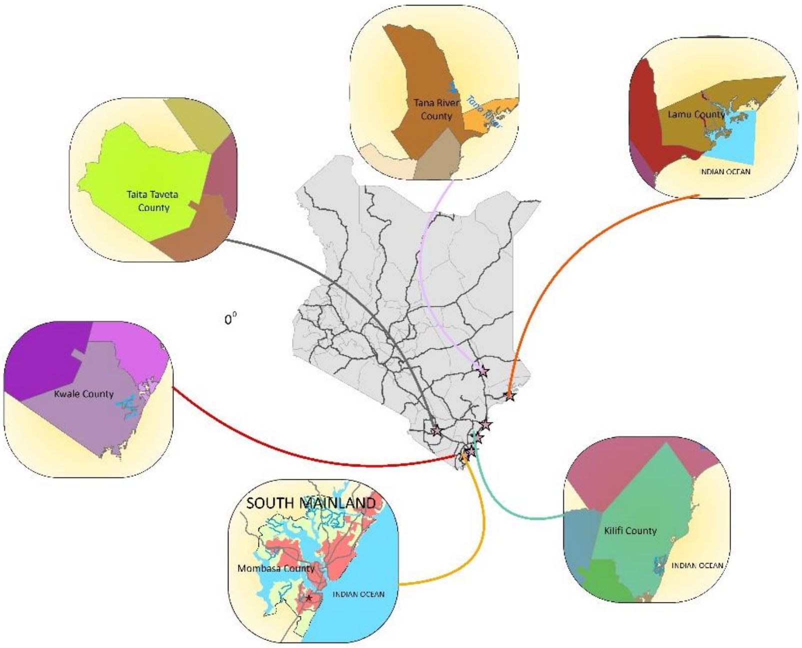
REPUBLIC OF KENYA

COAST WATER SERVICES BOARD

WATER AND SANITATION SERVICE IMPROVEMENT PROJECT – ADDITIONAL FINANCING (WaSSIP - AF)



Consulting Services for Wastewater Master Plan for Mombasa and Selected Towns within the Coast Region
Contract No. CWSB/WaSSIP-AF/C/10/2012

FINAL WASTEWATER MASTER PLAN REPORT FOR MOMBASA COUNTY

VOLUME 1: PART 1 OF 3 – MOMBASA ISLAND AND NORTH MAINLAND REPORT

MIBP
+PARTNERS
CONSULTING ENGINEERS

In Association with:

CES
Consulting Engineers
Salzgitter GmbH

BOSCH
HOLDINGS

MARCH 2017

"DOCUMENT CONTROL"

WATER AND SANITATION SERVICE IMPROVEMENT PROJECT – ADDITIONAL FINANCING (WaSSIP – AF)

Wastewater Master Plan for Mombasa and Selected Towns within the Coast Region

EMPLOYER:

Coast Water Services Board (CWSB)

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Wastewater Master Plan for Mombasa and Selected Towns within the Coast Region

FINAL WASTEWATER MASTER PLAN REPORT FOR MOMBASA COUNTY – PART 1 OF 3: MOMBASA ISLAND AND NORTH MAINLAND

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List of Abbreviations

CES	-	Consulting Engineers Salzgitter GmbH
CWSB	-	Coast Water Services Board
DWF	-	Dry Weather Flow
ESIA	-	Environmental and Social Impact Assessment
EA	-	Environmental Audit
ESIA	-	Environmental & Social Impact Assessment
GoK	-	Government of Kenya
IDA	-	International Development Association
M&E	-	Mechanical & Electrical
MWI	-	Ministry of Water and Irrigation
MIBP	-	Mangat, I.B. Patel & Partners
MOWASSCO	-	Mombasa Water Supply and Sanitation Company Ltd.
ToR	-	Terms of Reference
SoK	-	Survey of Kenya
WB	-	World Bank
WRMA	-	Water Resources Management Authority
WSB	-	Water Services Board
WSP	-	Water Service Provider
WSS	-	Water Supply and Sanitation
WSTF	-	Water Services Trust Fund
WWTP	-	Wastewater Treatment Plant

EXECUTIVE SUMMARY

E1 GOALS AND OBJECTIVES OF THIS STUDY

Goals and objectives are defined in the ToR (Paragraph 7.3) as, "The main goal of the Master Plan is to identify a sound and rational strategy for the development of sewerage services in Mombasa and selected Towns over the next twenty-five (25) years to improve the quality of effluent to rivers, Indian Ocean and groundwater and to safeguard the health of the city's residents."

The key objective of the proposed Master Plan for Mombasa Island and North Mainland is to come up with a phased investment programme for Immediate / Short Term Plan (2015 – 2020), Medium Term Plan (2021 – 2025), Long Term Plan (2026 – 2040) and recommend a treated effluent disposal / reuse strategy for the effluent in Mombasa Island and North Mainland.

E2 OBJECTIVES OF THIS REPORT

The Final Wastewater Master Plan Report presents the outputs of the Feasibility Study, the Selected Development Strategy and the Preliminary Design of the planned infrastructure for the Sanitation System of Mombasa Island and North Mainland.

The components of this Report include the following;

- Present Sanitation Situation in the Study Area & Proposed Immediate Interventions
- Future Sewerage System / Coverage Area Expansion
- Analysis of Sewage Generation and Network Analysis
- Formulation of Alternative Wastewater Management Strategies
- Detailed Evaluation of the Alternative Wastewater Management Strategies including Wastewater Treatment, Social / Environmental Assessment, Economic and Financial Analysis and Multi-Criteria Analysis
- Description of Selected Wastewater Management System Development Strategy
- Investment and Financial Management Plan
- Proposed Implementation / Development Schedule
- Summary and Recommendations of the Master Plan

E3 STUDY AREA AND DEMOGRAPHY

Mombasa County comprises of four distinct Service Areas i.e. Mombasa Island, North Mainland, South Mainland and West Mainland. The Study Area for this report combines Mombasa Island and North Mainland service areas. The current (year 2016) population of Mombasa Island is 176,000 and for Mombasa North Mainland is 468,000.

The sub-locations forming Mombasa Island and North Mainland, their total coverage areas as well as the study area are given in **Table E1** below and **Table E2** on **Page E-2** on **Page E-2.**;

Table E1: Sub-locations and Study Area for Mombasa Island

Sub-locations	Total Area (km²)	Coverage in the Study Area (km²)
Kizingo	2.16	2.08
Ganjoni	2.13	1.44
Mwembe Tayari	0.63	0.63
Majengo	1.48	1.48
Makadara	0.40	0.40
Mji Wa Kale	0.41	0.39
Bondeni	0.48	0.48
Tononoka	1.01	1.01
Tudor Four	1.72	1.68
Tudor	0.85	0.78
Railway	3.48	2.13
Total	**14.75**	**12.49**

Table E2: Sub-locations and Study Area for Mombasa North Mainland

Sub-locations	Total Area (km²)	Coverage in the Study Area (km²)
Kongowea	8.50	7.10
Maweni	6.47	4.67
Kisauni	8.18	6.19
Magogoni	8.33	7.29
Junda	7.52	3.68
Bamburi	12.45	9.60
Shanzu	7.32	5.29
Mwembe Legeza	11.09	8.29
Total	**69.86**	**52.11**

Figure E.1 below shows the Study Area of Wastewater Master Plan

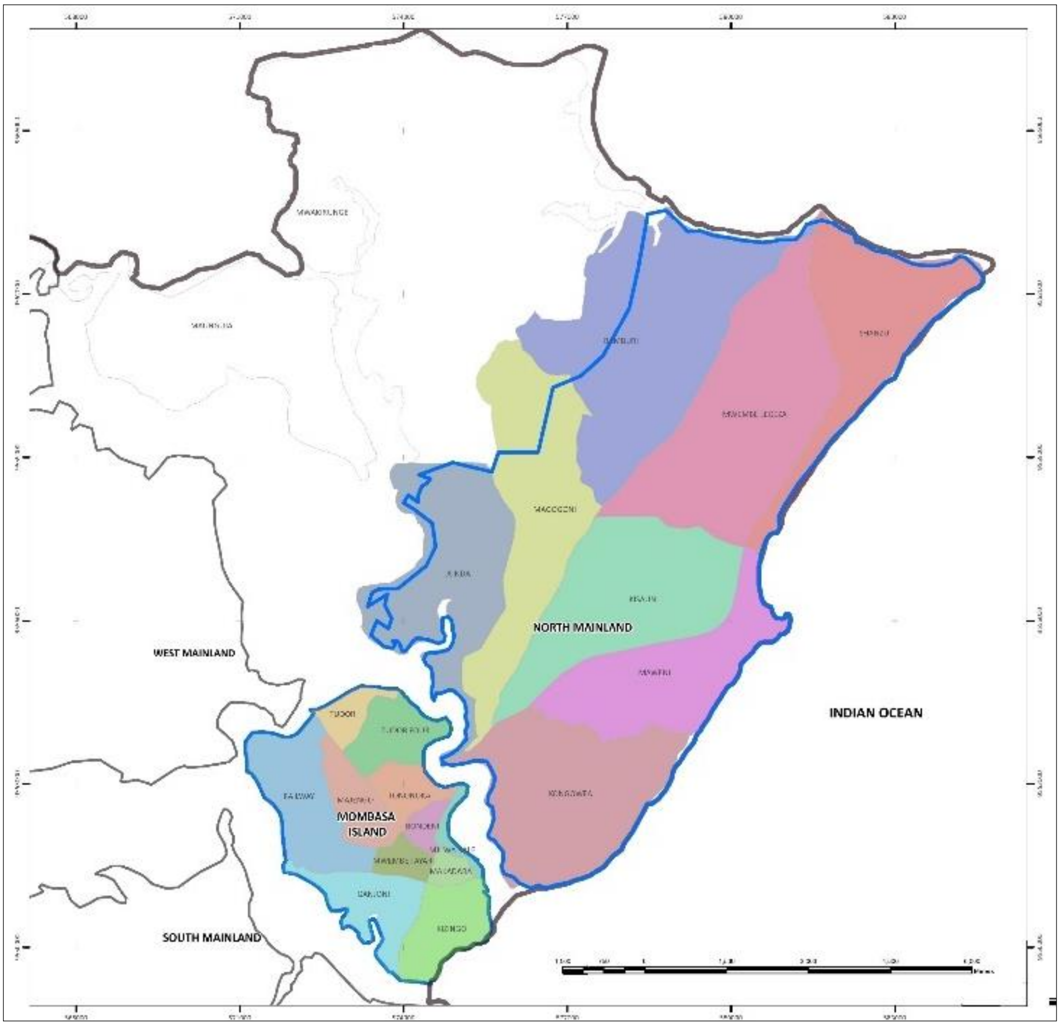


Figure E1: Study Area of Wastewater Masterplan for Mombasa Island and North Mainland

The analysis of previous demographic data obtained from Central Bureau of Statistics (CBS) indicates that the average annual growth rates for Mombasa Island and North Mainland in the inter-censal period (1999 – 2009) are **-1.8%** and **4.10%** respectively**.**

The future population of the Study Area has been projected based on a medium rate scenario with annual population growth rate of **3.0%** to Year 2040 based on the medium growth rate.

