)}{3.0 \times 6.2}$
	= 1.3 m
Sand pit Depth	= 0.2 × 1.3 m
	= 0.3 m →Minimun 0.3 m → OK
Expected Grit Removal	0.05 m3-removed Grit/ 1000m3-sewerage
	= 0.05 × 133666.5 ÷ 1,000
	= 6.68333 m3/d
4-2 Screen	
Average Velocity	= 0.45 m/s
Water Depth	= 1.3 m
Width	$= \frac{Q}{V \times H}$
	$= \frac{33,417 /(60 \times 60 \times 24)}{0.45 \times 1.3}$
	= 0.7 m
Expected Screen Waste	0.05 m3-removed screen waste/ 1000m3-sewerage
	= 0.05 × 133666.5 ÷ 1,000
	= 6.68 m3/d

Item	Calculation
4. Primary Clarifier	
4-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 44,800 m^3/d
Maximum hourly Flowrate	= 81,100 m^3/d
Overflow rate	= 35 $m^3/m^2/d$
Required Area for settling	= 44,800 ÷ 35 = 1,280 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	= 44,800 m^3/d ÷ 1,232 m^2 = 36.4 $m^3/m^2/d$ Range: 35～70m3/m2/d → **OK**
Settling Time	= (1,232 × 2.5 × 24) ÷ 44,800 = 1.7 hrs Range:About 1.5 hrs → **OK**
Req. Length of weir	= (14 − 1.6) × π = 39 m
Weir Loading rate	= 44,800 ÷ (39) ÷ 8 = 143.6 $m^3/m/d$

Item	Calculation
5. Primary Trickling Filter	
5-1 Reactor Requirements	
Design Flowrate	
Maximum Daily Flowrate	= 44,800 m^3/d
Maximum hourly Flowrate	= 81,100 m^3/d
Number of Reactor	n = 16 Reactors
Treatment Capacity	Qin = 2,800 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	= 44,800 m^3/d
Design PrimClar Flowrate	= 48,800 m^3/d
Design Reactor Flowrate	= 47,921 m^3/d
BOD loading ※	= 1.20 kg-BOD/(m3・d)
Influent BOD (of PC)	= 420 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-$R_{BOD\ removal}$) = 420 mg-BOD/L x (1- 0.4) = 252 mg/L
(2) Hydraulic Loading	
Hydraulic Loading	$= \dfrac{\text{BOD loading} \times \text{Filter Media Height}}{c_{BOD\_TRinflow}}$ $= \dfrac{1.20\ \text{kg-BOD}}{(\text{m3・d})} \times \dfrac{2.0\ \text{m}}{1} \times \dfrac{\text{L}}{252\ \text{mg-BOD}} \times \dfrac{1{,}000}{1}$
Hydraulic Loading	= 9.52 $m^3/m^2/d$
Diameter of TF	19 m (Max 45 m)
No. of basin	= 16 basins
Effective Area	= 19 ^ 2 ÷ 4 × π × 16 = 4,536 m^2
Actual Hydraulic Loading	= Q/A = 47,921 m3/d ÷ 4,536 m2 = 10.57 $m^3/m^2/d$ Range: 10~40 $m^3/m^2/d$(High-rate)
Actual BOD Loading	$= \dfrac{\text{Act. Hydraulic loading} \times c_{BOD\_TRinflow}}{\text{Filter Media Height}}$ → **OK** $= \dfrac{10.57\ \text{m3}}{(\text{m2・d})} \times \dfrac{252.0\ \text{mg-BOD}}{\text{L}} \times \dfrac{\text{L}}{2.0\ \text{m}} \times \dfrac{1}{1{,}000}$ = 1.33 kg/m3/d → Range: 0.3~16kg/m3/d → **OK**

Item	Calculation
(3) Effluent BOD IWEM Eq.	$$\frac{S_e}{S_i}=\frac{1}{1+k_{IWEM}\cdot\theta^{T-20}\left(\frac{a^m}{VLR^n}\right)} \quad (13.54)$$

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 ($m^3/d\cdot m^2$) 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 = 10.57 $m^3/m^2/d$

T = 20 ℃

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TABLE 13.25 Physical properties of commonly used trickling filter media [illegible]

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)		[illegible]	[illegible]	[illegible]	[illegible]
Rock (slag)		[illegible]	[illegible]	[illegible]	[illegible]
Corrugated plastic modules					
Cross-flow	PVC	[illegible]	[illegible]	[illegible]	[illegible]
Vertical flow	PVC	[illegible]	[illegible]	[illegible]	[illegible]
Random pack	PP	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

a = 100 m2/m3

Eq. 13.54 Denominator

$= 1 + 0.4 \times 1.089^{(20-15)} \times \left(\frac{100^{0.732}}{10.57^{1.396}}\right)$

= 1 + 0.4 × 1.53 × 1.082
= 1.663

Se	= Si / 1.663 = 252 / 1.663 = **151.6 mg-BOD/L**
Removed BOD	= Si -Se = 252 − 152 mg-BOD/L = 100.4 mg-BOD/L

Item	Calculation
Actual Hydraulic Loading	= Q/A = 47,921 m3/d ÷ 23,235 m2 = 2.07 $m^3/m^2/d$ Range: 1.4~4.2 m3/m2/d (Nitirifying TF) 1.0~4.0 m3/m2/d (Low-rate TF) → **OK**
Actual BOD Loading	$= \dfrac{\text{Act. Hydraulic loading} \times c_{BOD\ Tinflow}}{\text{Filter Media Height}}$ $= \dfrac{2.07\ \text{m3}}{(\text{m2}\cdot\text{d})} \times \dfrac{151.6\ \text{mg-BOD}}{\text{L}} \quad \dfrac{\text{L}}{2.0\ \text{m}} \times \dfrac{1}{1{,}000}$ = 0.16 kg/m3/d → Range: 0.16~0.19kg/m3/d → **OK**
(3) Effluent BOD IWEM Eq.	see below

$$\frac{S_e}{S_i} = \frac{1}{1 + k_{IWEM} \cdot \theta^{(T-15)} \left(\frac{a^m}{VLR^n}\right)} \tag{13.54}$$

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 ℃

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Table 13.25 Physical properties of commonly used trickling filter media [illegible]

Media type	Material	[illegible]	[illegible]	[illegible]	[illegible]
Rock [illegible]		[illegible]	[illegible]	[illegible]	[illegible]
Rock [illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]	PVC	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	PVC	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	PP	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

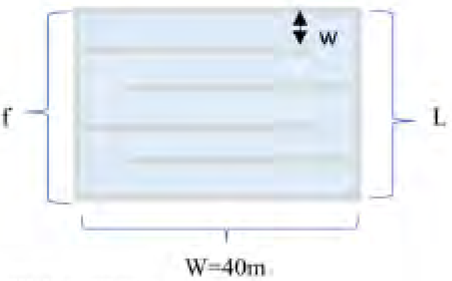
a = 100 m2/m3

Eq. 13.54 Denominator

= 1 + 0.4 × 1.089 ^(20 -15) ×((100 ^ 0.732) / (2.07 ^ 1.396))

= 1 + 0.4 × 1.53 × 10.54
= 7.458

Item	Calculation
Se	= Si / 7.458
	= 151.6 / 7.458
	= **20.4 mg-BOD/L**
Removed BOD	= 151.6 − 20.4 mg-BOD/L
	= 131.2 mg-BOD/L
(4) Nitrogen Removal	
Influent N	= 45 mg/L
Nitrogen Removal Rate: PC	= 18 %
Nitrogen Removal Rate: Double Tl	= 33 %
Effluent T-N	= 45 mg/L ×(1 − 0.18)×(1 − 0.33)
	= 24.7 mg/L
Effluent T-N Standard	= 25 mg/L (General Standards)
	⇒ **OK**
6-4 Forced air Ventilation	
(1) Required Airflow（Qa）	= 10～20 m3-air/kg-BOD removed × BOD removed per tower
Q per tower(q)	= 47,921 m3/d ÷ 16 towers
	= 2,995 m3/d per tower
	= 2.08 m3/min per tower
Removed BOD	= 131.2 mg-BOD/L
	= 0.131 kg-BOD/m3
BOD removed per tower	= 0.131 kg-BOD/m3 × 2,995 m3/d per tower
	= 393 kg-BOD/d per tower
	= 0.273 kg-BOD/min per tower
Required Airflow（Qa）	= 20 m3-air/kg-BOD removed × 0.273 kg-BOD/min per tower
	= **5.46 m3-air/min per tower**
7. Coagulation/Flocculation Canal	
7-1 Requirements	
Maximum Hourly Flowrate	= 81,100 m^3/d
Number of Canals	= 8
Flocculant Type	Polyferric Sulfate
Flowrate per canal(q)	= 81,100 m^3/d ÷ 8
	= 10,138 m^3/d
Soluble Phosphorus Ratio	= 75%
Soluble P	= 11 mg/L × 75%
	= 8 mg/L
Coagulant Dosage	$= \dfrac{\text{Soluble P}}{\text{P Atomic Weigh}} \times$ (Fe:P Ratio) × Fe Atomic Weight
	$= \dfrac{8}{31} \times 1 \times 56$
Coagulant Dosage	= 15 mg/L

Item	Calculation
7-2 Rapid Mixing Canal	
Mixing Time(=HRT)	= 2 minutes Range: 1~5 min
Velocity(v)	= 1.5 m/s
Depth（D）	= 0.3 m
Total Volume	= q × HRT
	= $\frac{10{,}138\ m^3/d \times 2\ min}{60\ min \times 24\ hr}$
	= 15 m3
Canal Width(w)	= q ÷ (v×D)
	= 10,138 m^3/d ÷ (1.5 m/s × 0.30 m) ÷ (24×60×60)
	= 0.261 m
	→ 0.26 m
Actual Velocity	= q ÷ (w×D)
	= 10,138 m^3/d ÷ (0.3 m× 0 m) ÷ (24×60×60)
	= 1.504 m/s
	→ **OK**
Canal Length(l)	= V ÷ A = V ÷ (W×D)
	= 15 m3 ÷ (0.26 m× 0.3 m)
	= 192.3 m
Let: Canal Structure Width(W)	= 40 m
Canal Structure folds(f)	= 5 folds
Let: Wall width	= 0.2 m
	
Canal Structure Length(L)	= w×f + Wall width × Wall numbers
	= 0.26 m× 5 + 0.2 m × (5 - 1)
	= 2.1 m
7-3 Flocculation Canal	
Hydraulic Retention Time	= 20 minutes Range: 20~30 min
Velocity Range(v)	= 15.0 ~ 30 cm/s Range: 15~30 cm/s
	= 0.15 ~ 0.3 m/s
Depth(D)	= 0.3 m
Total Volume(V)	= q × HRT
	= $\frac{10{,}138\ m^3/d \times 20\ min}{60\ min \times 24\ hr}$
	= 141 m3
Cross Sectional Dimension per Velocity 【v=15 cm/s】	
Target Velocity	= 0.15 m/s
Canal Width	= q÷(v×D)
	= 10,138 m^3/d ÷ (0.2 m/s × 0.30 m) ÷ (24×60×60)
	= 2.607 m
	→ 2.5 m

Item	Calculation
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	= 44,800 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
9. Disinfection	
9-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 44,800 m^3/d
Maximum hourly Flowrate	= 81,100 m^3/d
Peak Wet Weather Flowrate	= 202,400 m^3/d
Chlorine Contact Time	= 15 minutes
	= 900 seconds
Req. Volume	= 202,400 ÷ 24 ÷ 60 ÷ 60
	× 900
	= 2109 m^3
Depth	= 2 m
Width	= 2 m
Length	= 530 m = 108 m × 5 folds
Volume	= 2 × 2 × 530
	= 2120 m^3
Actual Contact Time	= 2120 ÷ 202,400 × 24 × 60
	= 15.08 min → **OK**
10. Sludge Treatment	
10-1 Sludge Thickening	
Target : Natabua Raw Sludge Only	
Solids (IN)	= 13.18 t/d
Solid Concentration	= 1.50 %
Sludge(IN)	= 879 m3/d
Solid Concentration(OUT)	= 2.00 %
SS loading	= 75 kg-DS/m2/d
Tank Depth	= 4 m
Maximum retention time	= 12 hrs
Number of Thickeners	= 8 tanks

Item	Calculation
Required Surface Area	= 13.18 t/d × 1000 kg/t ÷ 75 kg-DS/m2/d
	= 175.73 m2
Diameter of Basin(D)	= 6 m
Effective Area	= 6 ^ 2 ÷ 4 × π × 8 tanks
	= 226.0 m^2
	> 175.7 m^2
	→**OK**
Actual Loading	= 13.18 t/d × 1000 kg/t ÷ 226.0 m^2
	= 58.32 kg-DS/m2/d
	Range: 60~90 kg-DS/m2/d
	→**OK**
【Thickened Raw sludge from other WWTPS】	
Solids (IN)	= 7.50 t/d
Solid Concentration	= 2.00 %
Sludge(IN)	= 250 m3/d
Receiving Volume	2 days worth
Number of Tanks	2 tanks
Required Tank Volume	= 250 m3/d × 2 d ÷ 2 tanks = 250 m3 per tank
Storage Tank Depth	= 4 m
Tank Size	
r	= (250 m3 ÷(4 m ×π))^0.5
	= 5.00 m × 2 tanks
10-3 Sludge Dewatering	
(1) Input Sludge	
【Septage】	
Solids (IN)	= 1.56 t/d
Solid Concentration	= 0.02 %
Sludge(IN)	= 65 m3/d
【Excess Sludge】	
Solids (IN)	= 2.50 t/d
Solid Concentration	= 0.30 %
Sludge(IN)	= 833 m3/d
【Digested Sludge】	
Solids (IN)	= 17.81 t/d
Solid Concentration	= 0.50 %
Sludge(IN)	= 3716 m3/d
(2) Sludge Receival Tank	
Sludge Dewatering Operation	7 days in a week
Septage	1 days worth
Digested Sludge	1 days worth
Required Volume	
【Septage Storage】	= 65 m3/d × 1 d = 65 m3
【Digested Sudge Receival】	= 3,716 m3/d × 1 d = 3716 m3

Item	Calculation
Storage Tank Depth	= 4 m
Tank Size	
【Septage】 r	= (65 m3 ÷(4 m ×π))^0.5 ÷ 1 tanks
	= 3.00 m
【Digested Sudge】 r	= (3716 m3 ÷(4 m ×π))^0.5 ÷ 4 tanks
	= 5.00 m
(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
Operation Conditions	9 hrs in one day and 7 days in a week
	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
Solids (Required Dewatering Cap.)	= 1.56 × 7 ÷ 7 ÷ 9 × 1,000
	= 173.3 kg/d
Actual Dewatering capacity	= 70 kg/d
Number of Units	= 3 units
(4) Digested Sludge Dewatering	
	Solids (IN) = 17.81 ds-t/d
	Solids(OUT) = Digested Sludge×Recovery Rate×10^{-2}
	Solids (OUT) = 17.81 t/d × 95 % × 10^-2
	Recovery Rate = 95 %
	= 17.00 ds-t/d
	Sludge(OUT) = Solids÷Solids Concentration×10^{2}
	Sludge(OUT) = 17.00 t/d ÷ 25 % × 10^2
	Solid Concentration = 25 %
	Sludge(OUT) = 68 m^3/d

Item	Calculation
Solids	= 17.81 × 7 ÷ 7 ÷ 9
(Required Dewatering Cap.)	× 1,000
	= 1978.9 kg/d
Actual Dewatering capacity	= 400 kg/d
Number of Units	= 5 Units
11. 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 Phase 1 2250 m2 → **OK**
	= 0.3 ha Phase 2 750 m2
Dried Sludge	Dried Sludge Water Content 65 %
	Sludge Concentration 35 %
Solids (OUT)	= 1.50 t/d
Dried Sludge (OUT)	= 4.3 m3/d
【Digested Raw Sludge】	
Sludge Volume	= 68 m3/d × 150 d
	= 10200 m3
Sludge Depth	= 0.3 m
	42,446
Required Drying Bed Area	= 10200 m3 ÷ 0.3 m
	= 34,000 m2
Drying Bed Area	= 340 m × 100 m
	= 34,000 m2 → **OK**
	= 3.4 ha
	= 25,500 m2(第1期) = 200 x 127.5
	= 8,500 m2(第2期) = 200 x 42.5
Dried Sludge	Dried Sludge Water Content 65 %
	Sludge Concentration 35 %

Item	Calculation
Solids (OUT)	= 17.00 t/d
Dried Sludge (OUT)	= 48.6 m3/d
【Total Sludge Drying Bed Area】	= 3.7 ha = 2.9 ha Phase 1 + 0.8 ha Phase 2
12. Sludge Storage Space	
Sludge Storage Period	= 20 yrs
【Septage】	
Sludge Volume	= 4.3 m3/d × 20 yrs × 365 d = 31,390 m3
Sludge Depth	= 3.0 m
Required Storage Area	= 31,390 m3 ÷ 3.0 m = 10,464 m2
Septage Storage Area	= 105 m × 100 m = 10,500 m2 = 1.05 ha →OK
【Digested Sludge】	
Sludge Volume	= 48.6 m3/d × 20 yrs × 365 d = 354,780 m3
Sludge Depth	= 3.0 m
Required Storage Area	= 354,780 m3 ÷ 3.0 m = 118,260 m2
Sludge Storage Area	= 1183 m × 100 m = 118,300 m2 Phase1 88,725 m2 →OK = 11.83 ha Phase 2 29,575 m2
【Total Sludge Storage Area】	= 12.90 ha = 9.9 ha (Phase 1) + 3.0 ha Phase 2

Item	Calculation
7. Primary Treatment (Stormwater Sedimentation)	
Design Flowrate	= 4* Maximum Daily Flowrate
	= 4* 44,800 m^3/d
	= 179,200 m^3 /d
Required Retention Time	= 2.50 hrs
Required Volume	= 179,200.00 m3/d × 2.50 hrs ÷ 24
	= 18,667 m^3
Design Depth	= 3 m
Required Surface Area	= 6,222 m2
Stormwater Pretreatment Plant	= 85 m × 75 m × 3 m
	= 19125 m3 > 18,667 m^3
	→ **OK**

(2) Natabua Sludge Digestion + 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 + UASB 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.	250	m3/day

B. Thickened raw sludge from Natabua

Solids	10.54	t/day
Solids Con.	2.0	%
Sludge Vol.	527	m3/day

C. Excess sludge from Natabua

Solids	11.29	t/day
Solids Con.	0.4	%
Sludge Vol.	2,930	m3/day

D. UASB Sludge

Solids	0.34	t/day
Solids Con.	4.0	%
Sludge Vol.	9	m3/day

E. Total Input

Total actual sludge input

= 250 + 527 + 2,930 + 9

= 3,716 m3/day

Total SS = 7.5 + 10.5 + 11.3 + 0.34

= 29.67 t-ds/day

= 10,832 t-ds/year

SS Concetration		Sludge Volume Conversion	
1.0	%	2,967	m3/day
		1,083,200	m3/year
2.0	%	1,484	m3/day
		541,600	m3/year
3.5	%	848	m3/day
		309,486	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 = 50 % (Primary Clarifier)

Influent SS = 486 mg/L
Effluent SS of primary clarifier = 486 mg/L x (100%－ 50 %)
= 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 = 95 % (Primary Clarifier+TF+Final Clarifier)

Influent SS = 500 mg/L
Effluent SS of treatment system = 500 mg/L x (100%－ 95 %)
= 25.1 mg/L
SS removed by treatment system as raw/excess sludge = 500 － 25.054
= 475 mg/L

SS included in UASB sludge = 0.34 t-ds/d x 365 days/yr
= 124 t-ds/yr

Annual removed SS = 475 mg/L x 16,242,500 m3/year ÷ 1,000,000
+ 124 t-ds/yr
= 7,839 t-ds/year

Volume Conversion

SS Concetration		Volume Conversion
1.0	%	783,900 m3/year
2.0	%	391,950 m3/year
3.5	%	223,972 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	+	7,839
	=	29.6	t-ds/day	
	=	10,811	t-ds/year	

Volume Conversion

SS Concetration		Volume Conversion	
1.0	%	2,962	m3/day
		1,081,100	m3/year
2.0	%	1,481	m3/day
		540,550	m3/year
3.5	%	846	m3/day
		308,886	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 (Natabua)	mg/l	540	Input
		(Other WWTPs)	mg/l	486	Input
	④	SS removed	t-ds/year	10,811	Input

Category	No.	Parameter	Unit	Value	Calculation
Thickened Sludge	⑤	SS removed	t-ds/year	10,811	Input
	⑥	SS removed (2% concentration)	m3/year	540,550	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	4,756,840	= ⑤×⑦×⑧
	⑬	Annual methane gas production	Nm^3/year	2,854,104	= ⑫×⑨
	⑭	Hourly methane gas production	Nm^3/hr	326	= ⑬÷365÷24

Category	No.	Parameter	Unit	Value	Calculation
Power Generation	⑮	Annual energy production from methane gas	MJ/year	102,176,924	= ⑬×⑩
	⑯	Annual biogas power generation	kWh/year	9,082,394	= ⑮×⑪÷3.6
	⑰	Annual biogas power generation	MWh/year	9,082	=⑯÷1000
	⑱	Daily biogas power generation	kWh/day	24,884	=⑯÷365
	⑲	Hourly biogas power generation	kW	1,037	=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	2,967	Input
	Civil/Architectural	②	Cost	million JPY	1,257.4	=0.169×①^0.539 ×100
	Mechanical/Electrical	③	Cost	million JPY	1,120.8	=0.516×①^0.385 ×100
	TOTAL	④	Construction Cost	million JPY	2,378.2	=②+③
		⑤		million FJD	37.9	=⑥÷62.9

Category	Field	No.	Parameter	Units	Value	Calculation
O/M Costs	Input	⑥	Input Sludge Volume (1%SS Concetration)	m3/year	1,083,200	Input
	Labor,celectricity, consumables, etc.	⑦	Cost	million JPY	38.6	=0.171×⑥^0.390
	Repairs and Maintenance	⑧	Cost	million JPY	22.4	=③×0.02
	TOTAL	⑨	O/M Cost	million JPY	61.0	=⑦+⑧
		⑩		million FJD	0.970	=⑨÷62.9

###

2. Biogas Power Generation Plant

Category	Field	No.	Parameter	Units	Value	Calculation
Construction Cost	Input	①	Power Generation	kW	1,037	Input
	Civil/Architectural	②	Construction Cost	million JPY	33.1	=0.0263×①+5.8284
	Mechanical/Electrical	③	Construction Cost	million JPY	1,361.8	=1.3132×①
	TOTAL	④	Construction Cost	million JPY	1,394.9	=②+③
		⑤		million FJD	22.2	=④÷62.9

Category	Field	No.	Parameter	Units	Value	Calculation
O/M Cost	Input	⑥	Power Generation	kW	1,037	Input
	TOTAL	⑦	O/M Cost (Including labor and electricity)	million JPY	60.0	=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	37.9	1.0
Biogas Power Generation Facility	22.2	1.0
TOTAL	60.1	2.0

*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	3,716	m3/day	Input	
②	Digester Retention Time	40	days	Constant	
③	Total Digester Volume	148,620	m3	=①×②	
④	Digester Footprint	22,160	m2	=0.1491×③	23,213
⑤	Digester Footprint	2.2	ha	=④÷10000	

2. Biogas Power Generation Plant

No.	Parameter	Value	Unit	Calculation
①	Power Generation	1,037	kW	Input
④	Digester Footprint	926	m2	=0.8927×①
⑤	Digester 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 4-1 Setting Navakai WWTP Influent Water Quality Parameters

In the previous Regional Wastewater M/P and Municipal Sewerage M/P, the influent water quality for all WWTPs were set at a uniform value, applying the maximum value taken from adjusted raw influent data (2014-2018 annual averages, all WWTPs) and values adopted in past donor projects.

For the Pre-F/S, WWTP-specific influent water quality values were adopted, taking into consideration of 2019-2023 Navakai WWTP raw influent data provided by WAF.

The influent water quality for Navakai WWTP was set as shown in **Table A4-1.1**. Details on its calculation is explained in the following pages.

Table A4-1.1 Navakai WWTP Influent Water Quality

BOD (mg/L)	TSS (mg/L)	T-N (mg/L)	T-P (mg/L)
367	544	37	6

Source: Created by JET based on WAF data

(1) Raw Sewerage (Pipeline Sewerage)

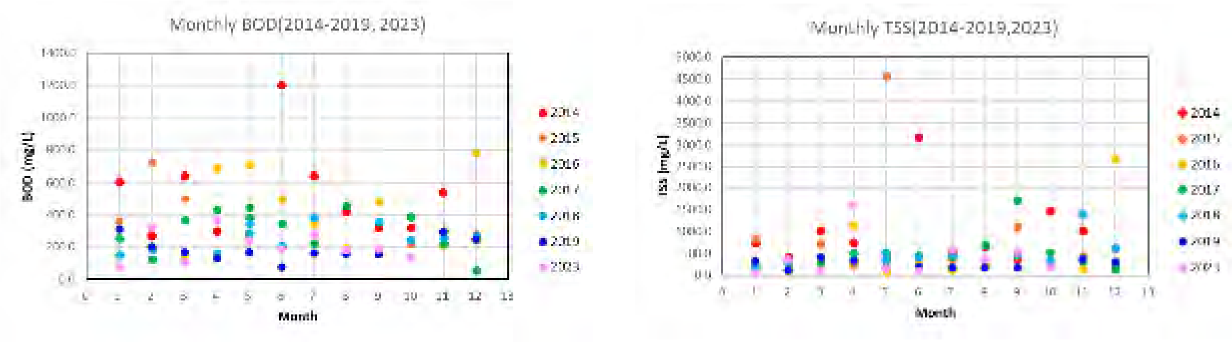
1) Selection of Raw Data

As previously stated in **APPENDIX 3-3**, raw influent data from 2014-2019 and 2023 was adopted for examination, excluding periods that were believed to be significantly affected by the decrease in tourist populations during the COVID-19 pandemic and Fiji border shutdowns.

2) Removing Outlier Data

WAF collects and analyzes influent samples taken from their WWTPs once a month. Raw influent data for Navakai WWTP showed some unusually extreme high/low results: BOD levels ranging from 4.0-1200.0 mg/L, and TSS levels ranging from 52.3-4563.0 mg/L. The collected data was examined for possible seasonal/annual trends but showed no apparent patterns, several being abrupt one-time events **(FigureA4-1.2**).

It was inferred that these readings were possible due to sample contamination or mis-recording of data, and direct application of all raw data would lead to over/under-estimation of influent water quality. Before further examination, outlier data (top 10% and bottom 10%) was removed from each data group. From the remaining data sets, the 80%tile value was set as Navakai WWTP's influent water quality (**Table A4-1.1**.).



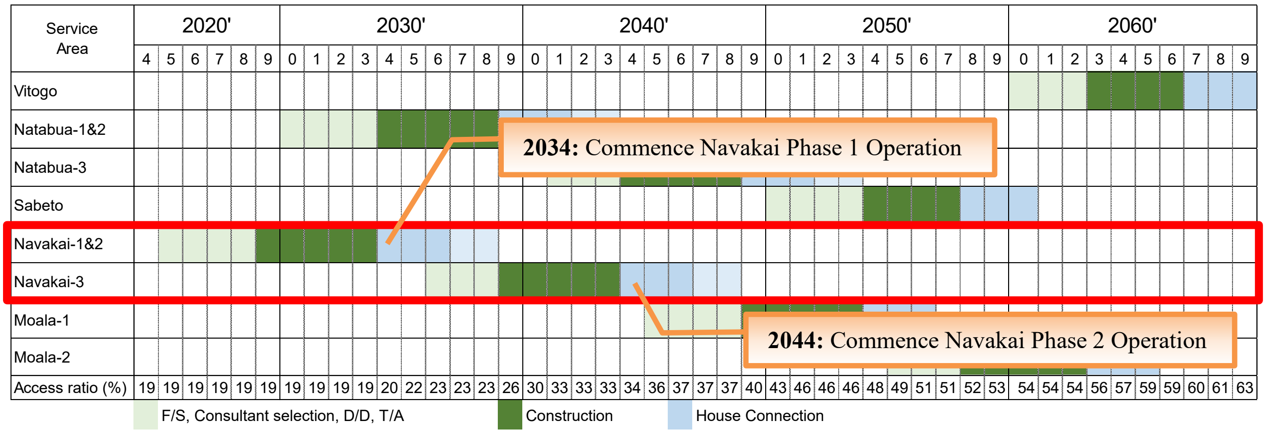
Source: Created by JET based on WAF data

Figure A4-1.1 Checking Seasonal Trends for Navakai WWTP Raw Influent Data

APPENDIX 4-2 Determining Navakai WWTP Phase 1/ Phase2 Treatment Line Numbers

(1) Setting Influent Flowrates for each Construction Phase

Due to its large requirement in treatment capacity, Navakai WWTP's facility will be constructed in two construction phases (**Figure A4-2.1**).



Source: Created by JET

Figure A4-2.1 Implementation Schedule for Navakai WWTP

Required treatment capacities of each phase was calculated based on their commencement schedule and the projected sewerage discharge (based on projected population growth of the sewerage service area) corresponding with that year. Namely, Navakai WWTP Phase 1 facilities must have the capacity to treat sewerage up until the commencement of Phase 2 facilities (2044), and Phase 2 facilities must be able to fulfill demands up until the completion of all house connection works (2048).

The projected population and sewerage flowrate to be treated by Navakai WWTP are shown in **Figure A4-2.2** and **Table A4-2.1**.

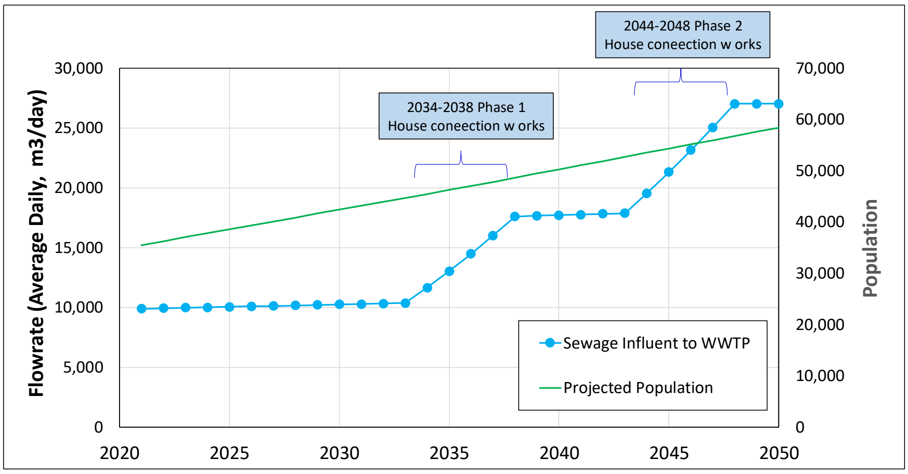


Figure A4-2.2 Navakai WWTP Sewerage Discharge vs. WWTP Treatment Capacity

Source: Created by JET

Table A4-2.1 Sewerage Discharge vs. Phase 1/Phase2 Treatment Capacity

Navakai WWTP Facilities	Year of Operation Commencement	Sewerage Discharge to be Treated (Average Daily Flowrate) (m^3/day)
Phase 1	2043	17, 879
Phase 2	2044	9,161
Total	2044 (Full Operation)	27,040

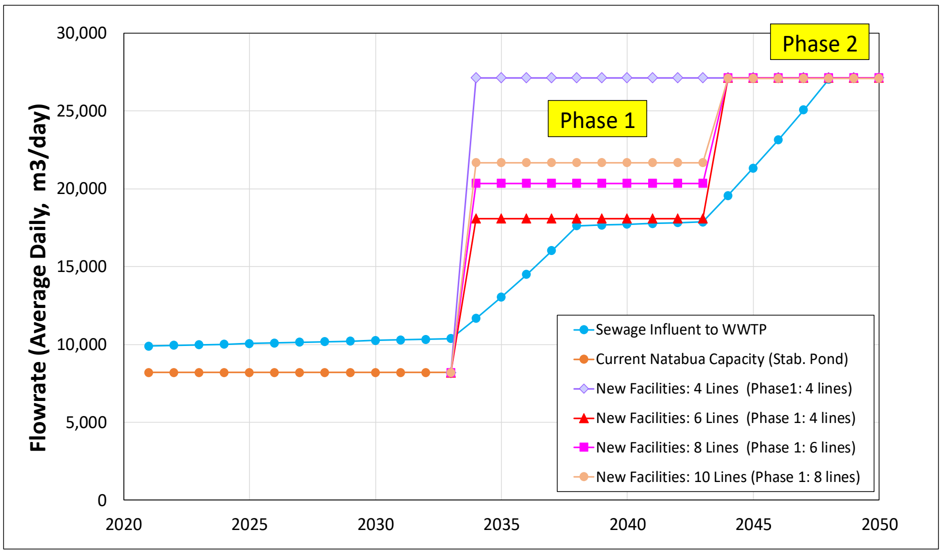
Source: Created by JET

(2) Determining Number of Treatment Lines

WWTPs often have even-number treatment lines, since this generally facilitates O&M and lessens required ME equipment units. Navakai WWTP's 4, 6,8, and 10-line scenarios were compared under the following conditions.

- Capacity of the operating treatment lines must fully cover the expected sewerage flowrate
- All treatment lines have same capacity throughout Phase 1 and Phase 2
- Even-number treatment lines in both Phase 1 and Phase 2 to facilitate O&M (ex. unified operation for all distribution chambers) and lessens required ME equipment units
- Treatment capacity of the treatment line does not subceed/exceed design constraints of treatment facilities (ex. HRT of oxidation ditches)
- Capacity of the operating treatment lines do not overly exceed sewerage flowrate

Figure A4-2.3 and **Table A4-2.2** shows the result of each scenario. Out of the four scenarios, the 6-line scenario had the least excess treatment capacity overall Thus the 6-line scenario was adopted for Navakai WWTP, constructing 4 line in Phase 1 and 2 lines in Phase 2.



Source: Created by JET

Figure A4-2.3 Navakai WWTP Multi-line System Scenario Comparison

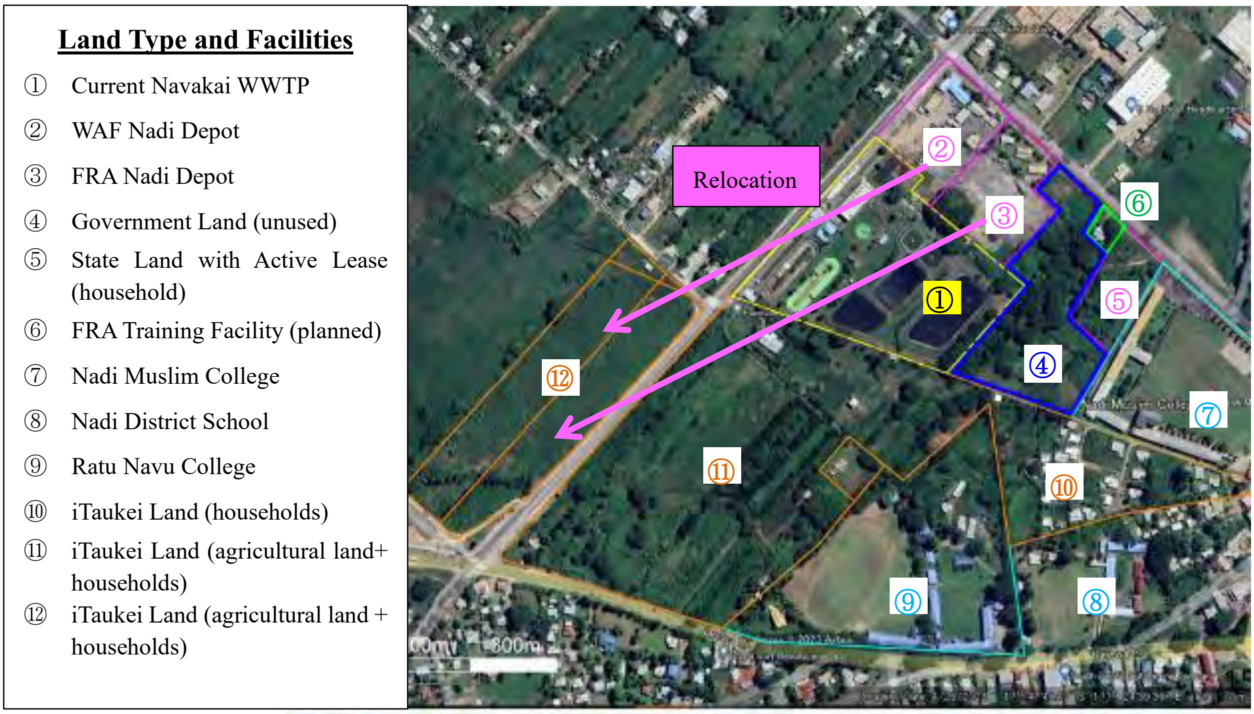
Table A4-2.2 Navakai WWTP Multi-line System Scenario Comparison

Year	Event	Facility in Operation	4 Line Scenario 6780 m3/d per line					6 Line Scenario 4520 m3/d per line					8 Line Scenario 3390 m3/d per line					10 Line Scenario 2710 m3/d per line				
			Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)	Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)	Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)	Lines Costructed	Lines Operating	Treatment Capacity (m3/d)	Sewage Influent (m3/d)	Excess Capacity (m3/d)
2021		Current	-	-	8,200	9,900	-	-	-	8,200	9,900	-	-	-	8,200	9,900	-	-	-	8,200	9,900	-
2022		Current	-	-	8,200	9,939	-	-	-	8,200	9,939	-	-	-	8,200	9,939	-	-	-	8,200	9,939	-
2023		Current	-	-	8,200	9,979	-	-	-	8,200	9,979	-	-	-	8,200	9,979	-	-	-	8,200	9,979	-
2024	Current Plant Operation	Current	-	-	8,200	10,018	-	-	-	8,200	10,018	-	-	-	8,200	10,018	-	-	-	8,200	10,018	-
2025		Current	-	-	8,200	10,058	-	-	-	8,200	10,058	-	-	-	8,200	10,058	-	-	-	8,200	10,058	-
2026		Current	-	-	8,200	10,097	-	-	-	8,200	10,097	-	-	-	8,200	10,097	-	-	-	8,200	10,097	-
2027		Current	-	-	8,200	10,136	-	-	-	8,200	10,136	-	-	-	8,200	10,136	-	-	-	8,200	10,136	-
2028		Current	-	-	8,200	10,176	-	-	-	8,200	10,176	-	-	-	8,200	10,176	-	-	-	8,200	10,176	-
2029		Current		4	27,120	10,215	16,905		4	18,080	10,215	7,865		6	20,340	10,215	10,125		8	21,680	10,215	11,465
2030	Phase 1	Current		4	27,120	10,254	16,866		4	18,080	10,254	7,826		6	20,340	10,254	10,086		8	21,680	10,254	11,426
2031	WWTP	Current		4	27,120	10,294	16,826		4	18,080	10,294	7,786		6	20,340	10,294	10,046		8	21,680	10,294	11,386
2032	Construction	Current		4	27,120	10,333	16,787		4	18,080	10,333	7,747		6	20,340	10,333	10,007		8	21,680	10,333	11,347
2033		Current		4	27,120	10,373	16,747		4	18,080	10,373	7,707		6	20,340	10,373	9,967		8	21,680	10,373	11,307
2034		Phase 1		4	27,120	11,673	15,447		4	18,080	11,673	6,407		6	20,340	11,673	8,667		8	21,680	11,673	10,007
2035	Phase 1 House	Phase 1		4	27,120	13,047	14,073		4	18,080	13,047	5,033		6	20,340	13,047	7,293		8	21,680	13,047	8,633
2036	Connections	Phase 1		4	27,120	14,497	12,623	4	4	18,080	14,497	3,583	6	6	20,340	14,497	5,843	8	8	21,680	14,497	7,183
2037		Phase 1		4	27,120	16,020	11,100		4	18,080	16,020	2,060		6	20,340	16,020	4,320		8	21,680	16,020	5,660
2038		Phase 1		4	27,120	17,618	9,502		4	18,080	17,618	462		6	20,340	17,618	2,722		8	21,680	17,618	4,062
2039		Phase 1		4	27,120	17,671	9,449		6	27,120	17,671	9,449		6	20,340	17,671	2,669		8	21,680	17,671	4,009
2040	Phase 2	Phase 1	4	4	27,120	17,723	9,397		6	27,120	17,723	9,397		6	20,340	17,723	2,617		8	21,680	17,723	3,957
2041	WWTP	Phase 1		4	27,120	17,775	9,345		6	27,120	17,775	9,345		8	27,120	17,775	9,345		8	21,680	17,775	3,905
2042	Construction	Phase 1		4	27,120	17,827	9,293		6	27,120	17,827	9,293		8	27,120	17,827	9,293		8	21,680	17,827	3,853
2043		Phase 1		4	27,120	17,879	9,241		6	27,120	17,879	9,241		8	27,120	17,879	9,241		8	21,680	17,879	3,801
2044		Phase 1 + Phase 2		4	27,120	19,562	7,558		6	27,120	19,562	7,558		8	27,120	19,562	7,558		10	27,100	19,562	7,538
2045	Phase 2 House	Phase 1 + Phase 2		4	27,120	21,320	5,800		6	27,120	21,320	5,800		8	27,120	21,320	5,800		10	27,100	21,320	5,780
2046	Connections	Phase 1 + Phase 2		4	27,120	23,152	3,968		6	27,120	23,152	3,968		8	27,120	23,152	3,968		10	27,100	23,152	3,948
2047		Phase 1 + Phase 2		4	27,120	25,059	2,061	6	6	27,120	25,059	2,061	8	8	27,120	25,059	2,061	10	10	27,100	25,059	2,041
2048		Phase 1 + Phase 2		4	27,120	27,040	80		6	27,120	27,040	80		8	27,120	27,040	80		10	27,100	27,040	60
2049		Phase 1 + Phase 2		4	27,120	27,040	80		6	27,120	27,040	80		8	27,120	27,040	80		10	27,100	27,040	60
2050		Phase 1 + Phase 2		4	27,120	27,040	80		6	27,120	27,040	80		8	27,120	27,040	80		10	27,100	27,040	60
			Total Excess Capacity				213,228	Total Excess Capacity				122,828	Total Excess Capacity				131,868	Total Excess Capacity				131,488

Source: Created by JET

APPENDIX 4-3 Navakai WWTP Alternative Layout Plan

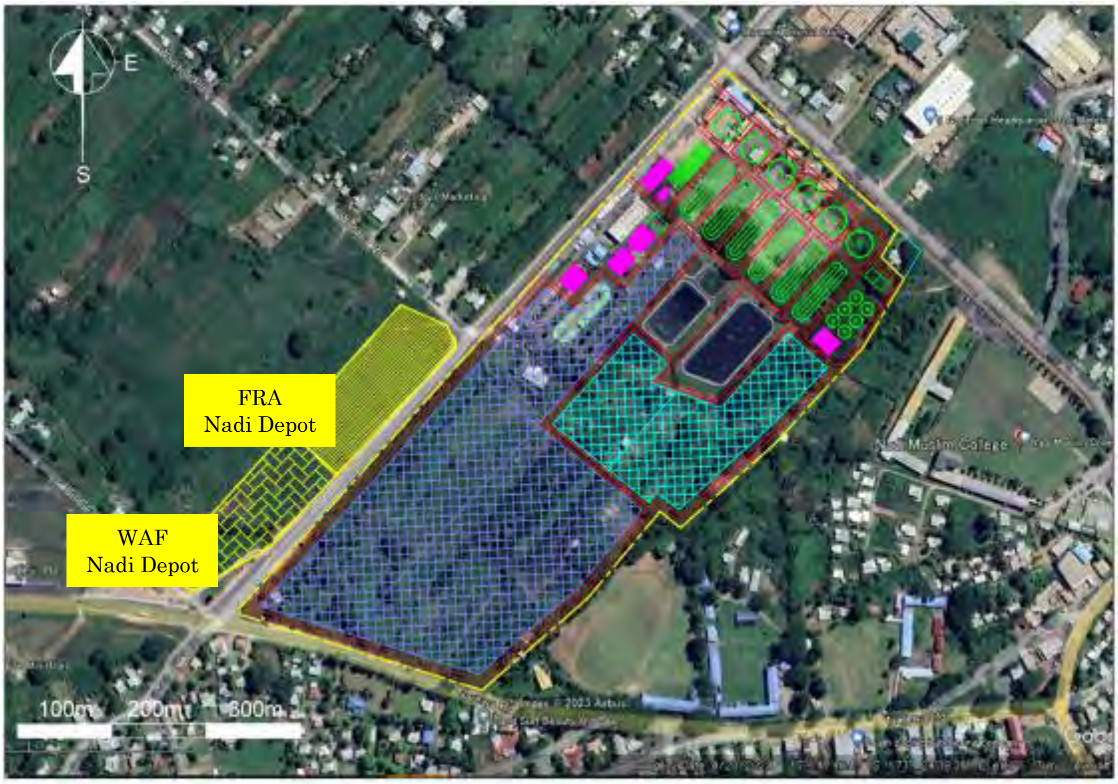
Upon examining the current land use conditions around Navakai WWTP, WAF notified that the exiting WAF Nadi Depot (**Figure A4-3.1**, ②) and FRA Nadi Depot (**Figure A4-3.1**, ③) could possibly be relocated to the i-Tauke land lots across the street from Navakai WWTP (**Figure A4-3.1**, ⑫).