A summary of the projected population of the Study Area is given in Table E3 and E4 on Page E-3 for Mombasa Island and North Mainland respectively.

Table E3: Summary of Population Projection within the Study Area – Mombasa Island

Sub-locations	2009	2015	2020	2025	2040
Kizingo	6,835	8,162	9,462	10,969	17,089
Ganjoni	6,904	8,244	9,557	11,079	17,261
Mwembe Tayari	8,047	9,608	11,139	12,913	20,118
Majengo	31,630	37,767	43,783	50,756	79,077
Makadara	8,795	10,501	12,174	14,113	21,988
Mji Wa Kale	10,095	12,055	13,974	16,200	25,239
Bondeni	9,927	11,854	13,742	15,931	24,819
Tononoka	17,196	20,533	23,804	27,595	42,992
Tudor Four	14,174	16,925	19,621	22,746	35,437
Tudor	16,431	19,620	22,745	26,368	41,080
Railway	5,207	6,217	7,207	8,355	13,017
Total	**135,242**	**161,486**	**187,207**	**217,024**	**338,117**

Table E4: Summary of Population Projection within the Study Area – North Mainland

Sub-locations	2009	2015	2020	2025	2040
Kongowea	54,381	64,934	75,276	87,265	135,956
Maweni	30,954	36,961	42,848	49,673	77,389
Kisauni	61,225	73,105	84,749	98,247	153,066
Magogoni	72,751	86,868	100,704	116,744	181,883
Junda	19,321	23,070	26,745	31,005	48,304
Bamburi	3,682	4,397	5,097	5,909	9,206
Shanzu	19,374	23,134	26,819	31,090	48,438
Mwembe Legeza	6,812	8,134	9,429	10,931	17,030
Kongowea	21,612	25,806	29,916	34,681	54,032
Total	**290,112**	**346,409**	**401,583**	**465,545**	**725,304**

E4 WATER DEMAND FORECAST

Water demand has been determined based on the regular / unsuppressed water consumption rates, projected populations, proposed land-use (health, industrial, institutional, commercial and residential zones) and on the premise that the water distribution network has full coverage of the Study Area.

Figure E2 below shows the projected trend in the combined water demand for the study area (Mombasa Island and North Mainland) up to the Ultimate Design Horizon (year 2040).

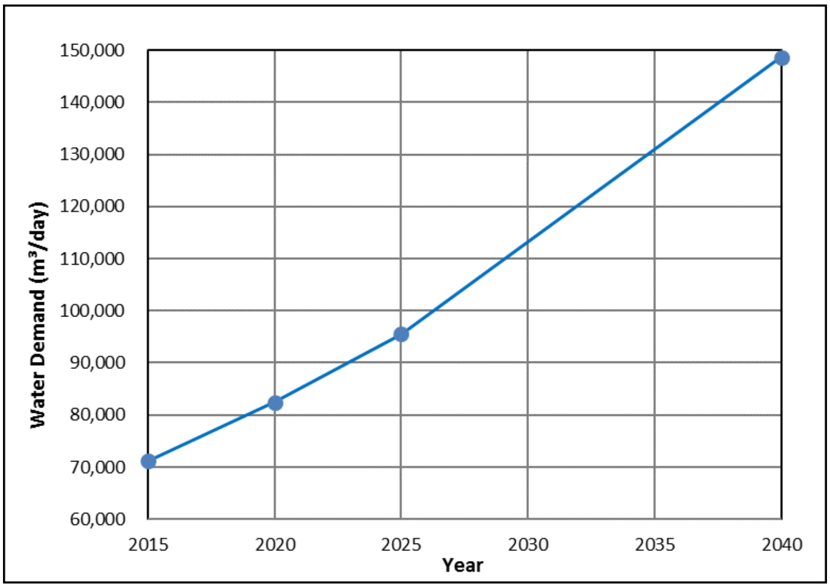


Figure E2: Water Demand Projection

E5 WASTEWATER FLOW PREDICTIONS

The total wastewater generated with each of the study area has been determined by the wastewater generated from the water consumed (sewage generation factor of 80%), infiltration into the sewers and splash flows. Assuming a regular water supply condition, and full coverage of water distribution system, the projected combined wastewater flow for the entire study area in the year 2040, is approximately **126,409 m³/day**.

However, achieving conditions of regular / unsuppressed water supply and full sewer connections in a Town with Sewerage System is nearly impossible. This is due to limited development of water resources, inadequate water distribution and sewerage networks and prevalent use of on-plot sanitation systems due to topography, affordability, unplanned settlement, etc.

To consider the above situation, the factors of Sewer Connectivity and Water Supply, given in **Table E5** and **Table E6** below have been adopted for the formulation of realistic wastewater generation projections.

Table E5: Sewer Connectivity adopted for Realistic Wastewater Generation Projection

Population Category Based on Income Levels	Sewer Connections	
	2021 - 2030	2031 - 2040
High Income	20%	80%
Medium Income	100%	100%
Low Income with Individual Water Connection	60%	80%
Low Income without Individual Water Connection	30%	40%

Table E6: Water Supply Status adopted for Realistic Wastewater Generation Projection

Population Category Based on Income Levels	Water Supply Status as a % of Regular Water Supply	
	2021 - 2030	2031 - 2040
High Income	50%	80%
Medium Income	50%	80%
Low Income with Individual Water Connection	50%	80%
Low Income without Individual Water Connection	50%	80%

Figure E3 below shows the comparative trends of wastewater flow generation for the combined Mombasa Island and North Mainland study area under Ideal condition (100% Sewer Connections and Regular Water Supply) and Realistic conditions;

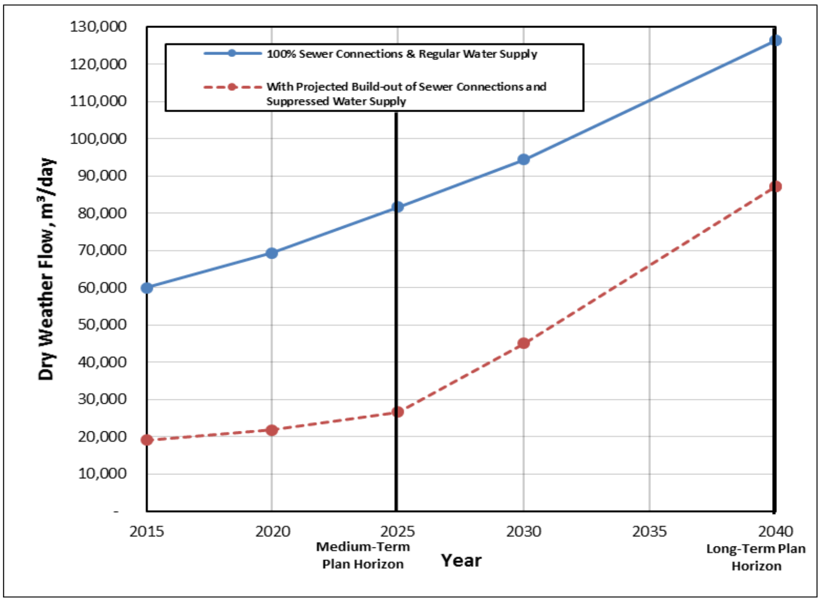


Figure E3: Comparative Projected Wastewater Flows up to Year 2040

From **Figure E3** above, the projected wastewater generation based on the projected build-out of sewer connections and suppressed water supply at the Years 2025 and 2040 is 26,600 m³/d and 87,300 m³/d respectively.

The design of Wastewater Management Scheme Components i.e. Sewerage System and Water Treatment Plants, has been based on the wastewater flow generation developed from the projected build-out of sewer connections and suppressed water supply.

E6 ALTERNATIVE WASTEWATER MANAGEMENT STRATEGIES

Three alternative Wastewater Management Schemes are feasible for Mombasa Island and North Mainland as briefly described below;

a) Alternative 1: Decentralized system with Existing Kizingo WWTP (Preliminary Treatment + Long sea outfall) for Mombasa Island and 2 Nr. Waste Water Treatment Plants (Waste Stabilization Ponds) for Mombasa North Mainland at Nguu Tatu and Shimo la Tewa.

b) Alternative 2: Centralised Waste Water Treatment Plant (Waste Stabilization Ponds) for Mombasa Island and Mombasa North Mainland at Nguu Tatu in Mombasa North Mainland.

c) Alternative 3: 2Nr Decentralized Waste Water Treatment Plants (Waste Stabilization Ponds) in Mombasa North Mainland i.e. at Nguu Tatu for Mombasa Island and larger part of North Mainland and at Shimo la Tewa for northern part of North Mainland.

The locations of these WWTP are shown in **Figure E4** below;

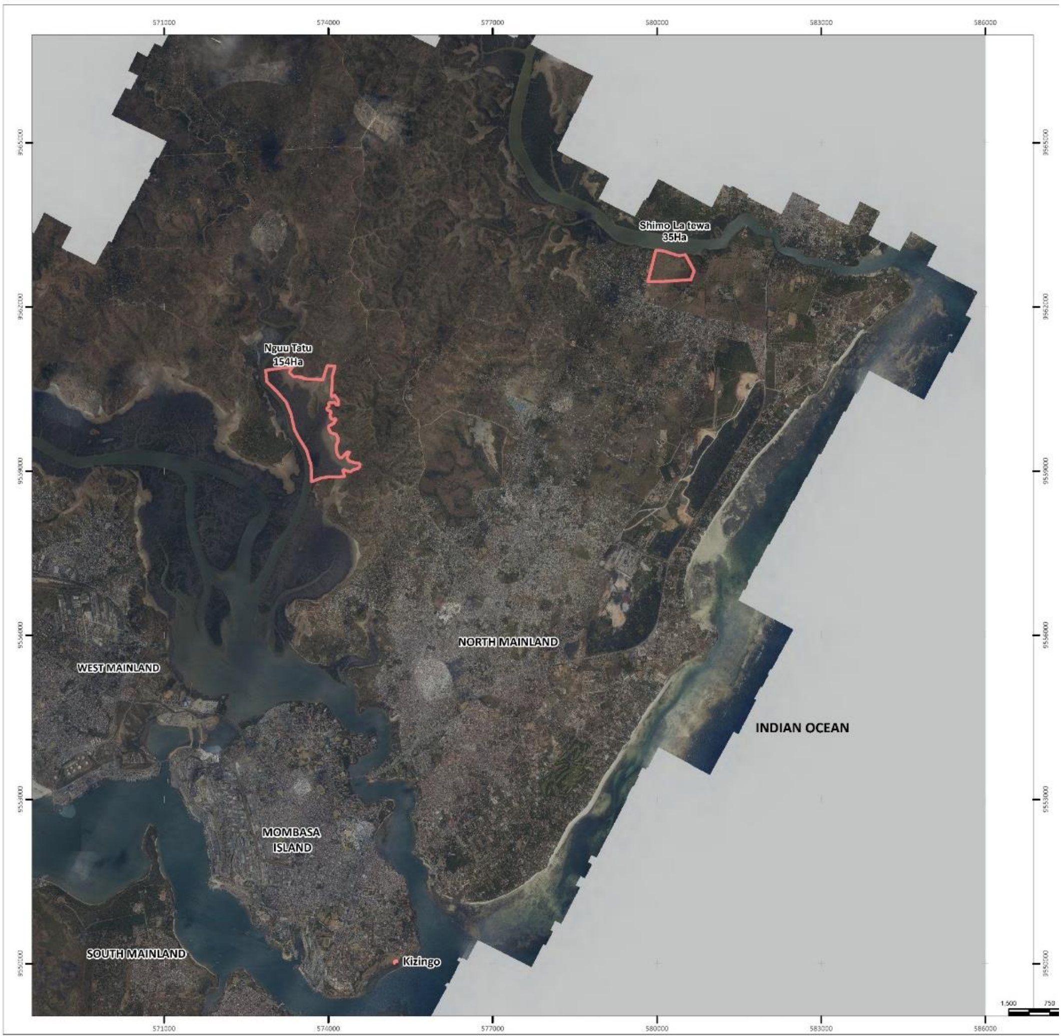


Figure E4: Locations of the Alternative Waste Water Treatment Plant

A summary of the proposed schemes for Mombasa Island and Mombasa North Mainland Town is given in **Table E7** below.

Table E7: Summary of Alternative Wastewater Management Schemes

Alternative Scheme	Conveyance System		Wastewater Treatment Plants			
	Secondary and Trunk Sewers (km)	No. of Pumping Stations	Location	Design Capacity (m^3/day)	Treatment Technology	Land Required (Ha)
1	Mombasa Island 90 Km	Mombasa Island 12	Existing Kizingo	25,000	Long Sea Outfall	1.0
	North Mainland 250 Km	North Mainland 17	Nguu Tatu	52,300	Waste Stabilization Ponds	115
			Shimo la Tewa	9,900		25
2	Mombasa Island 90 Km North Mainland 250 Km	Mombasa sland 12 North Mainland 17	Nguu Tatu	87,300	Trickling Filters and Maturation Ponds	125
3	Mombasa Island 90 Km North Mainland 250 Km	Mombasa sland 12 North Mainland 17	Nguu Tatu	77,300	Waste Stabilization Ponds	160
			Shimo la Tewa	9,900		25

E7 MULTI-CRITERIA ANALYSIS AND REVIEW OF DEVELOPMENT STRATEGIES

In the Multi-Criteria Analysis, alternative treatment trains and schemes have been evaluated to determine the most suitable wastewater treatment scheme for Mombasa Island and North Mainland.

A summary of the weighted totals for the alternative wastewater treatment trains is given in **Table E8** below.

Table E8: Weighted Totals for the alternative wastewater treatment trains

	Simplicity of Operations and Maintenance	*Net Present Value*	*Environmental Impacts*	*Land Requirement*	*Institutional Strength*	*Weighted Total*	*Rank*
Waste Stabilization Ponds	0.486	0.548	0.456	0.052	0.410	0.457	1
Composite Biofilters	0.11	0.23	0.26	0.09	0.13	0.198	3
Composite Oxidation Ditches	0.108	0.136	0.141	0.192	0.085	0.127	4
Long Sea Outfall	0.30	0.08	0.14	0.66	0.37	0.218	2

Similarly, a summary of the weighted totals for the alternative schemes developed for Mombasa Island and North Mainland is given in **Table E9** on **Page E-7**.

Table E9: Weighted Totals for the alternative schemes

	Simplicity of Operations and Maintenance	Net Present Value	Environmental Impacts	Potential for Reuse	Land Acquisition	Land Use	Weighted Totals	Rank
Decentralized Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	0.12	0.47	0.12	0.12	0.16	0.31	0.20	3
Centralized Scheme with 1Nr Trickling Filters and Maturation Ponds System for both Island and North Mainland	0.56	0.06	0.32	0.18	0.54	0.58	0.39	2
Decentralized Scheme with 2Nr WSP Systems for both Island and North Mainland	0.32	0.47	0.56	0.69	0.30	0.11	0.41	1

From the Multi-Criteria Analysis, a Decentralized Wastewater Management Scheme with 2 Nr. Wastewater Treatment Plants at Nguu Tatu and Shimo la Tewa comprising of Waste Stabilization Ponds Systems is the most suitable Wastewater Management Scheme and is recommended for Mombasa Island and North Mainland Sanitation Strategy.

Table E10 below gives a summary of the details of this recommended Wastewater Management Scheme.

Table E10: Details of recommended Wastewater Management Scheme – Decentralized Scheme

Alternative Scheme	Conveyance System		Wastewater Treatment Plant		
	Secondary and Trunk Sewers (km)	No. of Pumping Stations	Location	Treatment Technology	Land Required (Ha)
3	Mombasa Island - 90 Km North Mainland - 250	Mombasa Island 12 North Mainland - 17	Nguu Tatu 77,300 m^3/d	Waste Stabilization Ponds	160
			Shimo la Tewa 9,900 m^3/d		25

E8 PROJECT COSTS

The Capital Cost of the selected Wastewater Management Scheme for Mombasa Island and North Mainland has been worked out on the following basis;

a) Project Implementation planned to be carried out in two phases i.e. Medium-Term Plan (2020 -2025) and Long-Term Plan (2026 - 2040)
b) The Cost of Civil Works constitute the following fraction of the components total costs;
   - Wastewater Treatment Plant – 95%
   - Pumping Station – 60%
   - Sewers – 100%

Summary of the Capital Costs for the recommended Schemes is given in **Table E9** below;

Table E9: Capital Costs for the Selected Scheme

S/No.	Component	Costs (Kshs)	Costs (USD) [1]
1	**Land Acquisition**	**2,600,000,000**	**25,242,718**
2	**Civil Works**	**14,807,881,043**	**143,765,835**
2.1	Wastewater Treatment Plant	8,776,677,125	85,210,458
2.2	Pumping Stations	693,066,147	6,728,798
2.3	Sewers	5,338,137,771	51,826,580
3	**Electro-Mechanical Works**	**923,974,473**	**8,970,626**
3.1	Wastewater Treatment Plant	461,930,375	4,484,761
3.2	Pumping Stations	462,044,098	4,485,865
	Total Capital Cost	**18,331,855,516**	**177,979,180**

A summary of the Phased Investment cost for Mombasa Island and North Mainland Wastewater Management System is given in **Tables E10** and **E11** below;

Table E10: Costs for Medium-Term Plan (Year 2020 – 2025)

S/No.	Component	Cost (Kshs	Costs (USD)
1	Land Acquisition	2,600,000,000	25,242,718
2	Sewerage System	6,227,884,420	60,464,897
3	Wastewater Treatment Plant	5,132,870,065	49,833,690
	Total	**13,960,754,485**	**135,541,306**

Table E11: Costs for Long-Term Plan (Year 2026 – 2040)

S/No.	Component	Cost (Kshs)	Costs (USD)
1	Sewerage System	599,926,322	5,824,527
2	Wastewater Treatment Plant	4,581,754,015	44,483,049
	Total	**5,181,680,337**	**50,307,576**

The Operations and Maintenance Costs have been worked out on the following basis;

a) Electricity Costs at the Pumping Stations has been assumed to increase annually at 3.0% p.a. (same as population) due to increased sewage flow from the increased connections
b) Annual Maintenance Costs of the Schemes have been calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works
c) Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule

A summary of the Annual Operations & Maintenance Costs in the first year of operation of the Scheme is given in **Table E12** below;

Table E12: Annual Operations & Maintenance Costs (Year 1)

S/No.	Component	Costs (Kshs)	Costs (USD) [1]
1	Maintenance Costs	185,437,155	1,800,360.73
2	Electricity Costs	120,784,521	1,172,665.25
3	Staff Costs	8,286,793	80,454.30
	Total O&M Cost	**314,508,469**	**3,053,480.28**

[1] – Exchange Rate: 1 USD = 103 Kshs

E9 FINANCIAL AND ECONOMIC ANALYSIS OF THE SELECTED DEVELOPMENT STRATEGY

To provide indicators of economic viability and sustainability of the proposed sanitation system, it is important to carry out financial and economic analysis. Financial and economic analysis is used to produce standardised information on Projects, as a basis for making investment decision. The importance of economic analysis in an investment is to help select a Project that contributes to the welfare of a region or a country. On the other hand, financial analysis evaluates Project liquidity and profitability.