Source: Created by JET based on Ministry of Land data

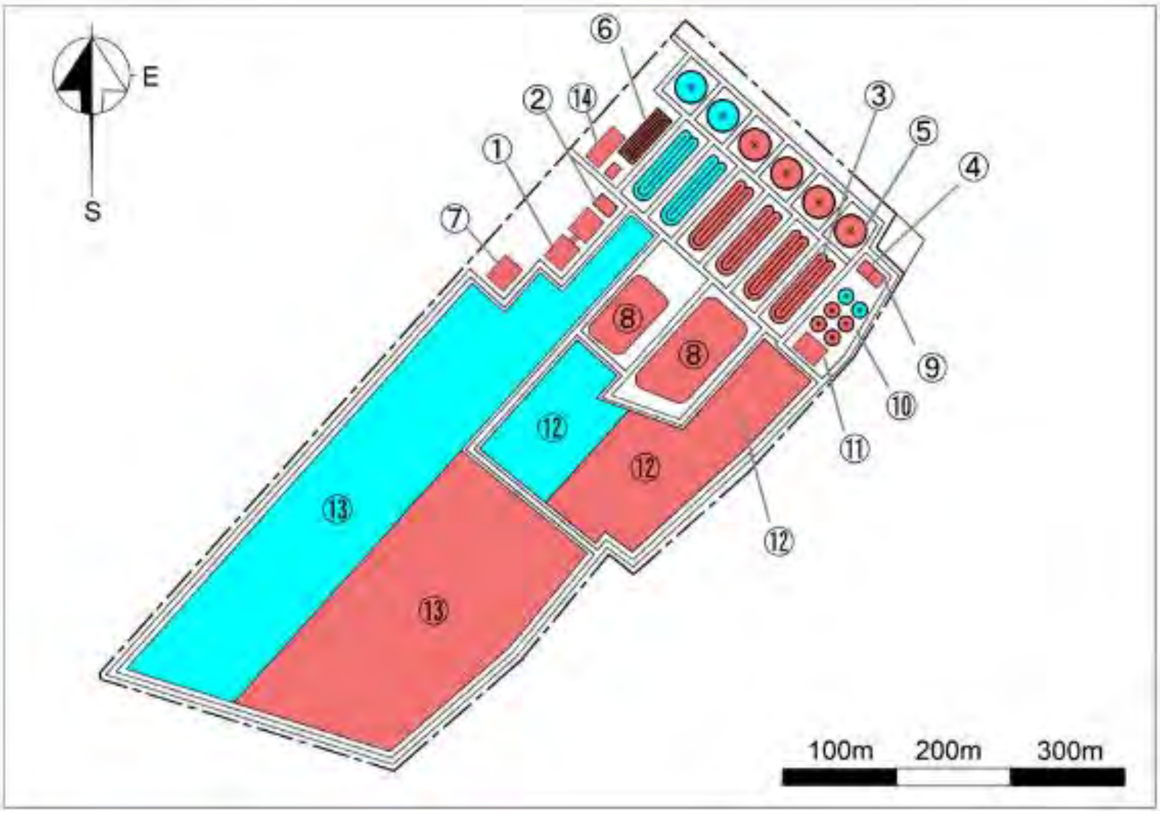
Figure A4-3.1 Current Land Use Situation around Navakai WWTP (March 2023)

Figure A4-3.2, **Figure A4-3.3**, **Table A4-3.1** shows the alternative layout plan for Navakai WWTP considering the relocation of the WAF and FRA depots, requested by WAF



Source: Created by JET

Figure A4-3.2 Navakai WWTP Alternative Layout Plan (Assuming Depot Relocation)



Source: Created by JET

Figure A4-3.3 Navakai WWTP Alternative Layout Plan (Phase 1/Phase 2 Facilities)

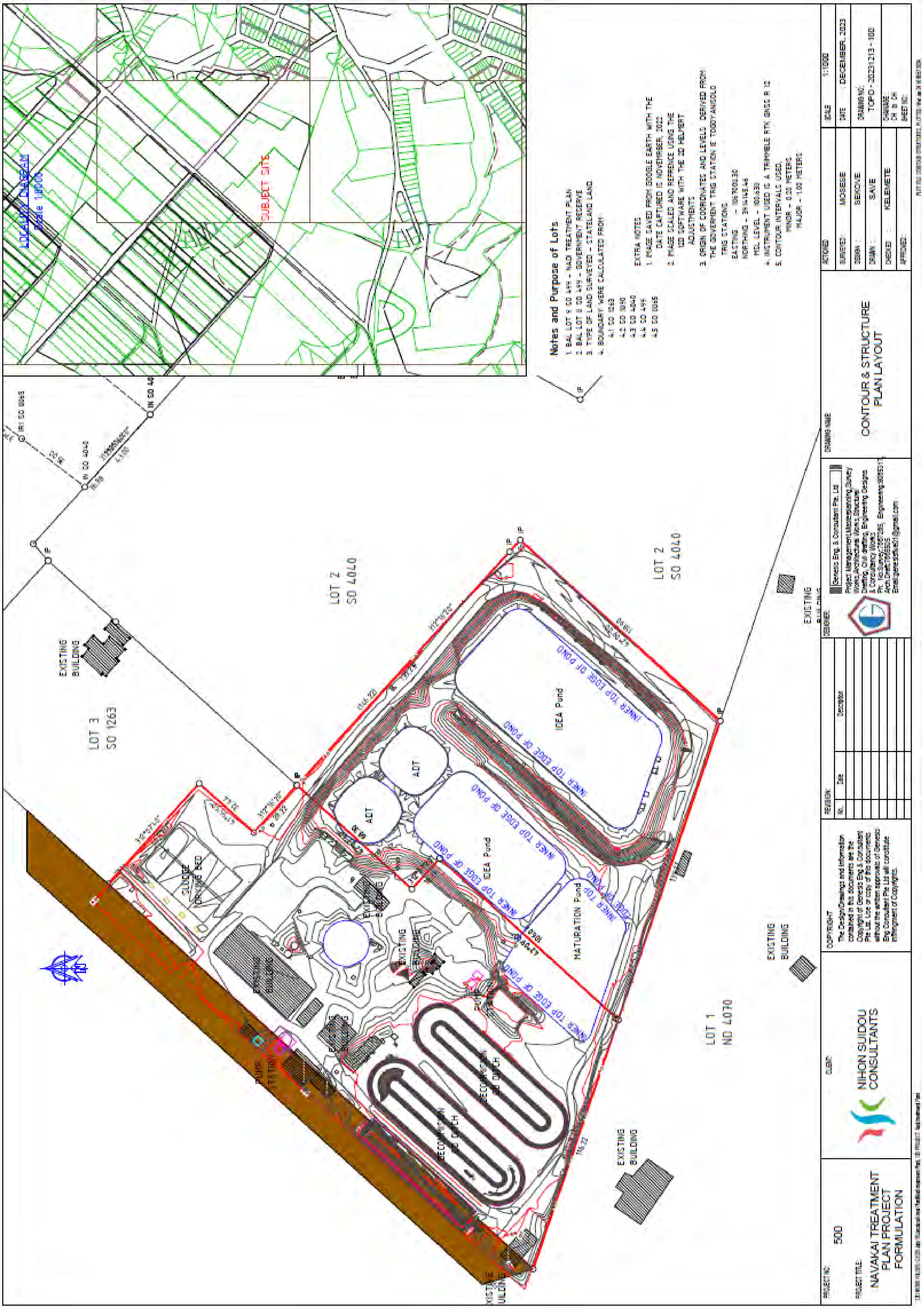
Table A4-3.6 Navakai WWTP Facilities (Alternative Layout)

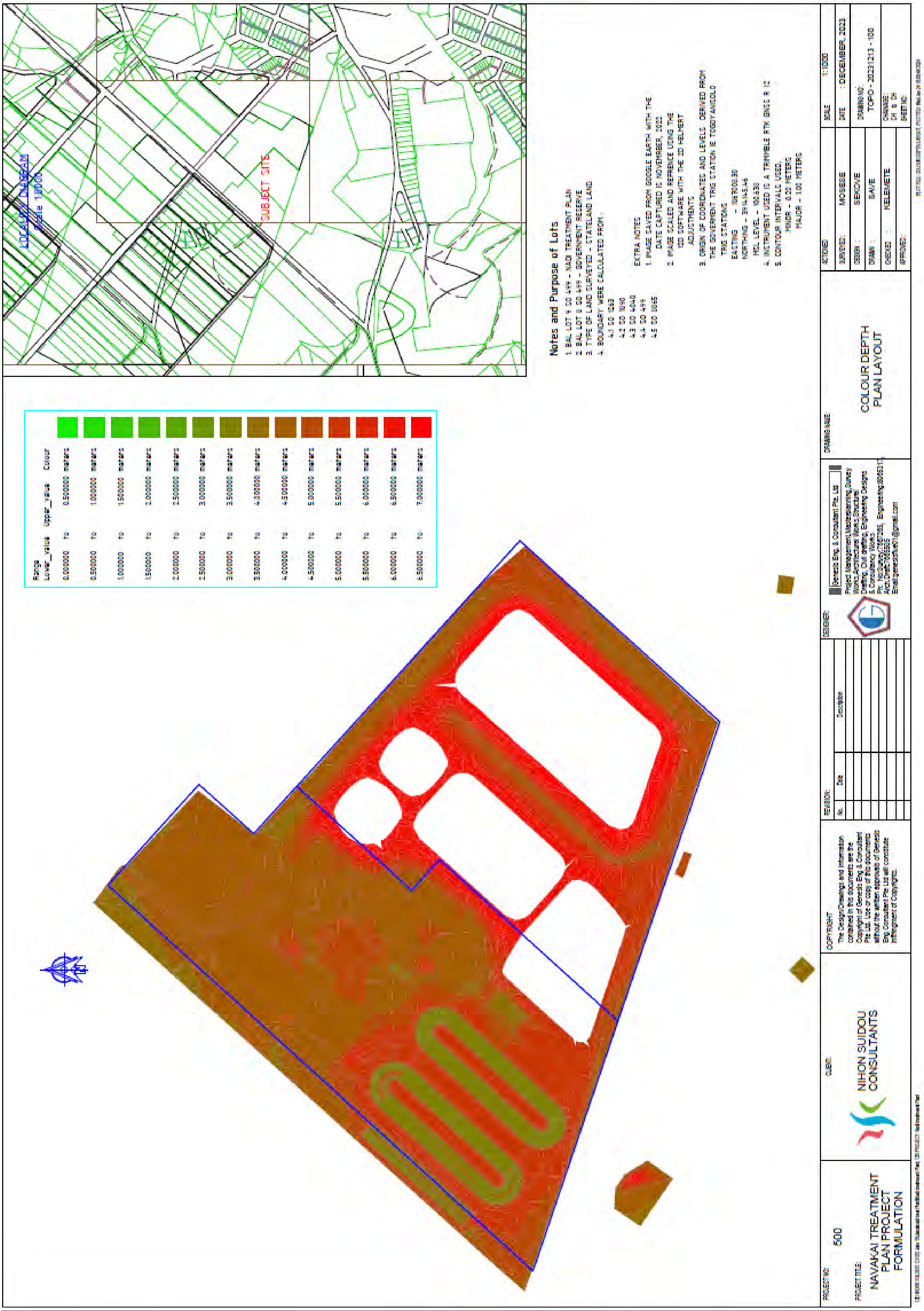
Ref. No.	Facility	Remarks
1	Inlet Pump Station	Includes Sewerage and Stormwater pumps
2	Distribution Chamber	Influent from: Inlet Pump Station Distribution to: OD tanks, Stormwater Sedimentation Ponds
3	Oxidation Ditch Tanks	HRT: 21.4 hr
4	Distribution Chamber	Influent from: OD tanks Distribution to: Final Clarifiers
5	Final Clarifiers	Diameter: 27 m
6	Disinfection Tank	Minimum contact time: 15 min.
7	Effluent Pump Station	Pump to Nadi River
8	Stormwater Sedimentation Pond	Utilize existing IDEA pond
9	Return Sludge Pump Station	
10	Sludge Receiving Tank	Diameter: 14 m
11	Sludge Dewatering Building	
12	Sludge Drying Beds	3.02 ha
13	Sludge Storage Space	10.77 ha
14	Administration Building	Includes emergency power generator and electricity room

Source: JET

APPENDIX 4-4 Navakai WWTP Survey Results


Notes and Purpose of Lots
SUBJECT SITE
LOT 2
SO 4040
LOT 3
SO 1263
BUILDINGVS AERIAL PLAN LAYLOUT
NIHON SUIDOU CONSULTANTS
500
NAVAKAI TREATMENT PLAN PROJECT FORMULATION
DECEMBER, 2023
1:1500


CONTOUR & STRUCTURE
PLAN LAYOUT
NAVAKAI TREATMENT
PLAN PROJECT
FORMULATION
NIHON SUIDOU
CONSULTANTS
LOCALITY DIAGRAM
SUBJECT SITE
LOT 3
SD 1263
LOT 2
SO 4040
LOT 1
ND 4070
EXISTING
BUILDING
IDEA Pond
MATURATION Pond
ADT
SLUDGE
DRYING BED
INNER TOP EDGE OF POND
DECEMBER, 2023


LOCATION DIAGRAM
Scale 1:10000
SUBJECT SITE
Notes and Purpose of Lots
1. BAL LOT 9 SO 499 - NADI TREATMENT PLAN
2. BAL LOT 8 SO 499 - GOVERNMENT RESERVE
3. TYPE OF LAND SURVEYED - STATELAND LAND
4. BOUNDARY WERE CALCULATED FROM :
4.1 SO 1263
4.2 SO 1890
4.3 SO 4040
4.4 SO 499
4.5 SO 8865
EXTRA NOTES
1. IMAGE SAVED FROM GOOGLE EARTH WITH THE DATE CAPTURED IS NOVEMBER, 2022
2. IMAGE SCALED AND REFRENCE USING THE 12D SOFTWARE WITH THE 2D HELMERT ADJUSTMENTS
3. ORIGIN OF COORDINATES AND LEVELS DERIVED FROM THE GOVERMENT TRIG STATION IE TOGOYAWSOLO TRIG STATIONS
4. INSTRUMENT USED IS A TRIMBLE RTK GNSS R 12
5. CONTOUR INTERVALS USED,
MINOR - 0.20 METERS
MAJOR - 1.00 METERS
Range
Lower_value
Upper_value
Colour
0.000000 to 0.500000 meters
0.500000 to 1.000000 meters
1.000000 to 1.500000 meters
1.500000 to 2.000000 meters
2.000000 to 2.500000 meters
2.500000 to 3.000000 meters
3.000000 to 3.500000 meters
3.500000 to 4.000000 meters
4.000000 to 4.500000 meters
4.500000 to 5.000000 meters
5.000000 to 5.500000 meters
5.500000 to 6.000000 meters
6.000000 to 6.500000 meters
6.500000 to 7.000000 meters
SCALE 1:1000
DATE : DECEMBER, 2023
SURVEYED : MOSESE
DESIGN : SEKOVE
DRAWN : SAVE
CHECKED : KELEMETE
TOPO - 20231213 - 100
DRAWING NAME:
COLOUR DEPTH PLAN LAYOUT
PROJECT NO:
500
PROJECT TITLE:
NAVAKAI TREATMENT PLAN PROJECT FORMULATION
CLIENT:
NIHON SUIDOU CONSULTANTS
COPYRIGHT
REVISION:
DESIGNER:
Genesis Eng. & Consultant Pte. Ltd

APPENDIX 4-5 Navakai WWTP Soil Survey Results

Soil survey studies were conducted at Navakai WWTP to obtain geotechnical data of the area. Soil boring tests were performed at two locations, Boring Hole N1 and Boring Hole N3, within the current WWTP boundaries **(Figure A3-5.1**) The soil boring test results are shown in the following pages.
It should be noted that in future stages of facility designs, additional boring tests should be conducted for the planned construction area outside of the current WWTP boundaries.

Source: ENTEC PTE Ltd.

Figure A3-5.1 Navakai WWTP Soil Boring Test Locations

(1) Boring Hole N1

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2)		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N1**
Job No.: 1381123.A	Start Date: 21-3-2024 Finish Date: 23-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543736.000 N: 8032594.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 24.60 m	Inclination: -90°	Sheet: 1 of 5

Columns: Type | Run | Fluid & Water | Piezometer | Geological Description | Legend | Weathering | Field Strength | Elevation (m MSL) | Depth (m) | Geological Unit | Defect Spacing (mm) | Defect Description | TCR (SCR) RQD (%) | Samples | Tests

Geological Description: Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clastic, subordinate qualifications, minor qualifications, additional structure, geologic unit.
Rock Description: weathering, colour, texture, fabric and orientation, NAME; strength, geologic unit.

Fluid & Water: 23.03.24 10:30 WL @ GL

Depth (m)	Geological Description	Geological Unit	TCR	Samples	Tests
0.00	FILL: GW gravel with trace of silt and sand, grey-brown, loose, moist. Fine to coarse grained, subangular to angular. CORE LOSS	FILL	30		
1.00	FILL: SW sand with trace of gravel, grey-brown, very loose, wet, fine to coarse grained. FILL: GW gravel trace silt and sand, grey-brown, very loose to loose, moist. Fine to medium grained, angular to subangular. CORE LOSS		25	SPT Sample 1 1.00	SPT 1.00 m 1 for 300mm 1 N=1 REC=0.15
2.00	CH Silty CLAY: brown. Soft to firm, moist. CORE LOSS	SURFICIAL DEPOSITS	30	SPT Sample 2 2.00	SPT 2.00 m 2,2,2 N=4 REC=0.35; WC= 40.6%
3.50	CH Silty CLAY: brown. Very soft to soft, moist. CORE LOSS		50	SPT Sample 3 3.50	SPT 3.50 m 1,1,1 N=2 REC=0.45; WC= 37.5% LL= 58% PL= 33% PI= 25%

Explanations:
Rock Mass Weathering – Fresh (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength – very low strength, low strength, medium strength, high strength, very high strength
TCR – Total Core Recovery
SCR – Solid Core Recovery
RQD – Rock Quality Designation
Rec – Core Recovery
Spacing of defects: VW – very widely spaced, W – widely spaced, M – moderately widely spaced, C – closely spaced, VC – very closely spaced, EC – extremely closely spaced

Samples and Tests
Small Disturbed Sample
Large Disturbed Sample
SPT – blows/300mm
Permeability Test
U100 Undisturbed Sample
Insitu Vane Shear Strength (kPa)
UTP – Unable to penetrate

Water
Level (date)
Inflow
Partial Loss
Complete Loss

Moisture Condition
D – Dry
M – Moist
W – Wet

Remarks
Hammer #01 efficiency: 72.0%

Water Level:
21/03/24: 5.07am WL @ 0.42mbgl.
23/03/24: 10:30am WL @ ground level

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N1**
Job No.: 1381123.A	Start Date: 21-3-2024 Finish Date: 23-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543736.000 N: 8032594.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 24.60 m	Inclination: -90°	Sheet: 2 of 5

Type	Run	Fluid & Water	Piezometer	Geological Description Soil Description: subordinate, particle size, MAJOR, minor; colour; structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description	FLR (SCR) RQD (%)	Samples	Tests
	5.00			SP SAND with trace of gravel and silt; grey. Loose; moist; fine to coarse grained.						SURFICIAL DEPOSITS				SPT Sample 4 5.00	SPT 5.00 m 4,3,5 N=8 REC=0.32 SSn 1.38
				SP Gravelly SAND; grey. Loose; moist; fine to coarse grained; gravel fine to medium grained; subrounded to subangular.										Sample 1 5.46	
				CORE LOSS.					6				40		
	6.50			SP SAND with gravel; grey. Loose; moist; fine to coarse grained; gravel fine grained, subrounded to subangular.					7					Sample 2 7.12	
				CORE LOSS.					8				31		
									9						
	9.50			SM SAND with silt, trace of clay and gravel; grey. Loose; moist; fine to coarse grained.									73	SPT Sample 5 9.50	SPT 9.50 m 2,2,3 N=5 REC=0.4

Explanations:
Rock Mass Weathering - Fresh (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced; W - widely spaced; M - moderately widely spaced; C - closely spaced; VC - very closely spaced; EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.0%

Water Level:
21/03/24, 5:07pm WL @ 0.42mbgl.
23/03/24, 10:30am WL @ ground level.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N1**
Job No.: 1381123.A	Start Date: 21-3-2024 Finish Date: 23-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543736.000 N: 8032594.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 24.60 m	Inclination: -90°	Sheet: 3 of 5

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
10.00	SP SAND with silt, trace of gravel, whitish grey. Loose, moist; fine to coarse grained; gravel, fine grained.		SURFICIAL DEPOSITS	75	Sample 3 10.00	
	CORE LOSS.					
11.00	SP SAND with trace of gravel and silt; whitish grey. Loose, moist; fine to coarse grained.	11		80	SPT Sample 5 11.00	SPT 11.00 m 3,3,5 N=8 REC=0.45 SG= 1.91t/m³
		12			Sample 4 11.90	SG= 2.11
	CORE LOSS.					
12.00	CH Silty CLAY with trace sand; pale white mottled grey. Soft, high plasticity, moist.			75	SPT Sample 7 12.50	SPT 12.50 m 4,5,7 N=12 REC=0.45
		13			Sample 5 13.32	WC= 25.3%
	CORE LOSS.					
14.00	SW SAND with trace of gravel and silt; pale brown. Medium dense, moist; fine to coarse grained.	14		80	SPT Sample 8 14.00	SPT 14.00 m 5,11,15 N=26 DB REC=0.1
	CORE LOSS.					

Column headings: Type; Run; Fluid & Water; Piezometer; Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure; strength, moisture condition, grading; bedding, plasticity, sensitivity, major qualifications, weathering of clasts; subordinate qualifications; minor qualifications, additional structure; geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME; strength, geologic unit); Legend; Weathering; Field Strength; Elevation (m MSL); Depth (m); Geological Unit; Defect Spacing (mm); Defect Description (type, orientation, spacing, roughness, persistence, aperture, infilling etc.); TCR (SCR) RQD (%); Samples; Tests.

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

Water Level:
21/03/24, 5.07pm WL @ 0.42mbgl.
23/03/24, 10.30am WL @ ground level.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N1**
Job No.: 1381123.A	Start Date: 21-3-2024 Finish Date: 23-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543736.000 N: 8032594.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 24.60 m	Inclination: -90°	Sheet: 4 of 5

Geological Description: Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit.

Columns: Type, Run, Fluid & Water, Piezometer, Geological Description, Legend, Weathering, Field Strength, Elevation (m MSL), Depth (m), Geological Unit, Defect Spacing (mm), Defect Description (type, orientation, spacing, roughness, persistence, aperture, infilling etc), TCR (SCR) RQD (%), Samples, Tests

Geological Unit: NADI SEDIMENTARY GROUP

Run	Geological Description	Depth (m)	TCR (%)	Samples	Tests
14.00	CORE LOSS (continued)		50		
15.50	HW-MW GP CONGLOMERATE with cobbles, matrix supported, pale brown mottled white, recovered as medium to coarse grained, angular to subangular, moist. CORE LOSS.	16	10		SPT 15.50 m 6,9,15 for 150mm N=50+ DB REC=0
17.00	CORE LOSS.	17			SPT 17.00 m 3,5,6 N=11 REC=0
	GP CONGLOMERATE, matrix supported, greyish black, recovered as medium to coarse grained, subrounded to subangular, moist. CORE LOSS.	18	7		
18.50	ML SILT with some sand and gravel, greyish black. Hard, moist. CORE LOSS.	19	45	SPT Sample 6 18.50	SPT 18.50 m 8,8,12 for 80mm N=50+ DB REC=0.34; WC=35.7%, LL=49%, PL=31%, PI=18%
19.20	HW-MW GP CONGLOMERATE, matrix supported, pale grey/dark brown, medium to coarse grained, subrounded to subangular, moist. CORE LOSS.		13		

Explanations:
Rock Mass Weathering - Fresh (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
Hammer #01 efficiency: 72.8%

Water Level:
21/03/24, 5.07pm WL @ 0.42mbgl.
23/03/24, 10.30am WL @ ground level.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: BH_N1
Job No.: 1381123.A	Start Date: 21-3-2024 Finish Date: 23-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543736.000 N: 8032594.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 24.80 m	Inclination: -90°	Sheet: 5 of 5

Type	Run	Fluid & Water	Piezometer	Geological Description (Soil Description: subordinate, particle size, MAJOR, minor; colour, structure strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts subordinate qualifications, minor qualifications, additional structure; geologic unit. Rock Description: weathering; colour, texture, fabric and orientation; NAME; strength; geologic unit)	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description (type, inclination, spacing, roughness, persistence, aperture, infilling, etc.)	TCR (SCR) RQD (%)	Samples	Tests
	20.00			HW-MW GP CONGLOMERATE, matrix supported, pale grey/ dark brown, dense to very dense, medium to coarse grained, moist.						NADI SEDIMENTARY GROUP				SPT Sample 10 20.00	SPT 20.00 m 5 for 50mm N=50+ DB REC=0.00
				CORE LOSS.									8		
	20.75								21				0		
	21.50			HW-MW GP CONGLOMERATE, matrix supported, pale grey/ dark brown, very dense, medium to coarse grained, moist.										SPT Sample 11 21.50	SPT 21.50 m 5 for 50mm N=50+ DB REC=0.00
				CORE LOSS.					22				1		
	23.00			GW SAND with traces of silt, dark grey. Very dense, fine to coarse grained, wet.					23					SPT Sample 12 23.00 Sample 6 23.15	SPT 23.00 m 9 for 90mm N=50+ DB REC=0.09
				CORE LOSS.					24				19		
	24.50			HW SUVA MARL: very low strength, dark grey, moist. Hole Terminated at 24.80 m									20	SPT Sample 13 24.50	SPT 24.50 m 10 for 150mm N=50+ DB REC=0.1

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - Blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
- D - Dry
- M - Moist
- W - Wet

Remarks
Hammer #01 efficiency: 72.8%

Water Level:
21/03/24, 5:07pm WL @ 0.42mbgl.
23/03/24, 10:30am WL @ ground level.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: IT	Checked by: AV

(2) Boring Hole N3

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: BH_N3
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 19-3-2024	Ground Level (m MSL)	Co-Ordinates (FMG): E 543499.000 N: 8032561.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 1 of 7

Columns: Type | Run | Fluid & Water | Piezometer | Geological Description (Soil Description: subordinate, particle size, MAJOR, minor, colour, structure, strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit) | Legend | Weathering | Field Strength | Elevation (m MSL) | Depth (m) | Geological Unit | Defect Spacing (mm) | Defect Description (type, orientation, roughness, persistence, aperture, infilling etc.) | TCR (SCR) Rec (%) | Samples | Tests

Run (m)	Geological Description	Geological Unit	TCR Rec (%)	Samples	Tests
0.00	FILL: CI Silty CLAY with gravel, trace of sand, brown, Firm, moist; gravel fine to medium grained.	FILL	50		
	CORE LOSS.				
1.00	FILL: SM SAND: grey-black, Loose, fine to coarse grained.		50	SPT Sample 1 1.00	SPT 1.00 m: 2,2,3 N=5 REC= 0.4; WC= 38.9% LL= 64% PL= 28% PI= 36%
	FILL: GP GRAVEL: grey, Loose, moist, fine to coarse grained, subrounded to rounded.				
	CORE LOSS.				
2.00	CH Silty CLAY with trace of sand, brown, Firm, moist.	SURFICIAL DEPOSITS	32	SPT Sample 2 2.00	SPT 2.00 m: 1,3,4 N=7 REC=0.2
	CH Silty CLAY with gravel, trace of sand, brown, grey, Firm, moist.				
	CORE LOSS.				
3.50	ML Sandy SILT: trace gravel, brown, Very soft, moist.		50	SPT Sample 3 3.50; Sample 1 3.85	SPT 3.50 m: 1,1,1 N=2 REC=0.45; Sg= 1.36t/m³
	CORE LOSS.				

Fluid & Water: 13-03-24 WL @ GL

Explanations:
Rock Mass Weathering - Fresh (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
Small Disturbed Sample
Large Disturbed Sample
SPT - Blows/300mm
Permeability Test
U100 Undisturbed Sample
Insitu Vane Shear Strength (kPa)
UTP = Unable to penetrate

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
Hammer #01 efficiency: 72.9%

*Note Siltstone (Suva marl) encountered after 30-30.6m.

Water Level:
13/03/24, 6:11pm WL @ ground level.
14/03/24, 6:40pm WL @ 1.54mbgl.
19/03/24, 7:02am WL @ 1.36mbgl.
20/03/24, 9:51am WL @ 0.83mbgl.
20/03/24, 4:43pm WL @ 0.46mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N3**
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 19-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543499.000 N: 8032561.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 2 of 7

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD	Samples	Tests
5.00	SW SAND with trace of organics and gravel grey. Medium dense, moist fine to coarse grained.		SURFICIAL DEPOSITS		SPT Sample 4 5.00; Sample 2 5.45	SPT 5.00 m 4,6,5 N=11 REC=0.4; WC= 8.5%, BD= 1.28t/m³
	CORE LOSS.	6		43		
6.50	CORE LOSS.	7		0		SPT 6.50 m 3,2,2 N=4 REC=0
8.00	SW SAND with trace of gravel and silt, pale grey. Very loose, moist fine to coarse grained.	8			SPT Sample 5 8.00; Sample 5 8.35	SPT 8.00 m 1 for 450mm N=0 REC=0.05
	CORE LOSS.	9		41		
9.50	SM SAND with silt and gravel grey. Loose, moist, fine to coarse grained.			60	SPT Sample 6 9.50	SPT 9.50 m 2,3,5 N=8 REC=0.45; WC= 30.8%

Column headings: Type; Run; Fluid & Water; Piezometer; Geological Description (Soil Description: subordinate, particle size, MAJOR, minor: colour, structure; strength, moisture condition, grading; bedding, plasticity, sensitivity, major qualifications, weathering of plasts, subordinate qualifications, minor qualifications, additional structure geologic unit. Rock Description: weathering, colour, texture, fabric and orientation: NAME, strength, geologic unit); Legend; Weathering; Field Strength; Elevation (m MSL); Depth (m); Geological Unit; Defect Spacing (mm); Defect Description; TCR (SCR) RQD; Samples; Tests.

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
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Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

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- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP - Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%
*Note Siltstone (Suva marl) encountered after 30-30.6m.
Water Level:
13/03/24, 6.11pm WL @ ground level
14/03/24, 6.43pm WL @ 1.54mbgl
19/03/24, 7.02am WL @ 1.38mbgl
20/03/24, 9.51am WL @ 0.83mbgl
20/03/24, 4.43pm WL @ 0.46mbgl

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N3**
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 19-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E 543499.000 N 8032561.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 3 of 7

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
9.50	SM SAND with silt and gravel; grey. Loose, moist; fine to coarse grained. (continued)		SURFICIAL DEPOSITS	60	Sample 4 10.15	
	CORE LOSS,					
11.00	SW Gravelly silty SAND with clay; brown. Medium dense; moist; fine to coarse grained; gravel, fine grained, subrounded to subangular.	11		30	SPT Sample 7 11.00	SPT 11.00 m 5,5,7 N=12 REC=0.45
	CORE LOSS,	12				
12.50	ML Sandy SILT with gravel; brown. Stiff, moist; sand, recovered as fine to coarse grained; gravel, fine grained, subrounded to subangular.	13		67	SPT Sample 8 12.50; Sample 5 13.50	SPT 12.50 m 4,4,6 N=10 REC=0.3
	CORE LOSS,					
14.00	GW Gravelly SAND with silt, trace of clay; brown. Medium dense; moist; fine to coarse grained; gravel, fine to medium grained, subrounded to subangular.	14		55	SPT Sample 9 14.00	SPT 14.00 m 5,6,9 N=15 REC=0.27
	SC Gravelly CLAY with sand; brown. Stiff, moist; gravel, fine to medium grained; sand, fine to medium grained.				Sample 6 14.60	
	CORE LOSS,					

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
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Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/150mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
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Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%

*Note Siltstone (Suva marl) encountered after 30-30.6m.
Water Level:
13/03/24, 6:11pm WL @ ground level
14/03/24, 6:43pm WL @ 1.54mbgl
19/03/24, 7:02am WL @ 1.36mbgl
20/03/24, 9:51am WL @ 0.83mbgl
20/03/24, 4:43pm WL @ 0.46mbgl

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

ENTEC PTE LIMITED
ENGINEERING & SCIENCE CONSULTANTS

ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).	Location: Navakai WWTP: Narewa Bypass, Nadi		No.: **BH_N3**
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 19-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543499.000 N: 8032581.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 4 of 7

Geological Description
Soil Description: subordinate, particle size, MAJOR, minor; colour; structure; strength; moisture condition; grading; bedding, plasticity, sensitivity, major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit.
Rock Description: weathering, colour, texture, fabric and orientation, NAME strength; geologic unit.

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
14.00	CORE LOSS. (continued)		SURFICIAL DEPOSITS	55		
15.50	SW Clayey SAND with silt and gravel; brown. Medium dense; moist; fine to medium grained; sand, fine to medium grained.				SPT Sample 10 15.50	SPT 15.50 m 8,8,9 N=17 REC=0.2
	CORE LOSS. (sand washout)	16		16		
17.00	SC Clayey SAND with silt and gravel; brown. Medium dense; moist; fine to medium grained; sand, fine to medium grained.	17			SPT Sample 11 17.00	SPT 17.00 m 7,7,9 N=16 REC=0.25
	Sandy GRAVEL; brown. Medium dense; moist; fine to coarse grained; subrounded to subangular; sand, fine to coarse grained.					
	CORE LOSS. (sand washout)	18		30		
18.50	HW-MW CONGLOMERATE; pale brown-grey. Very dense; moist; medium to coarse grained; subrounded to subangular.		NADI SEDIMENTARY GROUP			SPT 18.50 m 18 for 75mm N=50+ DB REC=0
	CORE LOSS. (sand washout)	19		7		

Explanations:
Rock Mass Weathering - Fresh (FR)
Slightly Weathered (SW), Moderately Weathered (MW)
Highly Weathered (HW), Extremely Weathered (XW)
Residual Soil (RS)
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
Small Disturbed Sample
Large Disturbed Sample
SPT - blows/300mm
Permeability Test
U100 Undisturbed Sample
Insitu Vane Shear Strength (kPa)
UTP = Unable to penetrate

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%
*Note Siltstone (Suva marl) encountered after 30-30.6m.
Water Level:
13/03/24, 6:11pm WL @ ground level.
14/03/24, 6:43pm WL @ 1.54mbgl.
19/03/24, 7:02am WL @ 1.38mbgl.
20/03/24, 9:51am WL @ 0.83mbgl.
20/03/24, 4:43pm WL @ 0.46mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N3**
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 19-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543499.000 N: 8032561.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 5 of 7

Type	Run	Fluid & Water	Piezometer	Geological Description	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description	TCR (SCR) RQD (%)	Samples	Tests
				Soil Description: subordinate, particle size, MAJOR, minor; colour; structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit.								(type, orientation, spacing, roughness, persistence, aperture, infilling etc.)			
	20.00			XW-HW CONGLOMERATE, matrix supported, whitish grey brown, very dense, recovered as [Sandy GRAVEL trace silt, whitish mottled brown. Very dense, coarse grained, moist.						NADI SEDIMENTARY GROUP				SPT Sample 12 20.00 Sample 7 20.29	SPT 20.00 m 11,12 for 100mm N=50+ DB REC=0.25
				HW-MW CONGLOMERATE, matrix supported, whitish grey brown, very dense, recovered as medium to coarse grain, subrounded to subangular, clasts of Marl, Limestone and Andesite. CORE LOSS.					21				49		
	21.50			SW SAND with trace of gravel, grey. Very dense, moist, fine to coarse grained.										SPT Sample 13 21.50	SPT 21.50 m 18 for 150mm N=50+ DB REC=0.15
				GP HW-MW CONGLOMERATE, matrix supported, brown-grey, very dense, medium to coarse grained, subrounded to subangular, clasts of Marl, Limestone and Andesite. CORE LOSS.					22				00		
	23.00			GP XW-HW CONGLOMERATE, recovered as sand and gravel. CORE LOSS.					23					SPT Sample 14 23.00	SPT 23.00 m 15,14,20 N=50+ DB REC=0.30
									24				29		
	24.50			GP XW-HW CONGLOMERATE, matrix supported, pale brown, grey, very dense, recovered as medium to coarse grain, subrounded to subangular. CORE LOSS.									25	SPT Sample 15 24.50	SPT 24.50 m 12,18,18 for 80mm N=50+ DB REC=0.28

Explanations:
Rock Mass Weathering - Fresh (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
Hammer #01 efficiency: 72.8%

*Note Siltstone (Suva marl) encountered after 30-30.6m.
Water Level:
13/03/24, 6:11pm WL @ ground level.
14/03/24, 8:43pm WL @ 1.64mbgl.
19/03/24, 7:02am WL @ 1.36mbgl.
20/03/24, 9:51am WL @ 0.83mbgl.
20/03/24, 4:43pm WL @ 0.46mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

ENTEC PTE LIMITED
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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2)		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N3**
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 18-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543489.000 N: 8032561.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 6 of 7

Run	Geological Description	Depth (m)	Geological Unit	TCR (SCR) RQD (%)	Samples	Tests
24.50	CORE LOSS. (continued)		NADI SEDIMENTARY GROUP	18		
26.00	SP SAND with trace of silt and clay: grey. Very dense, moist, fine to coarse grained. GP HW-MW CONGLOMERATE, matrix supported, pale brown, grey, medium to coarse grained, subrounded to subangular. CORE LOSS.	26		15	SPT Sample 15 26.00	SPT 26.00 m 10,25,1 for 20mm N=50+ DB REC=0.06
		27				
27.50	SW SAND with trace of silt and clay: grey. Very dense, moist, fine to coarse grained. GP HW-MW CONGLOMERATE, matrix supported, pale brown, grey, medium to coarse grained, subrounded to subangular, clasts of Limestone and Andesite. CORE LOSS.	28		19	SPT Sample 17 27.50	SPT 27.50 m 15 for 80mm N=50+ DB REC=0.02
28.25				0		
29.00	SP SAND with trace of silt and clay: grey. Very dense, moist, fine to coarse grained. GP HW-MW CONGLOMERATE, matrix supported, pale brown, grey, medium to coarse grained, subrounded to subangular. CORE LOSS.	29		20	SPT Sample 18 29.00	SPT 29.00 m 15,27 for 120mm N=50+ DB REC=0.04

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR = Total Core Recovery
SCR = Solid Core Recovery
RQD = Rock Quality Designation
Rec. = Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced.

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/300mm
- Permeability Test
- U100 Undisturbed Sample
- Insitu Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #01 efficiency: 72.9%
*Note Siltstone (Suva marl) encountered after 30-30.6m.
Water Level:
13/03/24, 6:11pm WL @ ground level.
14/03/24, 6:43pm WL @ 1.54mbgl.
19/03/24, 7:02am WL @ 1.36mbgl.
20/03/24, 9:51am WL @ 0.83mbgl.
20/03/24, 4:43pm WL @ 0.46mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

ENTEC PTE LIMITED
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ENGINEERING LOG BOREHOLE

Project: The Project for Formulation of Wastewater Treatment Master Plan in Western Division (Phase 2).		Location: Navakai WWTP, Narewa Bypass, Nadi	No.: **BH_N3**
Job No.: 1381123.A	Start Date: 13-3-2024 Finish Date: 19-3-2024	Ground Level (m MSL):	Co-Ordinates (FMG): E: 543499.000 N: 8032581.000
Client: Nihon Suido Consultants Co. Ltd	Hole Depth: 30.60 m	Inclination: -90°	Sheet: 7 of 7

Type	Run	Fluid & Water	Piezometer	Geological Description (Soil Description: subordinate, particle size, MAJOR, minor; colour, structure strength, moisture condition, grading, bedding, plasticity, sensitivity, major qualifications, weathering of clasts, subordinate qualifications, minor qualifications, additional structure, geologic unit. Rock Description: weathering, colour, texture, fabric and orientation, NAME, strength, geologic unit)	Legend	Weathering	Field Strength	Elevation (m MSL)	Depth (m)	Geological Unit	Defect Spacing (mm)	Defect Description	TCR (SCR) RQD (%)	Samples	Tests
				HW grey SUVA MARL; very low strength, moist										SPT Sample 19 30.00	SPT 30.00 m 13,20 for 150mm N=50+ CE REC=0.3
				Hole Terminated at 30.60 m					31						
									32						
									33						
									34						

Explanations:
Rock Mass Weathering - Fresh(FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Extremely Weathered (XW), Residual Soil (RS).
Relative Rock Strength - very low strength, low strength, medium strength, high strength, very high strength
TCR - Total Core Recovery
SCR - Solid Core Recovery
RQD - Rock Quality Designation
Rec. - Core Recovery
Spacing of defects: VW - very widely spaced, W - widely spaced, M - moderately widely spaced, C - closely spaced, VC - very closely spaced, EC - extremely closely spaced

Samples and Tests
- Small Disturbed Sample
- Large Disturbed Sample
- SPT - blows/100mm
- Permeability Test
- U100 Undisturbed Sample
- Hand Vane Shear Strength (kPa)
- UTP = Unable to penetrate

Water
- Level (Date)
- Inflow
- Partial Loss
- Complete Loss

Moisture Condition
D - Dry
M - Moist
W - Wet

Remarks
-Hammer #07 efficiency: 72.9%

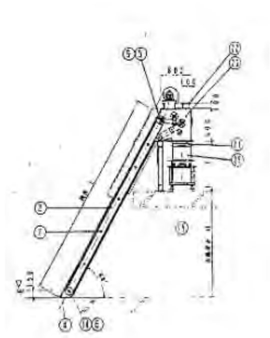
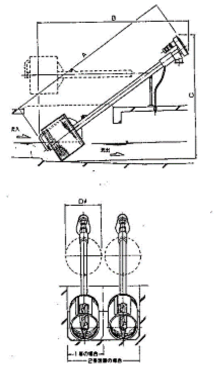
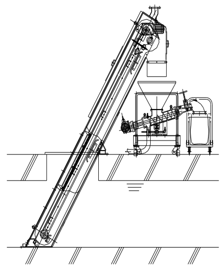
*Note Siltstone (Suva marl) encountered after 30-30.6m.

Water Level:
13/03/24, 6:11pm WL @ ground level.
14/03/24, 6:43pm WL @ 1.54mbgl.
19/03/24, 7:02pm WL @ 1.36mbgl.
20/03/24, 8:51am WL @ 0.83mbgl.
20/03/24, 4:43pm WL @ 0.46mbgl.

All dimensions in metres Scale 1:31	Contractor: Rockwell Pacific Pte Ltd	Rig/Plant Used: HANJIN	Logged by: AM	Checked by: AV

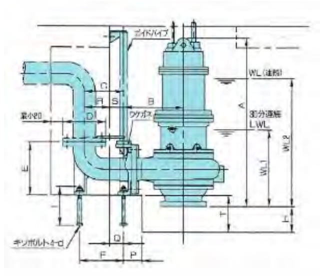
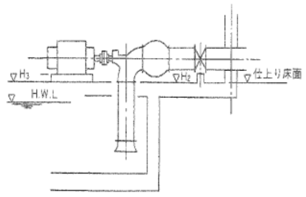
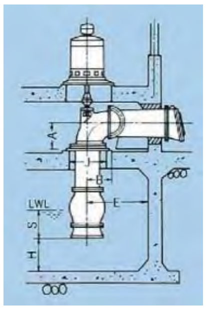
APPENDIX 4-6 Navakai WWTP Comparison/Selection of Mechanical Equipment

(1) Grit Removal Screen

	Automatic belt-running grit screen + Biaxal Screw Type	Drum type screen with dewatering mechanism	Continuous back-scraping type automatic grit screen + Residue dewaterer (Biaxial screw type)
Description	・Automatic screen and residue dewaterer integrated into a single unit. ・Automatic screen: rotating screen with V-shaped grooves that runs and scrapes up residue ・Residue Dewaterer: dewaters scraped residue using a biaxial screw 	・Residue supplemented by drum-type screen is conveyed by screw conveyor and dewatered in the press section ・Washing device can be installed in the drum-type screen section to wash the residue to some extent. 	・Residue trapped in front of the bar screen is scraped up by a comb-like rake attached to an endless chain at the back, scraped off when it returns at the top, and fed into a residue dewaterer connected to a chute 
Specifications	Screen width: 20-30mm Electric motor capacity: 0.4kW (600 width) Capacity of residue dewatering machine: 0.6m^3/h	Screen width: 15-25mm Electric motor capacity: 0.4kW (600 width) Capacity of residue dewatering machine: 0.1-0.5 m^3/h	Screen width: 15-25mm Electric motor capacity: 0.4kW (600 width) Capacity of residue dewatering machine: 0.6 m^3/h
Advantages	・Continuous scraping rakes allows large capacity ・Simple and reliable operation mechanism	・Continuously scraping rakes allows large capacity	・Continuous scraping rakes allows large capacity. ・Simple and reliable operation mechanism.
Disadvantages	・Necessary to cover the open machine to prevent odors	・The closed structure makes maintenance and management of the system less efficient ・Maintenance is performed by pulling it up to the top of the waterway	・A part of the screen needs to be cut off to allow the rake to pass through at the bottom of the channel ・An auxiliary screen must be installed to prevent dust from flowing downstream from the cut off part
Construction Cost	80	120	100
Maintenance Cost	100	110	100
Overall Cost Evaluation	90	110	100
Machine Performance	A	C	A
Overall Evaluation	A	C	B
	The "belt-run automatic grit screen+ residue dewaterer (two-axle screw type)" is highly efficient in combination with a dewaterer because of its high residue capturing performance and economic efficiency.		

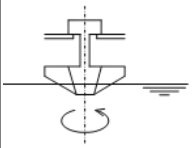
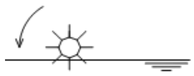
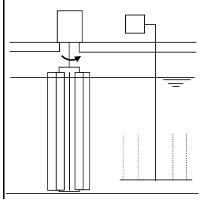
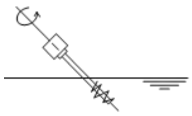
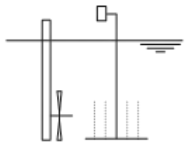
Source: Created by JET

(2) Main Pump

	Submersible sewerage pumps	**Horizontal-shaft semi-axial flow pump**	**Vertical-shaft semi-axial flow pump**
Description			
Pump efficiency	50 - 80% (φ100 -800)	70 - 85% (φ300 -3400)	75 - 80% (φ200 -1000)
Maintenance fee	・Detachable type is relatively easy to install/remove for maintenance and inspection. ・Regular mechanical seal maintenance is needed	・Pumps are set up external of the tank, allowing easy maintenance ・Installation of waterless shaft seal system requires maintenance of the mechanical seal.	・Pumps are set up external of the tank, allowing easy maintenance ・Installation of waterless shaft seal system requires maintenance of the mechanical seal.
	90%	100%	100%
Size and space	・Pump is placed inside the tank → smaller footprint ・Pumps and motors are submerged underwater, so only the machine hatch is on the dry floor.	・Requires largest vertical and horizontal installation footprint, (horizontal setup type external of the tank)	・The upper drawer installation footprint is larger due to the setup external of the tank
Construction cost	40 ～ 50 %	100 %	100 %
Auxiliary equipment	No shaft-sealed water pump required.	Requires a shaft-sealed water pump.	No shaft-sealed water pump required.
Measures to be taken in case of flooding	If a waterless shaft seal is installed, no vacuum pump or shaft water supply is required.	Requires a shaft-sealed water pump.	If a waterless shaft seal is installed, no vacuum pump or shaft water supply is required.
Evaluation	A	B	B
	In this plan, 'submersible sewerage pumps' will be adopted, taking into account flood prevention measures, maintainability, and economic efficiency and installment track record		

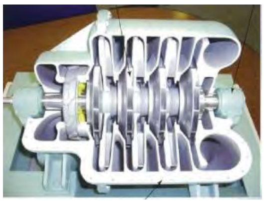
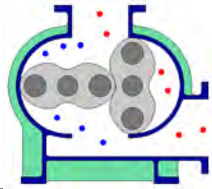
Source: Created by JET

(3) OD Basin Mixer

	Vertical shaft type	Horizontal shaft type	Vertical axis mixer + diffuser	Oblique-shafted type	Submerged propeller + diffuser
Description	・Vertical-shaft rotor is rotated near the water surface to provide a dispersing action by the dispersing blades. ・Simultaneously, the air/water-mixed liquid at the bottom of the aeration zone is pumped up to dissolve oxygen while mixing. 	・When the mixing blades are 20% to 30% submerged in water, they rotate to entrain air bubbles in the water, which are then subdivided. ・When the mixing blades exit the water, they bounce off the water droplets to supply oxygen. 	・Air is fed by a blower into a diffuser installed at the bottom of the tank. ・An out-of-tank driven mixer (with a vertical axis) rotates to mix and push out the air/ water-mixed liquid, creating a current underwater 	・A screw placed at an angle in the under-water section is swirled to draw in air using negative pressure to push out the air/water-mixed liquid, while mixing it with the screw blades. 	・Air is blown by a blower into a diffuser located at the bottom. ・A propeller installed in the underwater section rotates to mix the air bubbles and water, simultaneously creating a current underwear. 
Oxygen supply capacity (kg-O2/kWh)	2.5	2.3	3.0	2.2	3.5
Mixing capacity (power input density) (W/m³)	5.9	8.1	2.3	6.4	2.9
Economic Efficiency					
Equipment cost (%)	85	100	87	100	87
Required Power (kWh/m³・d)	0.28	0.325	0.25	0.28	0.22
Maintenance cost (%)	86	100	68	86	68
Restrictions on OD Channel Width	Required channel width: 5.5m - 7m	If the channel width is large, shaft deflection will occur and cause failure.	No restrictions on channel width	No restrictions on channel width	No restrictions on channel width
Overall Evaluation	Cannot be adopted with the channel width of this plan.	Currently, they are rarely employed.	Best overall score for equipment cost, maintenance cost, oxygen supply capacity, and power input density.	Equipment costs are higher because the number of units installed is greater in relation to the number of tanks.	Best overall score for equipment cost, maintenance cost, oxygen supply capacity, and power input density.
	D	C	A	B	A
	In this project, the 'vertical axis mixer+ diffuser' or 'underwater propeller + diffuser' which are equally economically advantageous for both equipment and maintenance cost., and can be applicable to the design width of the tank, can be adopted. For the project, the latter will be adopted for further works.				

Source: Created by JET

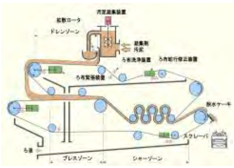
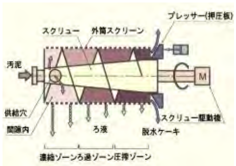
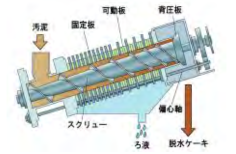
(4) Blowers

	Steel plate multi-stage turbo blowers	Rotary (Roots-type) blowers	Screw-Type Blower
Description	 	 	
caliber	Suction side: φ200 Output side: φ150	Suction side: φ200 Output side: φ150	Suction side: φ200 Output side: φ150
air volume	30m³/min	30m³/min	30m³/min
pressure	Suction pressure: 2kPa Discharge pressure: 60kPa	Suction pressure: 2kPa Discharge pressure: 60kPa	Suction pressure: 2kPa Discharge pressure: 60kPa
Advantages	・No refueling equipment or cooling water facilities are required. ・Air flow analysis and other technologies have improved efficiency. ・Smooth operation with low rotational vibration.	・Equipment costs are low. ・Experienced in small-scale or initial response.	・Packaged and compact. ・High efficiency due to continuous internal compression by screw. ・Auxiliary equipment is built into the package. ・High Blower Total thermal efficiency. ・No surging due to the volumetric system.
Disadvantages	・Surging occurs in some areas, so a surging limiter setting is required in the air flow control.	・Silencers required for noise control as they are not packaged. ・Inverter controllers use electronic equipment, so it is necessary to secure unit replacement parts for version upgrades and to take renewal measures corresponding to the service life of the equipment.	・Matrix converter control units use electronic equipment, so it is necessary to secure unit replacement parts for version upgrades and to take renewal measures corresponding to the service life of the unit.
Total thermal efficiency	57%	57%	70%
Pressure loss	・Silencers are not required, resulting in low pressure losses in the piping system.	・Silencers are required and pressure losses are high.	・Silencers are not required, resulting in low pressure losses in the piping system.
Airflow Control	・Inlet guide vane ・Controlled by adjusting the opening of the inlet guide vane, rather than by adjusting the speed of rotation ・Smooth operation with low rotational vibration.	・Inverter device ・Controlled by rotational speed. ・There is no surging area, but the noise level increases as the RPM increases.	・Matrix converter devices ・ It is controlled by the speed of rotation, but unlike inverters, it does not require harmonic countermeasures. ・No surging area and it is quiet due to the integrated cover, even when the speed increases.
Size	5,000×2,200×1,600	5,000×2,200×1,600	5,000×2,200×1,600
Weight	6.2 t	1.87 t	1.87 t

	Steel plate multi-stage turbo blowers	Rotary (Roots-type) blowers	Screw-Type Blower
Maintenance	・Protective instrument panels and individual forced lubrication devices are included and installed on the machine side for easy inspection. ・The centrifugal force of the cylindrically arranged runners (forward facing blades) draws in air and creates a swirling flow in a direction almost perpendicular to the axis of rotation. ・The swirling flow generated is rectified in one direction by the scroll and the required pressure is generated and supplied according to the number of runner stages, resulting in less pulsation and vibration and fewer failures.	・Protective devices are not attached but installed separately. ・Pressure pulsation due to 2- and 3-leaf rotors, requiring vibration countermeasures for piping, etc. ・Equipment body, rotor and inverter inspections are required.	・The operating panel, auxiliary equipment and protective devices are installed in a package that is easy to inspect, safe and reliable. ・The operating panel, auxiliary equipment and protective devices are installed in a package that is easy to inspect, safe and reliable. ・Since the air is compressed and blown by the screw, pulsation is smaller than with rotary blowers and smooth operation is possible.
Equipment Cost	100%	95%	90%
Maintenance cost	100%	97%	79%
Overall Evaluation	・High equipment and maintenance costs ・Low thermal efficiency. ・Building costs are high due to the large volume and heavy weight	・Resonance measures should be taken for piping where resonance occurs. ・Resonance measures should be taken for piping where resonance occurs. ・Low thermal efficiency.	・The control panel is installed on the surface of the package and allows for full operation and monitoring, making it easy to manage operations. ・No concern about surging caused by airflow control. ・Many have been introduced in other countries.
	Screw-type blowers are adopted in this project because they are superior in terms of thermal efficiency, equipment cost, maintenance cost, installation space and weight.		

Source: Created by JET

(5) Sludge Dewatering Machine

	Belt-press Dewaterer	Press-in screw press Dewaterer	Centrifugal Dewaterer	Multi-plate screw press Dewaterer
Description	The sludge is fed onto a filter cloth, gravity dewatered, then clipped between two filter cloths and pressed against rollers using the tension of the filter cloth to dewater it. 	Flocculated sludge is pressurized and fed at a constant pressure into the gap between the screen and the screw shaft, and the sludge is continuously dewatered through thickening, filtration and pressing by volume changes while moving from the inlet to the outlet due to the low-speed rotation of the screw. 	Sludge is fed into a rotating cylinder rotating at high speed, where centrifugal force separates solids of different specific gravity from water, and sludge cake is discharged by a screw-shaped discharger (conveyor) that is slightly differentiated from the rotating cylinder. 	Flocculated sludge flocculated in the service tank and mixing tank in the front section of the machine is gravity dewatered and separated into sludge and filter liquid. The screws are progressively thicker and narrower in pitch. Dewatering is carried out by the internal pressure created by this and the pressure applied from the back pressure plate. 
Target Sludge	・Mixed raw sludge ・Digested sludge. ・OD excess sludge, thickened sludge	・Mixed raw sludge ・Digested sludge. ・OD excess sludge, thickened sludge	・Mixed raw sludge ・Digested sludge. ・OD excess sludge, thickened sludge	・Mixed raw sludge ・OD excess sludge, thickened sludge
Auxiliary equipment	・Sludge supply system ・Chemical dosing system (polymer coagulant) ・Wash water pumps, ・Air compressors	・Sludge supply system ・Chemical dosing system (polymer coagulant) ・Wash water pumps, ・Air compressors	・Sludge supply system ・Chemical dosing system (polymer coagulant) ・Wash water pumps, ・Air compressors	・Sludge supply system ・wash water pumps. ・Chemical injection system (polymeric and inorganic coagulants)
Pre-treatment	Thickener tank required	Thickener tank required	Thickener tank required	No need for a thickener tank
Maintenance and management	・Sludge flocculation equipment, diffusion rotor, filter cloth tensioning device, filtration cloth meander corrector, filtration filter cleaning equipment, driving unit. ・One type of chemical	・Screws, outer casing screen, Screw driving unit ・One type of chemical .	・High-speed rotating equipment to be taken back to the factory for overhaul. ・One type of chemical	・Screws, fixed plate, movable plate, dorsal pressure plate, eccentric axis, driving device ・Two types of chemicals
	Difficult due to number of required parts	Easy due to small number of required parts	Needs to be taken back to the factory for overhaul/ minor repairs	Easy due to small number of required parts
Equipment cost	100%	82%	86%	35%
	Includes gravity thickener, dewatering/ conditioning equipment	Includes gravity thickener, dewatering/ conditioning equipment	Includes gravity thickener, dewatering/ conditioning equipment	Includes dewatering/ conditioning equipment
Maintenance costs	100%	68%	89%	89%
Overall Evaluation	In this project, the multiple plate screw press dewaterer will be adopted due to the following reasons ・Does not require a thickening process (thickening tank). ・Lowest sludge cake water content and excellent dewatering performance. ・Low equipment and maintenance costs			

Source: Created by JET

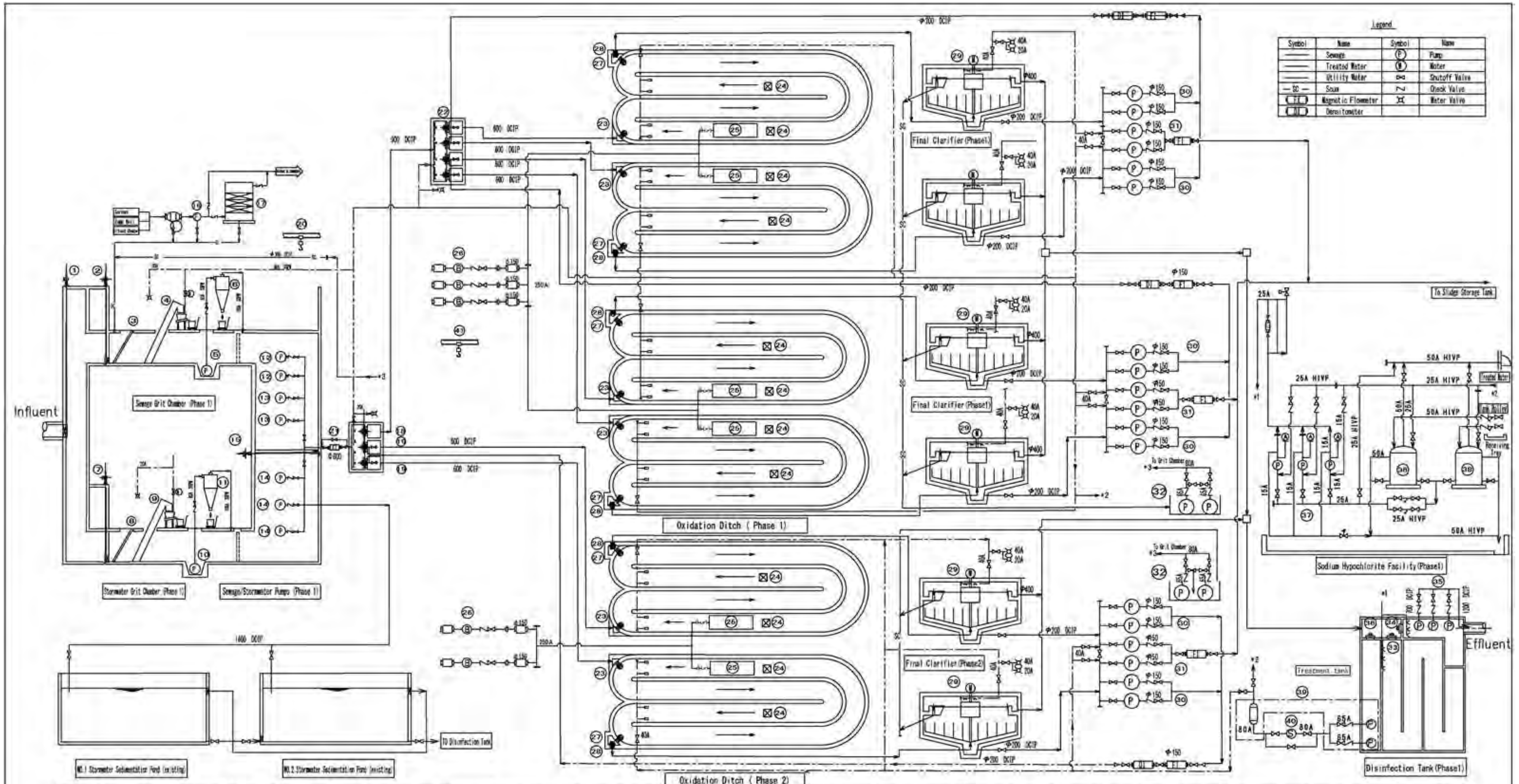
(6) Emergency Generator

	Diesel Engine Generator	Gas Turbine Generator
Description		
	The thermal energy of the intermittently exploding combustion gas is once converted into the reciprocating motion of the piston, which is then converted into the rotational motion of the crankshaft.	The thermal energy of the continuously burning combustion gas is directly converted into rotational motion by the turbine.
Generator Speed	Diesel, generator: 1,500rpm	Turbine: 22,000rpm, Generator: 1,500rpm
Fuel	Heavy oil, diesel oil	Heavy oil, kerosene, diesel oil
Fuel consumption	Small: 0.23-0.31 kg/kW・h	Large: 0.52-0.68 kg/kW・h
Grease consumption	Large: 1.36-2.72 g/kW・h	Small: 0.05-0.27 g/kW・h
Size/ Weight	Large and heavy	Small and light
Fuel air ratio	less	2.5-3 times more than the diesel
Maintenance Cost	Overhaul possible locally. Maintenance and inspection available by car mechanic.	Maintenance/overhaul must be conducted at factory
	50%	100%
Equipment Cost	100%	140%
Overall Evaluation	Diesel generators, which are advantageous in terms of equipment and maintenance costs, will be adopted in this project.	

Source: Created by JET

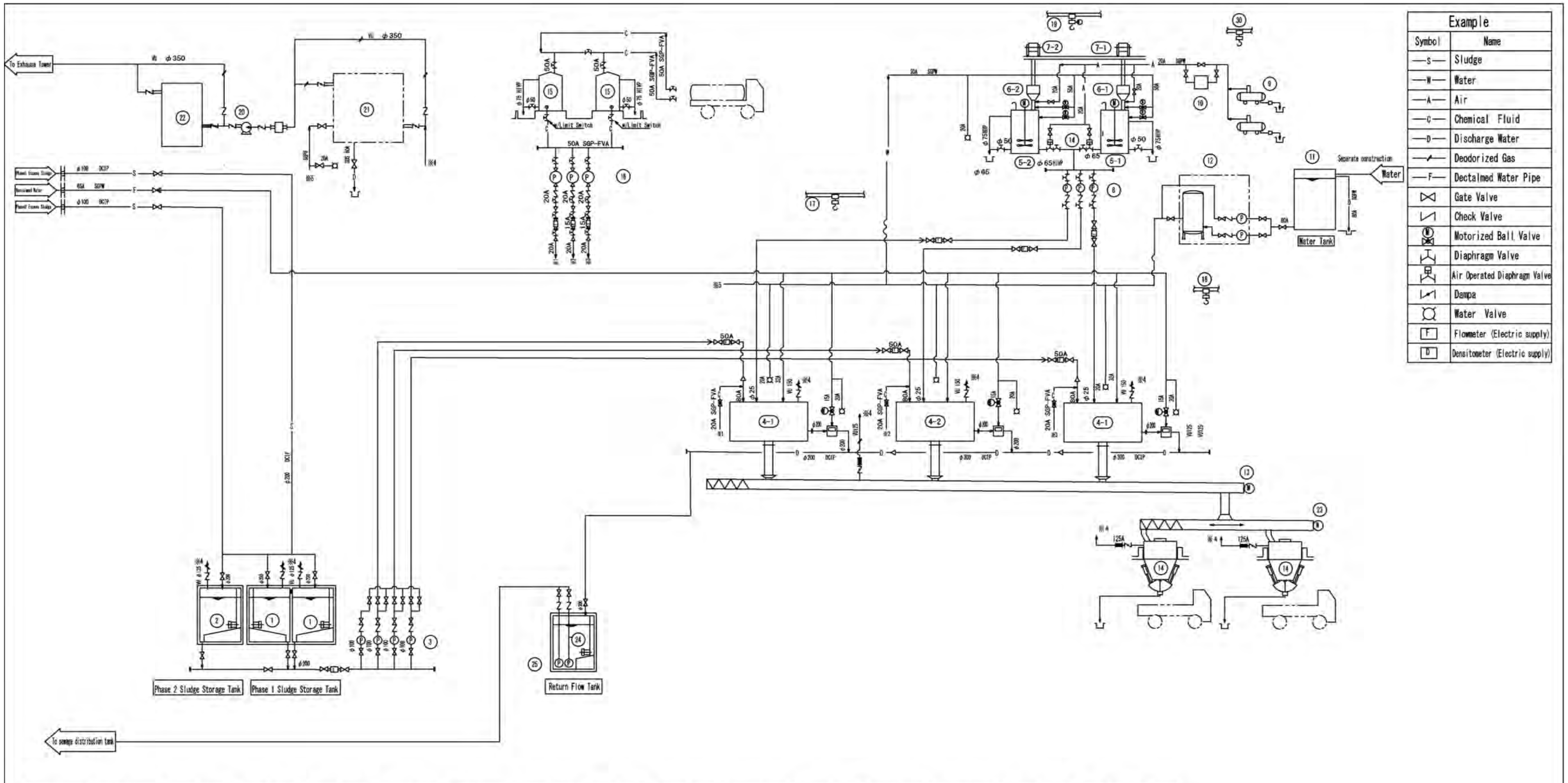
APPENDIX 4-7 Navakai WWTP Mechanical/Electrical Drawings

(1) Mechanical Equipment



NO	Name	Type	Specification	Motor output (kW)	Q'ty All	Q'ty Phase1	Q'ty Phase2	Remarks
1	Main Inlet Gate	Type: Outside Screw Material: Cast Iron	Width 1200×Height 1200	1.5	1	1	—	
2	Inlet Gate (Sewage)	Type: Outside Screw Material: Cast Iron	Width 450×Height 450	Manual type	3	3	—	
3	Coarse Screen (Sewage)	Hand-raked screen	[illegible]		3	3	—	
4	Automated Grit Removal Screen (Sewage)	Automatic belt-raking grit screen + Bleed screen	[illegible]	0.4	3	3	—	
5	Sand Pump (Sewage)	Suction screw type submersible pump	φ80mm×0.5m³/min×12m	5.5	3	3	—	
6	Cyclone-type Sand Separator (Sewage)	Capacity: 10m³/hr	Pressure loss: 60kPa	—	1	1	—	
7	Inlet Gate (Stormwater)	Type: Outside Screw Material: Cast Iron	Width 1000×Height 1000	Manual type	3	3	—	
8	Coarse Screen (Stormwater)	Hand-raked screen	[illegible]	—	3	3	—	
9	Automated Grit Removal Screen (Stormwater)	Automatic belt-raking grit screen + Bleed screen	[illegible]	0.4	3	3	—	
10	Sand Pump (Stormwater)	Suction screw type submersible pump	φ80mm×0.5m³/min×13m	5.5	3	3	—	
11	Cyclone-type Sand Separator (Stormwater)	Capacity: 30m³/hr	Pressure loss: 60kPa	—	1	1	—	
12	Phase 1 Sewage Pump	Suction screw type submersible pump	φ300mm×8.5m³/min×11m	30	2	2	—	Detachable type
13	Phase 2 Sewage Pump	Suction screw type submersible pump	φ450mm×19m³/min×11m	55	2(1)	—	2(1)	Detachable type
14	Stormwater Pump	Suction screw type submersible pump	φ800mm×35m³/min×8.5m	55	3(1)	3(1)	—	Detachable type
15	Pump Well Connecting Gate	Type: Outside Screw Material: Cast Iron	Width 500×Height 500		1	1	—	
16	Deodorizer Fan	Single-suction turbo fan	40m³/min×210mmAq	3.7	1	1	—	Grit Chamber machine room
17	Activated Carbon Adsorption Tower	Vertical activated carbon adsorption tower	40m³/min	—	1	1	—	Grit Chamber machine room
18	Phase1 OD Distribution Movable Weir	Type: Outside Screw Material: Cast Iron	Width 1000×Height 400	Manual type	1	1	—	
19	Phase2 OD Distribution Movable Weir	Type: Outside Screw Material: Cast Iron	Width 300×Height 400	Manual type	2	2	—	
20	Chain Hoist	Motorized chain hoist	1.0t×7m	0.9+0.4(hoist + traverse)	2	2	—	
21	Main Pump Flowmeter	Magnetic flowmeter	Diam.: 700mm	—	1	1	—	
22	OD Distribution Movable Weir	Type: Outside Screw Material: Cast Iron	Width 400×Height 300	Manual type	4	4	—	
23	OD Inlet Movable Weir	Type: Outside Screw Material: Cast Iron	Width 400×Height 300	Manual type	6	4	2	
24	Oxidation Ditch Mixer	Submerged propeller + air diffuser	φ1.8m	8	12	8	4	
25	Oxidation Ditch Diffusers	Ultrafine diffuser	Supplied Oxygen: 1,100kg-O2/day·unit		6	4	2	32 panels per unit
26	Blower	High-rate positive displacement screw blowers	Max air volume 17m³/min × 30kPa	45.0	5(2)	3(1)	2(1)	Packaged with control panel
27	OD Outlet Movable Weir	Type: Outside Screw Material: Cast Iron	Width 400×Height 300	Manual type	6	4	2	
28	OD Outlet Gate	Type: Outside Screw Material: Cast Iron	Width 800×Height 800	Manual type	6	4	2	
29	Final Clarifier	Peripheral-drive Column-supported type	Dia:25m×Water depth:4m	0.75	6	4	2	With manual scum skimmer
30	Return Sludge Pump	Suction screw sewage pump	φ150mm×1.8m³/min×10m	5.5	12	8	4	
31	Excess Sludge pump	Suction screw sewage pump	φ150mm×1.25m³/min×10m	3.7	6 (3)	4 (2)	2 (1)	
32	Scum pump	Suction screw type submersible pump	φ65mm×0.3m³/min×8m	0.75	4 (2)	2 (1)	2 (1)	Detachable type
33	Disinfection Tank Inlet Gate	Type: Outside Screw Material: Cast Iron	Width 1200×Height 1200	Manual type	1	1	—	
34	Bypass Gate	Type: Outside Screw Material: Cast Iron	Width 1200×Height 1200	Manual type	1	1	—	
35	Effluent Pump	Non-clogging submersible sewage pump	φ600mm×47m³/min×10m	110	3(1)	3(1)	—	
36	Treated Water Tank Inlet Gate	Type: Outside Screw Material: Cast Iron	Width 500×Height 500		1	1	—	
37	Hypochlorite Injection Pump	Diaphragm metering pump	[illegible]	0.4	3(1)	3(1)	—	
38	Hypochlorite Storage Tanks	FRP cylindrical tank	5m³		2	2	—	
39	Treated Water Pressure Tank Unit	Pressure tank unit	φ80mm×1m³/min×20m	7.5×2	1	1	—	[illegible]
40	Automatic Strainer	Automatic washing type	1m³/min	0.4	1	1	—	With control panel
41	Chain Hoist	Motorized chain hoist	1.0t×7m	0.9+0.4(hoist + traverse)	3	3	—	

Navakai WWTP (Nadi)
Sewage Treatment Equipment Flowsheet



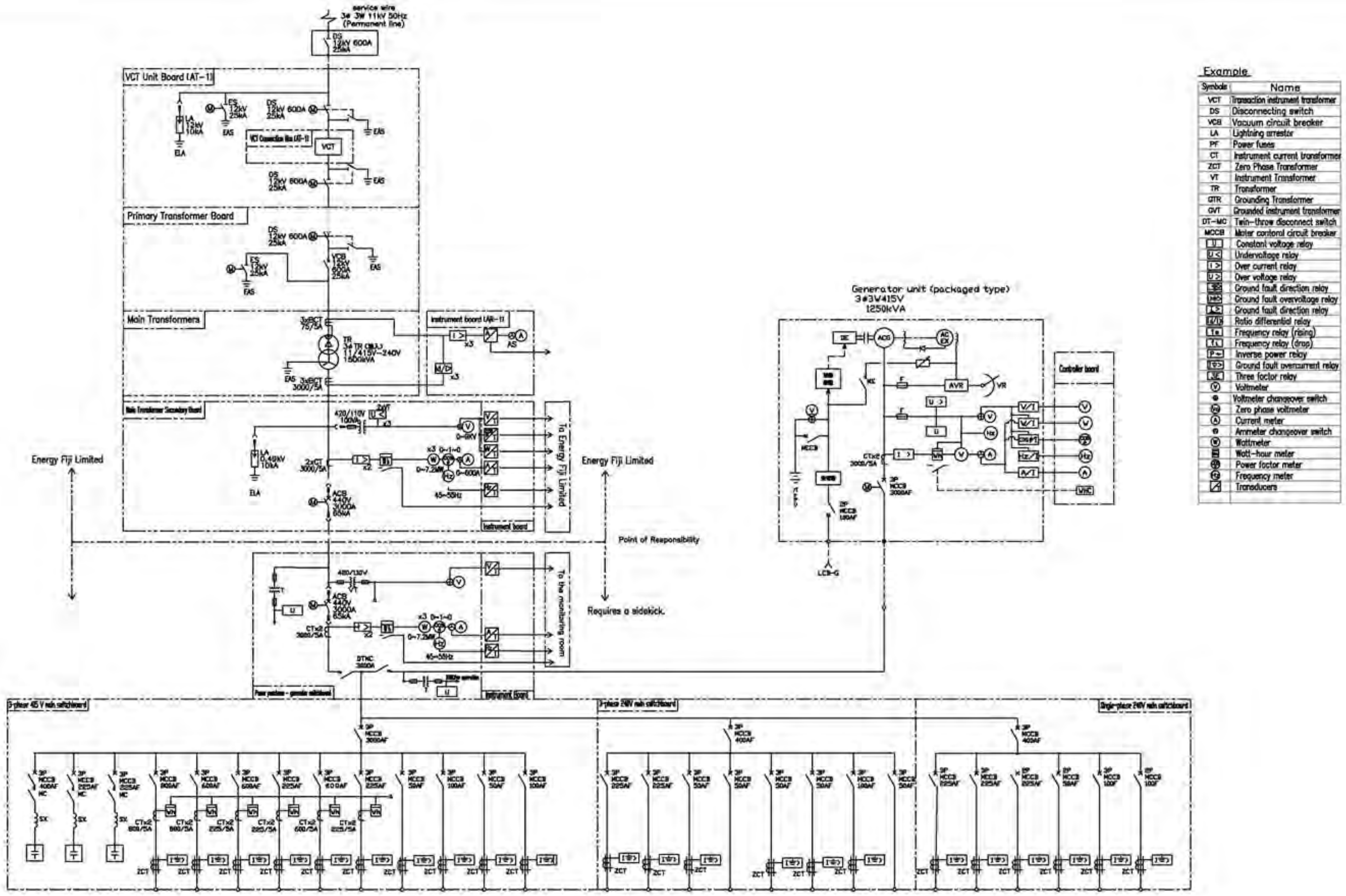
Equipment No.	①	②	③	④	⑤	⑥	⑦	⑧
Name	Phase 1 Sludge Storage Tank Mixer	Phase 2 Sludge Storage Tank Mixer	Sludge Supply Pump	Sludge Dewaterer	Chemical Storage Tank	Chemical Dosing Device	Chemical Container	Chemical Supply Pump
Type	Submerged mixer	Submerged mixer	Single screw type	Multi-plate screw press dewaterer	Vertical mixing tank	Adjustable continuous feeder	Invertable type	Single screw type
Specification	φ580 mm	φ580 mm	φ100×18.0～45.0m³/h ×196Kpa	400kg-DS/d	8 m³	Max 9000L/h Hopper 200L	0.5 m³	φ32×400～6000L/h ×196Kpa
Motorized output (kW)	5.5	5.5	7.5	8.3 or Lower	3.7	0.4	-	2.2
Unit (All / 1st / 2nd)	6 / 6 /	3 / - / 3	4(1) / 3(1) / 1	3 / 2 / 1	2 / 2 / -	2 / 2 / -	2 / 2 / -	3 / 2 / 1
Remarks			VVVF Control Equipment	With Control Panel		With Control Panel		VVVF Control Equipment

Equipment No.	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯
Name	Air Compressor	Dehumidifying Device	Water Tank	Water Supply Unit	Cake Transfer Conveyor	Sludge Cake Storage Hopper	Inorganic Flocculant Storage Tank	Inorganic Flocculant Supply Pump
Type	Portable type	Freezer type	Rectangular tank	Pressurized tank type water supply pump unit	Flight conveyors	Material: Steel plate Type: Square cut gate	Vertical mixing tank	Diaphragm type Electromagnetic metering pump
Specification	0.1m³/min ×0.73Mpa	0.1m³/min	8 m³	0.5m³/min ×343Kpa(35m)	600mm×32m	10 m³	5 m³	φ13×10～100L/h ×98Kpa
Motorized output (kW)	1.5	0.075(Single phase)	With FRP automatic water supply valve	7.5×2	7.5	2.2×2	FRP Type	2.2
Unit (All / 1st / 2nd)	2(1) / 2(1) / -	1 / 1 / -	1 / 1 / -	1 / 1 / -	1 / 1 / -	2 / 2 / -	2 / 2 / -	3 / 2 / 1
Remarks	With Control Panel	With Control Panel		With Control Panel		With Control Panel		VVVF Control Equipment

Equipment No.	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔	㉕
Name	Lifting Tool for Dewaterer Inspection	Lifting Tool for Loading/Unloading Machinery	Lifting Tool for Loading/Unloading Chemicals	Deodorizer Fan	Biological Deodorization Tower	Activated Carbon Adsorption Tower	Sludge Cake Distribution Conveyer to Hopper	Return Flow Tank Mixer	Return-flow pump
Type	Manual-type chain block	Manual-type chain block	Motorized chain block	Single suction turbo fan	Packed column tower	Vertical type tower	Flight conveyor	Submerged mixer	Screw-type submersible pump (Detachable type)
Specification	2t×8m H	2t×10m H	1t×4m H	40 m³/min	40 m³/min	40 m³/min	600mm×10m	φ580 mm	100Φ×0.5m³/min×10m
Motorized output (kW)			Hoist 0.8 + Traverse 0.4	3.7			1.5	7.4 or higher	0.2
Unit (All / 1st / 2nd)	1 / 1 / -	1 / 1 / -	1 / 1 / -	1 / 1 / -	1 / - / 1	1 / 1 / -	1 / 1 / -	1 / 1 / -	2(1) / 2(1) / -
Remarks									

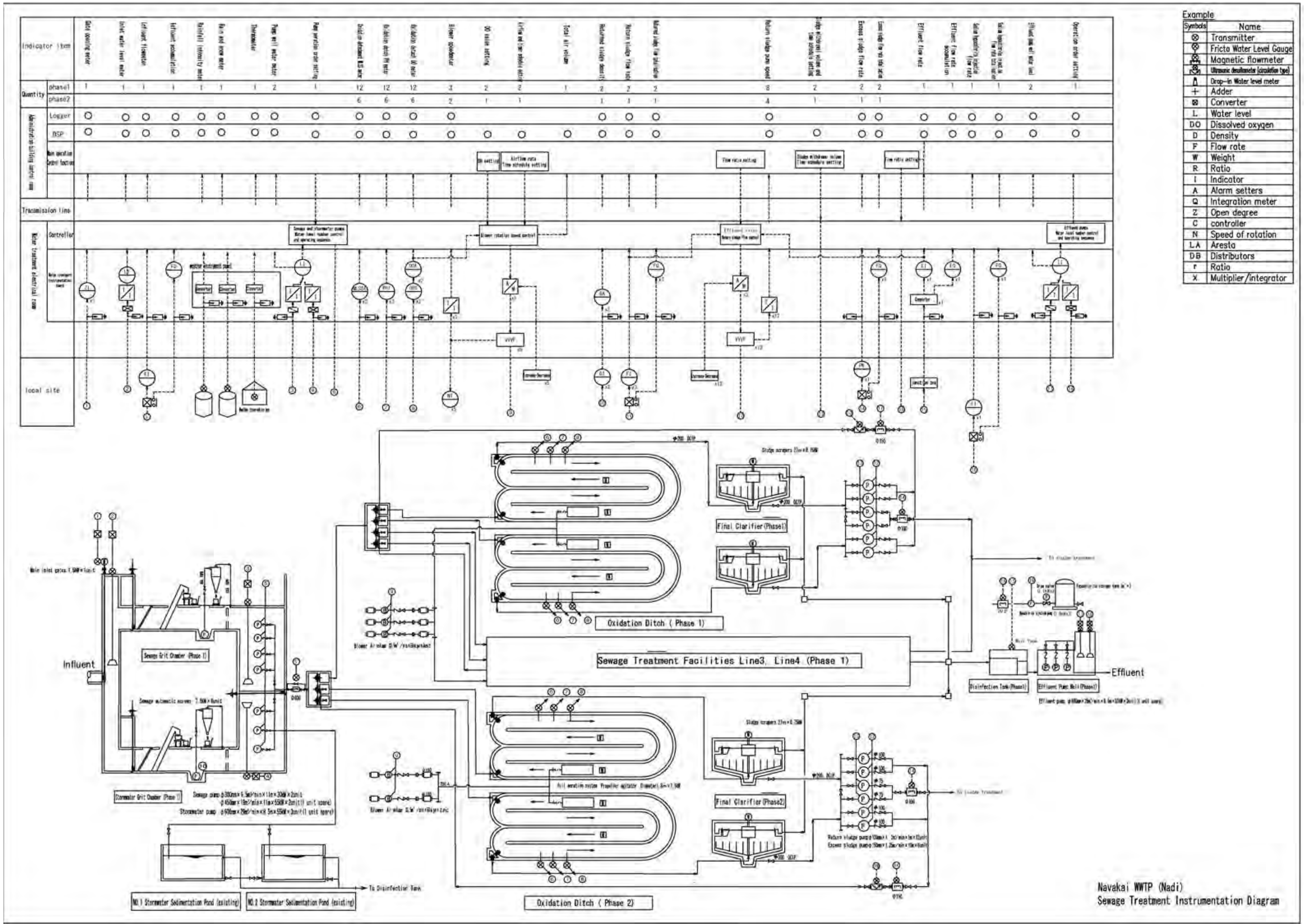
Navakai WWTP (Nadi)
Sludge Treatment Equipment Flowsheet

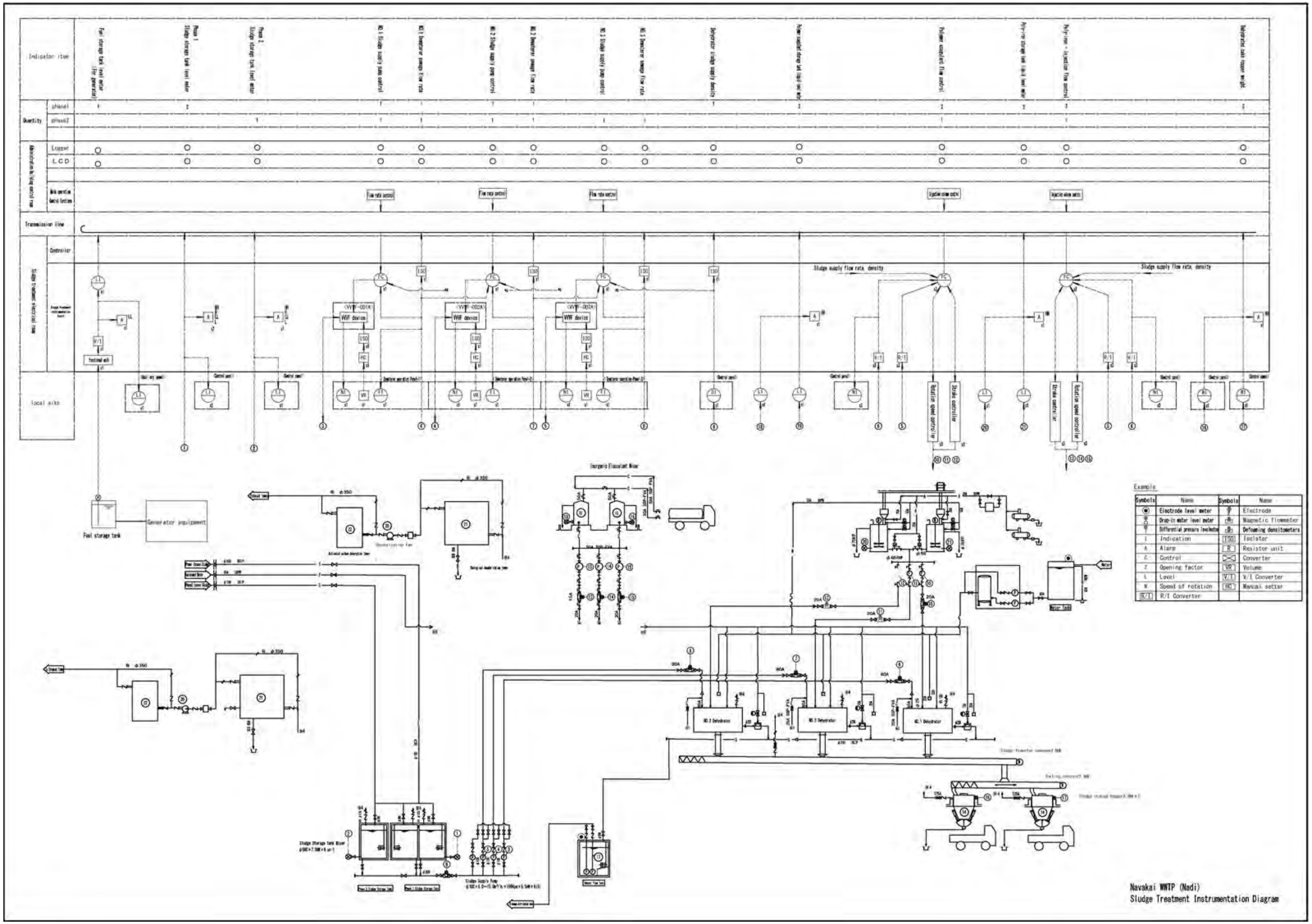
(2) Electrical Equipment



Load Name	SC	SC	SC	Sewage / screening Pump Equipment	Sewage treatment Line 1+Line2 Equipment	Sewage treatment Line 3+Line 4 Equipment	Sewage treatment Line 5+Line 6 Equipment	[illegible] Effluent pump Equipment	Sludge treatment Equipment	DC power supply unit	Auxiliary generator	Spare (1)	Spare (2)		Administration building Power supply	Sewage / screening Pump building Power supply	Sludge dewatering building Power supply	[illegible] Power supply	Sewage treatment facility working power	Sludge treatment facility working power	Spare (3)	Spare (4)	Administration Bld. lighting power supply	Grit Chamber Pump Equipment lighting power supply	Sludge dewatering building lighting power supply	Sludge treatment facility working power	Spare (5)	Spare (6)
Capacity Phase1	150kVar	75kVar	–	290	200	200	–	250	50	5kVA	10	–	–		70	70	50	5kVA	10	10	–	–	50	50	80	5kVA	–	–
Capacity Phase2	–	–	75kVar	–	–	–	100	–	15	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–
Remarks																												