The Capital Costs for the Investment Phases and their associated Operations and Maintenance Costs have been used to project the Annual Project Expenditure as summarized in **Table E13** below;

Table E13: Schedule of Annual Project Expenditures

Year	Project Cost, Kshs	O&M, Kshs	Depreciation, Kshs	Total Cost, Kshs
2021	3,351,019,379	-	-	3,351,019,379
2022	3,351,019,379	-	259,902,168.21	3,610,921,547
2023	3,351,019,379	314,508,468.77	389,853,252.32	4,055,381,100
2024	3,351,019,379	318,132,004.40	519,804,336.43	4,188,955,720
2025	-	321,864,246.09	519,804,336.43	841,668,583
2026	492,777,800	325,708,455.04	542,269,971.14	1,360,756,226
2027	492,777,800	329,667,990.25	561,379,681.38	1,383,825,472
2028	492,777,800	333,746,311.52	580,489,391.62	1,407,013,503
2029	-	337,946,982.42	580,489,391.62	918,436,374
2030	739,166,700	342,273,673.46	609,153,956.99	1,690,594,331
2031	985,555,600	346,730,165.22	585,805,911.28	1,918,091,677
2032	1,231,944,500	351,320,351.74	572,012,720.70	2,155,277,573
2033	492,777,800	356,048,243.85	529,554,964.76	1,378,381,009
2034	-	360,917,972.73	467,987,498.58	828,905,471
2035	-	365,933,793.47	467,987,498.58	833,921,292
2036	-	371,100,088.83	455,577,887.12	826,677,976
2037	-	376,421,373.06	446,524,200.13	822,945,573
2038	-	381,902,295.81	437,470,513.15	819,372,809
2039	-	387,547,646.25	437,470,513.15	825,018,159
2040	-	393,362,357.20	423,889,982.67	817,252,340
2041	-	393,362,357.20	423,889,982.67	817,252,340
2042	-	393,362,357.20	423,889,982.67	817,252,340
2043	-	393,362,357.20	423,889,982.67	817,252,340
2044	-	393,362,357.20	423,889,982.67	817,252,340
2045		393,362,357.20	374,094,704.24	767,457,061
2046		393,362,357.20	374,094,704.24	767,457,061

Assuming adoption of the proposed tariffs and attainment of the projected sewer connections, the projected financial statement has been determined and summarized in **Table E14** below;

Table E14: **Projected Financial Statement of the Project**

Project Income and expenditure Financial statement (Kshs)							
Year	**Total Project Revenue**	**Billings Not Recovered**	**Net Project Revenue**	**Operations & Maintenance**	**Annual Depreciation**	**Total Expenditure**	**Net Revenue**
2023	820,862,529	82,086,253	738,776,276	314,508,469	389,853,252	704,361,734	34,414,542
2024	820,862,529	82,086,253	738,776,276	318,132,004	519,804,336	837,936,354	-99,160,078
2025	1,002,495,389	100,249,539	902,245,850	321,864,246	519,804,336	841,668,596	60,577,254
2026	1,451,640,041	145,164,004	1,306,476,037	325,708,455	542,269,971	867,978,440	438,497,597
2027	1,451,640,041	145,164,004	1,306,476,037	329,667,990	561,379,681	891,047,686	415,428,351
2028	1,451,640,041	145,164,004	1,306,476,037	333,746,312	580,489,392	914,235,718	392,240,319
2029	1,451,640,041	145,164,004	1,306,476,037	337,946,982	580,489,392	918,436,389	388,039,648
2030	2,457,689,425	245,768,943	2,211,920,483	342,273,673	609,153,957	951,427,646	1,260,492,837
2031	2,457,689,425	245,768,943	2,211,920,483	346,730,165	585,805,911	932,536,092	1,279,384,391
2032	2,457,689,425	245,768,943	2,211,920,483	351,320,352	572,012,721	923,333,088	1,288,587,394
2033	2,457,689,425	245,768,943	2,211,920,483	356,048,244	529,554,965	885,603,225	1,326,317,258
2034	2,457,689,425	245,768,943	2,211,920,483	360,917,973	467,987,499	828,905,488	1,383,014,995
2035	2,457,689,425	245,768,943	2,211,920,483	365,933,793	467,987,499	833,921,309	1,377,999,173
2036	2,457,689,425	245,768,943	2,211,920,483	371,100,089	455,577,887	826,677,994	1,385,242,489
2037	2,457,689,425	245,768,943	2,211,920,483	376,421,373	446,524,200	822,945,591	1,388,974,891
2038	2,457,689,425	245,768,943	2,211,920,483	381,902,296	437,470,513	819,372,828	1,392,547,655
2039	2,457,689,425	245,768,943	2,211,920,483	387,547,646	437,470,513	825,018,178	1,386,902,304
2040	4,750,348,174	475,034,817	4,275,313,356	393,362,357	423,889,983	817,252,359	3,458,060,997
2041	4,750,348,174	475,034,817	4,275,313,356	393,362,357	405,782,609	799,144,986	3,476,168,370
2042	4,750,348,174	475,034,817	4,275,313,356	393,362,357	383,148,391	776,510,769	3,498,802,587
2043	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,082	3,507,856,274
2044	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,083	3,507,856,273
2045	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,084	3,507,856,273
2046	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,084	3,507,856,272

Besides the above revenue collected, the following additional direct/indirect benefits have been considered in the economic analysis:

- Cost savings to customers in terms of health benefits
- Cost savings in terms of safe sewage disposal to the environment

The results of the cost-benefit analysis confirm that the project has favourable BC ratios of between **1.14** to **1.47** The financial analysis confirms that the project has positive NPV of **Kshs 7,611,825,333** at 5% cost of capital and **Kshs 1,758,548,750** at 8% cost of capital and Financial Internal Rates of Return (FIRR) of **9.70%.**

Sensitivity analyses also indicate that the project viability is susceptible to shocks of 10% and 20% increase in O&M and project costs and reduction in net income.

On the other hand, the results of the economic analysis after including other economic benefits showed that the project have a **positive NPV of Kshs 3,061,239,678** and **EIRR of 14%** at 10% cost of capital.

It is therefore concluded that the Project is both financially and economically viable

E10 CONCLUSION OF THE MASTER PLAN

The current waterborne system in Mombasa Island requires extensive rehabilitation and expansion to sever the needs of the growing urban center. In areas of Mombasa Island and North Mainland where residents use on-plot sanitation means such as septic tanks and pit latrines and lacking a proper sludge management and disposal facility is a health hazard to the residents and an environmental risk.

As an immediate intervention, rehabilitation works on existing sewerage system, construction of Ablution Blocks at designated Public Places and a centralized Sludge Handling Facility is necessary. It is equally important to ensure procurement of Exhaust Vehicles to provide desluging and transport services. A summary of the Immediate Sanitation Measures and their costs estimates are given **Tables E15** and **16** below.

Table E15: Details of the Ablution Blocks – Immediate Sanitation Measures

Number Proposed	Details of each Ablution Block			Total Capital Cost	
	No. of Toilets	No. of Shower Rooms	Max. Daily capacity	Ksh.	USD
6	6	2	720	93,000,000	902,913

Table E16: Details of the Sludge Handling Facility – Immediate Sanitation Measures

S/No.	Component	Details	Total Capital Cost	
			Ksh.	USD
1	Tanker Discharge Bay	• Bar Screens, Collection Chamber, Hard-stand Washing Bay & Parking Space	58,299,957	566,019
2	Sludge Drying Beds	• 8 Beds; each 13 x 10m		
3	Twin-Septic Tanks	• 2 Tanks; each 98 m³ capacity		
4	Land Requirement	• 0.7 Ha		
5	Exhaust Discharge Tanker	• Minimum 1 Nr (Either owned by MOWASCO or Private Providers)	-	-

Table E17: Details of Rehabilitation Works – Immediate Sanitation Measures

Rehabilitation Works on Mombasa Island sewers	Total Capital Cost	
	Ksh.	USD
• Replacement of missing / vandalised manhole covers, • Repair of broken manholes, • unblocking of partially / fully blocked sections of the sewer line and flushing, • Identify, expose and raise above ground levels buried manholes, • Replacement of collapsed sections of the sewer line, • Supply of Aluminium Telescopic Ladders • Ancillary works on Pumping Stations.	24,781,000	2,147,694

To provide a sustainable sanitation system, a de-centralized wastewater management system comprising of a gravity sewage conveyance system with limited pumping (29 Nr Pumping Station) and a Waste Stabilization Ponds system based Wastewater Treatment Plant - ultimate capacities – 77,300 m³/d at Nguu Tatu and 9,900 m³/d at Shimo la Tewa and has been selected from the developed alternative schemes. The implementation of this strategy is to be carried out in 2 phases i.e. Medium Term Plan (2021 -2025) and Long Term Plan (2026 – 2040).

The implementation details of the selected Wastewater Management Scheme in the 2 Phases are given in **Tables E17** and **Table E18** below.