Navakai WWTP (Nadi)
Single Line Diagram 1


Example
Symbols
Name
Transmitter
Fricto Water Level Gauge
Magnetic flowmeter
Drop-in Water level meter
Adder
Converter
L
Water level
DO
Dissolved oxygen
D
Density
F
Flow rate
W
Weight
R
Ratio
I
Indicator
A
Alarm setters
Q
Integration meter
Z
Open degree
C
controller
N
Speed of rotation
LA
Aresta
DB
Distributors
r
Ratio
X
Multiplier/integrator
Indicator item
Quantity
phase1
phase2
Logger
DSP
Transmission line
Controller
local site
Influent
Effluent
Sewage Grit Chamber (Phase 1)
Stormwater Grit Chamber (Phase 1)
Oxidation Ditch (Phase 1)
Oxidation Ditch (Phase 2)
Final Clarifier(Phase1)
Final Clarifier(Phase2)
Sewage Treatment Facilities Line3, Line4 (Phase 1)
Disinfection Tank(Phase1)
Effluent Pump Well(Phase1)
NO.1 Stormwater Sedimentation Pond (existing)
NO.2 Stormwater Sedimentation Pond (existing)
To Disinfection Tank
To sludge treatment
Navakai WWTP (Nadi)
Sewage Treatment Instrumentation Diagram

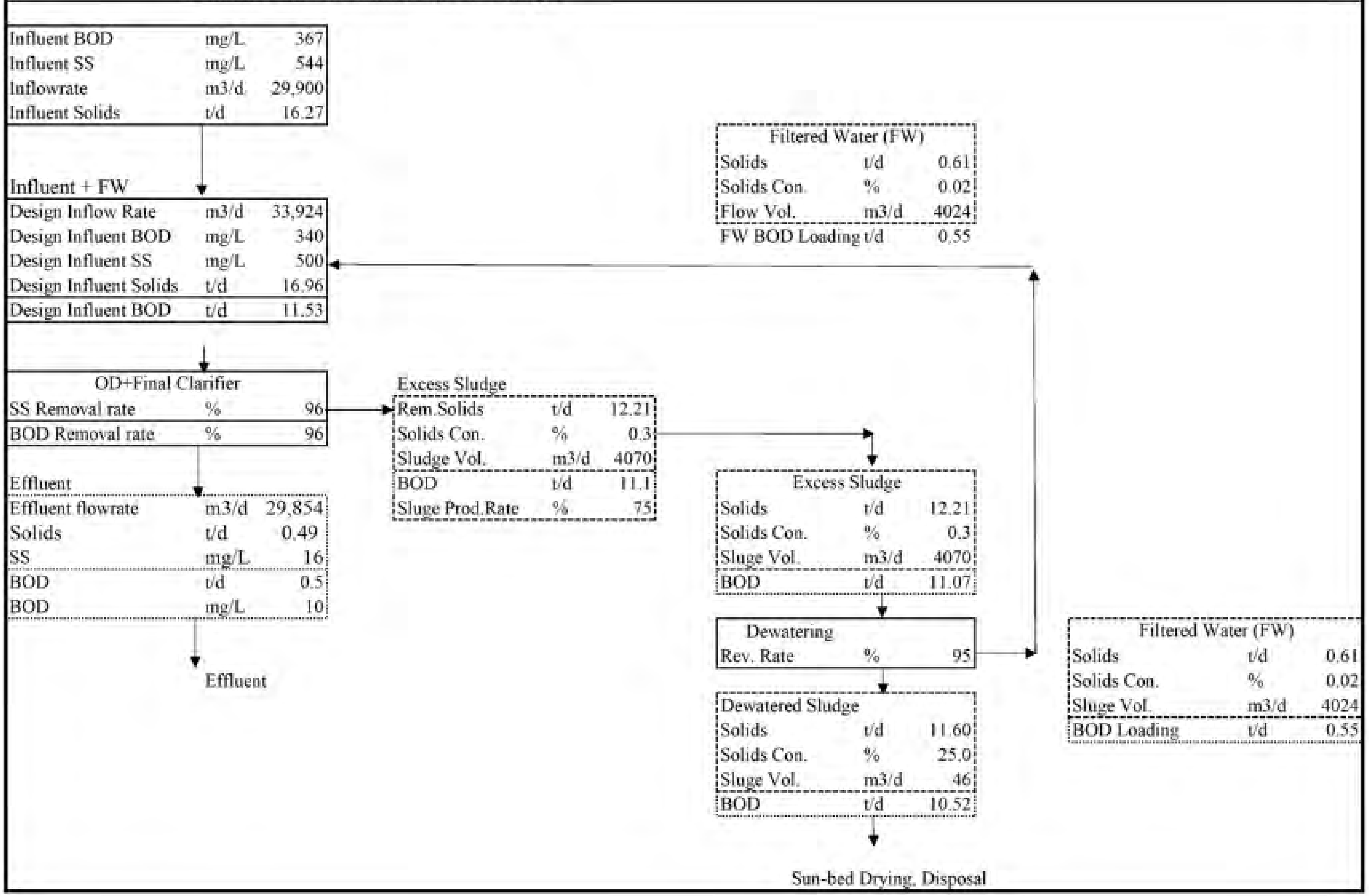

Indicator item
Quantity
phase1
phase2
Logger
LCD
Transmission line
Controller
Local site
Flow rate control
Fuel storage tank
Generator equipment
Sludge supply flow rate, density
Example
Symbols
Name
Electrode level meter
Drop-in water level meter
Differential pressure level meter
Indication
Alarm
Control
Opening factor
Level
Speed of rotation
R/I Converter
Electrode
Magnetic flowmeter
Defoaming densitometers
Isolator
Resistor unit
Converter
Volume
V/I Converter
Manual setter
Navakai WWTP (Nadi)
Sludge Treatment Instrumentation Diagram

APPENDIX 4-8 Navakai WWTP Capacity Calculation

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	27,040 m^3/d → 27,100 m^3/d
(2) Peak Dry Weather Flowrate	54,100 m^3/d
(3) Peak Wet Weather Flowrate	135,200 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	27,100 m^3/d
(2) Maximum Daily Flowrate	29,900 m^3/d
(3) Maximum Hourly Flowrate	54,200 m^3/d
(4) Peak Wet Weather Flowrate	135,300 m^3/d
1-3 Influent Wastewater Quality	
【Pipeline Sewerage】	
(1) BOD	367 mg/L
(2) SS	544 mg/L
【Trucked-in Domestic Septage】	
(1) BOD	250 mg/L
(2) SS	620 mg/L
【Total Influent Flowrate】	
(1) BOD	367 mg/L
(2) SS	544 mg/L
1-4 Design Influent	
(1) BOD	340 mg/L
(2) SS	500 mg/L
(3) T-N	37 mg/L
(4) T-P	6 mg/L
1-5 Removal Efficency	
(1) BOD	96 %
(2) SS	96 %
(3) T-N	85 %
(4) T-P	80 %
1-6 Effluent Wastewater Quality	SEZ Standards
(1) BOD	13.6 mg/L 20 mg/L → OK
(2) SS	20 mg/L 30 mg/L → OK
(3) T-N	5.6 mg/L 10 mg/L → OK
(4) T-P	1.2 mg/L 2 mg/L → OK

Item	Calculation
Sludge Production (Maximum Daily Flowrate)	
1-7 Waste Activated Sludge	Solids＝ Maximum Daily Flowrate × Influent SS × 0.96×0.75×10^{-6} Solids＝ 29,900 m3/d × 500 mg/L × 96 %×0.75× 10^-6 ＝ 10.8 ds-t/d Solid Concentration ＝ 0.3 % Sludge ＝ Solids÷Solids Concentration×10^2 Sludge ＝ 10.80 t/d ÷ 0.3 % × 10^2 Sludge(OUT) ＝ 3,600 m^3/d
1-9 Thickening	Solids (IN) ＝ 10.8 ds-t/d Solids(OUT) ＝ WAS × Recovery Rate×10^{-2} Solids (OUT) ＝ 10.80 t/d × 95 % × 10^-2 Recovery Rate ＝ 95 % ＝ 10.3 ds-t/d Sludge(OUT) ＝ Solids÷Solids Concentration×10^2 Sludge(OUT) ＝ 10.30 t/d ÷ 25 % × 10^2 Solid Concentratio ＝ 25 % Sludge(OUT) ＝ 42 m^3/d

2 Solids Mass Balance (Final Stage)



Item	Calculation
3. Sewerage Pump	
3-1 Grit Removal Chamber	
Design Flowrate	
Maximum Daily Flowrate	= 29,900 m^3/d
Maximum hourly Flowrate	= 54,200 m^3/d
Number of Chambers	= 3
Flowrate per Chamber	= 54,200 m3/d ÷ 3 = 18,067 m3/d
Width	W = 3.0 m
Target Grit	Specific Weigh = 2.65 Diameter = 0.2 mm and larger Settling Velocit = 21 mm/sec
Average Velocity	= 0.3 m/s
Retention Time（T）	= 60 sec Range: 30~60 sec
Hydraulic Load	= 1800 m3/m2/d
Chamber Length(L)	$= \frac{Q}{Ls \times W}$ $= \frac{18,067}{1800 \times 3.0}$ = 3.4 m → 3.5 m
Water Depth	$= \frac{T \times Q}{W \times L}$ $= \frac{60 \times 18,067 /(60\times60\times24)}{3.0 \times 3.4}$ = 1.3 m
Sand pit Depth	= 0.2 × 1.3 m = 0.3 m →Minimum 0.3 m → OK
Expected Grit Removal	0.05 m3-removed Grit/ 1000m3-sewerage = 0.05 × 54200.0 ÷ 1,000 = 2.71 m3/d
3-2 Screen	
Average Velocity	= 0.45 m/s
Water Depth	= 1.3 m
Width	$= \frac{Q}{V \times H}$ $= \frac{18,067 /(60\times60\times24)}{0.45 \times 1.3}$ = 0.4 m
Expected Screen Waste	0.05 m3-removed screen waste/ 1000m3-sewerage = 0.05 × 54200.0 ÷ 1,000 = 2.71 m3/d

Item	Calculation
4. Stormwater Pump	
4-1 Grit Removal Chamber	
Design Flowrate	
Maximum hourly Flowrate	= 81,100 m^3/d
Number of Chambers	= 3
Flowrate per Chamber	= 81,100 m3/d ÷ 3
	= 27,033 m3/d
Width	W = 3.0 m
Target Grit	Specific Weigh = 2.65
	Diameter = 0.2 mm and larger
	Settling Veloci = 21 mm/sec
Average Velocity	= 0.3 m/s
Retention Time (T)	= 60 sec Range: 30~60 sec
Hydraulic Load	= 1800 m3/m2/d
Chamber Length(L)	$= \dfrac{Q}{Ls \times W}$
	$= \dfrac{27{,}033}{1800 \times 3.0}$
	= 5 m
Water Depth	$= \dfrac{T \times Q}{W \times L}$
	$= \dfrac{60 \times 27{,}033 /(60\times60\times24)}{3.0 \times 5}$
	= 1.3 m
Sand pit Depth	= 0.2 × 1.3 m
	= 0.3 m →Minimum 0.3 m → OK
Expected Grit Removal	0.05 m3-removed Grit/ 1000m3-sewerage
	= 0.05 × 81100.1 ÷ 1,000
	= 4.055 m3/d
4-2 Screen	
Average Velocity	= 0.45 m/s
Water Depth	= 1.3 m
Width	$= \dfrac{Q}{V \times H}$
	$= \dfrac{27{,}033 /(60\times60\times24)}{0.45 \times 1.3}$
	= 0.6 m
Expected Screen Waste	0.05 m3-removed screen waste/ 1000m3-sewerage
	= 0.05 × 81100.1 ÷ 1,000
	= 4.055 m3/d

Item	Calculation
5. Oxidation Ditch	
5-1 Reactor Volume	
Design Flowrate	4983.33
Maximum Daily Flowrate	= 29,900 m^3/d
Maximum hourly Flowrate	= 54,200 m^3/d
Hydraulic Retention Time	= 24 hours
Req. Volume	= 29,900.00 m3/d × 24.00 hrs ÷ 24
	= 29,900 m^3
Shape of Reactor	Horseshoe
Water Depth	D = 3.5 m
Width	W = 4.5 m
Length	
	L = 60 m (Length of Tank's straight ditch)
Area	A = Width ×Water depth - 0.3 ×0.3×2/2
	= 4.50 m × 3.50 m − 0.3 × 0.3 × 2 ÷ 2
	= 15.7 m^2
Volume per Reactor	v = A * (4L+3πW)
	= (15.7 *(4* 60 +3π＊ 4.50)
	= 4433.8 m3/reactor
Number of Reactor	n = 6 Reactors
Total Volume	V = n*v = 6 * 4,434
	= 26,603 m^3
Actual	HRT = V÷Q*24
Hydraulic Retention Time	= 26,603 ÷ 29,900 *24
	= 21.4 hrs
	Range(Metcalf&Eddy): 16~30hr OK
5-2 Aerator	
(1) Design Parameters	
Maximum Daily Flowrate	= 29,900 m^3/d
Influent BOD	= 340 mg/L
Influent S-BOD	= 170 mg/L
Influent SS	= 500 mg/L
Influent Kj-N	= 37 mg/L
MLSS	= 4,000 mg/L
Effluent BOD	= 40 mg/L
Aerobic volume ratio	= 0.5
HRT	= 21.4 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 = 29,900 ÷ 6 = 4,983 m3/d X_i : Influent SS = 500 mg/L α : Sludge production rate per SS 0.75
ASRT	$= \frac{12\times 4{,}000\times 4{,}434}{24\times 4{,}983\times 500\times 0.75}$ = 4.7 日
(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 d < 4.70 d OK
(4) Prediction of C-BOD based on ASRT	
T	= 20 Celsius
C-BOD	= 9.75 × ASRT ^ -0.671 = 9.75 × 4.7 ^ -0.671 = 3.46 mg/L Assumming BOD/C-BOD is 3
BOD	= 3 × C-BOD = 3 × 3.46 = 10.4 mg/L < 40 mg/L OK (General Standards) = 10.4 mg/L < 20 mg/L OK (Significant Eco Zone Standards)

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) × 29,900 = 8,970 kg as BOD/d Denitrified N ; Assuming all nitrified N is denitrified.
OD1	= 0.6 × (8,970 − 1106.3 × 2.5) = 3,723 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 × 26,603 ÷ 2 × 4 × 0.8 = 4,257 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 ; 0.037 × 29,900 = 1106.3 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-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 = 29,900 ×(0.5 × 170 + 0.75 × 500 − 0.04 × 4,000 × 0.5)× 10^-3
	= 11,362 kg/d
	Nitrogen of WAS = 0.07 × 11,362 = 795.4 kg as N/d
OD3	= 4.57 ×(1106.3 − 0 − 795.4)
	= 1,421 kg as O_2/d
(8) Oxygen requirement in	
	Assuming Sludge return rate of: 100 %
OD4	= Oxygen in effluent
	= 1.5 × 29,900 ×(1+ 1.00) × 10^-3
	= 90 kg as O_2/d
(9) Actual Oxygen Requirement	
AOR	= OD_1 + OD_2 + OD_3 + OD_4
	= 3,723 + 4,257 + 1,421 + 90
	= 9,491 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 Aerators	= 12 Aerators (2 raerators per OD)
SOR	= **12,752** kg as O_2/d
SOR/reactor	= **1063** kg as O_2/d (per aerator)
	Required Oxygen $= \frac{12{,}752}{0.34 \times 29{,}900} = 1.3$ kg as O_2/kg per unit BOD
6. Secondary clarifier	
6-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 29,900 m^3/d
Maximum hourly Flowrate	= 54,200 m^3/d
Overflow rate	= 12 $m^3/m^2/d$
Required Area for settling	= 29,900 ÷ 12 = 2,492 m^2
Diameter of Basin	= 27 m
No. of basin	= 6 basins
Effective Area	= 27 ^ 2 ÷ 4 × π × 6 = 3,435 m^2
Depth of basin	= 4 m
Overflow rate	= 29,900 m^3/d ÷ 3,435 m^2 = 8.7 $m^3/m^2/d$ Range: 8～12m3/m2/d **OK**
Settling Time	= (3,435 × 4 × 24) ÷ 29,900 = 11.0 hrs Range: 6～12hr **OK**
Req. Length of weir	= (27 − 1.6) × π = 79.8 m (Outer Weir)
Weir Loading rate	= 29,900 ÷ (79.8 +) ÷ 6 = 62.4 $m^3/m/d$ Range: 25~100m3/m/d **OK**

Item	Calculation
7. Disinfection	
7-1 Basin Volume	
Design Flowrate	
Maximum Daily Flowrate	= 29,900 m^3/d
Maximum hourly Flowrate	= 54,200 m^3/d
Peak Wet Weather Flowrate	= 135,300 m^3/d
Chlorine Contact Time	= 15 minutes = 900 seconds
Req. Volume	= 135,300 ÷ 24 ÷ 60 ÷ 60 × 900 = 1410 m^3
Depth	= 2 m
Width	= 2 m
Length	= 360 m
Volume	= 2 m × 2 m × 360 m = 1440 m^3
Actual Contact Time	= 1440 ÷ 135,300 × 24 × 60 = 15.33 min OK
8. Sludge Treatment	
8-1 Sludge Dewatering	
Solids (IN)	= 10.8 t/d
Solid Concentration	= 0.30 %
Sludge(IN)	= 3,600 m3/d
(Sludge Storage Tank)	
Sludge Dewatering Operation	7 days in a week
Storage	1 days worth
Required Volume	= 3,600 m3/d × 1 d = 3600 m3 Phase 1 = 2,400 m3 Phase 2 = 1,200 m3
Storage Tank Depth	= 4 m
Tank Size r	= 7.0 m
Number of Tanks(n) Ph1	= 4 tanks
Ph2	= 2 tanks
Volume(V) Ph1	= π×r^2×h×n = 2463 m3 → OK
Ph2	= π×r^2×h×n = 1232 m3 → OK

Item	Calculation
(Sludge Dewaterer)	
Operation Conditions	9 hrs in one day and 7 days in a week
Solids	= 10.8 × 7 ÷ 7 ÷ 9
(Required Dewatering Cap.)	× 1,000
	= 1200.0 kg/d
Actual Dewatering capacity	= 400 kg/d
Number of Units	= 3 Units
Solids (OUT)	= 10.30 t/d
Solid Concentration(OUT)	= 25.00 %
Sludge(OUT)	= 42 m3/d
8-2 Sludge Drying Bed	
Sludge Drying Period	= 3 month
Drying Bed Volume	= 5 month's worth sludge
	= 150 d
Sludge Volume	= 42 m3/d × 150 d
	= 6,300 m3
Sludge Depth	= 0.3 m
Required Drying Bed Area	= 6,300 m3 ÷ 0.3 m
	= 21,000 m2
Drying Bed Area	= 115 m × 100 m × 2 Bed areas
	= 23,000 m2 OK
	= **2.3 ha**
	= 1.6 ha (Phase 1)
	+ 0.70 (Phase 2)
Dried Sludge	Dried Sludge Water Conter 65 %
	Sludge Concentration 35 %
Solids (OUT)	= 10.30 t/d
Sludge (OUT)	= 29.4 m3/d

Item	Calculation
8-3 Sludge Storage Space	
Sludge Storage Period	= 20 yrs
Sludge Volume	= 29.4 m3/d × 20 yrs × 365 d
	= 214,620 m3
Sludge Depth	= 3.0 m
Required Storage Area	= 214,620 m3 ÷ 3.0 m
	= 71,540 m2
Sludge Storage Area	= 48,000 m2 = **4.8** ha (第1期)
	24,000 m2 = **2.4** ha (第2期)
	= 72,000 m2 = **7.2** ha
	OK
9. Primary Treatment (Stormwater)	
Design Flowrate	= 4* Maximum Daily Flowrate
	= 4* 29,900 m³/d
	= 119,600 m³/d
Required Retention Time	= 2.50 hrs
Required Volume	= 119,600.00 m3/d × 2.50 hrs ÷ 24
	= 12,459 m³
Design Depth	= 3 m
Required Surface Area	= 4,153 m2
Maturation Pond Volume	= 40 m × 55 m × 3 m × 2 ponds
	= 13200 m3 > 12,459 m³
	OK
Existing IDEA Pond Volume	= 8233 m3
Existing Maturation Pond Volu	= 4289 m3
Total	= 12,522 m3 > 12,459 m³ OK

APPENDIX 7-1 Policies and Plans Related to Sewerage Sector Development and ESC

(1) Fiji Government National Development Plan 2017-2036

The 5-Year and 20-year National Development Plan recognizes the importance of tourism to the overall development of the country. Emphasised key long-term priorities include increasing the range of tourism products (sports tourism, cruise tourism, wedding tourism, retirement villages, medical tourism and conference tourism), filmmaking, regional communications/transport services, and other new initiatives.

Ecotourism and adventure tourism are also prioritised as opportunities to promote our unique biodiversity. The development of stronger tourism value chains is prioritised, including strengthened agricultural and fisheries links to promote locally grown foods and opportunities to promote traditional handicrafts and natural body products. There is a particular emphasis on expanding opportunities for women and MSMEs and ensuring that cultural heritage and heritage sites are both protected and promoted by the industry.

Investments in new sporting facilities built to international standards is recognised as necessary to position Fiji as a host for more international events. Expansion of the Fiji Airways fleet is identified as important for growing tourism through leasing of new aircrafts, and the development of new air connections and new routes. Domestic air services and upgrading works at domestic airports and airstrips over the next 20 years is also emphasised to support tourism dispersal.

Building on this, the Ministry of Finance, Strategic Planning, National Development and Statistics is currently leading the formulation of a new national development plan that seeks to strengthen the policy and planning within government, improve coordination, appraisal and selection of public investment projects, monitoring and evaluation of projects and strengthen national workforce planning and economic intelligence analysis.

(2) Fiji National Sustainable Tourism Framework (2024-2027)

The Fiji Government, through the Ministry of Tourism and Civil Aviation (MTCA), is developing a 10- year National Sustainable Tourism Framework (NSTF) that shares a collective vision for a sustainable Fijian tourism sector. With the support of the International Finance Corporation, (IFC), between August 2022-May 2023, over 600 stakeholders took part in a series of public private dialogues and focus group discussions on a range of topics.

The NSTF will articulate the strategic direction of the tourism sector from 2024 to 2034, providing a blueprint for Fijians to develop and benefit from the country's tourism resources. The design of the NSTF is based on thorough research, qualitative and quantitative evidence, recommendations from the National Economic Summit held in March 2023 and broad stakeholder consultations and feedback from tourism and tourism-related industries, government, civil society, communities, and development partners.

The NSTF will lay out a clear policy direction, with the high-level framework accompanied by an initial three-year Action Plan (2024-2027) focused on the continued tourism recovery from the COVID-19 pandemic, mitigating future economic shocks and striving for sustainable growth.

Fiji has made strong policy commitments to economic, environmental, social, and cultural sustainability across various international, regional and national policies, strategies and plans. This includes as part of the Climate Change Policy 2018-2030 and Climate Change Act, the Green Growth Framework, and the National Oceans Policy. By 2030, Fiji aims to source 100 percent of its electricity from renewable energy sources and be net-zero by 2050. Fiji is a signatory to various international conventions including the United Nations Framework for Action on Climate Change, Convention on Eliminating Violence Against Women, United Nations Declaration on the Rights of Indigenous Peoples and several others indirectly linked to the tourism sector.

In 2019, when 894,389 visited Fiji, the sector employed an estimated 34.5 percent of total formal economy workers or 62,277 employees. According to the Fiji Bureau of Statistics (FBoS) earnings in 2019, it contributed over 500 million FJD directly to total tax revenue representing around 18 percent of the government’s total tax revenue and over 2 billion FJD in foreign exchange earnings. Statistics from the provisional visitor arrivals show that from January 2023 to October 2023, approximately 772,172 visitors arrived in Fiji.

(3) Fiji National Economic Summit 2023

The Fiji National Economic Submit 2023 highlights the tourism industry as a key growth sector for Fiji. The Summit outlined achievable long-term (beyond five years), medium -term (three to five years), and short-term (less than two years) solutions for seven major issues the industry is now facing. These challenges and opportunities include:

1. Need for climate -resilient infrastructure in different areas of the country, particularly in the rural, northern, and outer islands zones
2. Migration of skilled labour
3. Growing tourism -related investments, particularly in line with Fiji Airways' development strategy and the need for the hotel inventory to match growing flight capacity
4. Improving sector -specific links to increase Fiji's agricultural outputs and lessen the country's dependency on imports
5. Greening the existing inventory and infrastructure to meet the sustainability agenda, including recycling and renewable energy
6. Accelerate business reforms to assist the development, expansion, and creation of new markets or niches by removing legislative bureaucracy
7. Prioritizing community -based operators and ecotourism

(4) Fiji National Culture Policy 2022-2032

Tourism is a cross-cutting theme within the culture policy and cultural tourism is identified as a specific priority to promote sustainable cultural tourism that nurtures culture, heritage, and the arts in Fiji. Cultural Tourism is identified as an important avenue to build local, region-al, and international understanding and provide opportunities to strengthen intercultural relations, reduce conflicts and support peacebuilding. The support of partners to address challenges presented by tourism is critical. These include potential sexual exploitation, drug abuse, distortion of aesthetic and ethical values, commercialization and loss of artistic tangible and intangible culture and undermining and distortion of cultural norms and values.

Close collaboration between the Department of Culture, Heritage and Arts of the Ministry of iTaukei Affairs, Culture, Heritage & Arts and the Department of Tourism is emphasised to support the development of quality cultural tourism experiences and products, and for fair and equitable provision and use of cultural and creative products and services. Specific strategies to support this include the establishment of public and private sector networks, strengthened marketing of cultural products, festivals, and services, improvements to the preparedness and accessibility of specific heritage sites, promotion of biodiversity (marine and natural land-based heritage); and actions to minimize the negative impacts to cultural and natural heritage sites and local communities. An indigenous tourism framework that aligns with the National Sustainable Tourism Framework is currently under development.

(5) iTaukei Land Trust Board (TLTB) The Greater West Land-use Master Plan (GWLMP)

The Greater West Landuse Master Plan (GWLMP) has finally been approved by the Department of Town & Country Planning (DTCP) for use in the high-potential areas between Serua and Tailevu North. The planning process commenced in 2018 and the Plan was submitted for endorsement to Director Town & Country Planning in October 2019.

This is a regional land use plan for the Western Region which aims to assist in directing key investment decisions for developers as well as decision-making authorities at what is now known to be “a hotspot for development”.

The Greater West Landuse Master Plan boundary stretches from Galoa in Serua to Korovou in Tailevu along the corridor of the Kings Road and Queens Road; from the high-water mark to the road and 10km inland from these highways for the purpose of strategically allocating and apportioning land uses for development, conservation and other land use types. The GWLMP will also be useful for the identification of growth centres for future planning and releasing of land by TLTB for leasing.

The DTCP, the key development approving authority in Fiji, had closely worked with TLTB in the entire planning process and the production of this Plan. As a result, this Plan becomes a synergized and integrated plan for TLTB, DTCP, and other key agencies in consultation with relevant stakeholders from government ministries, private institutions and NGO’s that had been a part of this project.

The GWLMP is important to guide TLTB in ensuring that more land is available and most importantly to guide our officers in the type of development and land to be released for leases that will create sustainable land use practices. In effect, this will also create LOU empowerment and enable them to make decision on the types of leases to be issued on their land as well as feeding the TLTB platform for on-going lease application process.

(6) iTaukei Land Trust Board (TLTB) Regional Land Release Plan for the Greater West and Coastal Region 2019-2039

The iTaukei Land Trust Board (TLTB) Regional Master Plan for the Greater Nadi – Lautoka corridor was approved by the Director of Town and Country Planning (DTCP) in 2008, and it serves to guide the overall character, physical form, growth, and development of iTaukei Land within the Greater West and Coastal Region (GWCR). In 2017, TLTB decided to revise its Greater West and Coastal Region Land Use Master Plan due to the changing conditions on the ground and also in terms of the increase in competing demand for various land uses in the region.

The Greater West and Coastal Area is Fiji's second fastest growing region, after the Greater Suva, and it accommodates approximately 315,838 people as compared to 884,887 people, which is slightly more than one third of the total population in Fiji (FBoS, 2017). The unprecedented growth in population and housing over the past decade has also brought inevitable challenges associated with rapid growth, such as increased traffic congestion, overcrowding, increased demand on land for various uses, increased demand on utilities, services and infrastructure, etc. These challenges are also part of the reason why the TLTB decided to revise its existing plans by using land as a key resource for development that considers both the needs of the present and future generations.

(7) Ministry of Local Government & Singapore Corporation Enterprise (SCE) 50 Year Master plan

The Ministry of Local Government in collaboration with the Singapore Corporation Enterprise (SCE) have finalized the Strategic Master Plan for Viti Levu and Concept Master Planning for Greater Suva, Nadi and Lautoka. The Concept Master Plan has been finalized and the final report has been handed over to the Ministry of Local Government. In the final stages of the project consultations, all stakeholders especially the strategic assets agencies and infrastructure agencies had supported the Master Plan. A Cabinet paper has been prepared and is being circulated for final comments prior submission to Cabinet. The Master Plan may be shared following a decision made by the Cabinet.

(8) Greater Western Corridor Master Plan for All State Land

The Land Use Planning & Development (LUPD) Team of the Ministry of Lands is currently working on its Master Plan for all State land in Fiji across the three regions.

In 2023, the LUPD team started the first pilot project for the for the Greater West Corridor Master Plan. The second draft of the West master plan has been completed and submitted to the various stakeholders including the Department of Town & Country Planning for their final comments.

Notably, the State lands around Navakai have been ear marked for future Special Use tourism development and commercial development. In Natabua, the surrounding state leases have also been ear marked for Industrial and commercial development. The LUPD indicated that they had not consulted with other utility provider including WAF in their earlier consultation processes. Therefore, WAF had requested they take on board the issues with water and wastewater for both Nadi and Lautoka as since they are proposing high density developments other than agricultural their Master Plans may not yield the outcomes if the development is not able to connect to these basic services and utilities.

The LUPD was asked to review the WAF Western Region's Wastewater Master Plans current and future land needs for WWTPs to be factored into their Landuse Master Plans prior to finalising their Greater Western Corridor Plan. WAF may also need to relook at the capacity and future demand calculation to factor in Lands Department's Master Plan and also for their land acquisition plans as well. There was no indication as to whether the Greater Western Corridor Plan would include the foreshore areas.

(9) Draft Mangrove Management Plan 2013

The draft Mangrove Management Plan was prepared for the Department of Environment as the focal point for the Mangrove Eco Systems for Climate Change Adaptation and Livelihood Project (MESCAL). It acts as a tool to administer, manage, facilitate and control development and management of mangroves in Fiji. Whilst the draft was prepared in 2013, it has yet to be endorsed by DoE and approved by the Parliamentary Cabinet and hence why it remains a draft despite going through a few reviews.

In 2013 with the Environmental Management Act (EMA 2005) in place, the adopted approach is to put in place a rigorous Environmental Impact Assessment (EIA) procedure. The EMA (2005) and its EIA Regulations (2007) appear to have had no positive impact at all on sustainable management of mangrove resources, rather poor EIA preparation and review has enabled unsustainable mangrove management.

Under the EMA, the Department of Environment (DoE) have considerable mangrove management responsibilities but is current capacity precludes the ability to address this. It has strong provisions for enforcement of many illegal activities, however, DoE's ability to use its legislation for enforcement purposes remain poorly developed. The DoE requires to work cooperatively with other agencies to monitor projects for compliance with conditions it has set.

Under current legislation as state land, mangroves may be converted to other uses by the Department of Land under Crown Lands Act. Before it can issue a development or other lease for mangrove conversion, Department of Land has to ensure that an EIA of the conversion proposal has been approved by the Department of Environment under the Environmental Management Act. The conversion of mangrove in the absence of an EIA is an offense even if a foreshore lease has been granted, an/or the mangrove is included in a freehold title.

According to the draft Mangrove Management Plan, research showed that mangroves are among the most carbon-rich forests in the tropics, containing on average 1,023mg carbon per hectare. Much if not most of the carbon storage (49-98%) is in the organic mangrove-rich soils. As such loss of mangroves contributes an order of magnitude more carbon emissions than terrestrial tropical forest (Donato *et al.,* 2011).

In a meeting with the DoE (held on 22 July, 2022), mangrove protection policies were discussed. The DoE strongly recommends that all projects should first think of avoiding mangroves or any sensitive areas, but depending on situations, other options such as offsetting (6-10 planting per cutting etc.) or compensation might be accepted in a project EIA.

(10) Draft Mangrove Conservation & Management Regulation 2022

In 2022, DoE has drafted the Mangrove Conservation and Management Regulations under the Environmental Management Act, which has underground rounds of consultations with key stakeholders in the public and private sector throughout Fiji. The feedback and comments made as part of the consultation process is currently undergoing review but DoE is still accepting review comments. The DoE is also planning to map all the mangroves across Fiji.

The DoE believes that with the condition of the effluent satisfying the effluent standards at the end of the discharge point, discharging to the ocean could be better, as more dilution is expected. However, this should be determined on a case-by-case basis, since discharge of nutrient rich water into low nutrient (oligotrophic) waters on coral coasts can negatively impact on the coral reef ecosystem. It is unclear as to whether effluent standards for discharging into mangrove areas will also be included into the Regulations.

This regulation may have impacts on any future site development works located in and around mangrove areas especially where it may require mangroves to be removed. Replanting programmes may be required or a total ban on removal of mangroves may hinder any development plans to existing or proposed new sites in and around mangrove areas.

(11) National Biodiversity Strategy Action Plan Year 2020-2025

In 1992, Fiji signed the International Convention on Biological Diversity (CBD) with 150 joining countries who were required to develop a National Biodiversity Strategy & Action Plan outlining the national strategies and actions that will contribute to the half of biodiversity loss. Fiji’s 5th National Report to the CBD noted that the country’s rich biodiversity contributes significantly towards food, agriculture, tourism, coastal protections, etc. However, the biodiversity is also under pressure including unsustainable forest management practices, mangrove removal, poor waste management practices, etc.

The NBSAP supports many legal acts Fiji, including but not limited to the Sewerage Act and Water Supply Act. It also took into account the latest environment national strategies and reports some of which are the Fiji National Climate Change Policy (2012), Fiji REDD+ Policy (2011), Fiji Integrated National Waste Management Strategy (2016-2020 draft), Forest Policy (2007), Mangrove Management Plan (2013) and National Policy Plan for Fijian Managements (1986).

(12) National Biodiversity Threat Assessment 2022

According to the latest report published by IUCN Oceania 2022 Ambition for Biodiversity, Fiji has the third largest mangrove resource in the Pacific Islands after Papua New Guinea (372,770 ha) and the Solomon Islands

(64,200ha) (Mangrove Management Committee 2013). The Forest Resource Assessment and Conservation (2017) recorded Fiji's mangrove cover to be 45,940 ha from Viti Levu, Vanua Levu and Taveuni. The assessment was updated in the 2019 to 47,440 ha which covered Cicia, Gau, Lakeba, Matuku, Moala, Ovalau, Viti Levu and Vanua Levu (O'Brien *et al*., 2021). There are eight mangrove species recorded from Fiji.

In 2016, Fiji's nearshore and offshore marine areas were evaluated against a set of criteria to identify Special, Unique Marine Areas or SUMAs. In total, 98 sites were identified as SUMAs. Along the coastline of Western Fiji, there are 12 SUMA sites.

(13) Fiji Forest Policy Statement 2007

The first National Forest Policy for Fiji was adopted in 1950 and gave rise to the 1953 Forest Act which together placed forestry primarily in the context of forest management for timber. In the 21st century, forestry's policy environment continues to change with increased emphasis on sustainable forest management, increased landowner's aspirations, climate change and globalization. The Fiji Forest Policy Statement was later established in 2007 providing an explicit requirement in respect of mangroves with priority to be given to the management of mangroves to maintain its ecological, cultural and social values as priority. In accordance with Department of Forestry current policy, commercial mangrove harvesting should be prohibited.

Under the Forest Decree (1992) mangroves are "forest" and the Forestry Department regulates the utilisation and management of all forest resources, but they only do so after Department of Lands have approved an application for mangrove harvesting and Forestry only regulate harvesting. They do not have a continual monitoring role or presence.

(14) Fiji REDD+ Policy 2021

The Fiji REDD+ Policy is implemented within the framework of the National Forest Policy 2007 and contributes to the national Forest Sector goal "Sustainable management of Fiji's forests to maintain their natural potential and to achieve greater social, economic and environmental benefits for current future generations." It has the overall objective of enhancing the national forest-based carbon balance by a) supporting and strengthening initiatives that address the drivers of forest-based carbon emission; b) encouraging the drivers of forest-based carbon sinks.

(15) Fiji National Climate Change Policy 2021

Climate change poses an ongoing threat to Fiji's constitutional commitments and values, national wellbeing, environmental stability, development priorities, and economic sustainability. To address this, the Fijian Government developed Fiji's first National Climate Change Policy (NCCP) in 2012. The NCCP (2012) served as the overarching policy instrument for climate change in Fiji and encompassed these issues at local, national and international level.

The NCCP (2018) is closely aligned with the objectives of the 5-is closely aligned with the objectives of the 5-

Year & 20-Year National Development Plan (NDP) and seeks to accelerate Fiji's progress towards achieving the Sustainable Development Goals (SDG), and other national, regional and global commitments.

The NCCP (2018) has three central policy pillars: human-rights based, gender-responsive and evidence-based, The Policy sets out the Governments' position on climate change and identifies eight core principles namely; sustainable well-being, social cohesion, inclusivity, partnership, agility, urgency, transparency and communication, and integrated learning.

Access to additional and alternative climate finance resources (bilateral, regional or multilateral and private sector resources) is urgently needed to enable the shifting of the paradigm to transform development and climate change challenges into tangible investments to scale up climate adaptation and mitigation solutions to achieve the national development goals and climate goals.

(16) National Liquid Waste Management Strategy & Action Plan 2007

The Fiji National Liquid Waste Management Strategy & Action Plan (2007) prepared by the Ministry of Environment, funded by the International Waters Programme of the Global Environment Fund Facility, the United Nations Development Program and the Secretariat of the Pacific Regional Environment Programme. The stakeholders that contributed to the formulation of this Strategy included South Pacific Applied Geoscience Commission now known as SPC, Ministry of Works, Ministry of Fijian Affairs, Municipal Councils, Rural Local Authorities, Ministry of Health and the private sector representatives as well as other stakeholders.

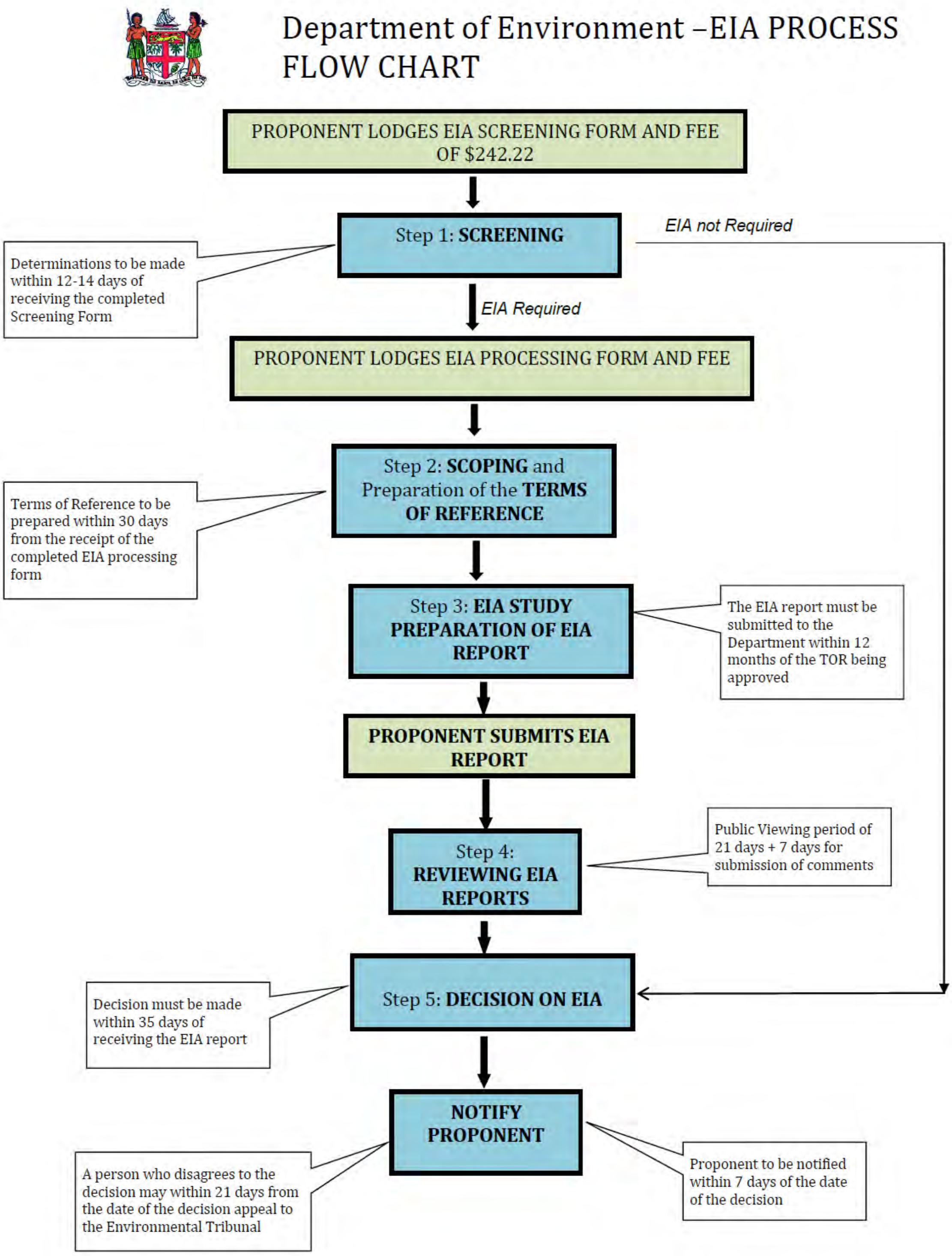
The different types of liquid wastes covered under the strategy includes domestic wastewater such as sewerage and greywater, which is collected by sewerage systems or goes into septic tanks; commercial and industrial wastewater, including that from the tourism industry; animal waste, marine shipping; urban stormwater; leachates from landfills/dumps; and sludge (septic tanks, industries and sewerage treatment plants).