Table E17: Summary of Implementation Cost: Medium-Term Plan Plan (2021 -2025)

S/No.	Component	Details	Cost (Kshs)	Cost (USD)
1	Land Acquisition	• 185 Ha	10,804,077,515	104,893,956
2	Sewers	• 225 – 1,200 mm Dia; Total length 340 km		
3	Pumping Stations	• 28 Nr		
4	Waste Water Treatment Plant	Waste Stabilization Ponds; • Capacity 38,650 m³/d at Nguu Tatu • Capacity 5,000 m³/d at Shimo la Tewa		

Table E18: Summary of Implementation Cost: Long-Term Plan Plan (2026 -2040)

S/No.	Component	Details	Cost (Kshs)	Cost (USD)
1	Sewers	• 100 – 225 mm Dia; Total length 31 km	4,927,778,000	47,842,505
2	Pumping Stations	• 1 Nr		
3	Waste Water Treatment Plant	Waste Stabilization Ponds; • Capacity 38,650 m³/d at Nguu Tatu • Capacity 5,000 m³/d at Shimo la Tewa		

Financial analysis of the selected Wastewater Management Scheme presented the following Financial Ratios / Performance Indicators;

- **Benefit – Cost (BC) Ratio;** 1.14 - 1.47
- **Net Present Values (NPV);** Ksh. 7,611,825,333 @ 5% cost of capital
  Ksh. 1,758,548,750 @ 8% cost of capital
- **Financial Internal Rate of Return (FIRR);** 9.70%

On the other hand, economic analysis presented the following Performance Indicators;

- **Net Present Values (NPV);** Ksh. 3,061,239,678 @ 10% cost of capital
  Ksh. 1,188,043,219 @ 8% cost of capital
- **Economic Internal Rate of Return (EIRR);** 14%

Sensitivity analyses also indicate that the project viability is susceptible to shocks of 10% and 20% increase in O&M and project costs and reduction in net income.

Thus, it can be concluded that the selected scheme is both financially and economically viable.

MAIN REPORT

1.0 PROJECT BACKGROUND

The Government of Kenya (GoK) through the Ministry of Water and Irrigation (MWI) has received "credit" from International Development Association (IDA) to undertake the Wastewater Master Plan for Mombasa and Selected Towns within the Coast Region.

Coast Water Services Board (CWSB) is a parastatal (Government Owned and Autonomous) and operates under the Ministry of Water and Irrigation. CWSB covers six Counties which are Mombasa, Kwale, Kilifi, Taita-Taveta, Lamu and Tana River.

The primary outcome of this Study will be to obtain the agreement of all major Stakeholders to a preferred Sewerage Development Strategy most applicable to their needs.

In August 2010, Kenya enacted a new constitution. The Constitution of Kenya 2010 has dramatically altered the administrative structure of the Government from the initial 8 Administrative Provinces to 47 Semi-autonomous Counties. This autonomy of the Counties vest powers and privileges in each County especially on the provision of essential public services such as Water, Sanitation, Education and other Social Services.

The WaSSIP-AF therefore targets the built-up areas of Towns in six Counties in the Coastal Region as follows:

Table 1.1: Project Selected Towns

S/No.	County	Urban Centre
1.	Mombasa County	Mombasa including Island, West Mainland, South Mainland / Likoni and North Mainland
2.	Kwale	Kwale, Ukunda / Diani and Part of Mariakani.
3.	Kilifi	Malindi, Kilifi, Watamu, Mtwapa and Part of Mariakani
4.	Taita Taveta	Voi and Taveta
5.	Lamu	Lamu Island
6	Tana River	Hola

The Terms of Reference (ToR) included seven Towns but in the course of the study five upcoming Towns (Mariakani, Taveta, Ukunda/Diani and Watamu) were added as an addendum.

It is therefore required that the formulated Program shall be aligned to respect and respond to the requirements of the new Constitution. A key benchmark of the new Constitution is stipulated under Chapter IV-BILL OF RIGHTS, paragraph 45(1) (b) and (d) which stipulates: *"Every person has the right to (b)............reasonable standards of sanitation and (d) clean and safe water in adequate quantities."*

A Location Plan for the twelve Project Towns is given in **Figure 1.1 on Page 1-2.**

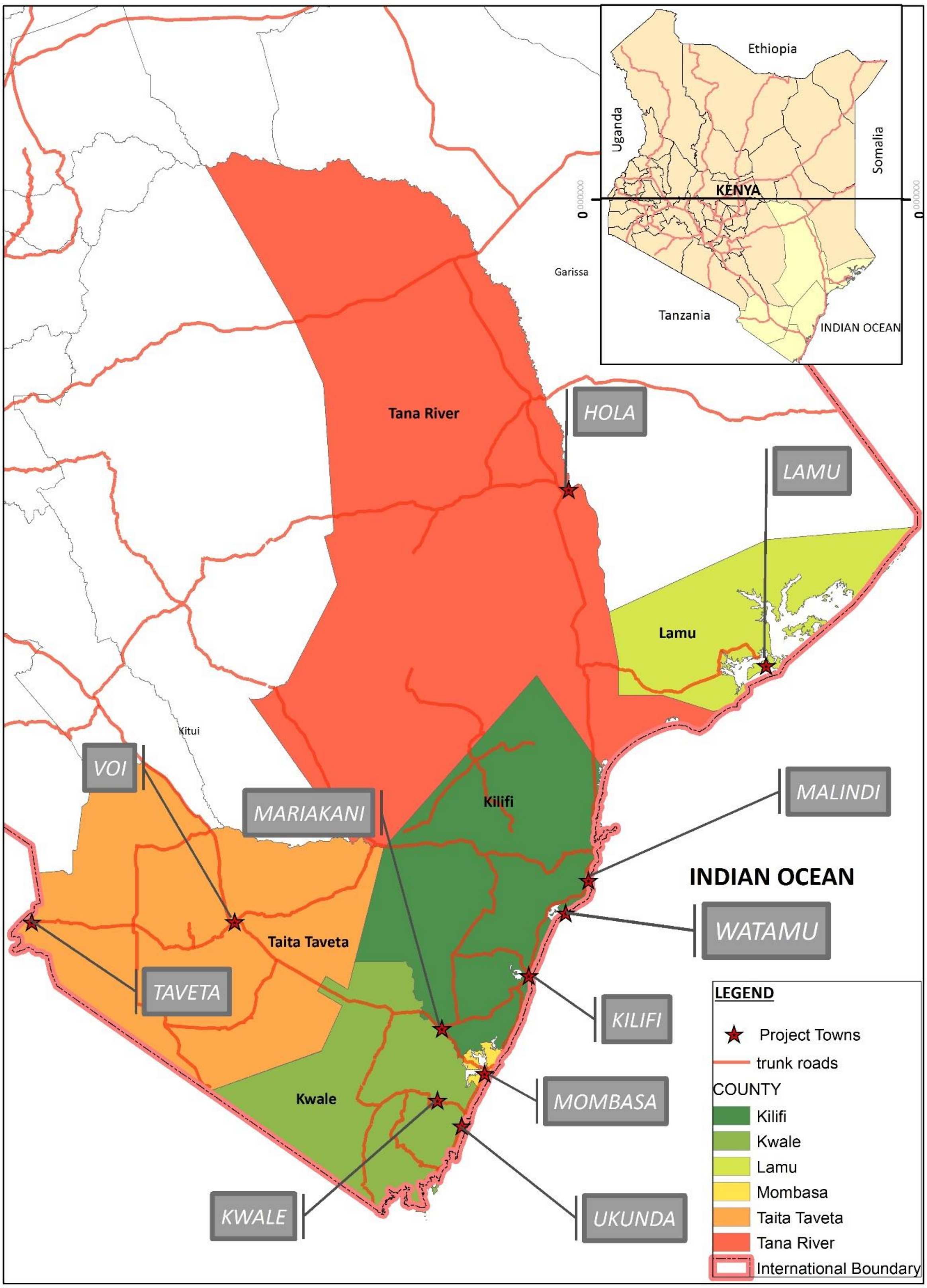


Figure 1.1: Location Plan for the Project Towns

1.1 Goals and Objectives of this Study

Goals and objectives are defined in the ToR (Paragraph 7.3) as, "The main goal of the Master Plan is to identify a sound and rational strategy for the development of sewerage services in Mombasa and selected Towns over the next twenty-five (25) years i.e. up to Year 2040, to improve the quality of effluent to rivers, Indian Ocean and groundwater and to safeguard the health of the residents of the Study Areas."

The key objective of the proposed Master Plan for Mombasa Island and North Mainland is to come up with a phased investment programme for Immediate / Short Term Plan (2015 – 2020), Medium Term Plan (2021 – 2025), Long Term Plan (2026 – 2040) and recommend a treated effluent disposal / reuse strategy for the effluent in Mombasa Island and North Mainland.

1.2 Execution of the Study

To meet the goals and objectives of the Study, the following reports have been submitted:

- D1 – Inception Report
- D2 – Report on Condition Survey and Environmental Audit of the Existing Facilities,
- D3 – Immediate Urgent Works Report / Final Design Report,
- D4 – Detailed Designs and Tender Documents for Immediate Urgent Works,
- D5A – Technical Note 1 – Socio Economic Conditions, Mapping & Land Use,
- D5B – Technical Note 2 – Waste Water Flow Predictions & Formulation of Sewerage Development Strategies,
- D7 – Preliminary Design Report for Medium Term Works including Phased Investment Schedule for Sewers and Waste Water Treatment Plants,
- D8 - Preliminary Environmental and Social Impact Assessment (ESIA) & Preliminary Resettlement Action Plan (RAP) for the Preferred Development Strategy

The Final Master Plan Report presents the outputs of the Feasibility Study, the selected Development Strategy and the Preliminary Design of the planned infrastructure for the Sanitation System of Mombasa Island and North Mainland.