The key objectives of the strategy were to:

- Reduce the amount of wastewater produced in Fiji
- Improve and upgrade waste management and disposal systems to improve wastewater quality
- Improve coordination of departments/stakeholders involved in regulating and managing liquid waste
- Improve awareness and practices of public in relation to sanitation/wastewater management.

Whilst the International Water Programme no longer exists, and since the formulation of the National Liquid Wastewater Management Strategy, the Waste Management Unit within the Department of Environment has tried to implement some of wastewater management strategies through the Waste Disposal & Recycling Regulations 2007 (commonly referred to as the Waste Regulations) under the Environmental Management Act 2005.

APPENDIX 7-2 Overview of Environmental Permit Procedures for 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

APPENDIX 7-3 Outline of Land Acquisition Procedures

1. Issue of Draft Land Acquisition & Resettlement Plan (LARP)

2. WAF to obtain letter from DOL confirming the historical arrangement between DOL and previous Ministry of Infrastructure and Works, which did not require them to apply for foreshore development leases over areas of foreshore and waterways and/or pay fishing rights compensation to Qoliqoli users, particularly for the outfall at Navakai into Nadi River and also for the mangrove and foreshore area for outfall at Natabua.

3. Issue draft Land Acquisition Plans and Scope of Works to DOL to enable liaison with iTaukei Land and Fisheries Commission/Department of Fisheries to confirm if fishing rights compensation is applicable for the outfalls and foreshore mangrove areas, and therefore, if a Fisheries Impact Assessment is required at Navakai outfall and at Natabua foreshore and outfall.

4. Prepare draft letter of intent for the Affected Persons/Displaced Persons.

5. Prepare questionnaire and assessment templates as part of the engagement with the Affected Persons.

6. Issue Land Acquisition Plans outlining permanent and/or any temporary areas required for development and use both existing and new based on the detailed engineering design for the WWTP sites.

7. Confirm land ownership, areas, and tenure (iTaukei reserve, state/iTaukei leased, or freehold).

8. Verify and approve Land Acquisition Plans by WAF Management and issue to DOL and TLTB identifying areas (permanent and temporary) to be acquired or leased or for easements.

9. Conduct titles/leases search in Government titles registration office for affected land ownership.

DOL/TLTB to verify with WAF for records and compensation discussions and provide contact details for landowners.

10. Determine numbers in *mataqali* group, landowners and users affected – referred to as Affected Persons, and identify any other vulnerable households not yet noted, including the elder, persons with disabilities, widowed or sickly.

11. Prepare individual Letters of Intent for each Affected Household (AHH) or Affected Persons (AP)

12. Undertake Socio-economic surveys & Commercial surveys to gather baseline socio economic data for consideration

13. Hold a series of community consultation as part of the EIA process and to disseminate design information as well as, land acquisition plans and gather any concerns from the affected persons.

14. Issue individual Letters of Intent to the AHHs or APs.

15. Obtain consent of Mataqali landowners for iTaukei reserve land (minimum of 60% signatories registered in the Vola Ni Kaubula (VKV) from Native Reserve land owners

16. Obtain signatures for the customary Qoliqoli Resource Users for endorsement by iTLFC – if applicable.

17. Undertake Fisheries Impact Assessment & Ratification by the Chairman of ILFC.

18. Cadastral pre-survey of land.

19. Determine and mark areas for each land parcel required.

20. Conduct inventory of losses by WAF's i- house land valuation team – land, trees, crops and provide valuation for compensation.

21. Undertake disclosure of updated entitlements, Grievance Redress Mechanism (GRM) and LARP implementation arrangements to affected persons

22. Undertake detailed consultations with relocating households on resettlement arrangements (where applicable) involving Ministry of Housing, Housing Authority and Department of Lands.

23. Undertake detailed consultations with AHHs/APs with affected livelihoods on transitional support and livelihood restoration arrangements (if applicable).

24. Negotiate compensation with landowners (freehold and *mataqali)*, and holders of Native/State Leases.

25. Negotiate with landowning unit during various consultation meetings to agree on compensation and document the outcomes for vetting and confirmation with WAF, DoL and TLTB.

26. Acquire State Land from DOL following review of land valuation and compensation figures by the Chief Valuer.

Acquiring Native Reserve and Native Lease land through TLTB following review of land valuation and compensation figures by the Chief Valuer.

27. WAF to submit the updated LARP for approval to WAF Board and Ministry of Finance/Donor Agencies.

LARP Implementation by WAF

28. Preparation of Sale and Purchase Agreement to issue to freehold owners and State lease and native lease holders to be endorsed by TLTB if native land before issued to the APs.

29. Payment of compensation to the qoliqoli resource users via DoL & iTLFC

30. Payment of compensation and allowances on the basis of 75% to the APs upon signing of the Sales & Purchases Agreement.

31. Issue Tender for Civil Works

32. Award of civil works contract, clearance of land, and briefing of contractor on safeguards.

33. Prepare LARP implementation verification reports for WAF Board and Ministry of Finance/Donor Agencies review and clearance.

34. Commencement of civil works (contingent on compensation and allowances being paid) – based on duration of construction period.

35. Contractor to complete as-built surveys particularly for pipeline easements and WAF to verify and prepare final survey plans for registration

36. Payment of balance compensation and allowances on the basis of 25% to the APs upon survey plan registration.

37. DOL & WAF Lands team completes land transfers or easement certificates for registration.

38. WAF submits the Land Acquisition and Compensation Completion Report to WAF Board and Ministry of Finance or Donor Agencies.

Monitoring Plan

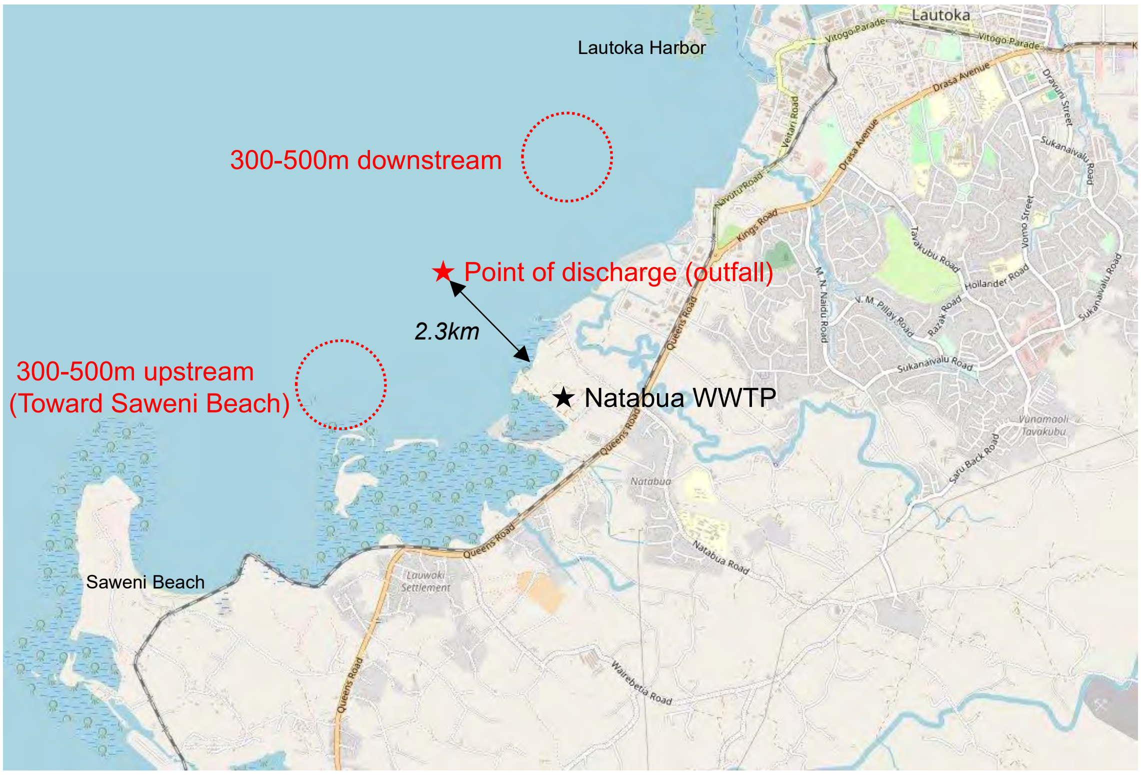
39. WAF starts APs socio-economic monitoring.

40. WAF submits progress report to WAF Board and Ministry of Finance/Donor Agencies on implementation of the LARP.

41. WAF conducts post-project survey and final monitoring report

APPENDIX 7-4 Water Quality Survey by WAF

(1) Natabua Wastewater Treatment Plant



Red - sampling locations
Note) The locations are approximation due to no GPS data provided.

Source: JET with Open Street Map

Figure A7-4.1 Sampling locations (Natabua Wastewater Treatment Plant)

Table A7-4.1 Ambient Water analysis results (Natabua Wastewater Treatment Plant)

Date	Weather	Location	ref #:	PHYSICAL ANALYSIS				SOLIDS	NUTRIENT SPECIES		OXYGEN DEMAND		MICROBIOLOGICAL ANALYSIS
				Temperature	pH	Conductivity	Salinity	Total Suspended Solids	Nitrate	Ortho-phosphates	Dissolved Oxygen	Biochemical Oxygen Demand	Faecal coliforms
				ºC	0-14	uS/cm	ppt	mg/L	mg/L	mg/L	mg/L	mg/L	1cfu/100ml
2022/3/3	Fine	Point of Discharge [Surface]	10844/21-22	24.6	7.88	46520.0	30.2	116.6	0.09	0.10	4.40	0.82	110,000
		300m towards Saweni Beach		24.7	8.06	47540.0	31.0	79.4	0.09	0.09	3.63	0.47	84,000
		300m towards Lautoka Harbour		24.8	8.04	47610.0	31.0	112.6	0.08	0.09	3.24	0.44	76,000
2022/6/30	Fine	500m Upstream	11432/21-22	23.3	8.04	51820.0	34.0	153.6	0.09	0.12	9.35	2.43	64,000
		Point of Discharge		22.8	8.10	52120.0	34.2	150.1	0.11	0.13	9.34	3.15	108,000
		500m Downstream		23.1	8.15	52250.0	34.3	156.1	0.10	0.11	9.14	0.97	56,000
2022/9/8	Fine	500m Upstream	10217/22-23	25.3	7.94	44830.0	29.0	173.2	0.10	0.11	10.33	0.46	84,000
		Point of Discharge		25.0	8.09	44850.0	29.0	176.9	0.11	0.12	9.00	0.52	114,000
		500m Downstream		24.9	8.11	45060.0	29.1	162.6	0.09	0.11	9.68	0.42	72,000
2023/1/2	Fine	Point of Discharge	10815/22-23	24.4	8.08	48400.0	31.6	144.8	0.15	0.15	8.17	0.67	N/A
		500m Upstream		24.0	8.10	48640.0	31.7	143.6	0.15	0.16	8.86	0.76	N/A
		500m Downstream		25.2	8.11	48650.0	31.8	148.0	0.15	0.15	8.52	0.65	N/A
2023/5/4	Fine	500m Upstream	11328/22-23	23.9	8.18	51400	33.7	53.4	0.08	0.10	10.3	0.68	440
		Point of Discharge		24.1	8.19	51111	33.5	69.8	0.08	0.09	9.89	0.75	6800
		500m Downstream		24.1	8.12	51410	33.7	70.8	0.08	0.09	10.0	0.88	900
2023/8/1	Fine	500m Upstream	10008/23-24	23.2	8.7	53150	35	197.2	0.14	0.14	10.8	0.61	9,400
		Point of Discharge		23.5	8.15	53240	35.1	201	0.12	0.12	11.2	0.78	740
		500m Downstream		23.7	8.1	53070	34.9	193.2	0.13	0.17	11.5	1.11	800
2023/11/1	Fine	Point of Discharge	10504/23-24	24.1	8.15	53200	35.1	133.8	0.11	0.09	10.1	1.18	10000
		500m Upstream		24.3	8.15	53000	35.0	121.1	0.12	0.1	13.0	0.68	740
		500m Downstream		23.0	8.09	52980	34.8	159.1	0.15	0.12	12.3	2.12	620

Source: WAF laboratory

(2) Navakai Wastewater Treatment Plant

Red - indicate sampling locations
Note) The locations are approximation due to no GPS data provided.

Source: JET with Open Street Map

Figure A7-4.2 Sampling locations (Navakai Wastewater Treatment Plant)

Table A7-4.2 Ambient Water analysis results (Navakai Wastewater Treatment Plant)

Date	Weather	Location	ref #:	PHYSICAL ANALYSIS				SOLIDS	NUTRIENT SPECIES		OXYGEN DEMAND		MICROBIOLOGICAL ANALYSIS
				Temperature	pH	Conductivity	Salinity	Total Suspended Solids	Nitrate	Ortho-phosphates	Dissolved Oxygen	Biochemical Oxygen Demand	Faecal coliforms
				ºC	0-14	uS/cm	ppt	mg/L	mg/L	mg/L	mg/L	mg/L	1cfu/100ml
2022/6/29	Fine	500m Upstream [Nadi Bridge]	11431/21-22	24.1	7.42	267.9	0.1	24.4	0.11	0.14	8.74	2.15	640,000
		Point of Discharge		24.2	7.38	544.1	0.2	51.4	0.31	0.77	7.72	7.52	4,200,000
		500m Downstream [Quarry]		24.3	7.25	1562.0	0.8	153.7	0.12	0.14	8.85	5.80	40,000
		1km Downstream [Under Denarau Bridge]		24.3	7.49	45040.0	29.1	162.5	0.1	0.11	9.16	2.69	52,000
2022/9/6	Fine	500m Upstream [Nadi Bridge]	10216/22-23	25.1	7.69	5326.0	2.9	19.9	0.11	0.13	20.23	1.49	1,120,000
		Point of Discharge		25.1	7.63	17000.0	10.0	68.0	0.12	0.12	27.08	4.45	8,800,000
		500m Downstream [Quarry]		25.0	7.68	18270.0	10.8	44.2	0.11	0.12	23.54	4.79	46,000
		1km Downstream [Under Denarau Bridge]		25.3	7.30	45280.0	29.4	172.9	0.10	0.12	21.25	6.51	9,600
2023/1/2	Fine	500m Upstream	10817/23-24	25.6	7.48	149.3	0.1	103.1	0.17	0.22	8.86	0.88	N/A
		Point of Discharge		25.7	7.42	487	0.2	13.2	0.45	0.79	6.31	6.11	N/A
		500m Downstream		25.6	7.87	169.1	0.1	52.1	0.17	0.21	7.96	1.68	N/A
		Denarau Bridge		25.2	7.62	40330.0	25.8	129.9	0.16	0.16	8.01	1.23	N/A
2023/5/2	Fine	500m Upstream -Nadi Bridge	11326/22-23	23	7.62	921.8	0.4	51.4	0.25	0.12	10.4	6.09	1160
		Point of Discharge		22.9	7.54	7629	4.2	35.1	0.08	0.11	11.2	4.02	11000
		500m Downstream (Quarry)		22.8	7.4	9231	5.1	36.6	0.20	0.13	10.9	2.62	1180
		1km Downstream (Denarau Bridge)		22.5	7.85	50290	32.8	112.3	0.19	0.09	10	1.53	108000
	Fine	500m Upstream -Nadi Bridge	10506/23-24	24.3	7.11	14930	8.6	53.2	0.16	0.42	12.2	2.37	112000
2023/8/2		Point of Discharge		24.7	7.16	14250	8.2	47.9	0.17	0.45	10.0	2.8	11000000
		500m Downstream (Quarry)		24.5	7.16	14340	8.3	34.9	0.16	0.44	15.3	2.27	64000
		1km Downstream (Denarau Bridge)		24.5	7.18	14290	8.2	49.5	0.14	0.42	15.8	1.76	60000
2023/11/2	Fine	500m Upstream -Nadi Bridge	10011/23-24	22.6	7.28	942.7	0.4	16.5	0.10	0.15	11.5	2.56	88000
		Point of Discharge		22.7	7.14	6276	0.4	65.5	0.12	0.16	10.9	2.03	1020000
		500m Downstream (Quarry)		22.9	7.67	6250	0.4	139.5	0.11	0.17	11.8	2.11	8000

Source: WAF laboratory

APPENDIX 7-5 Water Quality Survey Results Conducted in the M/P Project

Additional water sampling (water samples and measurements with a YSI-multi-meter) was undertaken for this ESC report, with a wet season survey undertaken 17 February 2024 and a dry season survey undertaken 19 July 2024. The parameters measured and locations of sampling are presented in **Table A7-5.1** and **Figure A7-5.1**. The results are presented in **Table A7-5.2**. These results were found to be similar to the values that WAF has obtained in 2022-23 and indicate that the Nadi River is highly polluted, and that most parameters are above water standards most of the time.

Table A7-5.1 Field Survey Parameters for Natabua and Navakai service areas

	Field survey	Location	Parameter	Frequency	Total samples
#1-1	Ambient water (surface water)	- 3 locations in Lautoka - 3 locations in Nadi	pH, DO, COD, BOD, TSS, T-N, NH4-N, NO3-N, T-P, Fecal Coliform, E-Coli, salinity, water temperature	Rainy season: Oct-March. 2024 Dry season: April-Sept 2024	18
#1-2	Ambient water (bottom water)	- 3 locations in Lautoka			

Source: JET

Source: JET

Figure A7-5.1 Nadi/Navakai sampling locations

Source: JET

Figure A7-5.2 Lautoka/Natabua sampling locations

Table A7-5.2 Field Survey Results

Wet Season (17/2/24)

NAVAKAI

Date	Weather	Location	Physical Parameters			SOLIDS	NUTRIENT SPECIES					OXYGEN DEMAND			MICROBIOLOGICAL ANALYSIS		LOCATION	
			Temperature	pH	Salinity	Total Suspended Solids	Total Nitrogen	Nitrate-N+Nitrite-N	Total Kjeldahl Nitrogen (TKN)	Dissolved Reactive Phosphorus	Total Phosphorus	Dissolved Oxygen	Biochemical Oxygen Dem	Chemical Oxygen Demand	Faecal coliforms	E-coli	Lat	Long
			°C	0-14	ppt	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN / 100mL	MPN / 100mL		
17/02/2024	Overcast	500 m Upstream	24.9	7.8	0.2	54.4	10	0.22	25	0.39	0.15	8.01	5.89	8.66	>10,000	>5,000	17°48'3.42"S	177°24'38.18"E
		Point of Discharge	24.7	7.56	4.5	61.4	33	0.23	35	0.31	0.12	7.76	3.88	5.56	>10,000	>5,000	17°48'3.46"S	177°24'26.34"E
		500 m Downstream	24.7	7.67	12.2	72.7	23	0.38	17	0.39	0.17	7.26	6.58	8.9	>10,000	>5,000	17°48'20.68"S	177°24'18.44"E

NATABUA

Date	Weather	Location	Physical Parameters			SOLIDS	NUTRIENT SPECIES					OXYGEN DEMAND			MICROBIOLOGICAL ANALYSIS		LOCATION	
			Temperature	pH	Salinity	Total Suspended Solids	Total Nitrogen	Nitrate-N+Nitrite-N	Total Kjeldahl Nitrogen (TKN)	Dissolved Reactive Phosphorus	Total Phosphorus	Dissolved Oxygen	Biochemical Oxyg	Chemical Oxygen Demand	Faecal coliforms	E-coli	Lat	Long
		Surface samples	°C	0-14	ppt	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN / 100mL	MPN / 100mL		
		500 m offshore	24.1	7.34	31.8	144.8	2.2	0.15	15	0.22	0.15	8.78	0.72	0.96	355	196	17°37'35.50"S	177°24'58.62"E
17/02/2024	Overcast	Point of Discharge	23.8	7.33	32.2	143.6	12	0.15	17	0.27	0.17	8.11	0.82	1.12	7200	314	17°37'52.04"S	177°25'0.25"E
		500 m inshore	23.7	7.23	32.1	148	6.4	0.15	11	0.21	0.15	8.91	0.64	0.84	210	124	17°37'20.39"S	177°24'53.29"E
		Bottom samples																
		500 m offshore (~5.0 m)	22.5	7.23	34.8	144.8	1.3	0.15	12	0.22	0.15	8.21	0.3	0.41	121	84	17°37'35.50"S	177°24'58.62"E
17/02/2024	Overcast	Point of Discharge	22.9	7.19	35	143.6	13	0.15	17	0.26	0.15	8.34	0.76	0.94	6600	194	17°37'52.04"S	177°25'0.25"E
		500 m inshore (~2.0)	23.6	7.44	34.9	148	3.3	0.15	8	0.21	0.15	8.53	0.34	0.41	240	124	17°37'20.39"S	177°24'53.29"E

Dry Season (19/7/24)

NAVAKAI

Date	Weather	Location	Physical Parameters			SOLIDS	NUTRIENT SPECIES					OXYGEN DEMAND			MICROBIOLOGICAL ANALYSIS		LOCATION	
			Temperature	pH	Salinity	Total Suspended Solids	Total Nitrogen	Nitrate-N + Nitrite-N	Total Kjeldahl Nitrogen (TKN)	Dissolved Reactive Phosphorus	Total Phosphorus	Dissolved Oxygen	Biochemical Oxygen Dema	Chemical Oxygen Demand	Faecal coliform	E-coli	Lat	Long
			°C	0-14	ppt	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN / 100mL	MPN / 100mL		
19/07/2024	Overcast	500 m Upstream	23.8	7.23	0.5	53.4	24	0.19	28	0.32	0.15	8.01	5.89	9.12	>10,000	>5,000	17°48'3.42"S	177°24'38.18"E
		Point of Discharge	23.8	7.21	0.7	51.5	28	0.27	23	0.44	0.11	7.76	3.88	7.87	>10,000	>5,000	17°48'3.46"S	177°24'26.34"E
		500 m Downstream	23.9	7.21	2.6	58.5	26	0.23	28	0.45	0.12	7.26	6.58	8.87	>10,000	>5,000	17°48'20.68"S	177°24'18.44"E

NATABUA

Date	Weather	Location	Physical Parameters			SOLIDS	NUTRIENT SPECIES					OXYGEN DEMAND			MICROBIOLOGICAL ANALYSIS		LOCATION	
			Temperature	pH	Salinity	Total Suspended Solids	Total Nitrogen	Nitrate-N + Nitrite-N	Total Kjeldahl Nitrogen (TKN)	Dissolved Reactive Phosphorus	Total Phosphorus	Dissolved Oxygen	Biochemical Oxygen	Chemical Oxygen Demand	Faecal coliform	E-coli	Lat	Long
		Surface samples	°C	0-14	ppt	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN / 100mL	MPN / 100mL		
		500 m offshore	23.6	7.65	35.2	123.4	3.1	0.15	16	0.15	0.16	8.5	0.66	1.13	5400	337	17°37'35.50"S	177°24'58.62"E
19/07/2024	Overcast	Point of Discharge	23.6	7.67	35.2	132.3	8.1	0.15	12	0.16	0.17	8.99	0.89	0.95	1250	224	17°37'52.04"S	177°25'0.25"E
		500 m inshore	23.7	7.89	35.1	131.1	7.2	0.15	12	0.16	0.15	9.2	0.74	0.76	900	256	17°37'20.39"S	177°24'53.29"E
		Bottom samples																
		500 m offshore (~5.0 m)	22.7	7.34	35.4	147.7	5.2	0.15	12	0.19	0.13	8.21	0.77	0.56	3400	133	17°37'35.50"S	177°24'58.62"E
19/07/2024	Overcast	Point of Discharge	22.3	8.03	35.2	156.4	5.6	0.15	15	0.15	0.15	8.22	0.76	0.58	6500	165	17°37'52.04"S	177°25'0.25"E
		500 m inshore (~2.0)	22.5	7.45	35.7	168.6	5.6	0.15	12	0.11	0.12	8.44	0.55	0.44	1250	112	17°37'20.39"S	177°24'53.29"E

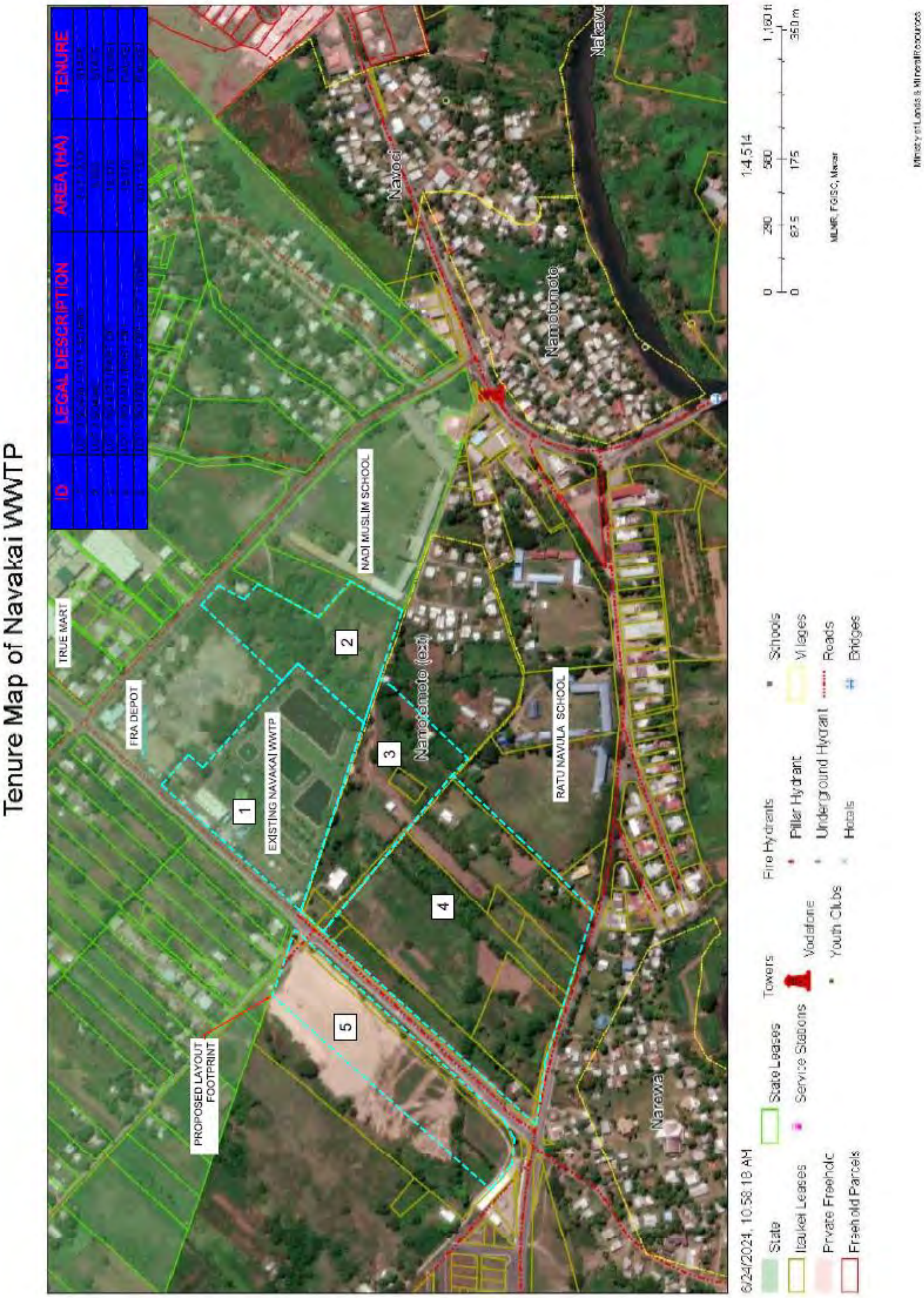
APPENDIX 7-6 Major Socio-Economic Indicators Around the Priority Project

Item		Total	Division	Province	Municipality	
			Western	Ba	Nadi	Lautoka
Polulation[1)]	Total	884,887	337,041	247,685	71,048	71,103
	Men	448,595	171,053	125,241	35,701	35,262
	Women	436,292	165,988	122,444	35,347	35,841
	Elderly persons (over age of 60)	80,483 (9.1%)	31,775 (9.4%)	23,147 (9.3%)	5,165 (8.6%)	9,008 (9.0%)
	Disabilities [2)] (% over age of 5)	113,595 (13.7%)	40,373 (12.7%)	30,242 (13.7%)	6,861 (10.7%)	7,632 (11.8%)
Ethnic composition [1)]	iTaukei	555,499	185,032	122,825	27,555	49,602
	Indo-Fijian	289,237	142,712	116,602	28,916	45,770
	Other groups	40,151	9,297	8,258	3,246	3,892
Informal settlement [1)]	Population	—	50,411	—	18,664	18,909
	Household	—	11,489	—	4,337	4,116
Unemployment rate [1)]	Total	4.5%	5.1%	5.3%	5.4%	7.5%
	Male	2.9%	3.1%	3.5%	3.7%	5.4%
	Female	7.8%	9.5%	9.4%	8.2%	11.5%
Poverty [2)]	Total	29.6%	28.6%	—	—	—
	Urban	23.0%	20.4%	—	—	—
	Rural	37.8%	30.5%	—	—	—
Average household size [1)]		4.6	—	—	—	—

Note: The poverty rate is based on Multidimensional Poverty.
Reference:
1) Fiji Bureau of Statistics, Fiji Census 2017
2) Fiji Bureau of Statistics, 2019-20 Household Income and Expenditure Survey Main Report

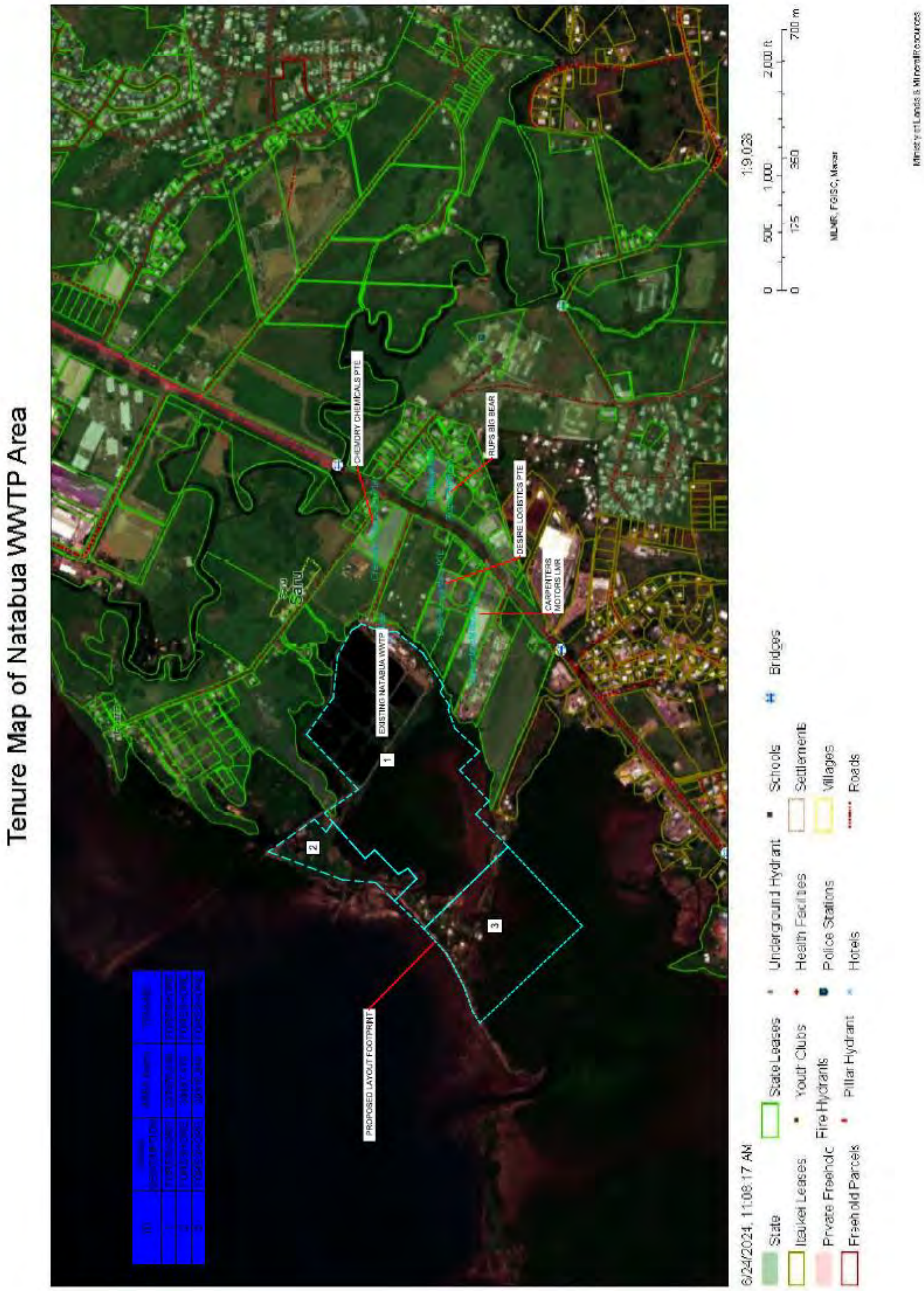
Source: Created by JET based on abode references

APPENDIX 7-7 Land Use Inventory



[Navakai WWTP, Nadi]

Land type	Lot - Plan	Description	Required land (ha)	Required for displacement				Note
				# of buildings		# of residents		
				Total	houses	Legal	illegal	
State land	Lot 9 SO499	Existing WWTP	2.170	-	-	-	-	Structures and operation area
State land	Lot 2 SO1890	Existing WWTP	2.120	-	-	-	-	Existing ponds x 5 (different sizes)
State land	Lot 2 SO4040 (part of)	Government Reserve	3.990	-	-	-	-	Vacant land otherwise used as vehicular access for Ministry of Works on Lot 3 SO1236
iTaukei land	Lot 1 ND4070	Multiple Leases issues – as on TLTB Map	15.370	-	7	-	-	Part is Native lease agreements for commercial development and Village extension
iTaukei land	Lot 1 SO1932	Automart Ltd	3.010	-	-	-	-	Native Lease agreements for commercial development


Tenure Map of Natabua WWTP Area
CHEMDRY CHEMICALS PTE
RUPS BIG BEAR
DESIRE LOGISTICS PTE
CARPENTERS MOTORS LMR
EXISTING NATABUA WWTP
PROPOSED LAYOUT FOOTPRINT
1
2
3
Saru
6/24/2024, 11:08:17 AM
State
Itaukei Leases
Private Freehold
Freehold Parcels
State Leases
Youth Clubs
Fire Hydrants
Pillar Hydrant
Underground Hydrant
Health Facilities
Police Stations
Hotels
Schools
Settlements
Villages
Roads
Bridges
1:9,028
0 500 1,000 2,000 ft
0 175 350 700 m
MLMR, FGISC, Maxar
Ministry of Lands & Mineral Resources

[Natabua WWTP, Lautoka]

Land type	Lot - Plan	Description	Required land (m2)	Required for displacement				Note
				# of buildings		# of residents		
				Total	houses	Legal	illegal	
State land	Area 1 F9-5	Natabua WWTP	23,677	-	-	-	-	Foreshore
State land	Area 2 F9-5	Mangroves/mud flats	33,488	-	-	-	-	Foreshore (Qoliqoli Resource Waiver needed)
State land	Area 3 F9-5	Naqiroso Settlement	90,319	-	18	-	105	Foreshore

APPENDIX 7-8 SPD Water Quality Survey Results

This summary presents the results of the 2022 FINAL monitoring report (Argo environmental Ltd), comparing to findings back at least 5 years of the biological characteristic (habitat, fish populations and benthic communities), water and sediment quality associated with South Pacific Distilleries dunder outfall at Natabua just south of Lautoka. The outfall is located in shallow coastal waters (approximately 20m water depth) 2.3km offshore from Natabua on the northwestern coast of Viti Levu. The local sewerage treatment plant also discharges treated wastewater through the outfall. To reduce the risk of interference for other pollution sources, the sampling sites have been selected to include locations potentially impacted by the dunder discharge (diffuser pipe) and a control location (20m, 100m, and 500 m SW of the outfall).

The below figure shows the proportion of substrate cover on the outfall near the diffusers compared with that remote from the diffusers for the 2022 survey.

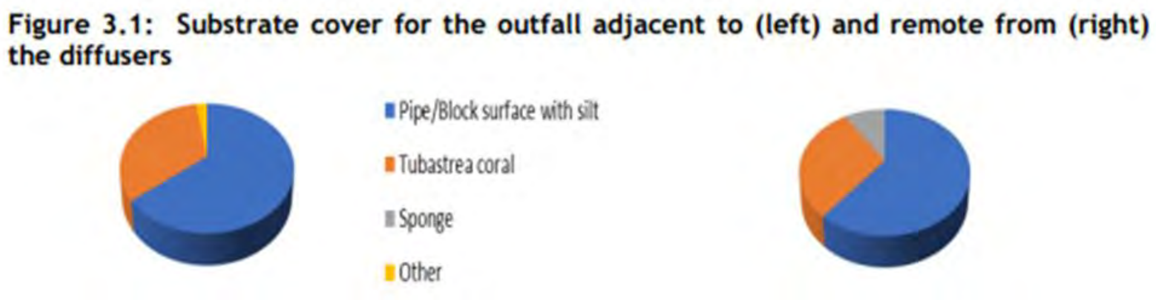


Figure A7-8.1 Proportion of substrate cover on the outfall near the diffusers compared with that remote from the diffusers

Fish species numbers for the pipe adjacent to and remote from the diffusers (6 and 7 species respectively) are similar to the range of those recorded in the last 7 years of surveys (5-15 and 6-9 respectively). As in previous surveys, the most abundant species observed at both locations are primarily the snappers and surgeonfish. The most consistently observed species, the surgeonfish and bannerfish, are once again present Appendix A.

A total of 11 species were identified in all samples including 4 species of crustacea (shrimps and crabs); 3 species of bivalve mollusc (clams); 1 species of gastropod mollusc (snail); and 1 species each of annelid and nemertean worm and a sipunculid. The total number of species recorded is similar to the 2020 survey and is lower than that of recent previous surveys (with the exception of 2010 survey) where between 14 and 20 species were recorded Appendix A.

Mean invertebrate abundance ranges from 6.3 ± 1.5 (20m site) to 12.7 ± 1.2 (500m site). Mean number of taxa ranges from 2.7 ± 0.6 (20m site) to 4.7 ± 0.6 (100m site). Total abundances of 19, 23 and 38 at the 20m, 100m and 500m sites respectively are within the range (2-616, 0-134 and 0-102 respectively) of that found in previous surveys. Total numbers of species of 4, 9 and 5 found at the 20m, 100m and 500m sites respectively are within the range (2-26, 0-16 and 0-13 respectively) of that found in previous surveys. Overall, like the recent previous surveys, any effect of the discharge on the benthic communities appears to be limited to the area directly adjacent to the outfall.

Overall, there is little difference between the sites closest to the outfall (20 and 100m) and the control site (500m) for water quality parameters measured. All parameters are below recognized water quality guidelines, results in Appendix A. Turbidity is low at all sites (0.3-0.7 NTU), Dissolved oxygen concentrations (93.6-96.0 g/m^3) are within the range of those recorded previously. Total nitrogen concentrations are <0.01 g/ m^3 and Total phosphorus concentrations range from 0.007-0.014 g/ m^3 at all sites are below the ANZECC (2000) default trigger value range of 0.12 g/ m^3 and 0.015 g/ m^3 respectively for slightly disturbed tropical marine ecosystems.

Sediment quality parameters are similar across all sites and within those recorded previously. The coarse material fraction is highest at the site closest to the outfall (likely to be due to shell material) decreasing with distance away from the outfall which is similar to previous surveys.

Overall, based on the results of the 2022 survey, the discharge of dunder appears to be having little or no effect on the instantaneous water quality, habitat and biological communities present along and adjacent to the outfall. Like previous surveys it is possible that the discharge of dunder and treated wastewater is affecting the benthic communities and sediment quality confined to an area directly adjacent to the outfall, but this is limited and is more likely to be due to the physical presence of the outfall structure itself (Argo Environmental Ltd 2022).

Table 3.2: Fish species found along the outfall in the 2013 - 2022 surveys

		Diffusers							Remote from Diffusers						
Common name	**Scientific Name**	**2013**	**2014**	**2015**	**2016**	**2018**	**2019**	**2022**	**2013**	**2014**	**2015**	**2016**	**2018**	**2019**	**2022**
Surgeonfish	*Acanthurus sp.*	3	3		3		3	2	2	3	3	3	3	3	
Bluefin trevally	*Caranx melampygus*		3												
Brassy trevally	*Caranx papuensis*	3	3		3			3	3	3		3			4
Bigeye trevally	*Caranx sexfasciatus*	2				3				3	3		3		
Coachwhip trevally	*Carangoides oblongus*														
Butterflyfish sp	*Chaetodon sp.*	2								2	1				
Southseas devil damselfish	*Chrysiptera taupou*														
Grouper sp.	*Epinephelus sp*	1	3	1				3						2	1
Bannerfish sp	*Heniochus sp*	2	2	2	2	2	2	2	2	2	3	2	3	2	4
Bluestreak cleaner wrasse	*Labroides dimidiatus*	1				1	1			2		2			
Blackspot snapper	*Lutjanus ehrenbergii*	3	3	2	3	3	3	3	3	3	3	2	3		2
Flametail snapper	*L fulvus*	3	3	2	3					3	3		3		2
Dory snapper	*L fulviflamma*										2				
Onespot snapper	*L monostigma*	3							3						
Bluestripe snapper	*L kasmira*	3													
Mangrove jack	*L argentimaculatus*	2	3	3	3	2	3	3	3		3	3	3	2	
Circular spadefish	*Platax orbicularis*	2													
Longfin batfish	*Platax tiera*		3		1					3					
Sweetlips	*Plectorhinchus sp.*	2							1						
Semicircle angelfish	*Pomacanthus semicirculatus*												1		
Emperor angelfish	*Pomacanthus imperator*														1
Lemon damsel	*Pomacentrus moluccensis*	3										2			
Turkey lionfish	*Pterois volitans*														
Striped mackerel	*Rastrelliger kanagurta*		3		3		3					3			
Vermiculated spinefoot	*Siganus vermiculatus*														4
Pickhandle barracuda	*Sphyraena jello*				3										
	Total number of species	**5**	**15**	**10**	**5**	**9**	**5**	**6**	**6**	**6**	**9**	**8**	**8**	**7**	**7**

Notes: Numbers of fish are presented as one of four abundance codes: 1 = Single (one individual). 2 = Few (2 - 10), 3 - many (11- 100), 4 - Abundant (more than 100). Note that due to poor visibility both the 2008 and April and November 2009 surveys remote from the diffuser could not be completed. * likely to be the same school.

Table 3.3: Infaunal benthic invertebrate species identified in surveys conducted between 2008 and 2022

Order	Species	2008	Apr09	Nov09	2010	2011	2012	2013	2014	2015	2016	2018	2019	2022
Gastropoda	*Acteon* sp.				✓									
	Atys cyclindricus	✓	✓	✓	✓	✓								
	Atys sp.				✓									
	Architectonia sp.				✓									
	Balcius sp.	✓	✓		✓									
	Buccinum sp.										✓			
	Bullina lineata						✓	✓	✓	✓				
	Cavolina tridentata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	Cerithium sp.				✓	✓								
	Clavus sp.				✓									
	Dentalium sp.				✓									
	Epitonium sp.	✓	✓	✓	✓									
	Gemmula sp.				✓									
	Heliacus sp.				✓									
	Inella sp.				✓									
	Mitra sp.					✓	✓	✓		✓	✓			
	Mitrella sp.				✓									
	Murex tribulus				✓									
	Nassarius crematus	✓	✓	✓	✓		✓	✓		✓	✓			✓
	Natica sp.				✓						✓			
	Neritina sp.						✓							
	Peristernia sp.				✓	✓								
	Pterygia sp.	✓	✓	✓										
	Rhinoclavis sp.	✓	✓			✓								
	Rissoina sp.				✓									
	Sinum sp.	✓	✓	✓			✓	✓						
	Terebra sp.					✓	✓	✓		✓	✓			
	Turridrupa sp				✓									
	Turritella sp.	✓	✓		✓	✓								
	Vermetidae sp.			✓										
	Vexillum sp.	✓	✓	✓	✓	✓	✓	✓						
	Unided sp.				✓		✓							
	Unided whelk sp.							✓						

Table 3.3 (cont.): Infaunal benthic invertebrate species identified in surveys conducted between 2008 and 2022.

Order	Species	2008	Apr09	Nov09	2010	2011	2012	2013	2014	2015	2016	2018	2019	2022
Bivalvia	*Anadara antiquata*	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
	Atactodea striata	✓	✓	✓			✓	✓	✓	✓				
	Codakia sp.												✓	✓
	Crassostrea sp.						✓							
	Fabulina sp.	✓	✓									✓	✓	✓
	Perna sp.								✓	✓				
	Septifer sp.						✓							
	Tellina sp.					✓	✓	✓	✓	✓				
	Terebra sp.											✓		
Crustacea	Unidentified amphipod sp.							✓	✓	✓	✓	✓	✓	
	Grapsid crabs	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
	Mantis shrimp larvae	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Hermit crab										✓			
	Unidentified shrimp sp.	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
	Xanthidae crab sp unided												✓	✓
Echinodermata	Brittle star sp.					✓	✓	✓	✓	✓	✓	✓	✓	
Nematode	Unidentified sp.				✓			✓	✓	✓	✓	✓	✓	✓
Annelida	Unidentified sp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Sipunculida sp.											✓		✓
Piscine	Unidentified fish larvae			✓	✓		✓	✓	✓	✓		✓		✓

APPENDIX 7-9 Stakeholder Consultations

Project Name:	**JICA SEA Project Specific Nadi Lautoka - Phase 2**		
Place of Meeting:	Commissioner Western Office, Lautoka		
Meeting Date:	Wednesday, April 24th 2024	**Meeting Time:**	10.00 AM
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific – Social Specialist
- Yuriko Kudo, JICA – Environmental Specialist (via zoom)

Stakeholders

- Tevita King, PLANIT Pacific – Social Team
- Tabitha King, PLANIT Pacific – Social Team
- Apolosi Lewaqai, Ministry of Rural & Maritime Development - Commissioner Western
- Alifereti Abeniaga, MRMD, District Officer Nadi
- Joseva Rokoroi, MRMD – Provincial Administrator Ba
- Sitiveni Tavaga, MRMD – District Officer Lautoka/Yasawa
- Jone Bacau, MRMD – Divisional Planning Officer

Item	Action
1. Introductions • The Commissioner Western welcomed and thanked the attendees for their presence. He then handed it over to Jacqueline Hughes (PLANIT Pacific Social Team) to briefly introduce the Wastewater Treatment Master Plan – Phase 2. She advised that the project team would then present the details of the project. • Commissioner Western made apologies as the WAF team had been in an accident and was unable to attend the meeting.	
2. Presentation by Project Team • A PowerPoint presentation was made by Yuriko Kudo (JICA Team via zoom) explaining the Project for Formulation of Wastewater Treatment Master Plant in Western Division (2nd Phase) and the Pre-F/S for Priority Project Stakeholder Consultation. • A brief overview of the project was explained detailing the background, project phasing, selection of the priority project and the pre-feasibility study and schedule.	

3. Discussion Session

- During the presentation the Commissioner Western commented on the need to discuss with TLTB how to get the approval of the landowners in Namotomoto (Nadi). He raised an issue that some of the land in the area has already been given out for lease for commercial purposes. He also stated that for the native reserve land, the villagers need to be informed that if the issues of capacity and expansion at Navakai WWTP are not addressed, it could impact them as the landowners by restricting any further development to other native land that they have because WAF will not be able to facilitate them and allow their development to connect to Navaikai WWTP. He stated that the government will not approve any further development to other land until this issue is resolved. He further detailed the process of acquisition of native reserve land stating that WAF will need to start this process to secure the land as soon as possible and if not identify alternative areas.
- The Commissioner further stated that the issue with the Natabua WWTP was that most of the state land identified for extended area has a lot of informal settlements to which Jackie (PLANIT) stated that resettlement/relocation would need to be factored in as a significant impact and whether the Commissioner thought it would be a difficult issue to deal with. The Commissioner confirmed that some relocation/resettlement of communities has already occurred and that the State needed to address this issue of relocation with WAF.
- Jackie (PLANIT) mentioned that Fiji Roads Authority (FRA) and Water Authority Fiji (WAF) have their own Lands Teams that usually work with the Lands Department Valuation Teams and that their internal teams will need to come up with the valuations and packages and take it to Lands Department to facilitate. She confirmed that the project team has been in touch with Lands Department to verify all the ownerships for any leases that have been issued and will verify all the settlements and affected persons in the area. Jackie stated that the key to this feasibility study is to know the timeframes then the resettlement timeframes and budgets can go hand in hand to be factored in.
- The Commissioner raised the issue of the amount of time being taken to do the feasibility study as the Commissioner's office has been receiving many development applications and noted the Vitogo-Sabeto corridor is developing very quickly. He added that a relocation was done from a settlement in Nasowata to land owned by the people of Vitogo. He stated that the challenge was working on the feasibility study of the areas that are currently under pressure (Natabua & Navakai), while also considering Vitogo and Sabeto to avoid multiple relocations down the line.
- Jackie (PLANIT) responded that the details/locations of the five areas are in the regional masterplan and they can shared with the Commissioner's office to be made aware of WAF's plans. She added that during earlier consultations there were questions raised as to why the WWTP was being put in prime foreshore areas but the key issue is that wastewater treatment plant needs to be at a lower level as the lines needs the gravity otherwise lots of money will be spent trying to pump it uphill rather than having it flow downhill by gravity. She stated that it was cost prohibiting to take these wastewater facilities and move them into the mountains which is why most of them are along the low-lying foreshore areas. She stated that unfortunately its playing catchup to current developments which is why Nadi and Lautoka will have to be accelerated because it is already over capacity.

- Commissioner Western stated that their Head of Division meetings, was one of the main issues that is brought up by the CO's is that even when there is little rain the wastewater overflows into the Nadi River/Lautoka area.
- Jackie responded that not only is the plant undersized and overcapacity but that the network lines are also outdated. Extensions of the network cannot be considered until the current plant and network can take the load. In addition to the areas that are to be acquired, there is also the need for large areas for more ponds and when they desludge the ponds, for storage of the sludge. At the moment there is nowhere to dump the sludge and the Councils and DoE have not agreed to dumping into the current dump sites at Vunato. The project team is also looking at other ways to use the sludge whether its for agricultural purposes or treated and reused. If an alternative use can be found, the area requirement for the sludge will reduce.
- Jackie (PLANIT) stated that another issue is the acquisition of a foreshore lease to extend the outfall pipe in Natabua to get better mixing of the treated wastewater being discharged out to sea and away from the land. A qoliqoli/Fisheries Impact Assessment will also need to be undertaken.
- Jackie (PLANIT) asked the stakeholders if there were any complaints from the current outfall in Natabua to which the response was none that they were aware of, however he stated that that foreshore area was well used for fishing and for crabbing by the local communities.
- The Commissioner Western questioned what the impact for the Navakai WWTP outfall had on the communities. Jackie (PLANIT) stated that WAF do have wastewater/water quality testing which is submitted to DoE and whatever is treated from the upgraded WWTP will have to be to DoE's discharge standard. She also stated that Dr Shaw Mead has been looking at all the past water quality results and it is something that has to be improved as the levels were high. Jackie (PLANIT) specified that during the JICA flood study in the area, it was identified that the Narewa village community near the outfall in Navakai did not use the river much for fishing but the concern was for the downstream communities (Moala and Yavusania) who mostly use it for fishing and crabbing. Alifereti (DO Nadi) mentioned that the upstream communities also use the river for harvesting kai (freshwater mussels). Jackie (PLANIT) stated that since it is also affected by tide, the upstream communities are likely to be impacted too.
- Jackie (PLANIT) mentioned that verification would also be needed on whether an FIA would be needed in the Nadi River area and who are the traditional qoliqoli owners in order for WAF to follow the process.
- The Commissioner asked the timeframe of the feasibility study and how far consultations gone to which Jackie responded that the final draft report would be presented in July of this year to all the stakeholders and that this was the beginning of the consultation process for this phase of the project.
- The Commissioner gave his full blessing for the project and restated that it was one of the recurring issues in their Head of Division meetings. He revealed that they are trying to control the development that is putting pressure on the already aged/aging infrastructure. He expressed his gratitude to JICA and the Govt of Japan for carrying out this feasibility study and hopes that they will also fund the project itself.
- Jackie (PLANIT) stressed the need for information sharing of developments/proposed developments across the board so that infrastructure providers can plan long term. The Commissioner Western agreed and stated that the government is supportive of the integrated approach and encouraged his team to share information not only within government but within business communities and NGOs to address the needs of the communities and to complement each other.

- The Commissioner Westerns office advised that should the project team and WAF require further assistance with other stakeholders and the landowners, his office will be happy to facilitate and assist.

With no further questions from the attendees, the meeting was closed.

4. Actions from Meeting

- Share presentation to the Commissioner Western's office, in particular, Mr Jone Bacau, MRMD – Divisional Planning Officer so that he can plug it into their programme.

Commissioner Western Office

JICA WAF Phase 2 Wastewater Masterplan 10am.

Nadi & Lautoka 24/04/2024.

Name	Organisation/ Departments/Community	Role	Contact Details
Jackie Hughes	PLANIT Pacific	Social Consultant	[redacted]
Teuta King	PLANIT	- -	
Talattee King	PLANIT	- -	
Abeleneh Abening	Rural Maritime Development	DO Nadi	
Joseva Boiruvou	✓ ✓ ✓	PA Bo J	
Litiveni Tavaga	✓ ✓ ✓	DO Lautoka / Yasawa	
Jone Bacau	✓ ✓ ✓	DPD	
Apolosi Lewaqai	✓ ✓ ✓	Commissioner Western	
Yuniko Kudo	JICA Team	Environmental Specialist	
~~Shan Mead~~	~~eCoast~~	~~Local Environmental Consultant~~	

Project Name:	**JICA SEA Project Specific Nadi Lautoka - Phase 2**		
Place of Meeting:	Lautoka City Council, Lautoka		
Meeting Date:	Wednesday, April 24th 2024	**Meeting Time:**	11.30 AM
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific – Social Specialist
- Yuriko Kudo, JICA – Environmental Specialist (via zoom)
- Shaw Mead, eCoast – Environmental Consultant

Stakeholders

- Tevita King, PLANIT Pacific – Social Team
- Tabitha King, PLANIT Pacific – Social Team
- Abdul Mofid, LCC- Acting Manager Building/Engineering Services
- Shameer Khan, LCC- Team Leader Assets
- Rouhit Karan Singh, LCC- Acting Head of Services
- S Dass, LCC- Acting Director Building/Engineering Services
- Shalend P Singh, LTC, Health Department
- Mohammed Anees Khan, LCC- Chief Executive Officer

Item	Action
1. Introductions • The CEO Lautoka City Council welcomed and thanked the attendees for their presence. He then handed it over to Jacqueline Hughes (PLANIT Pacific Social Team) to briefly introduce the Wastewater Treatment Master Plan – Phase 2. She advised that the project team would then present the details of the project.	
2. Presentation by Project Team • A PowerPoint presentation was made by Yuriko Kudo (JICA Team) explaining the Project for Formulation of Wastewater Treatment Master Plant in Western Division (2nd Phase) and the Pre-F/S for Priority Project Stakeholder Consultation. • A brief overview of the project was explained detailing the background, project phasing, selection of the priority project and the pre-feasibility study and schedule.	

3. Discussion Session

- During the presentation Jackie (PLANIT) stated that the main reason for the large area of expansion is to cater for sludge disposal where one of the key issues is currently that WAF is not allowed to dispose the sludge taken out from the ponds at the Vunato dumpsite hence the extra area for the sludge to be placed onsite while looking for options where it can be treated/reused for agricultural purposes or any other purposes that may be allowed. Shalend (LCC Health Manager) stated that they have noted the idea of having the sludge mixed with compost but tests need to be done to see whether it is suitable for use and if so, LCC can take some of the sludge. Jackie (PLANIT) asked where that would be done to which the CEO responded that there is a compost yard in Vunato rubbish dumpsite – an opportunity to take the stockpile and be mixed with the organic compost. Yuriko (JICA) questioned what the organic compost would be used for. CEO stated that it will be for Council's use for agricultural purposes, flower gardens and some sold.
- Jackie (PLANIT) stated that the main concern is quality of the sludge. Yuriko (JICA) stated that the Department of Environment (DoE) had warned about the quality of the sludge and what if it contains heavy metals or other contaminants. She also stated that the soil testing and looking at the quality of the sludge is very important and it needs to be discussed with WAF and DoE to also be involved.
- Shalend (LCC) also raised concerns about the volume of the sludge as LCC is doing mini composting and unsure if they are able to cater for the whole amount of sludge. Jackie (PLANIT) requested quantities of sludge from JICA to see if the tonnage per month/ratio of mix is able to be accommodated. Yuriko (JICA) mentioned they can refer to the Municipal Sewerage Masterplan/comparison matrix for the information. Jackie (PLANIT) stated that the information will be extracted from the reports and sent to the LCC Health Department to have a look at the quantities, most likely that they will not be able to accept all but some. She stated that there might need to be talks with Fiji Sugar Corporation (FSC) or some other fertilizer companies and questioned what fertilizer companies were available.
- CEO stated that there is South Pacific Fertilizers which import and Rooster Poultry that started composting their own chicken waste. He stated that there could be potential partnership with FSC to combine it with the bagasse and other waste to use it in the sugarcane farms.
- LCC member stated that when human waste is dried it is not like chicken manure, and that it is has a sandy texture. It is to be seen whether mixing it with the market waste compost the nutrients and quality will be maintained.
- Shalen (LCC) encouraged the JICA Team experts to share whether it is possible or not or if there are any case examples. He also questioned what the current WQ level of compliance was for the outfall pipe at Natabua.
- Dr Shaw Mead (eCoast) stated the water quality results are similar to those that WAF has been taking. He discussed the faecal coliform levels and total suspended solids are high.
- LCC member questioned if there was any WAF advisory to the residents of the area to state the perimeters that is unsafe to swim/fish/crab. Jackie responded that at this stage there is none but it can be raised with WAF.
- CEO mentioned that most of the land demarcated for the WWTP expansion is state owned and has been earmarked for Industrial/Commercial uses.
- CEO also stated that it would be good to have some perimeters marked out in case of unforeseen circumstances where WAF might need to discharge without

treatment. Jackie (PLANIT) questioned whether there would need to be any buffers to restrict development so that businesses/residents are not close to the actual plant. CEO stated that a special purpose development can be discussed with DTCP to work out a buffer zone.

- Shalen recommended that an embankment be used as in Kinoya WWTP to prevent certain level of smell (so that the smell goes up from the bund and not across).
- CEO stated that once the masterplan is done there can be a meeting with DTCP to set development provisions.
- Jackie asked whether LCC is familiar with any resettlement programs/projects. CEO responded that there have been resettlements in Taiperia and Nasowata. She stated that the locations/areas/layouts for other WWTP's in Vitogo and Sabeto will be shared to preserve the buffer areas and to avoid multiple relocations.
- Shalen (LCC) asked whether WAF have spoken to the Vitogo landowners. Jackie responded that they have been attending stakeholder meetings but since Natabua and Navakai are priority sites, Vitogo has only been identified in the regional plan and once they decide to implement only then will the landowners be further consulted. She added that the issue to raise with WAF/TLTB/Lands Department and which Commissioner Western also raised was that they be engaged now so they do not lease out their land in support of the development. She added that if they lease out their other lands, they could be restricted in development because there are no wastewater facilities to connect to.
- CEO recommended that once WAF have identified their footprint needed, to begin acquiring the land instead of asking landowners to allow them to develop their infrastructure freely.
- Shalen (LCC) asked whether this project is only for developing a masterplan or if it will be executed. Jackie (PLANIT) responded that they are currently looking at feasibility and to know how much money it will actually cost and what issues will be faced before they decide how they are going to do the detailed design and roll it out.
- Shalen queried whether the network will be upgraded as it has been raised as a key issue to which Jackie (PLANIT) responded that until the WWTP has the capacity to receive, the waste and treat it they cannot move onto the network. Shalen (LCC) offered that instead of extending the current network, the existing network can be repaired/upgraded to which he listed the issues faced with the current network/WWTP. Jackie (PLANIT) requested LCC to provide that list of all the areas and issues faced to be passed onto the WAF Operations Asset Manager.
- Shalen also recommended that WAF create policies/laws/regulations for onsite treatment where businesses/restaurants must meet the WAF standards before discharging which Council is happy to enforce.
- Jackie (PLANIT) stated that the presentation would be shared with Council to allow them to provide the project team the list of issues there and also any other information that may be a concern in terms of the expansion of the WWTP.
- Yuriko (JICA) queried whether LCC was facing capacity issues with the Vunato dumpsite to which LCC responded that with increasing development and they now have problems managing solid waste – they cover Lautoka, Nadi, Denarau. He stated that they have the capacity to manage but are in need of funding to address operational issues.
- CEO stated that there is currently 50 acres at the Vunato dumpsite but in the long term there are plans to relocate in land like in Naboro.
- LCC questioned whether South Pacific Distilleries is required to have their own treatment plant. Yuriko (JICA) responded that currently they are not required but discharge their wastewater next to the inlet of the outfall pipeline

together with the treated wastewater effluent. She added there is some discussion between WAF and SPD for future treatment of SPD's wastewater.

- CEO (LCC) offered that WAF need to develop a policy/law to relieve their burden and to pass it on to those industries that generate this type of waste to treat it before discharging it. LCC also added that DoE should regulate these facilities at how best businesses/industries can do full treatment before connecting to a public system.

With no further questions from the Council attendees, the meeting was closed.

4. Actions from Meeting

- LCC to provide a running list of issues/concerns within the Lautoka town planning that is currently facing issues with wastewater for JICA team to pass on to WAF operations/assets manager.
- JICA team to share sludge quantities requiring storage or reuse to LCC for consideration of mixing with their organics for composting at Vunato.
- JICA team to share the locations of the land area requirements for Vitogo and Sabeto for LCC's future consideration
- LCC to provide list of developments already approved next to or in the area of extension for Natabua WWTP

LCC

JICA WAF Phase 2 Wastewater Masterplan

Nadi & Lautoka

11:30am
24/04/24

Name	Organisation/ Departments/Community	Role	Contact Details
Abdul Mofid	Lautoka City Council	Acty Manager Bldg / Eng. Servi	[redacted]
Shameer Khan	✓ ✓ ✓	Team Leader Assets	
Rouhit Karan Singh	✓ ✓	AG. Head of Services	
S. Das		Acting Director Building & Engineering Services	
Shalend P Singh	Lautoka City ✓	shalends@lautokacitycounci	
Mohammed Anees Khan	LCC	khanm@lautokacitycouncil.com	
Tevita King	PLANIT Pacific	Social Team	
Tabitha King	PLANIT Pacific	" "	
Jackie Hughes	" "	" "	
Yuiko Kudo	JICA Team	Environmental Specialist	
Shaw Mead	eCoast	Environmental Consultant	

Project Name:	**JICA SEA Project Specific Nadi Lautoka - Phase 2**		
Place of Meeting:	Nadi Town Council, Nadi		
Meeting Date:	Wednesday, April 24th 2024	**Meeting Time:** 2.30 PM	
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific – Social Specialist
- Yuriko Kudo, JICA – Environmental Specialist
- Shaw Mead, eCoast – Environmental Consultant

Stakeholders
- Tevita King, PLANIT Pacific – Social Team
- Tabitha King, PLANIT Pacific – Social Team
- Malakai R, TLTB – Estate Assistant (Operation)
- Saliceni Raiwalui, Nadi Town Council – Chairman
- Premila Pathak, NTC – Manager Com. Service
- Muni Gopal Reddy, NTC – Acting CEO
- Veceli Tuiweli, NTC – Building Inspector
- Aisake Raratabu, DTCP Lautoka – Principal Town Planner
- Meli Naco, NTC – Planning & Engineering
- Josaia Korilavesau, WAF – Infrastructure Planning
- Isireli Veitokiyaki, WAF – Infrastructure Planning
- Prem Chand, NTC – Special Administrator

Item	Action
1. Introductions • The Acting CEO of Nadi Town Council welcomed and thanked the attendees for their presence. He then handed it over to Jacqueline Hughes (PLANIT Pacific Social Team) to briefly introduce the Wastewater Treatment Master Plan – Phase 2. She advised that the project team would then present the details of the project.	
2. Presentation by Project Team • A PowerPoint presentation was done explaining the Project for Formulation of Wastewater Treatment Master Plant in Western Division (2nd Phase) and the Pre-F/S for Priority Project Stakeholder Consultation. • A brief overview of the project was explained detailing the background, project phasing, selection of the priority project and the pre-feasibility study and schedule.	

3. Discussion Session

- Veceli (NTC) commented during the presentation of the area required for the expansion of WWTP in Navakai that most of the land has already been earmarked for the Namotomoto and Navoci village extension as confirmed by TLTB that it is native reserve.
- NTC queried that if the current land that is proposed for the WTTP extension cannot be obtained/acquired what other options are to be considered. Jackie (PLANIT) responded that WAF will have to look at options within the state land or a different site for Navakai all together which will be a costly exercise and also will result in restriction of development.
- Yuriko (JICA) questioned whether the village reserve or the WWTP was the main priority as the land demarcated for expansion of the plant is critical to their design. Jackie (PLANIT) stated that the project will need to be explained to the landowners of Namotomoto and Navoci to see if other areas of native reserve land could be identified and considered for village expansion or whether other native reserve land close by can be considered for the sludge stockpiling. She added that the project team will need to organize a meeting with the landowners, TLTB, Commissioner Western and other relevant stakeholders on how to address land acquisition in these areas required for Navakai expansion.
- Premila (NTC) raised concerns of the close proximity of the WWTP to the schools in the area and if it will face any health impacts. Jackie (PLANIT) stated that it has been factored into the design where buffers will have to be incorporated to address odours etc.
- NTC further stated that with the upgrade of the Navakai WTTP so long WAF is in compliance with water quality standards there is no issue.
- A/CEO (NTC) stated that the whole area outlined for expansion is within the flood zone area and queried whether that would affect the storage of sludge. Jackie (PLANIT) stated that the JICA design team is aware of this and are factoring it into their design.
- Meli (NTC) suggested that it would be easier for FRA to find space to relocate their offices to avail some much-needed land to which Yuriko (JICA) responded that there would still not be enough area for the total expansion. Meli (NTC) added that the biggest issue for the Navakai WWTP would be acquiring land. Jackie (PLANIT) stated that this project will need assistance from government bodies to help deal with the landowners.
- Aisake (DTCP) commented that WAF should seek government assistance to which WAF representatives responded that budget submissions have already been made in October 2023 in anticipation for the new budget in the next financial year that includes the budget for acquiring land required for the expansion.
- Aisake (DTCP) questioned as to where most of the smell comes from at the WWTP, is it the sludge or ponds. WAF stated the smell comes from the raw sewerage and not the sludge. Aisake also queried whether sludge can be stored offsite. WAF responded that it is costly to transport it to a separate location and would increase their operational costs compared to having it onsite. Aisake suggested a state lease land that was for sale opposite the new Grace Roads commercial development which was going for $1m. WAF said they would consider it though it may still be far away and still require the transportation of sludge to that site which could be costly.
- NTC member questioned what the volume of outflow was from Navakai WWTP. He mentioned that the villages in the surrounding areas were advised

in their Tikina meetings not to eat anything from the river. He also mentioned that due to the tidal effect the sewerage is carried upstream and farmers cannot irrigate from the river because it is too polluted. It is critical that we get the quality of water discharged into the river improved. CEO Nadi Town Council also mentioned that Denarau too faced the same issue with DoE as they were using the Nadi river water for irrigation of the golf course but the water from the river also had high faecal coliform counts and were advise to refrain from using the river water.

- Aisake (DTCP) asked if there were any case studies from Japan or other countries of similar or new WWTP that could be imitated. WAF responded that they are currently still trying to standardize all WWTP across Fiji in terms of operations and eventually extract service providers to manage the WWTP while providing compliance. Jackie (PLANIT) reiterated that if WAF standardize it WAF will make sure they have the parts and people to service the system as it is no point in getting a high-tech mechanical plant that can give us the water quality standard but it breaks down and is not operational for months after being installed. Also, the mechanical plants also require a lot more power to operate which also raises the cost of operations. The system that is selected needs to be cost effective or else it will not be feasible to implement.
- NTC member queried how often the desludging process happens to which WAF responded every 4-5 years. NTC also commented that the main challenge is acquiring the land for expansion and the longer it takes the more the cost escalates in terms of compensation for land and other costs to increase over time. They mentioned that a way forward would be to incentivize the villages in the area by connecting them to the network.
- The meeting ended with all in attendance in support of meeting with the landowners in order to facilitate

With no further questions from the villagers, the meeting was closed.

4. Actions from Meeting

- PLANIT to liaise with WAF and Commissioner Western's office to organize a meeting with the landowners and Lands Department regarding the native reserve land for village extension and also any other native reserve land available in close proximity for consideration by WAF.
- Nadi Town Council and DTCP to confirm development approvals issued for the subject state land to enable contact with the developer to understand timeframes of development.

NTC.

JICA WAF Phase 2 Wastewater Masterplan 2:30pm

Nadi & Lautoka

24/04/24

Name	Organisation/ Departments/Community	Role	Contact Details
AWAKAKI R	TLTB, NADI	ESTATE ASSISTANT	[redacted]
SALICENI Raiwalui	CHAIRMAN NTC	–	
Premila Pathak	Nadi Town Council	Manager Com. Service	
Muni Gopal Reddy	Nadi Town Council	ACEO	
Veceli Tuiwe	NTC	Bldg. Inspector	
Aisake Ravatabu	DTCP Ltka	Principal Town Pl	
Meli Nawo.	N.T.C	Planning & Engineering	
Josaia Kasilavesau	W.A.F	Infrastructure Plan	
Teinali Veitokiyaki	W A F	"	
Prem Chand.	NTC	Special Administrator	
Jackie Hughes	PLANIT Pacific	Social Team	
Tevita Kane	–	–	
Tabitha King	–	–	
Yuiko Kudo	JICA Team	Environmental Specialist	
Shaw Mead	eCoast	Environmental Consultant	

Project Name:	**JICA SEA Project Specific Nadi Lautoka - Phase 2**		
Place of Meeting:	Lands Department		
Meeting Date:	Monday, May 27th 2024	**Meeting Time:** 10:30 to 11:30 AM	
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific – Social Specialist
- Josaia Korilavesau, WAF – Infrastructure Planning
- Isireli Veitokiyaki, WAF – Infrastructure Planning

Stakeholders

- Apisai Vulawalu – Assistant Director of Lands
- Bulou M. Maka - Land Use Planning & Development Team (LUPD)
- Seini Nakawa - Land Use Planning & Development Team (LUPD)
- Sainimere Toalagi - Land Use Planning & Development Team (LUPD)

Item	Action
1. Introductions • The ADL Apisai Vulawalu welcomed and thanked the attendees for their presence. He informed those present at the meeting that the Ministry of Lands & Mineral Resources was in the process of working on its Master Plan for all State land in Fiji across the 3 regions.	
2. Presentation by Land Use Planning & Development Team & WAF Team • A PowerPoint presentation was made by LUPD to show WAF, the draft Master Plan for the state lands in and around Navakai Wastewater Treatment Plant and Natabua Wastewater Treatment Plant • A brief overview of the WAF Western Region Master Plan project was explained detailing the background, project phasing, selection of the priority project and the pre-feasibility study and schedule.	
3. Discussion Session • The LUPD team stated they started the 1st pilot project for the Greater West Corridor Master Plan in 2023. The 2nd draft of the West Master Plan has been completed and submitted to the various stakeholders including the Department of Town & Country Planning for their final comments.	

- Notably, the State lands around Navakai have been ear marked for future Special Use tourism development and commercial development. In Natabua, the surrounding state leases have also been ear marked for Industrial and commercial development. The LUPD indicated that they had not consulted with other utility provider including WAF in their earlier consultation processes.
- WAF had requested they take on board the issues with water and wastewater for both Nadi and Lautoka as since they are proposing high density developments other than agricultural their Master Plans may not yield the outcomes if the development is not able to connect to these basic services and utilities.
- The LUPD was asked to review the WAF Western Region's Wastewater Master Plans current and future land needs for WWTPs to be factored into their land use Master Plans prior to finalisng their Greater Western Corridor Plan.
- WAF agreed that they may also need to relook at the capacity and future demand calculation to factor in Lands Department's Master Plan and also for their land acquisition plans as well. There was no indication as to whether the Greater Western Corridor Plan would include the foreshore areas.
- During the presentation Jackie (PLANIT) stated that the main reason for the large area of expansion is to cater for sludge disposal where one of the key issues is currently that WAF is not allowed to dispose the sludge taken out from the ponds at the Vunato dumpsite hence the extra area for the sludge to be placed onsite while looking for options where it can be treated/reused for agricultural purposes or any other purposes that may be allowed.
- The LUPD team stated that they would look at some of the state lands in and around the Navakai wastewater treatment plant to see if there were any expired or expiring leases that could be of interest to WAF for sludge stockpiling but that the requirement would need to be in close proximity as WAF was trying to avoid the cost of carting sludge distances away thus increasing the operating costs.
- The LUPD team stated that WAF should talk to FRA and Ministry of Works to relocate their depot sites but WAF stated that even if that area was cleared, they would still need more land as the area of land occupied by FRA and Ministry of Works was not sufficient. LUPD also suggested to talk to NFA which WAF said they would start their land acquisition process as they had already allocated it in their next budget.
- The ADL also identified some area near airport held by either CAFFI or AFL that could also be considered as well as Housing Authority's site in Nawaka behind Martintar. WAF stated that they could consider another Wastewater Treatment Plant at Nawaka so would then have a discussion with Housing Authority to discuss this further.
- The LUPD stated that they would review WAF 's comments and consider talking to utilities like EFL regarding power supply and WAF stated that Water was also an issue for Nadi and that their Water Master Plan could also be shared for their consideration.

With no further questions or issues to discuss, the meeting was closed.

4. Actions from Meeting

- WAF shared the information and area of land required by the proposed expansion of the Navakai and Natabua Wastewater Master Plans.

Project Name:	**JICA SEA Project Specific Nadi Lautoka - Phase 2**		
Place of Meeting:	National Fire Authority		
Meeting Date:	Wednesday, July 24th 2024	**Meeting Time:** 2:00 PM	
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific – Social Specialist
- Tevita King, PLANIT Pacific – Planning Technician
- Isireli Veitokiyaki, WAF – Infrastructure Planning

Stakeholders

- Joel Israel – Manager Fire Safety & Compliance and Properties, NFA

Item	Action
1. Introductions • J Hughes of PLANIT Pacific gave an introduction to the JICA funded WAF wastewater regional master plan for Phase 1 and 2. Phase 2 focus was on the Navakai and Natabua Wastewater Treatment Plants. Specifically, NFA was being met to discuss NFA's vacant land adjacent to the Navakai Treatment Plant in order to ascertain as to whether they have plans for the site or whether they would be willing to relocate if WAF facilitated the relocation.	
2. NFA's Presentation of its Master Plan for State Lease Site • J Israel explained that NFA had a master plan recently approved to develop the site into their training centre. He explained that currently NFA did not have a training centre and when they undertake training for their new recruits, it is held at their national HQs site in Walu Bay. However, their training needs are required to be upgraded and their master plan to which he was referring to (and attached), has a mask structure for climbing stairs up to 25m for simulating fires in high rise structures which was now growing in the cities. Their training centre also has accommodation and telecommunications centre, but will not be run as a fire station. • J Israel explained that NFA finally received their budget in 24/25 to start the project and therefore, it would be difficult for them to stop now and give it up. He said he would need to brief his CEO and then come back to us but that he saw the need for the Navakai treatment plants expansion. He said they would also be willing to meet with the other agencies to see the best way forward for all.	

3. Discussion Session

- WAF explained that they had had discussions with AFL/CAAF on the availability of land to relocate the other utility services including Ministry of Works and Fiji Roads Authority depot sites also located adjacent to Navakai Treatment Plant. That there was a parcel of state lease land held by CAAF that was in the runway approach lights that could be a potential however, it did have height restrictions which we would need to have confirmed. ○
- During the presentation Jackie (PLANIT) stated that the main reason for the large area of expansion for both Navakai and Natabua Treatment plant sites is to cater for sludge treatment and disposal where one of the key issues is currently that WAF is not allowed to dispose the sludge taken out from the ponds at the Vunato dumpsite hence the extra area for the sludge to be placed onsite while looking for options where it can be treated/reused for agricultural purposes or any other purposes that may be allowed.
- WAF explained that currently the master plan does not show any use for the land for ponds or the treatment plant but want to use the land as a potential buffer with landscaping to provide screening from the existing school that is adjacent to the NFA site.
- J Hughes also explained that with NFA's master plan having accommodation units close to the treatment ponds at Navakai was not ideal in terms of odour so NFA would need to be mindful of this.
- NFA also indicated that they were approached by Nadi Town Council for the same land for NTC's depot but NFA advised them that they would not give it up as they really needed the training centre to which they now have their budget for.

With no further questions or issues to discuss, the meeting was closed.

4. Actions from Meeting

- WAF to organize a joint meeting with Minister of Infrastructure with Ministry of Works, Fiji Roads Authority and National Fire Authority to discuss the possibility of relocation to another site. Meeting to include CAAFi and AFL as well as Lands Department and iTLTB.
- NFA to inform their CEO of the proposed upgrade to Navaikai Treatment Plant and the need for their site as a buffer between the plant and the school.
- However, PLANIT received an email after the meeting from the new CEO of NFA, Mr. Puamau Tagivetaua Sowane, to confirm that they will not be giving up their land at Navakai as they plan to go ahead with their Master Plan. See attached email.

Project Name:	**JICA Nadi & Lautoka Master Plan**		
Place of Meeting:	Nadi Airport – Operations Room		
Meeting Date:	Monday, July 22nd 2024	**Meeting Time:** 2.30 PM	
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific— Facilitator/Presenter
- Tevita King, PLANIT Pacific - Land & Resettlement Team
- Tabitha King, PLANIT Pacific
- Aleksio Rabaka, PLANIT Pacific
- Isireli Temo Veitokiyaki, Water Authority of Fiji
- Emily Smith, Water Authority of Fiji

Stakeholders

- Manil Reddy, Fiji Airports
- Eliki Vakadranu, Fiji Airports
- Lorina Filipe, Civil Aviation Authority of Fiji (CAAF)
- Makiti Raratabu, CAAF
- Mosese Ratucicivi, CAAF
- Mushraan, Fiji Airports

Item	Action
1. Introductions • Jacqueline Hughes from PLANIT Pacific welcomed everyone and briefly introduced JICA SEA Project Specific Nadi Lautoka - Phase 2 project.	
2. Presentation by PLANIT • A PowerPoint presentation was done in the English language briefly explaining the project and to inform the stakeholders of land required by JICA & WAF. • Explanation of the reasons for the land required • Responding to the stakeholder comments and issues through Q & A • Explaining next steps and indicative timeframes	
3. Discussion Session • Jaqueline (PLANIT) further discussed the Navakai and Natabua Wastewater Treatment Plant (WWTP) in terms of upgrading it for current/existing development and future development in the next few years. She mentioned two	

Clean Water & Sanitation for a Better Life additional plants in Sabeto and Moala as two other sites that will be developed for wastewater treatment plants.

- She added that Navakai has been struggling for a number of years with its capacity hence the need for upgrading to be able to take the current capacity as well as additional capacity. She added that the JICA study team in looking at the existing Navakai WWTP have identified some areas of land immediately adjacent to the existing plant as future areas being required for upgrade. However, the iTaukei land that has been identified has been indicated by the landowners in the earlier consultation meeting that the area has been earmarked for village extension area (village reserve) and would like to relocate some of the Navoci and Namotomoto villagers to that area due to overcrowding and flooding in the village. This relocation is a concern for WAF as it is too close to the WWTP.
- She further discussed that the surrounding areas needed to be acquired by WAF mainly for sludge drying and stockpiling and it is preferred that this be close to the existing plant as transportation costs would be too expensive. She stated that little by little the areas that the JICA study team have identified for the growth of the plant is slowly diminishing due to development interest and therefore, WAF is trying to look for possible alternative options of land parcels to potentially relocate FRA and Ministry of Works depot sites and maybe NFA or for options of stockpiling treated sludge.
- She stated that the Lands Department recommended that the project team talk to AFL & CAAF to see if they had any spare land in close proximity that WAF could purchase or lease from them as further options.
- Eliki (AFL) stated that the only available land near Navakai was the Fiji Airports transmitter site next to Enamanu cemetery. However, he added that what was not visible on Vanua view was the fact that there are 12 antennas with 24-hour security surveillance with no entry permitted unless access is allowed. He said given these access restrictions, it would not be viable to have truckloads of sludge stockpiled on this site.
- Isireli (WAF) queried what the purpose of the high-level security was for and Eliki (AFL) stated that it was mainly for people and animals which can affect transmission signals.
- Jacqueline (PLANIT) asked if it was a possibility to dump stockpiles in the area to which Eliki replied that they would not agree to it.
- Eliki (AFL) further added that their VHF radios are also installed there and if anything were to happen there, planes would not be able to land in Nadi. He stated that that land is a very strategic asset for AFL. He mentioned that they have received so many interests/offers for the land (leasing/development) before but their position remains the same – to restrict access and use. He stated that it is the only parcel of land that AFL owns.
- Makiti (CAAF) stated that they also have vacant land in the area. Jacqueline asked about having restricted access issues, to which Makiti responded that there are a few accesses to the area so that may help. He discussed that there is a strip of land in the middle on the approach to the airstrip where critical infrastructure is and that, belongs to Fiji Airports where the approach lights are.
- Eliki (AFL) revealed that part of the land is in the process of being transferred to AFL and that discussions have been ongoing at ministerial level and is for the extension of the runway which is why CAAF acquired it in 1994.
- Jacqueline (PLANIT) asked if there were any restrictions on either side of the strip. Eliki (AFL) shared that they are currently trying to fence the approach lights and maybe considering a 20-meter buffer on either side. Despite this there is a lot of land around this around that could be considered for use.
- Makiti stated that CAAF is looking at developing the area where the plan is for CAAF to move their current location of offices to this vacant land closer to behind

Martintar Area. Jacqueline asked if there were issues with the height of stock piles, and CAAF said possibly but not as much as if the sludge would attract the presence of wildlife, which is one of the major issues at Nadi Airport that would result in CAAF reconsidering leasing the land to WAF.

- Jacqueline stated that WAF will be creating more ponds so the desludging will maybe happen once every three to five years and the sludge would need an area to dry so it could be that WAF dries it back where the plant is and then only transport it to CAAF land when needed or the people who need it for fertilizer will come and take it directly form the plant. Isireli (WAF) added that if there is no need for storage then there is no need for extra land but because there is no active sludge management plan in place at this stage, the space is needed for storage.
- Makiti (CAAF) questioned how long it would usually take for stockpile to be cleared by farmers or those in need of it. Jacqueline (PLANIT) responded that the consultants have spoken with fertilizer companies in Lautoka to see whether they would be interested to take it but the issue there is sludge content and parameters of the sludge will need to be confirmed. She added that at this time the sludge will probably sit there for a couple of years before it goes, especially depending on the content. Makiti asked how much land is WAF looking to acquire to which Jacquleine responded 21.28 hectares which is likely to come down if they can secure FRA and the extra area of land on the side.
- Makiti (CAAF) questioned with the current stockpiling are there any presence of wildlife or birds to which Isireli (WAF) responded not if it is dried well enough. Jacqueline discussed that the current Navakai treatment plant is currently over capacity and not treating the wastewater as well as WAF would like it to the standards and so once all the new treatment systems are in place it would be to the treat and discharge wastewater to World Health Standards. If they have enough drying area then it should dry a lot faster given the weather. Jacqueline added its mainly the ponds that attract the birds then the actual sludge itself. She stated that with the news system that the JICA study team are looking at they do no envisage the birds to be an issue if the system is running at 100 percent and at best rates.
- Jacqueline (PLANIT) stated that the native land area further in the back, off the Denarau By- Pass Road, is low lying area which floods and the landowners mentioned that they have a development lease over it, so WAF is running out of land options in close proximity.
- Eliki (AFL) shared that there was a vacant freehold land opposite of the CAAF freehold land on the corner of Wailoaloa Road and Denarau By Pass Road, and a title search should be conducted to liaise with the owner. He added that a compulsory acquisition be done as soon as possible and if it's for a public purpose which should not be too much of an issue - as they did for the Nadi Airport land.
- Makiti (CAAF) raised that judging from the amount of area required by WAF it is almost 60 percent of their total freehold area.
- Eliki (AFL) asked what the vision for WAF is for the next 20 years – will it still be there or relocated to another site. Jacqueline responded that because it's connected to all the existing development, to shut it down and relocate it is totally not viable since the network is already existing. She mentioned that the reason why its lower and closer to the foreshore is because of the force of gravity it has less cost and multiple pump stations are not needed to pump it all the way up to the highlands or rural back lands. Isireli (WAF) also added that new piping would also be needed and that would take too long.
- Jaqueline (PLANIT) stated that TLTB, Lands, and DTCP all have masterplans and Lands has identified all the area towards Wailoaloa, Enamanu and Navakai for future tourism and commercial purposes which will all need to be connected to Navakai WWTP. She added that if they cannot connect to a WWTP, the land developers will only develop 20 percent of the land in floor area for residential

and for Commercial C only 50 per cent. Developers will not be able to get maximum yield and/or will have to give up land for their own treatment facility.

- Jacqueline added that currently WAF is discharging into Nadi River but because of its overcapacity the standard of discharge is compromised. She stated that of equal importance to have wastewater you need water which is also an issue for WAF in Nadi where there is not enough water as well and WAF are trying to solve both issues whilst still allowing development, hence trying to secure land for the future.
- Jacqueline (PLANIT) stated that WAF can write and have further discussions on the CAAF land as an option and will also look into the freehold land suggested as well.
- Makiti (CAAF) stated that there would be restrictions to the land in terms of height and the wildlife issue as it is a critical space approaching the runway.
- Manil (AFL) stated that they currently have a masterplan and will be looking into the extension of the runway and a cargo facility in the future, so WAF needs to get in quick.
- Jacqueline (PLANIT) asked about the old WWTP near the runway to which Makiti mentioned that it had been decommissioned and waste from the planes were discharged there. Eliki (AFL) stated that the area is already earmarked for runway extension in their masterplan.

4. Actions from Meeting

- WAF to look into relocating FRA and Ministry of Works depot to the CAAF site or look at the possibility of the site for stock piling
- WAF to look into freehold land opposite CAAF land and conduct title search.