- D9 – Final Master Plan Report

1.3 Objectives of this Report

The Tasks to be addressed in the Final Master Plan Report include the following:

- Present Sanitation Situation in the Study Area
- Immediate Measures for the improvement of Sanitation Systems
- Future Sewerage System / Coverage Area Expansion
- Analysis of Sewage Generation and Network Analysis
- Formulation of Alternative Wastewater Management Strategies
- Detailed Evaluation of the Preferred Development Strategy including Wastewater Treatment, Social / Environmental Assessment, Economic and Financial Analysis and Multi-Criteria Analysis
- Selection of Wastewater Management Strategies
- Resolution of Issues raised by the detailed Evaluation including Preliminary Risk Management Plan
- Investment and Financial Management Plan
- Proposed Implementation / Development Schedule
- Conclusion of the Master Plan

2.0 PROJECT AREA DESCRIPTION

2.1 Location and Administration

Mombasa is the second largest city and major seaport of Kenya, located in south-eastern part within the country. It is located between the Latitudes 3° 80´ and 4° 10´ S and Longitudes 39° 60´ and 39° 80´ E.

Mombasa is the most important port city in the East African Region. In the national context, after Nairobi (the capital city), Mombasa acts as a natural magnet for urban-rural migration due to its location, economic opportunities and administrative role within Kenya. Some of the other main urban centres / towns surrounding Mombasa are Malindi, Kwale, Kilifi, Lamu, Mariakani and Voi. Administratively, Mombasa County is divided into six sub-counties / constituencies namely Changamwe, Jomvu, Kisauni, Nyali, Likoni and Mvita.

The water supply and sanitation systems in Mombasa County is managed by Mombasa Water Supply and Sewerage Company Ltd, MOWASSCO.

2.2 Study Area

Mombasa County comprises of four distinct Service Areas that are physically separated by the creeks that surround Mombasa Island. The four Service Areas are Mombasa Island, North Mainland, South Mainland and West Mainland.

The Study Area for this report combines Mombasa Island and North Mainland service areas and the possibility of managing wastewater from Mombasa Island separately or combined with Mombasa North Mainland has been explored in this Master Plan. Other considerations used in delineation of Study Area are the projected Land-Use Plans for year 2040 and the nature / trend of developments and population densities.

Mombasa Island has a total of eleven (11) sub-locations. Since the whole Island is classified as an urban area, all the eleven sub-locations form part of the study area. The current (year 2016) population of Mombasa Island is 176,000.

Mombasa North Mainland is made up of ten (10) sub-locations. The coverage of the study area for the Wastewater Master Plan comprises of parts of 8 sub-locations making up approximately 75% of Mombasa North Mainland. The current (year 2016) population of the study area in Mombasa North Mainland is 468,000.

The sub-locations forming Mombasa Island and North Mainland, their total coverage areas as well as the study area are given in **Tables 2.1** and **2.2** on **Page 2-2**;

Table 2.1: Sub-locations and Study Area – Mombasa Island

Sub-locations	Coverage in the Study Area/ Total Area (km²)
Kizingo	2.16
Ganjoni	2.13
Mwembe Tayari	0.63
Majengo	1.48
Makadara	0.40
Mji Wa Kale	0.41
Bondeni	0.48
Tononoka	1.01
Tudor Four	1.72
Tudor	0.85
Railway	3.48
Total	**14.75**

Table 2.2: Sub-locations and Study Area – Mombasa North Mainland

Sub-locations	Total Area (km²)	Coverage in the Study Area (km²)
Kongowea	8.50	7.10
Maweni	6.47	4.67
Kisauni	8.18	6.19
Magogoni	8.33	7.29
Junda	7.52	3.68
Bamburi	12.45	9.60
Shanzu	7.32	5.29
Mwembe Legeza	11.09	8.29
Total	**69.86**	**52.11**

Figure 2.1 on **Page 2-3** shows the coverage of the Study Area of Wastewater Master Plan for Mombasa Island and North Mainland**.**

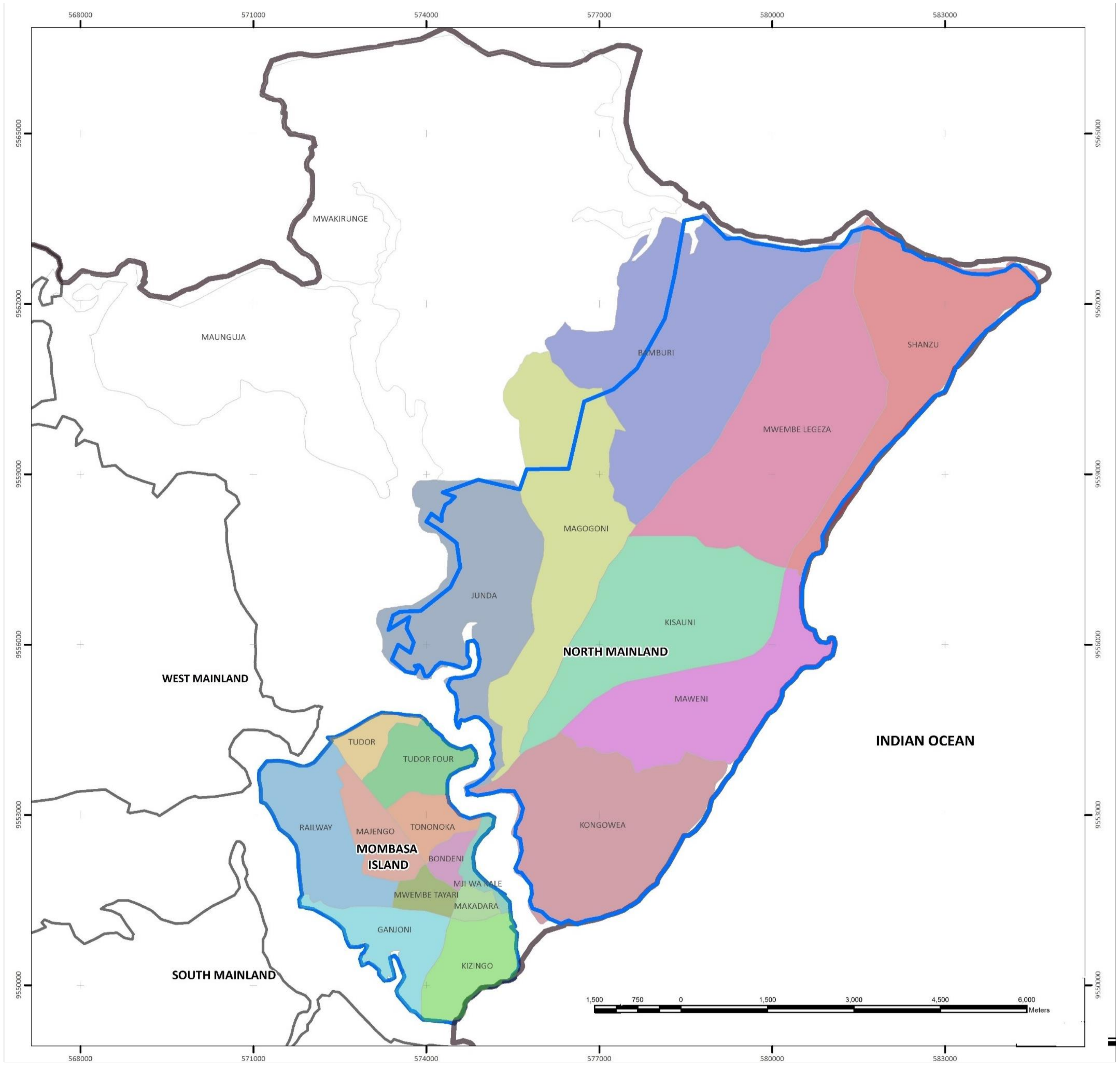


Figure 2.1: Sublocations in Study Area of Wastewater Masterplan for Mombasa Island and North Mainland

2.3 Climate

Mombasa has a tropical wet and dry climate. The rains occur during the inter-monsoonal period, with the long rains starting from March to June, while the short rains occur from October to December.

Mombasa is generally hot and humid all year round. The mean daily temperature ranges between 22°C to 29.5°C. Average relative humidity along the coastal belt is 65% but decreases towards the hinterland. The lowest temperature is experienced during the long rains season.

2.4 Topography, Geology and Soils

Mombasa County is divided into three physiographic belts i.e.:

The 'Coastal Plain' forms the white sandy beaches next to the Indian Ocean. The land formation is a build-up of eroded reef material i.e. corals, sand and alluvial deposits on the inshore side of the reef.

The 'Foot Plateau' occurs after the coastal plain made up of Jurassic shale rock which is broken/dissected through erosion. In some places, it is overlain with residual sandy plateau.

The Nyika Plateau is in the higher areas covered by Duruma Sandstone series and older rocks to the west.

2.5 Economic Activities

Tourism is the most important economic activity in Mombasa Island and North Mainland with a significant number of high standard hotels, medium standard hotels and tourist villas.

Mombasa Port on Mombasa Island is the largest sea port in East Africa and handles goods for Kenya, Uganda, Southern Sudan and other neighbouring countries. This port generates a large transit population which creates demand for services in Mombasa.

Mombasa Island is also the administrative centre for Mombasa County and Commercial developments are also prevalent providing services to the huge residential population.

2.6 Existing Water Supply and Sanitation Systems

2.6.1 Water Supply

Mombasa County is supplied by bulk water from four different sources; Baricho Wellfield, Mzima Springs, Marere Springs and Tiwi Aquifer. These ground water sources require minimal treatment after abstraction. Water is then conveyed to Mombasa and en-route towns and urban centres.

Details of the sources of these water supply schemes for Mombasa County are summarised in **Table 2.3** and **Figure 2.2** on **Page 2-5**.