(12)

JICA/Water Authority of Fiji - Phase 2 Social Environmental Assessment for Western Wastewater Project - Priority Cities Nadi & Lautoka Pre-Feasibility
Consultation Meeting Attendance Register
AFL/CAAFi - 22nd July 2024

PLANIT

Name	Organisation/ Departments/Community	Position	Contact Details (mobile & email)
Manil Reddy	Fiji Airports	Senior PM - T	[redacted]
Elki. Vakadrau	✓	Estates Officer	
Lorina Filipe	CAAF	Legal officer	
Makiti Raratabu	✓✓	STANSI	
MOSESE RATUCUCU	✓✓	AI - RAUW	
Mushraan	Fiji Airports	Senior Drafting Tech	
Emily Smith	WAF		
Isireli Veitokiyaki	WAF		
Jackie Hughes	PLANIT		
Tewita King	P		
Aleksio Rabaka	✓		
Tabitha King	✓		

Project Name:	**JICA Nadi & Lautoka Master Plan**		
Place of Meeting:	Navoci Village Hall		
Meeting Date:	Monday, July 22nd 2024	**Meeting Time:** 11.00 AM	
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Jacqueline Hughes, PLANIT Pacific— Facilitator/Presenter
- Tevita King, PLANIT Pacific - Land & Resettlement Team
- Josaia Koroilavesau, Water Authority of Fiji
- Isireli Temo Veitokiyaki, Water Authority of Fiji
- Emily Smith, Water Authority of Fiji

Stakeholders

- Veceli Tuiweli, Nadi Town Council
- Meli Naevo, Nadi Town Council
- Antereh Abewuya, DO Nadi Office
- Nemani T, Ba Provincial Office
- Aisake Raratabu, DTCP
- Rachel Hoyt, Lands Department
- Lia Tuivuya, Lands Department
- Malakai Rayaqayaqa, EA iTLTB
- Milaele Koroivulaono, SEO iTLTB

Navoci Village members

- *Epeli S., Nakoyacake – Turaga ni Yavusa*
- *Viliame Vikoso, Nakoyacake - Turaga ni Yavusa Tukani*
- *Tomasi W. Nakoyacake - Turaga ni Yavusa*
- *Iliaseri Varo, Nakoyacake – Turaga ni Mataqali Naobeka*
- *Ovini Varoi, Natogo*
- *Tomasi Naulumatua, Nakoyacake, Natoutou*
- *Anare Naivatuov, Nakovacake, Navoci Secretary*
- *Lewavai Uluinadi, Nakovacake, Navoci Villager*
- *Navitatuai B., Nakovacake,Navoci Villager*
- *Kuini, Nakovacake, Navoci Villager*
- *Meredani. S, Nakovacake, Navoci Villager*
- *Merelesita Valu, Nakovacake, Navoci Villager*

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- *Vika. S, Nakovacake, Navoci Villager*
- *Mereisi N, Nakovacake, Navoci Villager*
- *Sakiasi Vonolagi, Nakovacake, Navoci Villager*

Item	Action
1. Introductions • The DO presented the project team's Sevusevu. • The Turaga ni Koro & Nemani from Ba Provincial office welcomed everyone and briefly introduced the project. He then handed it over to Jackie Hughes (Facilitator/Presenter) to present and inform the WAF development and land requirements	
2. Presentation by PLANIT • A PowerPoint presentation was done in the English language briefly explaining the project and to inform the landowners of land required by JICA & WAF. • Explanation of the reasons for the native land required • Responding to the villagers and stakeholder comments and issues through Q & A • Explaining next steps and indicative timeframes	
3. Discussion Session • A question was raised by a village leader on the village reserve land that is proposed to be used by WAF but which is to be noted as future village extension and relocation area – Jackie noted that the area being referred to and expressed concerns that the villagers will be moving closer to the sewerage treatment plant (STP) particularly, if they do relocate into that village extension area identified. • The village leader stated that this village extension area is needed not only for the relocation of their growing village population but also for future development for the Yavusa Nakayavucake. He asked why the treatment plant could not be moved to the interior as their land was prime land for development – Jackie mentioned that it would be very expensive to move the existing Navakai Treatment Plant in land and states that everyone is already connected to the existing Navakai Plant and whilst it would be a costly affair, it is just not practical and not that simple because those that are connected now cannot just simply be disconnected and reconnected, as WAF will have to build the new plant and then build the pipe networks to reconnect them all again, which makes upgrading the existing Plant the only feasible option. She also mentions that in the regional master plan, there are two other sites that have been identified to help cater for the additional load on the Navakai site	

and also those who are currently not on the network. These two new areas are in Sabeto and Moala, which are on either ends of Nadi Town.

- The village leader also questions about the waste that will be dried and left on the land, what will happen to it? – Jackie explains that after drying the spoil for a period, it will then be taken off site, hopefully by a company that may have use for it, like a fertilizer company. This all has to be identified and worked out, but for now that is why there is the additional area of land required adjacent to the site, to stock pile the sludge until WAF finds a use for it. If WAF is able to find a use for it, off site, then the area of land required for expansion will reduce significantly.
- A village member questions if this request has come through iTLTB and NLFC as they are the 2 arms of the government that come before the village level – Jackie mentions that the Nadi Town Council (NTC) has advised the JICA Study Team & WAF Project team to go through iTLTB which has been done, and iTLTB were supposed to confirm the areas within the identified land areas for acquisition, which ones have been issued with leases and so JICA & WAF can liaise NLFC for the balance areas (if within Native Reserve). But there will be more consultations so it can be made known to the landowners the status of the land as we get more detailed design information. The village members were advised that this was just an initial meeting to update the landowners of the project and the need for additional land and how this may affect native land, and that WAF's acquisition and projects team will come back for more consultation meetings with the landowners when they have firmed up the design options and land required for the future expansion.
- Jackie asked the question of relocation numbers and how many villagers from Namotomoto and Navoci villagers are likely to be relocated to the identified village extension area and when? – A village representative asked to the questions to be forwarded to NLC who can give exact numbers. The village secretary advised that there is a serious problem of overpopulation in the two village and not enough land space within the existing villages to cater for these numbers. It is mentioned that some homes house (ie. 3 families) have already relocated to the village extension area. Jackie mentioned that the WAF team will likely meet with Housing Authority to find out more information on their housing project in Waqadra for the Nadi area, and so it would be useful to know how many from the village may need housing. The village secretary mentions that they will try and get numbers and families affected and respond in writing to the team. The village secretary in addition to over-crowding in the villages, flooding and bursting of the river banks was also a concern requiring villages to move away from the river.
- Jackie informs the villagers that the JICA & WAF team are hoping to have talks with FRA and Ministry of Works on the potential relocation of their depots located adjacent to the site as well as have talks with NFA who also own a vacant property at the rear of the existing Navakai Treatment Plant site. This is mainly to maximize the space for development by WAF but also to look at including some buffer areas and landscaping areas where trees can be planted and bunds installed to help address some of the odour issues (in the event there is a problem with the Plant).
- A question was raised by a villager on whether or not the river is safe to fish from or use – Jackie informed those present at the meeting that currently, because the treatment plant is overloaded and working beyond its full capacity,

it is not able to treat the waste as effective and efficient as it is designed to do, so therefore, the discharged "treated" water is not to the standard it should be. This is the reason we need the expansion of the Plant. Therefore, if this development is successful and we are able to have more ponds, the treatment of the waste will be higher standard and the water going into the river will be of better quality that what is now. Nadi Town Council Health Department has raised this health concern with WAF and WAF continues to have on going water quality monitoring and hopefully the upgrade takes place soon.

- A question was asked if there will be more ponds built on the site and if WAF had looked at other treatment options. Jackie mentions that we will need more ponds built because this type of system works best for Fiji in terms of operational issues. Even though other options have been assessed and tried, like mechanized systems, these are very costly, requires trained technical maintenance team and availability of spare parts which is ongoing and hard to maintain.
- The village secretary mentions that the villagers are already relocating to the village extension areas – Jackie said that there will be a cut-off date, as to who will be considered as part of the relocation/resettlement if WAF decides to proceed with the upgrade, acquisition and relocation. So earlier and on-going consultation is key and important.
- A villager asked again the question of the relocation of the treatment plant as an option as the proposed site beside the existing WWTP is prime location for the village for relocation and future development that would generate income for the village, e.g using the river for River Saffari etc ; to which Jackie replied that it would be a costly affair and that everyone in Nadi is already connected to the current site, with piping works already in place, to relocate the plant, would not be feasible
- A villager raised a point that as a village, they do not have a lot of land to be able to give to WAF. They are already short of land and limited.
- Another villager asked if the land is given and the WWTP is upgraded, will the villages be connected also, to which Jackie informed them that that was WAF's intention to connect all the villages and the settlements nearby to the system and that is why the volume of the land is needed.
- A village member asked exactly how much area of land is needed, and Jackie responded approximately 21.28 Ha.
- Jackie asked about the land across the proposed additional area of native land to which she was advised that it had a 40-year development lease. Jackie also mentioned that they have been in talks with lands department for state leases but there are not many and it was a concern for WAF that Lands Department was also doing their Master Plan for all State lands earmarking the areas in Enamanu and Wailoaloa for Commercial and Tourism development which would also be required to connect to the Navakai Treatment Plant. Therefore, increase the demand and urgency for the upgrade.
- The secretary mentioned that WAF came to the village about a sewer line to be installed that would run through and between the native village extension land and the Ratu Navula School.
- The Yavusa Secretary asked if the ponds would be on Native land or State land, to which Jackie mentioned that most of the ponds would be on the State land while the Native land will be mainly used for the drying of sludge and

also buffer zones such as trees and bunds to help with screening some of the odour (if any).

- A villager and former employee of AFL, asked about the old sewerage treatment plant that was run by AFL and why they closed it and why WAF cannot just use that as the infrastructure is already exiting. Jackie noted that the team is having a meeting later on with AFL and CAAF and will raise it to them as well. However, Jackie mentioned that it is probably because the ponds attract birds and this would not be good within the airport and flight path zones.
- A village head complained about the foul smell that comes to the village and the 3 schools when the dry sludge gets wet in the rainy seasons and asked it to be taken care of; Jackie noted this and explains that it is likely to come from the ponds and this is mainly because the system is overloaded.
- The village secretary mentions that they will take in all the requests and issues that the JICA & WAF team have raised in this meeting and discuss with the villagers and respond in writing to the WAF team.
- The authorities present, iTLTB, DTCP, NTC, & Lands department, spoke on behalf of their offices and their future plans concerning this development and mentioned that it was really critical for the Navakai Treatment Plant expansion as all the development plans that the villagers or any other investors have for their land and properties in Nadi would be restricted and we would not be able to maximise returns on the development if Navakai does not have the capacity for them to connect to. They requested the landowners to really discuss carefully and asked if we can all work together to find a solution that will benefit all.

With no further questions from the villagers, the meeting was closed by the Assistant Roko.

4. Actions from Meeting

- WAF to follow up with on-going consultations with the Native landowners once the design is further detailed and firm up any future potential users of the treated sludge to reduce the expansion area required for the treatment and stockpile of the sludge
- WAF to include consultations with NLFC with regards to the native reserve land that may also be required and to discuss the operational impact to the native reserve land, particularly if it is to be used for residential purpose/relocation of villagers
- WAF to liaise with TLTB on the potential to acquire any development leases identified as part of the extension areas
- WAF to follow up with Department of Lands on any expiring state leases that WAF can acquire for potential relocation of FRA and Ministry of Works depot
- WAF to meet with Housing Authority to get an update on their Waqadra Housing development and also Ministry of Housing on resettlement options by Government

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JICA/Water Authority of Fiji - Phase 2 Social Environmental Assessment for
Western Wastewater Project - Priority Cities Nadi & Lautoka Pre-Feasibility
Consultation Meeting Attendance Register
Navoci Village - 22nd July 2024

PLANIT

Name	Organisation/ Departments/Community	Position	Contact Details (mobile & email)
1/ ~~Nottaigoto~~	~~Nakovacak~~ [illegible]		[redacted]
Epeli - Sunilumu	Nakovacake	T/ Noinaqa Gov	
Viliame . Nikoso	Nakovacake	T/Y - Tukani	
Tomasi Waqalevu	Nakovacake	T/Y - Botichakula	
Iliasera Varo	Nakovacake	T/M. Naobeka	
Avikash Abenaya	DO Nadi office	DO Nadi	
Newany. T	Ba Provincial office	Nakavaka (Rok	
Ovini Varo		Natogo	
Tomasi Naulumatua	Nakovacake	Navatonitoni	
Veceli. V. Tuiweli	NTC	Bldg. Inspector	
Meli Naevo	"	" "	
Anare Naivalavu	Nakovacake	Navoci/NTI secretary	
Lewavai Uluinadi	v/	Navoci Vill.	
Navitalai B	//	Navoci Village	
Kuini.	—	Navoci "	
Meredani . S.	—	N "	
Merelesita . Valu	Nakovacake.	Navoci	
Vika S.	Nakovacake	Navoci	
Mereisi N .	Nakovacake	Navoci	
Sakiasi Vonotagi	Nakovacake	Navoci	
Aisake Ravatabu	DTCP	Lautoka	
Rachel Hoyt	Lands Dept.	Lautoka.	
Emily Smith. U	WAF	Suva	

JICA/Water Authority of Fiji - Phase 2 Social Environmental Assessment for Western Wastewater Project - Priority Cities Nadi & Lautoka Pre-Feasibility

Consultation Meeting Attendance Register

Navoci Village - 22nd July 2024

PLANIT

Name	Organisation/ Departments/Community	Position	Contact Details (mobile & email)
Ima Tuwiuya	Lands	Dep Sec	[redacted]
Isireli Temo	WAF	SAP	
Josaia Koroilavesau	"	MAP	
Malakai Ravasakula	TLTB	EA	
Mikaele Korotu...	TLTB	SEO	
* JOSAIA KORO1	WAF	MIP	
Jackie Hughes	PLANIT	Social Consultant	
Tevita Kuku	PLANIT	—	

APPENDIX 7-10 Stakeholder Consultations (Draft Final Report Stage)

Project Name:	**JICA Nadi & Lautoka Master Plan**		
Place of Meeting:	Tanoa Waterfront Lautoka – Conference Room		
Meeting Date:	Thursday, August 1st 2024	**Meeting Time:**	10:00 AM
Prepared By:	PLANIT Pacific Pte Limited		

Attendees:

Project Team

- Seru Soderberg, Water Authority of Fiji
- Emily Smith, WAF
- Thomas Hughes, WAF
- Isireli Temo Veitokiyaki, WAF
- Akash Chandra, WAF
- Salesi Uluilakeba, WAF
- Kelereyani Luvu, WAF
- Lidia Rakacikaci, WAF
- Satoshi Wakasugi, JICA
- Yoshiyuki Choso, JICA (zoom)
- Yoko Kotegawa, JICA (zoom)
- Shinichi Wada, JICA (zoom)
- Yuriko Kudo, JICA
- Nila Prasad, JICA
- Yoshinobu Nakajima, JICA
- Kiyohiko Hayashi, JICA
- Jacqueline Hughes, PLANIT Pacific
- Tevita King, PLANIT Pacific
- Tabitha King, PLANIT Pacific

Stakeholders

- Jimi Taniela, FMF Foods Limited
- Thomas Magnus, Investment Fiji
- Nirmala Devi, Natabua Community Member
- Rama Devi, Natabua Advisory Council Member
- Rosi Lele, Natabua Community Member Advisory Council
- Ratu Sireli V, Natabua Community Member
- Amelia Bai, Taiperia Community Member
- Siteri Metuisela, Taiperia Community Member
- Savenaca Kaunisela, Taiperia Community Member
- Marica Vayaru, Taiperia Community Member
- Josefa Saumailagi, Department of Waterways
- Peter Watts, Vulani Island Limited
- Fantasha Lockington, Fiji Hotel & Tourism Association
- Dick Lockington, Qanville Landlord & Tenants Association

- Jone Tabakaucoro, Housing Authority
- Paul Forrest, Model Towns Charitable Trust
- Vilikesa Nuku, Telecom Fiji Limited
- Semi Ravuaceva, TFL
- Vikant Sharma, Energy Fiji Limited
- Prasheel Chand, EFL
- Lavenia R, Department of Town & Country Planning West
- Vilashni, DTCP West
- Rouhit Singh, Lautoka City Council
- Shameer Khan, LCC
- Shalendra Dass, LCC
- Mohamed Anees Khan, LCC
- Maikeli L, Civil Aviation Authority of Fiji
- Mosese Ratucicivi, CAAF
- Alitia Namua, Public Rental Board
- Mataiasi Tabanikau, Ministry of Health & Medical Services
- Isimeli Tuiteci, MOHMS
- Vinceta, Natabua Community Member
- Jone Bacau, Commissioners Office West
- Ms. Freeda Fremlin – Principal Project Planning and Policy Analyst, Ministry of Economy (zoom)
- Ms. Makereta Tuima – Senior Monitoring and Evaluation Officer, MoE (zoom)
- Mr. Steven Shivneshwar – Project Assistant, MoE (zoom)
- Uraia Rakaria, Lands Department
- Shaolin Lay, Nadi Town Council
- Veceli Tuweli, NTC
- Apisai Vulawalu, Ministry of Lands
- Sitiveni Tavaga, Commissioner Westerns Office
-

Item	Action
1. Introductions Jacqueline Hughes (PLANIT Pacific) welcomed and thanked the attendees for their presence briefly introduced the Wastewater Treatment Master Plan – Phase 2. She advised that the project team would then present the details of the project.	

2. Presentation by PLANIT

- A PowerPoint presentation was done in the English language explaining the Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase)
- Explanation of the Environmental and Social Considerations (ESC) Study for the Priority Project: Municipal Sewerage Plans for Lautoka and Nadi
- Responding to the stakeholder comments and issues through Q & A
- Explaining next steps and indicative timeframes

3. Discussion Session

- Mohammed Khan (Lautoka City Council) questioned whether WAF has already acquired land for the proposed master plan upgrade developments in Navakai and Natabua, to which Jacqueline Hughes (PLANIT Pacific) responded that WAF has already budgeted for this financial year to start the acquisition process. Seru Soderberg (Water Authority of Fiji) also mentioned they are trying to acquire land not just for these sites but the other sites in Vitogo, Sabeto and Moala.
- Fantasha Lockington (Fiji Hotels & Tourism Association) queried whether there were any considerations being given to reduce energy or greener energy options for keeping the wastewater treatment plants alive as Fiji is moving towards greener energy. Seru (WAF) stated that WAF have been looking into greener avenues to carry out the recommended works at the earliest stage as possible.
- Fantasha (FHTA) queried what was being done in relation to the illegally connected population that has been contributing to WAF's overcapacity and if any public announcements are being done to address the issue. Seru Soderberg (WAF) responded that public announcements will be taken on board in addition to smoke testing exercises to address the issue of illegal connections. He added that WAF has covered Suva City in the last financial year and discovered that 90% of all businesses are illegally connected to the sewer system which is one of the reasons the system is being overloaded due to flows that the system is not designed for. Once that reduction is addressed WAF has an opportunity to plan the infrastructure needed. Further, he mentioned that under the Trade Waste Policy, the proposed amendment to the Fees and Charges empowers WAF to go out and hold businesses who illegally dump chemicals into the system accountable.
- Fantasha (FHTA) also queried what was being done in the meantime to address overcapacity since the project timeframe is 9 years. Seru (WAF) stated that they are currently working towards the wastewater infrastructure from Denarau to Navakai treatment plant. WAF has done the tender and expect works to begin this financial year while there are also plans for expansions and upgrading for systems that connect to the main treatment plant. He stressed that the main target for WAF is to get rid of the illegal disconnections.
- Mohammed (LCC) representative elaborated that when building approvals are done, LCC and WAF vet the connections which is proof for them to legally connected. After the approval of plans or final certification, contractors cut corners and connect illegally which is why there is more coming out that is supposed to be like, stormwater and kitchen/shower water. He added that once they tackle the illegal connections, WAF will be able to address the capacity issue. Mohammed also shared that the Department of Town and Country Planning is currently undertaking a 50-year masterplan which should also be considered as it will open up land to development and also more loads for WAF to be required to take in the system.

- Isimeli Tuiteci (Ministry of Health & Medical Services) asked whether the land owners for the land that is required by WAF will be fairly compensated or substituted. He also queried what would happen if there is a mechanical or electrical fault and how it would be addressed. Jacqueline Hughes (PLANIT Pacific) responded that there will be ongoing negotiations and consultations with the landowners and affected persons who may or may not be required to be resettled or relocated and this will only be confirmed once the design of the plant is further detailed. As for the any electrical faults, as part of the design, the plants will be required to have backup generators that will kick in as soon as the power goes off from the mains.
- Veceli Tuiweli (Nadi Town Council) asked that in terms of native land around Navakai, if the landowners do not give their consent would that be the end of the project or will WAF acquire land through compulsory acquisition. Jacqueline (PLANIT) stated that WAF has also met with Civil Aviation Authority of Fiji (CAAF) and Airports Fiji Limited (AFL) earlier as recommended by Lands Department for the availability of other lands. Lands Department are also looking for alternative sites that may have expiring leases potentially for the sludge stockpiling after drying treatment. She stated that CAAF have indicated that they have a site that they could potentially sell though it is located in the flight path of the runway where the approach lights are, so will need to be looked at quite carefully. She added that it is not too far from the existing site and is a possible option to be explored if the landowners do not agree to give up their land.
- Peter Watts (Vulani Islands Limited) questioned the urgency of the project and mentioned that while driving past the treatment sites there is the unsavory smell of the plant. He queried if something could be done in a staged way to deal with the crisis before any land would be obtained, as well as if the pump stations would also be upgraded. Seru (WAF) responded to the odour issue stating that this financial year they are investing in non-infrastructure interventions to deal with the odour with more of a chemical approach to assist with controlling odour at the treatment plant. Seru added that in terms of the pump stations an upgrade is required since some of the pump stations have already surpassed their loading and as stated it will be done in stages, as and when developments occur. Peter also asked if the treatment plants will be upgraded themselves and if some chemical treatment be put in before land is bought. Seru reemphasized that the focus was on disconnecting all illegal connections which contributes to 60% of the wastewater in the treatment plants, and if WAF can achieve this they can get some of their capacity back. He added that the biggest hindrance at the moment was that they do not have the legal tools to implement disconnections. He stated that they can serve businesses and households notices for illegal connections but not much can be done after that. He mentioned that they currently have a Fees and Charges which is at the SG's office being formalized which is what they will use to enforce to deal with the challenges of illegal connections.
- Mataiasi Tabanikau (MOHMS – Nadi Rural Health Office) stated that the ecoli and fecal coliform numbers are way over WHO standards. He stressed the need to manage or mitigate the number of microorganisms that are entering Nadi River and that he is hopeful that WAF has something in place for the next financial year to manage the current situation on site before going onto the bigger plans. Mataiasi added that they have received a lot of concerns from the surrounding communities in regards to the water quality where most of the communities rely on the river as a livelihood as well. He stated that they have also received cases from the government hospitals of children as young as 5 years old who have waterborne infections and skin infections and is looking forward to WAF implementing this financial year something to manage that. He stated that injecting chemicals for control at the Plant will be good and he would like to see

further tests to show that these chemicals also do not end up in the waterways too, causing more social and community health concerns.

- LCC representative stated that equally important to add to the list of legislations is the Public Health Act as well as the Litter Decree, which gives powers for the Councils to look at the nuisance in terms of fining the public/businesses, to ensure that litter is not being dumped into waterways. He added that municipalities have their own sewerage bylaws which is in line with WAF's so those households illegally connecting to WAF's sewer line must follow regulations in which council's can monitor and enforce on behalf of WAF.
- Peter (Vulani Islands Ltd) queried if the treatment ponds on Denarau are incorporated in the new plans. Seru (WAF) elaborated that the wastewater pump station in Denarau is part of the planned upgrade works and WAF has already gone out to tender with potential contractors to undertake the work. Seru stated that the challenges they are working around with the Denarau is the infiltration and are looking at how best to address the infiltration that is affecting the pump station. He shared that just two days ago there was an incident with a wastewater treatment plant overflowing in the Marriot and upon investigating there were gravel and rocks which had gone into the system. The issue had been fixed 3 times in 12 hours where the same thing was discovered – rocks.
- Jone Tabakaucoro (Housing Authority) queried how the 60% of illegal connections will be factored into the upcoming developments. Seru (WAF) stated that with the increasing developments, the loading will be staged and will not be as much as when the development is complete. He remarked that removing the illegal connections and the infiltration is key because the loading of the plants now is more to do with infiltration rather than anything else. He shared that for most of the sites, those legally connecting, the combined loading does not hit the maximum treatment capacity of the plant and for most of the sites.
- Jacqueline (PLANIT) questioned if there would come a time in the next 5-6 years where WAF may say to developers that they cannot connect to Navakai. Seru (WAF) stated that it is a possibility if the infrastructure cannot meet the demand but that is also why the Water Sector Strategy 2050 has been developed. The Western region is looking to spend $161 million dollars within the next 6 years and between 2031-2050 about $1billion dollars. He stressed the need for all sectors to invest in wastewater infrastructure in the coming years to ensure it is able to keep in par with development.
- Rosi Lele (Natabua Advisory Councilor Member) expressed her concerns of the rate of development going through Natabua causing the plant to choke and lack space to expand the treatment plant in Natabua in the next few years.
- Veceli (NTC) followed up his earlier questioned that since the native land in Navakai is the most viable option for the extension of the treatment plant are there any options available to the landowners for compensation through land swap with state land. Jacqueline (PLANIT) stated that it is a possibility to be discussed with Lands Department who are currently doing their masterplan. Jacqueline directed the question to Apisai Vulawalu (Ministry of Lands) to facilitate the exchange. Apisai (MoL) stated that it is something that needs to be considered because of the national interest. He added that they are still awaiting approval of their landuse masterplan from DTCP but if there is a need, amendments can be made to the masterplan.

- Fantasha (FHTA) added that Fiji cannot grow or develop more especially in terms of diversifying the economy if there is no support for WAF to put in their water systems and improve wastewater management systems which needs to be prioritized.

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- Mohammed (LCC) shared in terms of the sludge storage that the Cabinet has approved a project for a westernized landfill that will cater for Sigatoka up to Rakiraki and will be located somewhere around Nadi and Lautoka. He stated that he has been told that 100 acres is being looked at. He offered that if land is not able to be acquired by WAF, there could be allocations for WAF to stockpile at the new landfill which could potentially be used for composting. He stated that UNDP is currently doing the feasibility study and have already visited the landfills in the West, and he recommends that WAF consult with UNDP and Ministry of Local Government on the options available.
- Peter (Vulani Islands Ltd) queried if there was an opportunity to harvest biogas. Jacqueline (PLANIT) stated that biogas was looked at as an option. Yoshinobu Nakajima (JICA) also stated that the preferred option was to outsource the generation of biogas to company or to the private sector to come and take and process it themselves.

4. Actions from Meeting

- WAF to share powerpoint presentation and stakeholder list and contact details for the benefit of stakeholders continued networking and exchanging of information. Further for influential stakeholders such as Fiji Hoteliers Association, major developers and the Councils and other Ministries, to lobby government/Ministry of Finance, to support WAF's budget in order to accelerate funding to reduce the timeframes of rolling out these two major infrastructure upgrade projects which will help benefit development and investment in both Nadi and Lautoka.
- WAF to consider putting in a submission to Lands Department requesting a land swap for the native land owners.
- WAF to continue to pursue sludge management plans and options, including talking to Ministry of Agriculture, Fiji Sugar and UNDP on the use of the treated sludge to reduce the area required for stockpiling of the treated sludge.

JICA/Water Authority of Fiji - Phase 2 Social Environmental Assessment for Western Wastewater Project
Priority Cities Nadi & Lautoka Pre-Feasibility
Stakeholder Consultation Meeting Attendance Register
Tanoa Waterfront Conference Room
10:00am, 1 August 2024

Name	Organisation/ Departments/Community	Position	Contact Details
Jimi Tamedo	FMF Foods Lt	GM Operation	[redacted]
Thomas Navuso	Investment Fiji	Regional Manager	[redacted]
Nirmala Devi	NATA BUA		[redacted]
RAMA DEVI	NATA BUA DAC		[redacted]
Rosi LELE	NATABUA COMMUNITY	SOCIAL WORKER	[redacted]
Amelia Bai	Taipena Community	ADC	[redacted]
SITERI METUISELA	TAIPERIA COMMUNITY	COMMUNITY SECT	[redacted]
Savenaca Kaunisela	Taipena Community	Community settle	[redacted]
Marica Vayaru	Taipena Community	Community sect	[redacted]
THOMAS HUGHES	WAF	Strategic Asset Plann	[redacted]
Sam Soderberg	WAF	Operations	[redacted]
Akash Chandra	WAF	Regional Asset Planne	[redacted]
Sailesi Uluiwaleba	WAF	NAVAKAI SEWERAGE	[redacted]
Satoshi Wakasugi	JICA Fiji	Resident Representa	[redacted]
JOSEFA SAUMAILAGI	DEPARTMENT OF WATERWAYS	TECHNICAL OFFICER - WEST	[redacted]
Peter Worth	Vulani Island Ltd	Director	[redacted]
Fantasha Lockington	FHTA (Hotel & Tourism Ass)	CEO	[redacted]
Dick Lockington	Qanville Landlords Tenants Ass (QLTA)	VP	[redacted]
Jone Tabakaucoro	Housing Authority (Nasese)	Engineer	[redacted]
Emily S. Vanicau	WAF		[redacted]
Isireli Veitokiyaki	WAF		[redacted]
Paul Forrest	MTCT	GM.	[redacted]

(22)

JICA/Water Authority of Fiji - Phase 2 Social Environmental Assessment for Western Wastewater Project
Priority Cities Nadi & Lautoka Pre-Feasibility
Stakeholder Consultation Meeting Attendance Register
Tanoa Waterfront Conference Room
10:00am, 1 August 2024

Name	Organisation/ Departments/Community	Position	Contact Details
Kelerayani Lawa	WAF	ENVIRONMENT OFFICER	[redacted]
VILIKESA · NUKU	TFL	TEAM LEADER	
Semi Rawaceva	✓	Planner.	
Vikant Sharma	EFL	Acting Team Leader	
Prashneel Chand	EFL	Good Electrical Engineer	
Lavenia R.	DTCP - West	STPA - West	
Vilashni D	DTCP - West.	STPA - West	
R. Sireli. V	Nadroga/Navosa	Environment	
Rohit Singh	LCC	Manager Health	
SHAMEER Khan	LCC	Team Leader AUD	
SHALENDRA DASS	L.C.C	ACTING DIRECTOR BUILDING ENGINEERING SER	
M. Anees Khan	LCC	CEO	
Ma'inda Laliqavoka	CAAF	Snr AD Insp	
MOSESE RATUVOU	CAAF	AI-VRAWN	
Alitia Namua	PRB	Housing & Estate officer	
MATAIASI T	MOHMS	EN. HEALTH Officers	
LIMELI T	/		
V NCETA	NATABUA		
Jone Bacani	Commissioner Western Office	DPO	
Makarete Tuima	M. O Finance (Zoom)	(National Planning	
Yoshiyuki Chosho	JICA (Zoom)	Expert Team	
Kuniko Kudo	JICA		
Unaisi Rakoria	Lands Department	DLMW	

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JICA/Water Authority of Fiji - Phase 2 Social Environmental Assessment for Western Wastewater Project
Priority Cities Nadi & Lautoka Pre-Feasibility
Stakeholder Consultation Meeting Attendance Register
Tanoa Waterfront Conference Room
10:00am, 1 August 2024

Name	Organisation/ Departments/Community	Position	Contact Details
Shaelin	Nadi Town Council	Health Inspector	[redacted]
Veseli, T	NTC	Bldg. Inspector	
Jacqueline Hughes	PLANIT Pacific	Social consultant	
Tevita Kite	✓ ✓	✓	
Tabitea Kite	✓ ✓	✓	
Apisai Vulawalu	Ministry of Lands	Assistant Director Lan	
Sitiveni Tavaga	Commissioner Westerns Office	District Officer Ltka	
LIDIA RAKACIKACI	WAF	T/O LTW	
Nila Prasad	JICA	Senior Program Officer	
Yoshinobu Nakajima	JICA Team		
Kiyohiko Hayashi	JICA Team		
Freeda Franklin	Ministry of Finance	Principal Project P	
Steven Shivneshwar	✓	Project Assis	
Shinichi Wada	JICA Expert Team		
Yoko Kotegawa	JICA Expert Team		

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APPENDIX 8-1 Cash Flow

(1) FIRR: Cash Flow

Year	Expenditure Without Project	Capital Expenditure Total	O&M Expenditure Total	Incremental Expenditure Total	Incremental Income Total	Incremental Cash Flow for FIRR
2028	7,061	90,256	0	83,194	229	(82,966)
2029	7,061	136,673	0	129,611	229	(129,383)
2030	7,061	120,137	0	113,076	229	(112,847)
2031	7,061	120,137	0	113,076	229	(112,847)
2032	7,061	120,137	0	113,076	229	(112,847)
2033	7,061	150,174	3,773	146,885	263	(146,623)
2034	7,061	150,174	4,924	148,037	271	(147,765)
2035	7,061	150,174	6,395	149,507	497	(149,010)
2036	7,061	150,174	6,395	149,507	396	(149,111)
2037	7,061	0	10,076	3,015	1,702	(1,313)
2038	7,061	0	10,534	3,473	2,197	(1,941)
2039	7,061	0	11,784	4,723	2,723	(2,850)
2040	7,061	0	12,635	5,574	2,685	(2,888)
2041	7,061	0	12,635	5,574	2,539	(3,034)
2042	7,061	0	12,635	5,574	2,539	(3,034)
2043	7,061	0	12,635	5,574	2,539	(3,034)
2044	7,061	0	12,635	5,574	2,539	(3,034)
2045	7,061	0	12,635	5,574	2,539	(3,034)
2046	7,061	0	12,635	5,574	2,539	(3,034)
2047	7,061	0	12,635	5,574	2,539	(3,034)
2048	7,061	0	12,635	5,574	2,539	(3,034)
2049	7,061	0	12,635	5,574	2,539	(3,034)
2050	7,061	0	12,635	5,574	2,539	(3,034)
2051	7,061	0	12,635	5,574	2,539	(3,034)
2052	7,061	0	12,635	5,574	2,539	(3,034)
2053	7,061	(681,024)	12,635	(675,451)	2,539	677,990
					FIRR=	-2.8%

Source: JET

(2) EIRR: Cash Flow

Year	Cost Without Project	Capital Cost Total	O&M Cost Total	Incremental Cost Total	Incremental Benefit Total	Incremental Cash Flow for EIRR
2028	7,061	83,125	0	76,063	229	(75,835)
2029	7,061	83,125	0	76,063	4,727	(71,336)
2030	7,061	107,426	0	100,365	9,226	(91,139)
2031	7,061	107,426	0	100,365	13,725	(86,641)
2032	7,061	107,426	0	100,365	18,223	(82,142)
2033	7,061	132,133	3,617	128,688	25,958	(102,730)
2034	7,061	132,133	4,720	129,791	34,576	(95,215)
2035	7,061	132,133	6,130	131,201	47,208	(83,994)
2036	7,061	132,133	6,130	131,201	51,605	(79,596)
2037	7,061	0	9,659	2,598	60,610	58,012
2038	7,061	0	10,098	3,036	77,417	74,380
2039	7,061	0	11,296	4,235	97,620	93,385
2040	7,061	0	12,111	5,050	114,615	109,565
2041	7,061	0	12,111	5,050	118,967	113,917
2042	7,061	0	12,111	5,050	123,466	118,416
2043	7,061	0	12,111	5,050	127,964	122,914
2044	7,061	0	12,111	5,050	132,463	127,413
2045	7,061	0	12,111	5,050	136,962	131,911
2046	7,061	0	12,111	5,050	141,460	136,410
2047	7,061	0	12,111	5,050	145,959	140,909
2048	7,061	0	12,111	5,050	150,457	145,407
2049	7,061	0	12,111	5,050	150,457	145,407
2050	7,061	0	12,111	5,050	150,457	145,407
2051	7,061	0	12,111	5,050	150,457	145,407
2052	7,061	0	12,111	5,050	150,457	145,407
2053	7,061	(577,632)	12,111	(572,582)	150,457	723,040
					EIRR=	9.0%

Source: JET

APPENDIX 8-2 Results of the Households Survey

JET conducted a household interview survey on water supply and sanitation in March 2024. Interviews were conducted with 200 residents from each of the target cities of Nadi and Lautoka, for a total of 400 people who responded directly to questionnaires (the interview questionnaire is included in the end of this Appendix).

(1) Respondent Characteristics

The number of persons per household and the average and median income of the respondents are shown in **Table A8-2.1** below. Respondents were cooks, taxi drivers, office workers, agricultural workers, shop clerks, hotel workers, and many other occupations. Comparing respondents' household incomes, the median was the same in both Nadi and Lautoka at 1,000 FJD/month, but the average income in Nadi was 45% higher than in Lautoka. The average household size in both cities was 5 persons, the average income was 1,880 FJD/month and the annual income was 22,550 FJD/year.

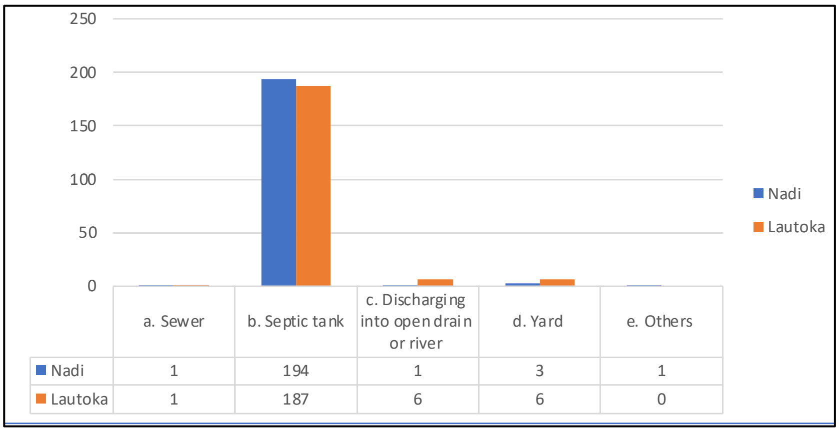
Table A8-2.1 Number of Persons per Household and Average and Median Household Income

Item	Nadi	Lautoka	Both Cities
Number of people in the household	5.3	4.7	5.0
Household income per month (FJD) Mean	2,202	1,522	1,879
Household income per month (FJD) Median	1,000	1,000	1,000

Source: JET

(2) Sewer Connection Status

The house connection status of the surveyed households is shown in **Figure A8-2.1** below. In both cities, 95% of households use septic tanks for wastewater treatment, while 4% of households discharge untreated wastewater into rivers or gardens.

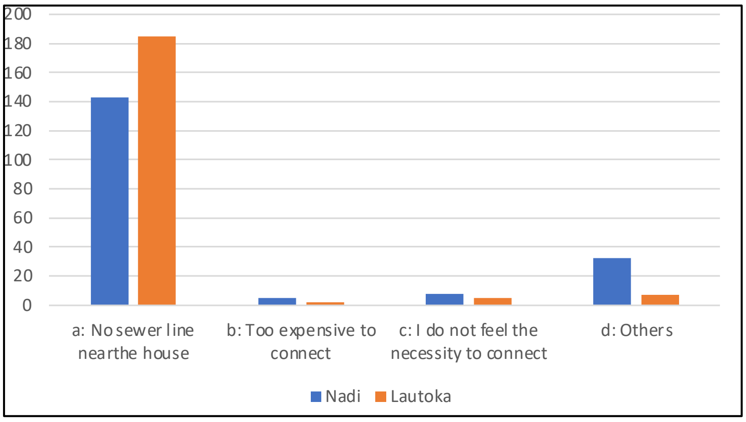


Source: JET

Figure A8-2.1 Sewer Connection Status

There was one connected household in Nadi and one in Lautoka. Both households wanted the sewerage system to be improved, but did not want to incur additional costs for the improvement. There was also no response regarding the current level of sewerage payments.

The majority of unconnected households cited the lack of sewerage network in their area as the reason (**Figure A8-2.2**). In Nadi, over 10% of respondents were unconnected, and other reasons included using self-treatment facilities due to the lack of sewerage facilities in their area.



Source: JET

Figure A8-2.2 Reasons for not being connected

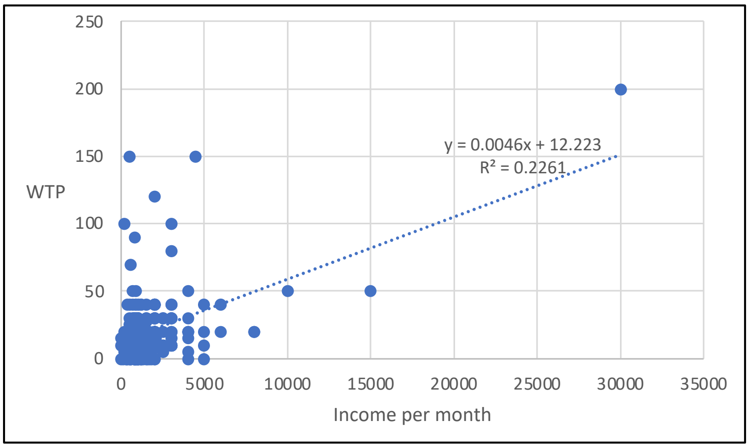
(3) Willingness to pay for sewerage services

Table A8-2.2 shows the willingness/month and income/month for households in Nadi and Lautoka. Both the mean and median willingness to pay are high in Nadi. There is a rough correlation between willingness to pay and household income.

Table A8-2.2: Willingness to Pay and Mean and Median Household Income (FJD)

Item	Nadi	Lautoka	Both Cities
Willing to Pay: Mean	25	16	21
Willing to Pay: Median	20	15	15

Source: JET



Source: JET

Figure A8-2.3 Relation Between Household Income and Willingness to Pay

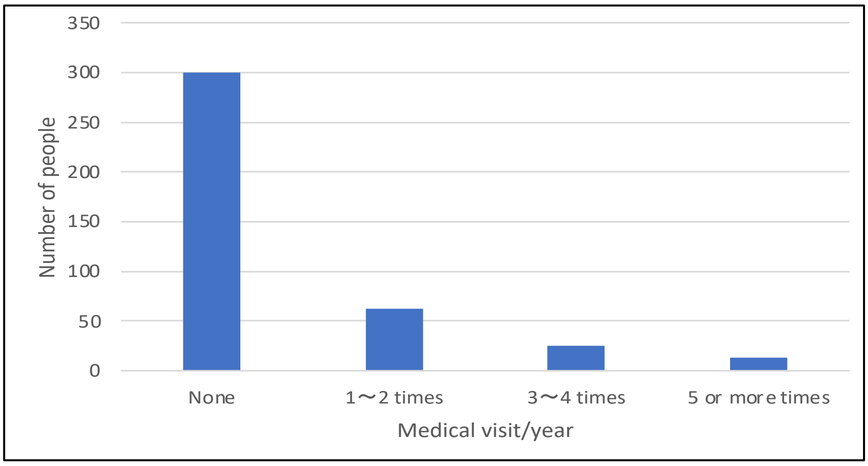
(4) Treatment for Inadequate Water Sanitation

Table A8-2.3 below shows the number of people treated per year, the average cost per treatment, the average number of treatments, and the average treatment cost in both cities for diseases caused by inadequate water sanitation (diarrhea, dysentery, typhoid, cholera). In this survey, all responses indicated that the cause of the illness was diarrhea. The average cost per treatment was 49 FJD. Of the total 400 people treated in both cities, 300 did not receive treatment even once a year (**Figure A8-2.4**). About 10% were treated three or more times per year.

Table A8-2.3 Number of people treated per year, average cost per treatment, average number of treatments/year, average treatment cost/year (FJD)

Item	Nadi	Lautoka	Both Cities
Number of person to medical visit	65	35	100
Average expense per treatment (FJD)	52	41	49
Average medical visit to the doctor/year	1.0	0.4	0.7
Average cost for treatment (FJD) /year	16	5.9	11.0

Source: JET



Source: JET

Figure A8-2.4 Histogram of Number of Diarrhea Treatments/ Year for Surveyed Residents in Both Cities

(5) Impact of Water Quality Protection on Public Water Body

The impacts of pollution caused by underdeveloped sewerage systems were presented as coastal pollution, foul odors, garbage, and a decrease in tourism. Next, respondents were asked about their willingness to pay for water quality protection measures implemented through the sewerage project for Nadi and Lautoka area.

To estimate willingness to pay for protection of public water body, Contingent Valuation Method (CVM) was applied, which allows for the valuation of non-use values of the environment. This is a stated choice method that directly asks people how much they are willing to pay and how much compensation they will accept for environmental changes.

The questions were presented in a double-bounded format, with two-branch willingness-to-pay choices presented twice. The averages and medians obtained through statistical processing are shown in **Table A8-2.4.**

Both the average and median willingness to pay for households in Nadi are higher than in Lautoka. As with the willingness to pay for sewerage, this may be due to the difference in average income between the two cities.

Table A8-2.4 Mean and Median Willingness to Pay by CVM

Item	Nadi	Lautoka	Both Municipalities
Willing to Pay: Mean	76	53	65
Willing to Pay: Median	38	18	27

Source: JET

(6) Water Supply

In this interview survey, we also asked questions related to water supply. The results are shown below. In the above survey, 30% of the respondents think that the current water tariff is high. In addition, 30% think that the water is not safe to drink and buy bottled water.

Table A8-2.5 Water Supply Responses

Item	Nadi	Lautoka	Both Cities
Usage cost for public water /month (FJD)			
Mean	47	35	41
Median	30	30	30
Evaluation for cost of public water supply			
Expensive	55	68	123
Normal	105	113	218
Cheap	40	19	59
Number of non-public water user	4	0	4
Average cost for non-public water /month (FJD)	26	-	26
Presence of private water vendor for tank water	29	10	39
Cost per water tank (18 litter, FJD): Median	20	20	20
Do you buy any bottled water? Yes	147	112	259
No	53	88	141
Reason: Water is contaminated. Not safe for drinking	70	49	119
Bottled water (500cc) consumed /day			
Mean	6	3	5
Median	4	2	3

Source: JET

(7) Cost of Electricity and Communication

In the same survey, we also asked questions related to electricity and communication costs. The results are shown in **Table A8-2.6.**

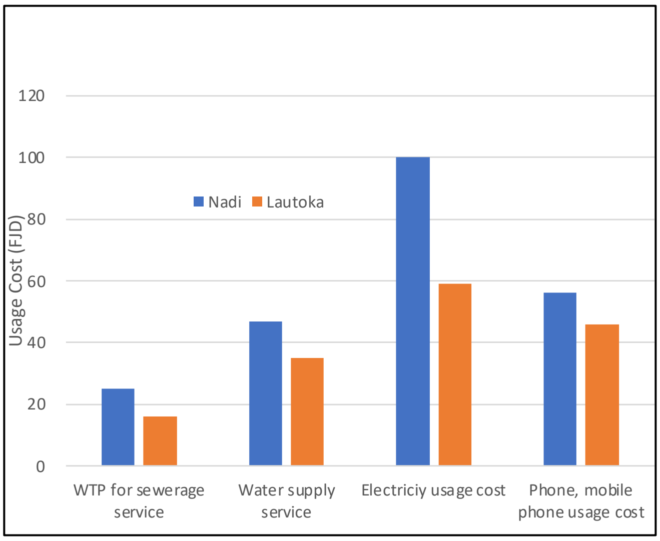
Table A8-2.6 Average cost of electricity and communication (FJD/month)

Item	Nadi	Lautoka	Both Cities
Electricity usage cost /month (FJD) Mean	100	59	79
Phone, mobile phone cost /month (FJD) Mean	56	46	51

Source: JET

(8) Comparison of Willingness to Pay for Sewerage, Water, Electricity and Communication Costs

A comparison of willingness to pay for sanitation, water, electricity and communication costs (per FJD/month) is shown in **Figure A8-2.5**. Communication costs are the highest, about twice as high as water. On the other hand, willingness to pay for sewerage is the lowest, at half the cost of drinking water. Compared to other living expenses, willingness to pay for sewer connection fees is relatively low.



Source: JET

Figure A8-2.5: Willingness to Pay for Sewerage, Clean Water Consumption, Electricity Consumption and Communication Costs (FJD/month)

APPENDIX 9-1 Results of Sewerage Sludge Analysis

		Zinc (mg/kg)	Copper (mg/kg)	Arsenic (mg/kg)	Lead (mg/kg)	Chromium (mg/kg)	Cadmium (mg/kg)	Molybden (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)
Sludge Sample	Navakai	1300	750	9	400	160	2	17	< 0.5	28	4
	Natabua	310	135	22	13	93	< 1	< 5	< 0.5	37	1
Existing Guidelines	EPA *1	250	200	20	200		3		1	60	
	WHO *2			8	84		4		7	107	6
	AWA *3 (Grade C1)	200-250	100-200	20	150-300	100-400	1		1	60	3
	AWA *3 (Grade C2)	2500	2500	60	420	500-3000	20		15	270	50
	US EPA Land Application CCL*4	7500	4300	75	840	3000	85	75	57	420	100
	US EPA Land Application PCL*4	2800	1500	41	300	1200	39	―	17	420	100
	US EPA Surface Disposal *5	―	―	30	―	200	―	―	―	210	―
	EU Land Application *6	2500-4000	1000-1750		750-1200	―	20-40	―	16-25	300-400	―
	Japan Fertilizer Application *7	―	―	50	100	500	5	―	2	300	―

*1: EPA guidelines, Environment Protection Authority, Department of Environment and Natural Resources, ADELAIDE, October 1996 updated June 1997.

*2: WHO guidelines for the safe use of wastewater, excreta and greywater 2006. Maximum tolerable soil concentrations of various toxic chemicals based on human health protection.

*3: Guidelines for Sewerage Systems Biosolids Management, November 2004. Guideline Biosolids Contaminant Grade Values

"*4 US EPA, Land application

CCL＝Ceiling Concentration limits, Max allowable concentration of pollutant in sewerage sludge applied to land Sewerage sludge exceeds, cannot apply to land

PCL= Pollutant concentration limit Most stringent pollutant limit, ensure minimum quality of sewerage that can be applied on long-term basis"

*5: US EPA, Surface Disposal Unit boundary to property line 0 m ~ less than 25 m, https://www.ecfr.gov/current/title-40/chapter-I/subchapter-O/part-503

APPENDIX 10-1 Minutes of Meeting on JCC

(1) Final JCC on August 6th, 2024

Minutes of Meetings
on
The Fifth 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 Final 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 6th August 2024 by the chairperson of the JCC and others.
As a result of the discussions, both sides understood and agreed upon on the matters referred to in the document attached hereto.

Suva, August 6th, 2024

Mr. Paula BALEILEVUKA
Permanent Secretary
Ministry of Public Works,
Meteorological Services and Transport

Mr. Seru SODERBERG
Chief Operating Officer
Water Authority of Fiji

若杉 聡

Mr. Satoshi WAKASUGI
Resident Representative
JICA Fiji Office

中嶋 宜信

Mr. Yoshinobu NAKAJIMA
Team Leader
JICA Expert Team

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ATTACHED DOCUMENTS

1. Selection of the Priority Projects for Pre-F/S
The JICA Expert Team (hereinafter referred to as "JET") presented three case options for the Pre-F/S target projects.

Case	Target Area	Project Components
Case-1	Natabua	Upgrading of Natabua WWTP, ocean outfall pipe, septage treatment facilities, expansion of sewer networks and construction of pumping stations
Case-2	Navakai	Upgrading of Navakai WWTP, rehabilitation of main trunk, expansion of sewer networks and construction of pumping stations
Case-3	Natabua	Upgrading of Natabua WWTP, Ocean outfall pipe, Septage treatment facilities
	Navakai	Upgrading of Navakai WWTP

JET proposed to select Case-3 due to its high priority in terms of efficiency (cost per pollutant load removal), as well as meeting legal compliance for effluent quality. JCC had no objections to it.

2. Planning Basis and Design Conditions
JET explained that the design flow in Phase 1 is 29,600m³/day for Natabua WWTP (75% of the total treatment capacity), and 19,700m³/day for Navakai WWTP (66% of the total treatment capacity). JCC had no objections to it.

3. Natabua WWTP
JET presented the completed view layout of Natabua WWTP and explained the hydraulic loads, basin numbers and shapes of its main facilities. JCC had no objections to it.

4. Navakai WWTP
JET explained the completed layout view and alternative layout view (relocation of existing WAF and FRA depots) of Navakai WWTP, and explained the hydraulic loads, basin numbers and shapes of its main facilities. JET also explained the mechanical and electrical facilities (including odor control facilities) planned to be adopted in the WWTP. JCC had no objections to it.

5. Environmental and Social Considerations
JET summarized the key environmental and social effects of the WWTPs as follows:

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[Natabua WWTP]
WWTP site expansions will require much mangrove removal; associated regulations were checked for potential methods to mitigate environmental impacts. The resettlement of a nearby informal settlement was concluded as inevitable, and considerations should relocation sites/alternative livelihoods due to poverty level of residents.

[Navakai WWTP]
Discharge of treated water to Nadi River is a concern for riverside communities due to possible impacts on livelihoods and coastal mangroves. ITaukei lands close to WWTP must be secured for sludge drying/storage space. The consideration of land availability will need to continue to be given careful attention for expansion of Navakai WWTP. JCC had no objections to it.

6. Implementation Schedule
JET explained the implementation schedule of the upgrading projects of Navakai WWTP and Natabua WWTP. The upgraded facilities are planned to start operation in 2033 for Navakai WWTP, and 2037 for Natabua WWTP. JCC had no objections to it.

7. Cost Estimation
JET explained the setting conditions for project cost estimations. The estimated construction cost was 232 million FJ$ for Natabua WWTP, and 133 million FJ$ for Navakai WWTP. JET also presented the estimated amounts of loan portion and Fijian portion (government overhead) when applying international funds. JCC had no objection to it.

8. Project Effect
JET first explained the target values for project effect indicators, such as effluent quality and daily average flowrate for Natabua WWTP and Navakai WWTP. JET indicated that the financial IRR is -2.8% at the current tariff of 0.20FJ$/$m^3$, and that 0.70FJ$/m^3 is necessary to cover the O&M expenses. For the economical IRR, JET indicated EIRR is 9.0% in the Pre-F/S stage considering additional benefit of maintaining tourism income through environmental protection. JCC had no objections to it.

9. Conclusion and Recommendation
In conclusion, JET explained the following four items.
- ✓ This priority project will properly treat wastewater and contribute to meet compliance for effluent standard
- ✓ Priority project is economically viable

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- ✓ Projects are in line with Fiji's National Development Plan
- ✓ Project impacts will be sustainable through securement of O&M budget and structure

For recommendation, JET explained the following seven items.

- ✓ Consultation for secure the WWTP site
- ✓ Formulation of the effective sludge utilization and disposal plan
- ✓ Water quality impacts on the discharge ocean area in the Feasibility Study
- ✓ Additional soil surveys during the Feasibility Study
- ✓ Septage treatment for regions outside of the planned service area
- ✓ Secure the O&M Budget
- ✓ Organizational Structure on O&M

10. Other Items Discussed

- ✓ The MoF's update of the National Development Plan is close to cabinet approval, with the target year set at 2049. The revised NDP's chapter for the wastewater sector is referring to the Master Plan by this project
- ✓ The launch of the Master Plans formulated in this project is proposed by JICA.
- ✓ WAF mentioned that it will be difficult to achieve 70% access by 2036 as the existing coverage is in the 20% range.
- ✓ WAF asked about the possibility of JICA co-financing with other donors for the WWTP upgrading project, and JICA explained that Climate Change Center to facilitate GCF access is going on.
- ✓ As part of efforts to reduce sludge disposal, WAF is in discussions to use dried sludge as a fertilizer. Direct application is currently not recommended by the DOE due to the high iron content in the sludge. A Memorandum of Understanding (MOU) is currently being drafted with the Ministry of Agriculture for future works.

ANNEX 1: Presentation material for Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase), August 6th, 2024, JICA Expert Team

ANNEX 1

Project for Formulation of Wastewater Treatment Master Plan in Western Division (2nd Phase)

Joint Coordination Committee (Final)

6th August 2024

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Nihon Suido Consultants Co., Ltd.
Yachiyo Engineering Co., Ltd.

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2. Opening remarks form WAF
3. Opening remarks form JICA Fiji Office
4. Background and Previous Outcomes
5. Summary of the Pre-F/S
6. Discussion/ Q&A
7. Closing Remarks

Main Purpose of 5th JCC
To get basic approval above item 5

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1. Welcome and Introduction

2. Opening remark from WAF

Mr. Seru Soderberg — Chief Operating Officer, Water Authority of Fiji

3. Opening remark from JICA Fiji Office

Mr. Wakasugi Satoshi — Resident representative, JICA Fiji Office

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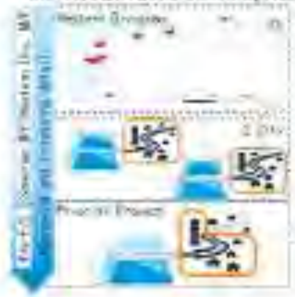
4. Background and Previous Outcomes

1. Background and introduction
✓ Strategic improvement of the sewerage infrastructure in the Western Division is requested



- Regional Wastewater M/P in whole Western Division
- Municipal Sewerage M/P for Priority Cities
- Pre-F/S for the Priority Projects

4

ANNEX 1

4. Background and Previous Outcomes

2. Target Area

5

4. Background and Previous Outcomes

3. Outline of the Project

Output 1	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 4 Capacity on sewerage management of WAF and relevant agencies will be strengthened
Output 2	Municipal Sewerage M/P in priority cities and/or towns identified in the Regional Wastewater M/P will be formulated. (2 cities)	
Output 3	Pre-F/S including sludge management for priority sewerage project(s) selected in the Municipal Sewerage M/P will be conducted	

Overall objective
- Encourage treatment capacity improvement and facility expansion
- Contribute to improvement of sanitation and water environment

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4. Background and Previous Outcomes

4. Project Phasing

	Main Contents	2021	2022			2023				2024			
		1st Year				2nd Year				3rd Year			
		1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Output 1	Regional Wastewater M/P												
Output 2	Municipal Sewerage M/P												
Output 3	Pre-F/S												
Output 4	Capacity Development on sewerage management												
Report													

Phase 1　Phase 2

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4. Background and Previous Outcomes

Summary of the 1st Year: Regional Wastewater M/P

- ✓ Wastewater Treatment Master Plan to achieve the National Development Plan (NDP) of "70% population of centralized treatment access in 2036"
- ✓ Targeting six municipalities in the Western Division (Lautoka, Nadi, Ba, Tavua, Rakiraki and Sigatoka)
- ✓ Setting sewerage area to achieve 70% access for the future projected population in 2036 (266,000/380,000 persons)
- ✓ Set priorities for sewerage system development
- ✓ Alternatives to achieve 70%, including decentralized treatment of septic tank sludge
- ✓ Minute of Meetings on 3rd JCC on September 19th 2022

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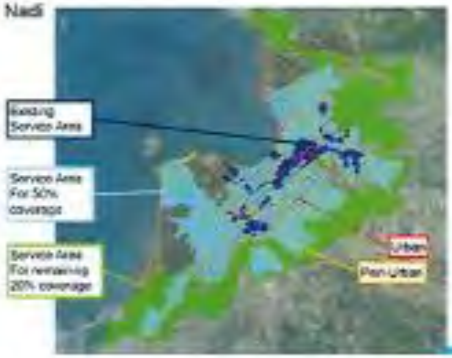
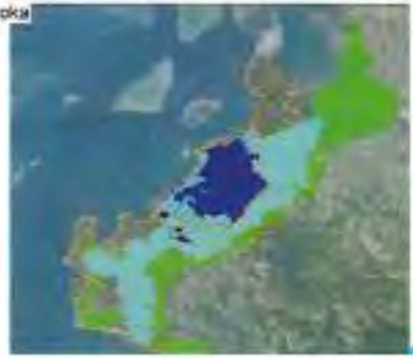
ANNEX 1

Future Sewerage Service Area



9

Future Sewerage Service Area



10

Future Sewerage Service Area

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Prioritization for Sewerage System Development

Result of Prioritization

By Analytical Hierarchy Method (AHP)

	Nadi	Lautoka	Ba	Tavua	Rakiraki	Sigatoka
Total Score	76.6	84.7	44.8	38.5	43.6	43.2
Priority	2	1	3	6	4	5

Criteria	Rating		Sub Criteria	Rating	Point
Population	[illegible]	1	[illegible]	[illegible]	[illegible]
		2	Population density	[illegible]	[illegible]
Sanitation	[illegible]	3	[illegible]	1.00	[illegible]
Urban Development	[illegible]	4	No. of hotels	[illegible]	[illegible]
		5	[illegible]	[illegible]	[illegible]
Water Environment	[illegible]	7	[illegible]	[illegible]	[illegible]
		8	[illegible]	[illegible]	[illegible]

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ANNEX 1

Alternatives to Achieve 70% in 2036

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Summary
Status in 2036

Access ratio for centralized system: 34%
Safely managed sanitation services: 70%

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Summary
Status in 2053

Access ratio for centralized system: 70%
Safely managed sanitation services: 90%

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4. Background and Previous Outcomes

Summary of the 2nd Year: Municipal Sewerage M/P

- ✓ 20-year master plan to define major sewerage facilities with a target year of 2043
- ✓ Lautoka and Nadi as target cities
- ✓ Sewerage service area divided into 5 (Vitogo, Natabua, Sabeto, Navakai and Moala)
- ✓ Determination of wastewater treatment process
- ✓ Centralized treatment of septage at Natabua WWTP
- ✓ Consideration of biogas generation from sewage sludge
- ✓ Minute of Meetings on 4th JCC on September 19th 2023

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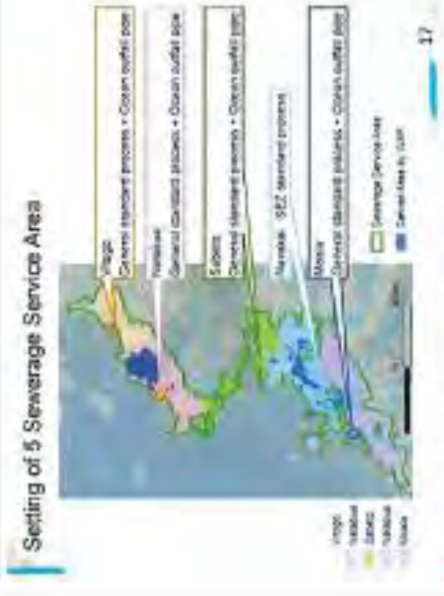
ANNEX 1


Setting of 5 Sewerage Service Area
Vitogo
General standard process + Ocean outfall pipe
Natabua
General standard process + Ocean outfall pipe
Sabeto
General standard process + Ocean outfall pipe
Nawaka : SEZ standard process
Moala
General standard process + Ocean outfall pipe
Sewerage Service Area
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Assessment of Treatment Process
Summary of Treatment Process by each service area
Lautoka
Vitogo
Trickling Filter + ocean outfall
General
Natabua
Trickling Filter + ocean outfall
General
Nadi
Sabeto
Trickling Filter + ocean outfall
General
Nawaka
SEZ
Moala
Trickling Filter + ocean outfall
General
Trickling Filter
Oxidation Ditch
18


Layout of Vitogo Sewerage System
Vitogo (Lautoka)
Vitogo WWTP
Service Area
Pumping Stations
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Layout of Vitogo WWTP
Vitogo (Lautoka)
20

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ANNEX 1


Layout of Natabua Sewerage System
Natabua (Lautoka)
Natabua WWTP
Service Area
Existing Service Area
21


Layout of Natabua WWTP
22


Layout of Sabeto Sewerage System
Sabeto (Nadi)
Sabeto WWTP
Service Area
Pumping Stations
23


Layout of Sabeto WWTP

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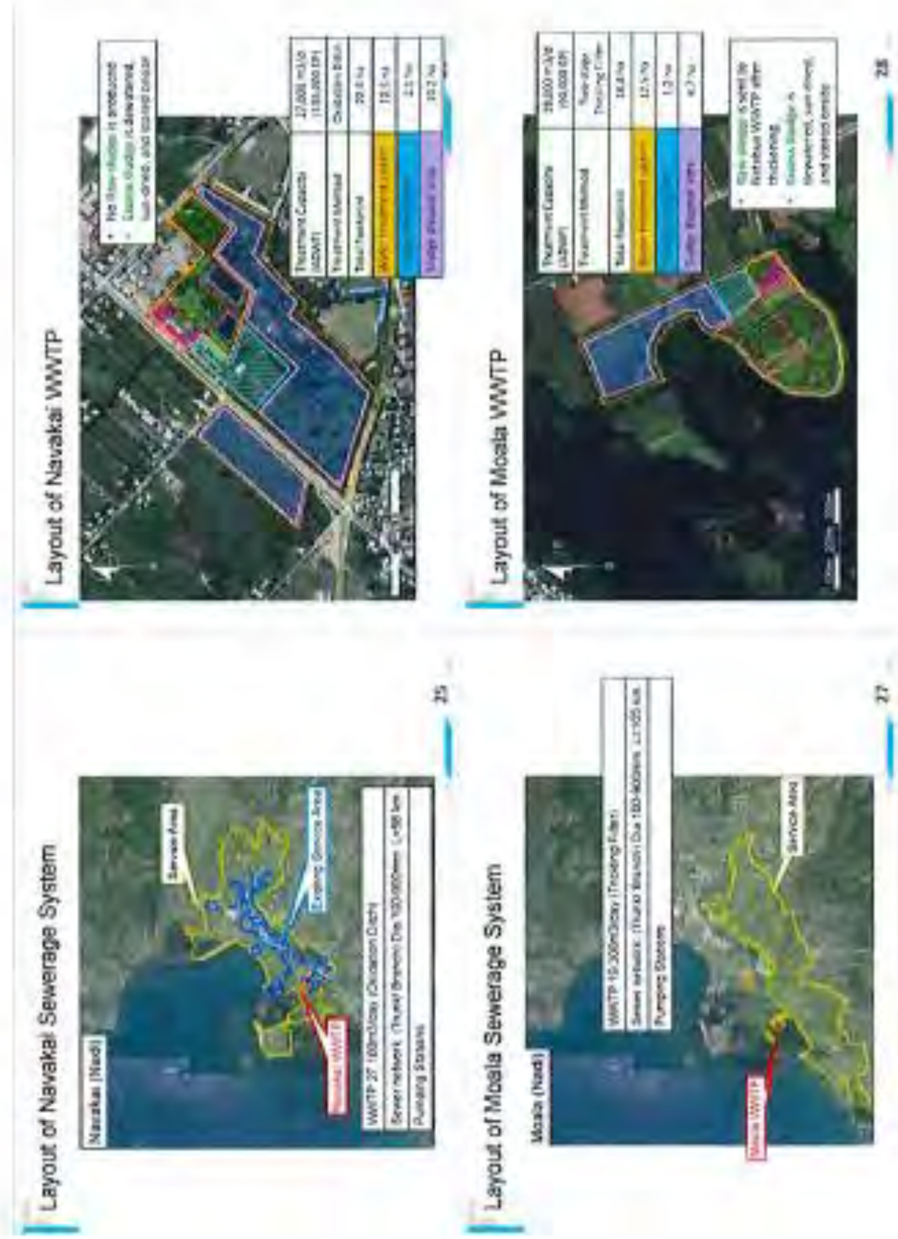
ANNEX 1


Layout of Navakai Sewerage System
Layout of Navakai WWTP
Layout of Moala Sewerage System
Layout of Moala WWTP

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ANNEX 1

Decentralized System

Option Service Assessment

✓ 2 cases are considered to evaluate the efficiency of Septage Treatment

Case 1	Case 2
Centralized STP at Natabua	Decentralized STP at Viligo & Moala

STP: Septage Treatment Plant

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Centralized System

Sludge Reuse

Outline of Process Flow (Natabua: Trickling Filter)

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4. Background and Previous Outcomes

Summary of the Capacity Strengthening

- ✓ 9 Online trainings with the cooperation of Fukuoka City.
- ✓ As part of OJT, an On-site lecture was given on how to conduct a Transparency test at the Navakai WWTP.
- ✓ Japan Visit Program provided the knowledge and information on sewerage works with participants (MPW, WAF, MOF, DOE and MoLG)

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WEB Trainings by Fukuoka City

✓ 9 Online Trainings with assistance from Fukuoka City

	Training Program	Date
1	Sewerage Business Operation	2022/April/20
2	Sewerage Planning	2022/Jul/13
3	Sewerage Pipeline Design	2022/July/19
4	Wastewater Treatment Plant Design (Mechanical, Electrical, Civil Works)	2022/July/28
5	Wastewater Treatment / Sludge Treatment Technology	2022/Nov/24
6	Pipeline Maintenance and Management	2023/Apr/24
7	Mechanical and Electrical Equipment Maintenance	2023/Apr/25
8	Regulation of Industrial Wastewater Discharge	2023/Jul/26
9	Project Management	2024/ May/23

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ANNEX 1

OJT Training in Navakai WWTP

- November 9th 2023 in Navakai WWTP
- Lecture for measurement of transparency & SV
- OJT for measurement of effluent transparency at the discharge point

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Japan Visit Program (Dec. 8th 2023/ 2weeks)

- Participants visited the facilities listed below and had discussions with Fukuoka City.
  - 5 WWTPs
  - Sewage pipe rehabilitation site
  - Sewage pipe cleaning site
  - Sewage public-awareness facility
  - Johkasou education center

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5. Summary of the Pre-FS

Draft Contents of Pre-F/S

5-1.	Selection of the Priority Projects for Pre-F/S
5-2.	Planning Basis and Design Conditions
5-3.	Natabua WWTP
5-4.	Navakai WWTP
5-5.	Environmental and Social Considerations
5-6.	Implementation Schedule
5-7.	Cost Estimation
5-8.	Project Effect
5-9.	Conclusion and Recommendations

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5-1. Selection of the Priority Projects for Pre-F/S

(1) Outline of Municipal Sewerage M/P

WWTP	Outline of facilities		[illegible]
[illegible]	WWTP	Trickling Filter (Q=[illegible] m³/day)	130
	Sewer	Dia 100-600mm L=41 km	75
	P/S	12 pumping stations	30
Natabua	WWTP	Trickling Filter (Q=44,520m³/day)	401
	STP	Mechanical dewatering	11
	Sewer	Dia 100-750mm L=64 km	92
	P/S	30 pumping stations	24
Saweni	WWTP	Trickling Filter (Q=[illegible] m³/day)	130
	Sewer	Dia 100-400mm L=49 km	120
	P/S	33 pumping stations	27
Navakai	WWTP	OD (Q=29,[illegible] m³/day)	312
	Sewer	Dia 100-600mm L=58 km	94
	P/S	37 pumping stations	28
[illegible]	WWTP	Trickling Filter (Q=19,[illegible] m³/day)	271
	Sewer	Dia 100-900mm L=155 km	181
	P/S	58 pumping stations	58

Sewer includes Trunk and Branch only

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ANNEX 1

5-1. Selection of the Priority Projects for Pre-F/S

(2) Service area to be focused

- Natabua and Navakai have many residential area, and high commercial economic zone exist.
- Vitogo, Sabeto and Moala is still developing area.
- Area-wised selection, Natabua and Navakai service area have high priority for sewerage development.

- Priority project is selected from the components of Natabua or Navakai.

5-1. Selection of the Priority Projects for Pre-F/S

(3) Selection of the Priority Projects for Pre-F/S

[illegible]	[illegible]	[illegible]
Case 1	Natabua	WWTP 21,000m³/day (Trickling Filter 1/2) Ocean Outfall pipe, Sewage Treatment
		Sewer network (Trunk/ Branch) L=[illegible] km, Pumping Stations
Case 2	Navakai	WWTP 13,500m³/day (OD Process 1/2)
		Rehabilitation of Main trunk L=[illegible] km Sewer network (Trunk/ Branch) L=[illegible] km, Pumping Station
Case 3	Natabua	WWTP 21,000m³/day (Trickling Filter 1/2) Ocean Outfall pipe, Sewage Treatment
	Navakai	WWTP 13,500m³/day (OD Process 1/2)

- Case 3, which involves upgrading both WWTPs, is a high priority in terms of efficiency (cost per removed pollutant load).
- Meet legal compliance for effluent quality from the existing WWTPs.
- Upgrading of both WWTPs is appropriate components as a priority project for Pre-F/S.

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5-2. Planning Basis and Design Conditions

(1) Target Area

✓ Natabua and Navakai Service Area

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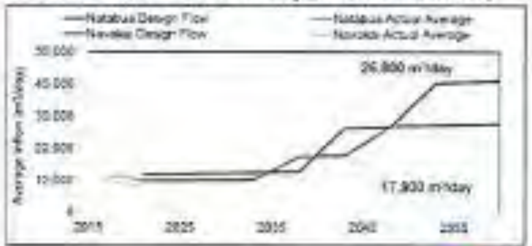
5-2. Planning Basis and Design Conditions

(2) Design Flow and Capacity for Phase 1

✓ Considering 2 step developments of both WWTPs
✓ Natabua WWTP: 29,600m³/day (75% of Ultimate flow)
✓ Navakai WWTP: 19,700 m³/day (88% of Ultimate flow)



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ANNEX 1

5-3. Natabua WWTP

5-3. Natabua WWTP

Facility	Load	Shape and Number of Basins
Sewerage Grit Chamber	Hydraulic Load 1,800m³/m²/d	4 chambers Rectangular, 2 m × 4 m
Stormwater Grit Chamber	Hydraulic Load 1,800m³/m²/d	4 chambers Rectangular, 3 m × 6 m
Primary Clarifier	Overflow Rate 35m³/m²/d	6 basins Circular, Dia. 14 m
Stage 1 Trickling Filter	Hydraulic Load 9.5 m³/m²/d	12 towers Circular, Dia. 19 m
Stage 2 Trickling Filter	Hydraulic Load 2.5 m³/m²/d	12 towers Circular, Dia. 43 m
Coagulation Flocculation Channel	Velocity Rapid mixing 1.5m/s Floc formulation 0.16m/s ～ 0.30m/s	6 channels Rectangular Rapid mixing 0.3m × 180 m × 0.3 m Floc formulation 1.3m/2.0m/2.5m × 80 m × 0.3 m
Final Clarifier	Overflow rate 10m³/m²/d	6 basins Circular Dia. 27 m
Disinfection Tank	Chlorine contact time 15 min	1 basin Rectangular, 2m × 470 m × 2 m
Stormwater Sedimentation Pond	HRT: 2.5 hrs	1 basin Open cut, 75m × 105 m × 3.8 m

5-4. Navakai WWTP

5-4. Navakai WWTP(other option)

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ANNEX 1

5-4. Navakai WWTP

Facility	Load	Shape and Number of Basins
Sewerage Grit Chamber	Hydraulic Load 1,800m3/m2/d	3 chambers Rectangular, 3 m × 3.5 m
Stormwater Grit Chamber	Hydraulic Load 1,800m3/m2/d	3 chambers Rectangular, 3 m × 5 m
Oxidation Ditch Basin	HRT 21.4 hrs.	4 basins Horseshoe Shape 4.5m × 280.5 m × 3.5m
Final Clarifier	Overflow Rate 9 m3/m2/d	4 basins Circular: Dia. 27 m
Disinfection Tank	Minimum Chlorine contact time 15 min	1 basin Rectangular: 3m × 380 m × 2 m
Stormwater Sedimentation Pond	HRT: 2.5 hrs.	2 basin* Open cut, 43m × 91 m × 3.0 m Open cut, 30m × 54 m × 3.0 m

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5-4. Mechanical and Electrical Facilities

Considered in selecting M&E equipment:
Cost (initial, running cost), Ease of procurement in Fiji (or Australia, NZ)

- "Belt-run automatic dust remover + residue dewaterer (biaxial screw type)": highly efficient in combination with a dehydrator because of its high residue capturing performance and economic efficiency
- "Submersible sewage pumps": flood prevention measures/ maintainability/ economic efficiency/ track record
- "Vertical water flow device + diffuser" or "submerged propeller + diffuser": good equipment and maintenance costs/ tank width
- Screw-type blowers: thermal efficiency/ equipment cost/ maintenance cost/ installation space and weight
- Multiple plate screw press dehydrator: not require a thickening process / Lowest cake moisture content/ Construction and maintenance costs
- Diesel generators: equipment and maintenance costs
- "Activated carbon adsorption process" and "biological deodorization tower process" for odor control facilities: easy maintenance / high deodorization efficiency/ ease of procurement

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5-4. Mechanical and Electrical Facilities

Odor Control Facilities

Treatment System	Wastewater Treatment System	Sludge Treatment System
Target Facilities	- Influent Pump Station (influent chamber, grit removal chamber, pump well)	- Sludge Receival Tank - Sludge Dewatering Building
Odor Control Process	Activated carbon adsorption	Biological deodorization tower + Activated carbon adsorption

Activated Carbon

Biological deodorization tower

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5-4. Mechanical and Electrical Facilities

Load and Consumption of both WWTP

WWTP	Phase	Max Load (kW)	Contract Load (kW)	Daily Consumption (kWh/Day)	Annual Consumption (MWh/Day)
Navakai	Phase 1	[illegible]	[illegible]	[illegible]	[illegible]
	Phase 2	170.9	708	11,844	4,323
Natabua	Phase 1	[illegible]	[illegible]	[illegible]	[illegible]
	Phase 2	227.9	906	15,204	5,549

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ANNEX 1

5-5. Environmental and Social Considerations

Summary of Key Environmental and Social Effects: Natabua WWTP

- It would physically encroach heavily into the existing mangrove, and coastal wetland area. It is proposed to offset this by replanting mangroves in the periphery.
- The potential mitigation of impacts and the associated regulations (e.g., the Environmental Management Act (2005), offset mitigation for the removal of vegetation (e.g., plant 8x the mangroves removed).
- When the social effects for Natabua are considered, resettlement of informal settlement is inevitable (approx. 18 households), with those required to be relocated are likely to be below the poverty line, so the area they are relocated to should have access to better services and considerations for their alternative livelihoods.

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5-5. Environmental and Social Considerations

Summary of Key Environmental and Social Effects: Navakai WWTP

- The informal community of Naqiroso and Taiperia Settlement and other local communities place significant value on the mangroves along the coast, that not only provides them with a source of gathering food and resources, but it also helps to mitigate some of the effects from sea level rise.
- The Nadi River is currently used as the discharge site, which is also a concern for the local village communities adjacent which include downstream villages.

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5-5. Environmental and Social Considerations

Summary of Key Environmental and Social Effects: Navakai WWTP

- The social effects for Navakai are similar but not as significant as the site in Natabua with regards to resettlement, with Fijian native land (iTaukei) Land needed for the sludge drying beds, and storage. These proposed sludge areas are adjacent to 3 schools, village extension area for settlement and future development plans, which may also have an impact. Land availability due to these pressures of development will be a significant issue for WAF in terms of Navakai WWTP's growth.

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5-5. Environmental and Social Considerations

- Individual stakeholder consultations between May and July 2024
- The final workshop on August 1 in Lautoka with 62 participants

1	Department of Environment
2	Department of Lands
3	Department of Town & Country Planning
4	Fiji Roads Authority
5	Provincial Office Ba
6	Nadi Town Council
7	Lautoka City Council
8	Taiperia & Naqiroso Settlement Leaders
9	[illegible]
10	Divisional Office Nadi & Lautoka
11	TLTB Nadi
12	[illegible] Landowners (Navoci Village)
13	National Fire Authority
14	Airports Fiji Limited
15	Civil Aviation Authority of Fiji

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ANNEX 1

5-6. Implementation Schedule

✓ Operation of Upgraded WWTPs will start

Navakai WWTP: 2033

Natabua WWTP: 2037

Item \ Year	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Feasibility Study	■										
Selection of Consultant		■									
Detailed Design/Bidding document			■								
Bidding/ Evaluation				■							
Construction of Navakai WWTP					■	■	■				
Construction of Natabua WWTP								■	■	■	■

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5-7. Cost Estimation

(1) Construction Cost

	Component	Construction Cost (mil. FJD)
Natabua WWTP	WWTP 34,000m³/day (Trickling filter:75% capacity)	
	Civil facility	102
	Mechanical Equipment	44
	Electrical Equipment	29
	Ocean Outfall pipe	26
	Septage Treatment	31
	Total	232
Navakai WWTP	WWTP 20,000m³/day (OD Process: 67% capacity)	
	Civil facility	54
	Mechanical Equipment	43
	Electrical Equipment	19
	Outfall pipe	17
	Total	133

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5-7. Cost Estimation

(2) Setting for estimation of Project Cost

No.	Item	Value
1	Exchange Rate (as of May 2024)	1USD=2.24FJD 1USD=151.37JPY 1FJD=67.55JPY
2	Price Escalation Rate (Foreign Currency)	2.7%
	Price Escalation Rate (Local Currency)	3.6%
3	Physical Contingency Rate	Construction:5% Consultant 10%
4	Value Added Tax (VAT)	15%
5	Import Tax	15%
6	Administration Cost	5%
7	Interest rate (Construction)	2%
	Interest rate (Consulting Service)	0.2%

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5-7. Cost Estimation

(3) Total Project Cost

Item	Loan Portion (Million FJD)	Loan Portion (Million JPY)	Fijian Portion (Million FJD)	Fijian Portion (Million JPY)	Total (Million FJD)	Total (Million JPY)
A. ELIGIBLE PORTION	547	[illegible]	—	—	547	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
B. NON ELIGIBLE PORTION	—	—	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
TOTAL (A+B)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C. Interest during Construction	[illegible]	[illegible]			[illegible]	[illegible]
D. Front End Fee	[illegible]	[illegible]			[illegible]	[illegible]
GRAND TOTAL (A+B+C+D)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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ANNEX 1

5-8. Project Effect

(1) Target Value of Indicators

	Indicator	Current (2023)	Target Value
Natabua WWTP	Effluent quality (mg/L)	BOD: 35, TSS: 27	BOD<40, TSS<60
	Effluent standard compliance rate (%)	BOD: 62.5% TSS: 87.5%	BOD: 100% TSS: 100%
	Daily average flowrate (m³/day)*	10,800	26,000
	Treated Population (people)	54,000	134,000
Navakai WWTP	Effluent quality (mg/L)	BOD: 69, TSS: 91	BOD<20, TSS<30
	Effluent standard compliance rate (%)	BOD: 40% TSS: 62.5%	BOD: 100% TSS: 100%
	Daily average flowrate (m³/day)*	8,800	17,000
	Treated Population (people)	44,000	60,000

* Estimated value from revenue water

Current treated population is estimated by dividing the inflow volume by unit water consumption of 200L/day/capita

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5-8. Project Effect

(2) Financial Analysis

❖ Financial & Economic Valuation of pre-F/S

Based on preliminary calculation of expenditure

➢ Financial IRR: Business return to WAF

- Financial IRR = - 2.8% at tariff F$0.20/m³
- Tariff F$0.70/m³ is necessary to cover O&M expense

➢ Rising tariff rate is necessary for business continuity

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5-8. Project Effect

(3) Economical Analysis

❖ Economic IRR: Economic Benefit to Fiji

Plan	Benefit	EIRR
M/P	- Willing to pay (WTP) for sewerage - Waiving cost for septic tank and maintenance and dredging sledge - Additional space by removing septic tank	1.9%
Pre-F/S	- WTP for environmental protection - Medical cost saving	Plus 0.9%
	- Maintaining tourism income through environmental protection	Plus 6.2%
	Total	9.0%

➢ 6.0% of ADB standard: Projects such as preventing environmental pollution, reducing poverty in rural areas etc.

➢ EIRR shows the priority project is economically viable.

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5-9. Conclusion and Recommendations

(1) Conclusion

✓ This priority project will properly treat wastewater and contribute to meet compliance for effluent standard
- improving the water quality of the coastal area
- allowing for the continued development of tourism

✓ Priority project is economically viable

✓ In line with Fiji's National Development Plan

✓ Project impacts will be sustainable through
- Efforts to build O&M capacity
- Securement of the O&M budget

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ANNEX 1

5-9. Conclusion and Recommendations

(2) Recommendations for F/S

1. Consultation for secure the WWTPs site
2. Formulation of the effective sludge utilization and disposal Plan
3. Water quality impacts on the discharge ocean area in the Feasibility Study
4. Additional soil surveys during the Feasibility Study
5. Septage treatment for outside of the sewerage service area
6. Secure the O&M Budget
7. Organizational structure on O&M

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End of Explanation of
Summary of the Pre-Feasibility Study
for the Priority projects

Vinaka

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6. Q&A Session/ Discussion

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- ✓ The Draft Final Report (DFR) will be handed over by the JICA Fiji Office in mid-August.
- ✓ JET asked Fijian side to submit comments on the DFR within two weeks.
- ✓ JET will make modification based on the comments and submit the Final Report (FR) to JICA HQ.
- ✓ The FR will be sent from JICA HQ to the JICA Fiji Office, and shared with Fijian side.

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ANNEX 1


7. Closing Remark from MPW
Mr. Mohammed Nistar Khan
Director Water and Sewerage
Ministry of Public Works,
Meteorological Services and
Transport
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APPENDIX 10-2 Consideration of applying OD Process to Natabua WWTP

(1) MPW Comments

MINISTRY OF PUBLIC WORKS, METEOROLOGICAL SERVICES AND TRANSPORT

Nasilivata House
87 Ratu Mara Road, Samabula
Private Mail Bag, Suva, Fiji

Telephone : (679) 3384111
Website : www.mims.gov.fj

10th September, 2024

JICA Fiji Office
Level 8, Suva Central Buiding
Renwick Road
Suva
Fiji

Dear Mr.Hideaki Iwase

RE: FINAL DRAFT REPORT ON WASTEWATER MASTERPLAN FOR THE WESTERN DIVISION

Thank you for your submission of the above-mentioned report. The team has reviewed the reports and comments are listed below:

- Oxidation Ditch system would be a better treatment option compared to the trickling filters. The Department staff as part of the Technical Committee had seen similar system in Japan during the training workshop. This system is dual control and is very effective. The sludge is aerobic and there will be less odour from the plant considering the town vicinity. The major component is the Maezawa flow controller and the diffusers.
- According to our experience, oxidation ditches (Pasveer) had been very successful in Fiji and these could be further improved to MBBR system without much design change. The footprint will not change.
- The Trickling Filter will require a large footprint, and the coagulation and flocculation of the nutrients will be a burden on the chemical slag production. We would need storage space for the slag. While the Trickling filter has advantages if properly maintained, the primary and secondary clarifiers will have septic and denitrified sludge if not properly handled. This will be very odorous.
- The trickling filter media type is important because the plastic type is not very effective according to experience.

We thank JICA for the opportunity to be involved during the Project and the review of the Draft Final Report and look forward to hearing from you on the way forward for the Project.

Please feel free to contact Mr. Vishwa Jeet on email vishwa.jeet@moit.gov.fj or mobile 9708645 for further information.

Yours Sincerely,

M.N.KHAN
Director Water and Sewerage
For Permanent Secretary

(2) Response to MPW's comments dated on 10th September 2024

The Oxidation Ditch process and MBBR process are excellent wastewater treatment processes and the OD process was proposed for the Navakai WWTP in this project. However, the TF method was proposed for the other 4 WWTPs for the following reasons.

1. The selection of treatment process was considered with high-weighted on ease of maintenance and maintenance costs in the Municipal Sewerage M/P. The use of a treatment process that consumes much electricity such as the OD method, was limited to Navakai WWTP where the effluent standards are strict. And the TF method which consumes less electricity was proposed for the other WWTPs.

2. In the Municipal Sewerage M/P, the footprint of each process was also estimated that footprint of OD was about 80% of that of TF. OD was selected for Navakai WWTP, where it is difficult to extend the WWTP site around the existing site. Natabua WWTP has fewer restrictions than Navakai situation. And the other three WWTPs are new and candidate sites of WWTPs are considered to minimize the disturbance of urban development.
   The biggest problem with the land is not which process to be adopted. The problem is that there is no place to dispose of the treated dry sludge, so the on-site sludge storage must be planned in the WWTP site, and the first priority is to consider a plan for effective reuse/disposal of the sludge.

3. The TF process has a primary clarifier and produces raw sludge. Raw sludge is high in calories and it is possible to generate electricity from the digester gas produced by anaerobic digestion. This is in line with Fiji NET ZERO, which aims to reduce greenhouse gas emissions in the sewerage sector. In contrast, the sludge produced by the OD system is low in calories and it has been found that TF is better from an energy reuse perspective.

4. Regarding the filter media for TF process, the suitable media will be compared and selected in the F/S and detailed design. As for the selection of filter media, further discussion with your Ministry will be requested.

Of course, if the discharge standards for WWTPs are tightened in the future, it becomes necessary to comply with the standards for, the introduction of the OD method etc. will also have to be reconsidered.