Table 2.3: Summary of Existing Water Systems for Mombasa County

Baricho Wellfield – Serving Mombasa North Mainland and part of Mombasa Island	Location	Baricho Waterworks, Kilifi County
	Abstraction method	8 Boreholes
	Total Yield	Approx. 96,000 m³/day
Mzima Springs serving Mombasa West Mainland and part of Mombasa Island	Location	Tsavo National Park, Taita Taveta County
	Abstraction method	Headworks at Mzima 1
	Current Production	Approx. 35,000 m³/d
Marere Springs serving Mombasa Island, West Mainland and South Mainland	Location:	Shimba Hills Game Reserve, Kwale County
	Abstraction method	Headworks
	Current Abstraction:	10,000 m³/d
Tiwi Wellfield serving South Mainland	Location	Kwale County
	Abstraction method	12 Boreholes
	Current Production	10,000 m³/d

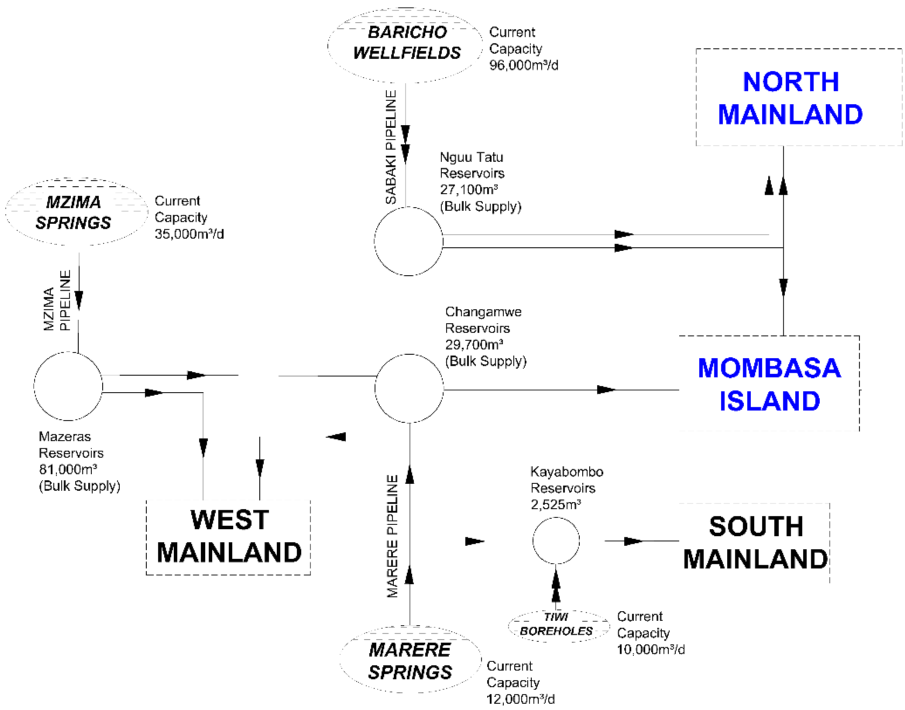


Figure 2.2: Schematic of Existing Water Supply System in Mombasa

The Water Supply for Mombasa County is generally insufficient and requires extension of the Souce Works and Distribution Network to adequately serve the urban and peri-urban areas and cater for the future needs of the growing population. Preparation of a Water Distribution Master Plan is in progress to address these challenges.

Also upon implementation of Mwache Dam for Mombasa and Kwale Counties which is currently at design review stage, it is expected that the water deficit will greatly reduce.

2.6.2 Sanitation System

2.6.2.1 Mombasa Island System

In 1962, a piped Sewerage Scheme was built on Mombasa Island to serve the densely populated area of the Old Town. This was the first phase of a strategy to provide sewers to the whole of Mombasa Island which only covered a small area of the Central Business District. Since then, minimal expansion has been undertaken on the sewerage system.

Within the Sewerage system, four small pumping stations are located along the edge of the sewered area adjacent to the sea, to lift wastewater from localized low areas into the Sewerage Collection System. A Tunnel links the sewer network with Kizingo Wastewater Treatment Plant, located in the South-East corner of the Island at Ras Serani. A short sea outfall of approximately 40 m long discharges the partially treated effluent from the Treatment Plant into the Ocean. A Layout Plan outlining the Island Sewerage System and location of Kizingo WWTP is provided in **Figure 2.3** on **Page 2-7**.

Small Sewerage Schemes to serve individual Housing Estates on the Island, such as Tudor Estate, Buxton Estate, and Makande Estate were constructed in the 1960s. Each of the Housing Estates located at the opposite end of the Island to the Kizingo Treatment Plant was provided with its own communal septic tank and soakage pit. Tudor Estate and Makande Estate were provided with pumping stations to pump the wastewater into the septic tanks. None of the sewerage schemes as well as pumping stations is operational.

The Old Town Wastewater Collection System excluding the Main Outfall Tunnel, has a total sewer network length of approximately 20 km, with pipe sizes varying in diameter from 150mm up to 600mm. The 150mm size pipes are made of pitch fibre and the remainder are precast concrete pipes. No expansion of the Old Town Sewerage System has taken place since its construction over fifty years ago.

The Major Collection Tunnel that connects Old Town Sewerage Network to the Kizingo Treatment Plant has a cross-sectional area of 1.9m^2. The estimated capacity of the tunnel is 3m^3/s and it was clearly designed to accept the future wastewater flows from a large part of the Island, not only the Old Town.

The Treatment Plant at Kizingo was designed to provide only preliminary treatment (screening and grit removal) and primary treatment (sedimentation). The Inlet Works was designed for a Dry Weather Flow of 32,500 m^3/day. Construction of the Sedimentation Tanks was phased and the initial installation has a settlement capacity for a Dry Weather Flow of only 3,000m^3/day. The Treatment Plant has been out of operation for many years. All the M&E equipment is missing (Jan 2015) and a by-pass arrangement directs discharge of sewage into the ocean through a 40m long outfall pipe at Ras Serani. The Outfall Pipe is broken at a point approximately 18m offshore and leakage at this point is visible.

No treatment was provided to the sludge collected from the Sedimentation Tanks in the Kizingo Treatment Plant; instead, it was pumped directly into the ocean each day through the outfall pipe during periods when the tide was going out, so that it would be transported by the tide out to deep water for greater dilution.

2.6.2.2 Mombasa North Mainland System

There is no sewerage system in the Mombasa North Mainland except for minor schemes to serve specific housing estates, such as Kisauni Estate on the North Mainland. Most of these privately owned systems are in poor condition.

Since sewer network is non-existent in these service areas, majority of the institutions / households make use of on-site disposal systems such as pit latrines, open defecation and septic tanks for their sanitation needs.

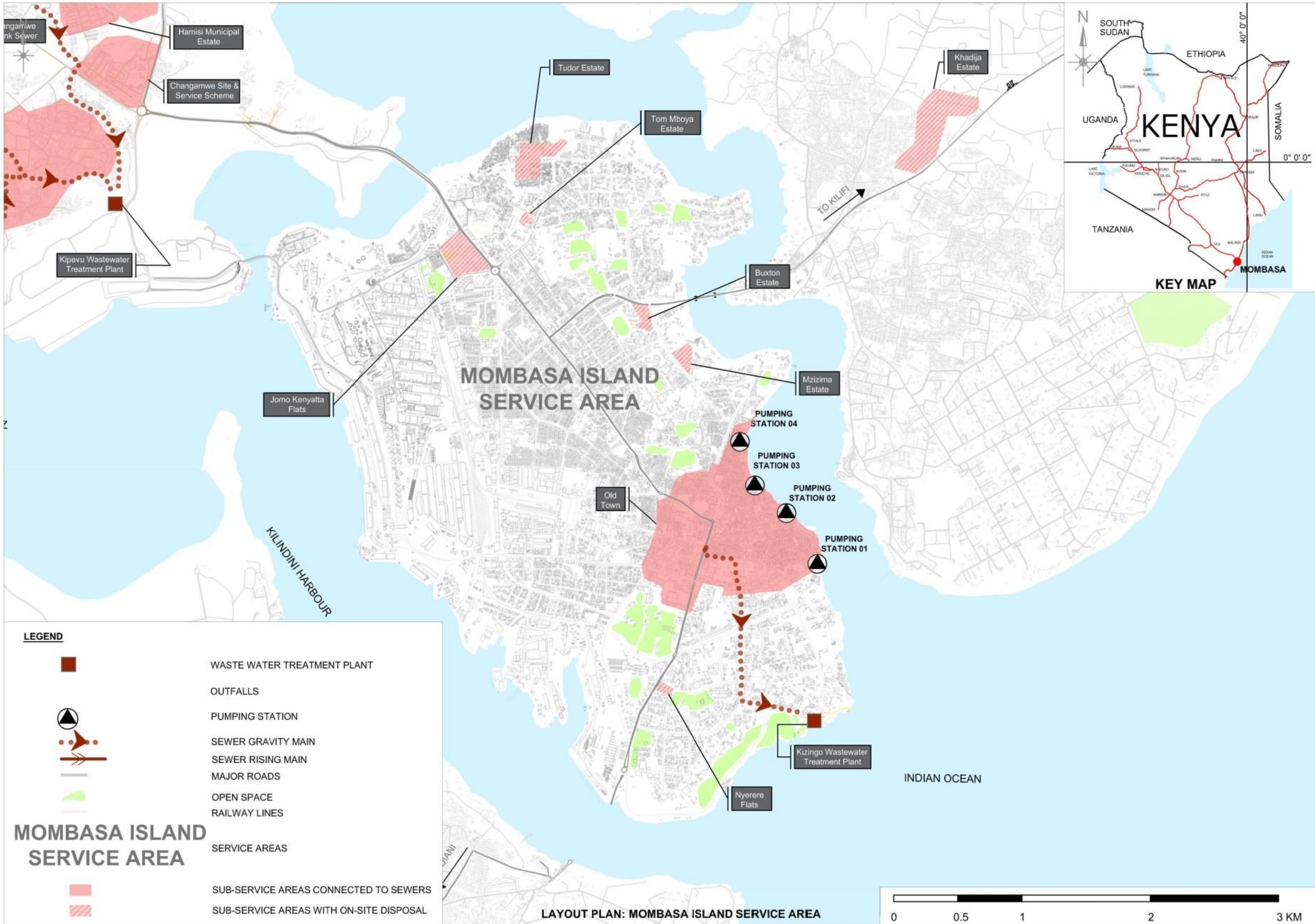


Figure 2.3: Layout Plan – Existing Sewerage System in Mombasa

2.7 Immediate Measures for the Improvement of Sanitation Systems

In situations of suppressed water supply, the use of on-plot sanitation systems though unsustainable environmentally is manageable. If the water supply situation is improved through the development of additional water resources and expansion of water distribution networks, as planned for Mombasa Island and North Mainland, the use of on-plot sanitation systems will not suffice and thus health and environmental hazards are bound to occur.

In summary, the current sanitation infrastructure in Mombasa Island and North Mainland is insufficient to meet the sanitation needs of the growing population and there is need for a development of a water-borne sanitation system which is environmentally sustainable.

The Final Wastewater Master Plan for Mombasa Island and North Mainland describes the development strategy for the long-term water-borne sanitation system comprising of a wastewater collection / conveyance system and the treatment / proper disposal of the treated effluents. However, the long-term sanitation strategy is not planned for immediate implementation.

In consideration of the current sanitation systems and the growing sanitation needs, an immediate intervention is urgently required. Thus, Immediate Sanitation Measures have been developed. These measures include rehabilitation of the existing sewerage system, construction of Ablution Blocks in public places and Sludge Handling Facilities as described in the following sub-sections.

2.7.1 Rehabilitation Works on Mombasa Island

a) Existing Sewerage System

From condition survey carried out, it was established that the Mombasa Island Sewerage System comprises of the following:

- Total number of Manholes - 503Nr
- Length of Sewers as follows:
  - 150mm - 972m
  - 175mm - 12,915m
  - 225mm - 2,261m
  - 300mm - 555m
  - 375mm - 413m
  - 450mm - 417m
  - 600mm - 2,347m
  - Total Length - 19,878m
- Sewered Area - 1.6km^2

b) Results of Condition Survey

A summary of the results of the Condition Survey is outlined in **Table 2.4** below.

Table 2.4: Outline of Results of Condition Survey of Secondary Sewers, Jan 2015

Item Nr	Description	Unit	Quantity
1.	Partially blocked manholes	Nr	60
2.	Fully blocked manholes	Nr	26
3.	Manholes with minor flow obstruction	Nr	28
4.	Partially blocked sewers	m	1,414
5.	Fully blocked sewers	m	1,012
6.	Sewers with unobstructed flow	m	3,565
7.	Overflowing manholes	Nr	-
8.	Buried manholes that require raising above the ground	Nr	37
9.	Missing / broken manhole covers	Nr	-
10.	Damaged manhole cover slabs	Nr	-

c) Rehabilitation Works on sewerage system

The following rehabilitation works will be carried out:

- Replacement of missing / vandalised manhole covers
- Repair of broken manholes
- Unblocking of partially / fully blocked sections of the sewer line and flushing
- Identify, expose and raise above ground levels buried manholes
- Replacement of collapsed sections of the sewer line
- Supply of Aluminium Telescopic Ladders

d) Rehabilitation of Mombasa Island Pumping Stations

- The structures of all the pumping stations (Total 4Nr) were reported to be sound with no visible sign of deterioration. However, rehabilitation works are required for buildings and site and ancillary works i.e. security lighting, drainage system, buildings, fencing, etc.

2.7.2 Ablution Blocks

Ablution Blocks are essential in Mombasa Island and North Mainland for improved access to sanitation facilities especially in public places e.g., markets, bus stops, etc. They are important to market vendors, market customers, long distance travelers, bus operators and the general public. Their locations in Mombasa Island and North Mainland will be selected in consultation with the CWSB and the Mombasa County Government.

Considering the population densities and the number of public utilities, a total of five (5) Ablution Blocks is proposed for construction in Mombasa Island and total of three (3) for Mombasa North Mainland. Each Ablution Block comprises of six (6) toilets and two (2) Shower Rooms with equal number for each gender i.e. Ladies and Gents. The allocated number of toilets in each Ablution Block ensures provision of sufficient service levels for the target population. It is estimated that on average, a user spends 5 minutes in the facility. Thus, for a single facility with 6 toilets and 10 hours of operation in a day, a maximum number of 720 persons can be served in a day.

Each section (ladies and gents) is provided with a toilet fitted with special amenities for use by disabled persons. The "Gents" are provided with separate urinals to increase the service levels especially during the peak hours

The shower rooms are equipped with a dressing area and hand-wash basins. In addition, a spacious common area with hand-wash basins, hand driers and wall mounted mirrors is provided.

Each of the units is fitted with coat hangers behind the doors for convenience. To enhance natural lighting within the facility, transparent polycarbonate roofing material have been incorporated in the design. Proper ventilation is ensured by the louvered windows and gap between the ring beam and the roof. The gap is fitted with louvre blocks and plastic coated coffee tray wires to prevent insect entry.

A septic tank with a holding capacity of 16 m^3 is provided at the facility for storage and partial treatment of sewage. The septic tank will require desludging after every 3 months with septage disposal at the proposed Sludge Handling Facility, to be implemented as part of the immediate sanitation intervention. In addition, a 5,000-litre water tank mounted on a 3.5m high reinforced concrete tower within the facility provides a 3-day storage of clean water.

Other services provided at the site include; electricity for use at night and for security lighting, and security / controlled access through chain link fence and a 4m wide metallic gate.

Permission to use the facility is to be on a pay-per-use basis. This is an effective model used in many parts of the country to raise money required for operation and maintenance. A personnel office complete with a storage room shall be provided at the entrance of the facility with grilled opening for ease of payment before use.

A typical Site Layout, Plan and Elevations of the proposed Ablution Block are given in **Figures 2.4 and 2.5** on **Pages 2-11** and **2-12 respectively.**

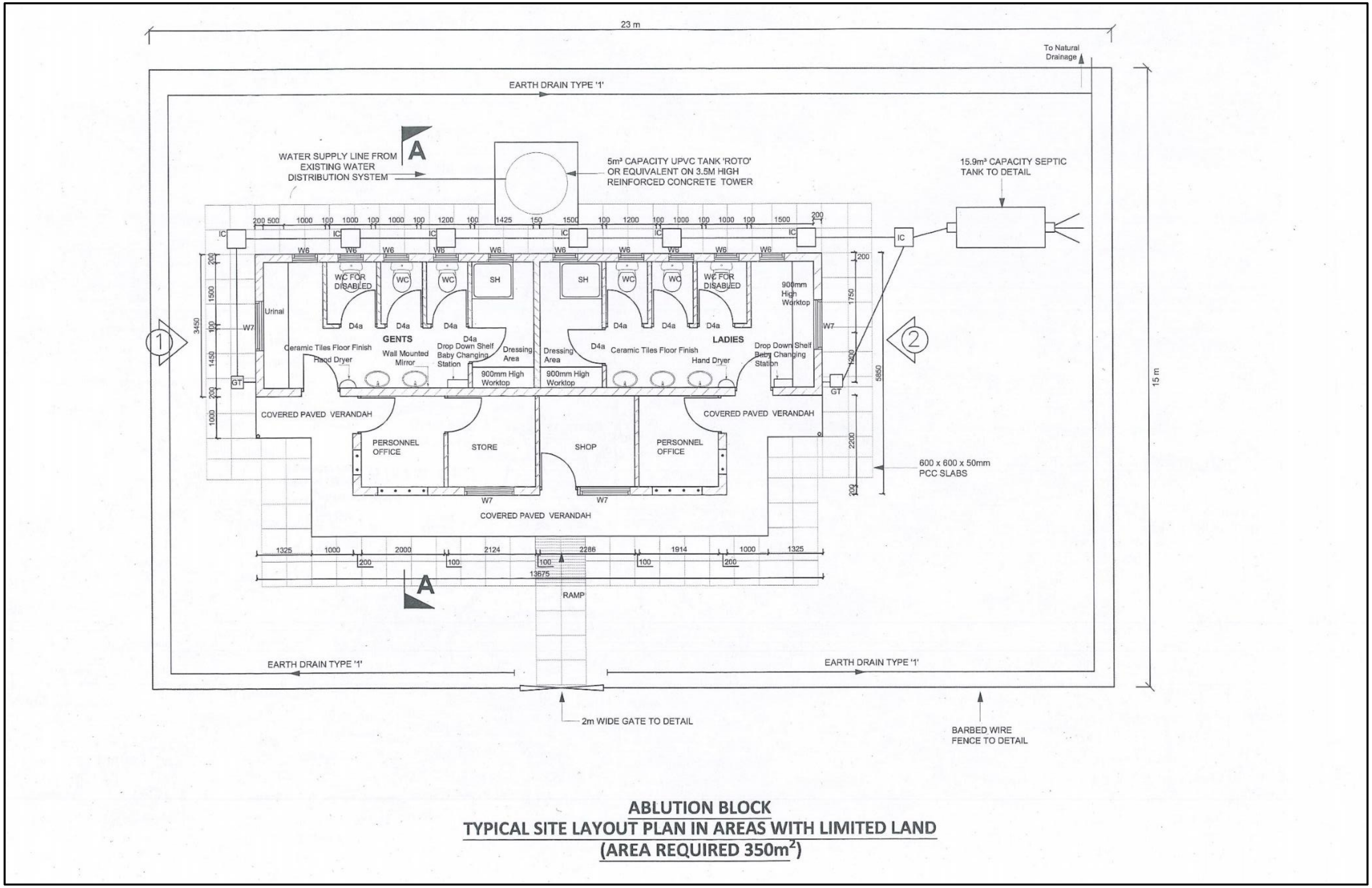


Figure 2.4: Typical Site Layout Plan for an Ablution Block

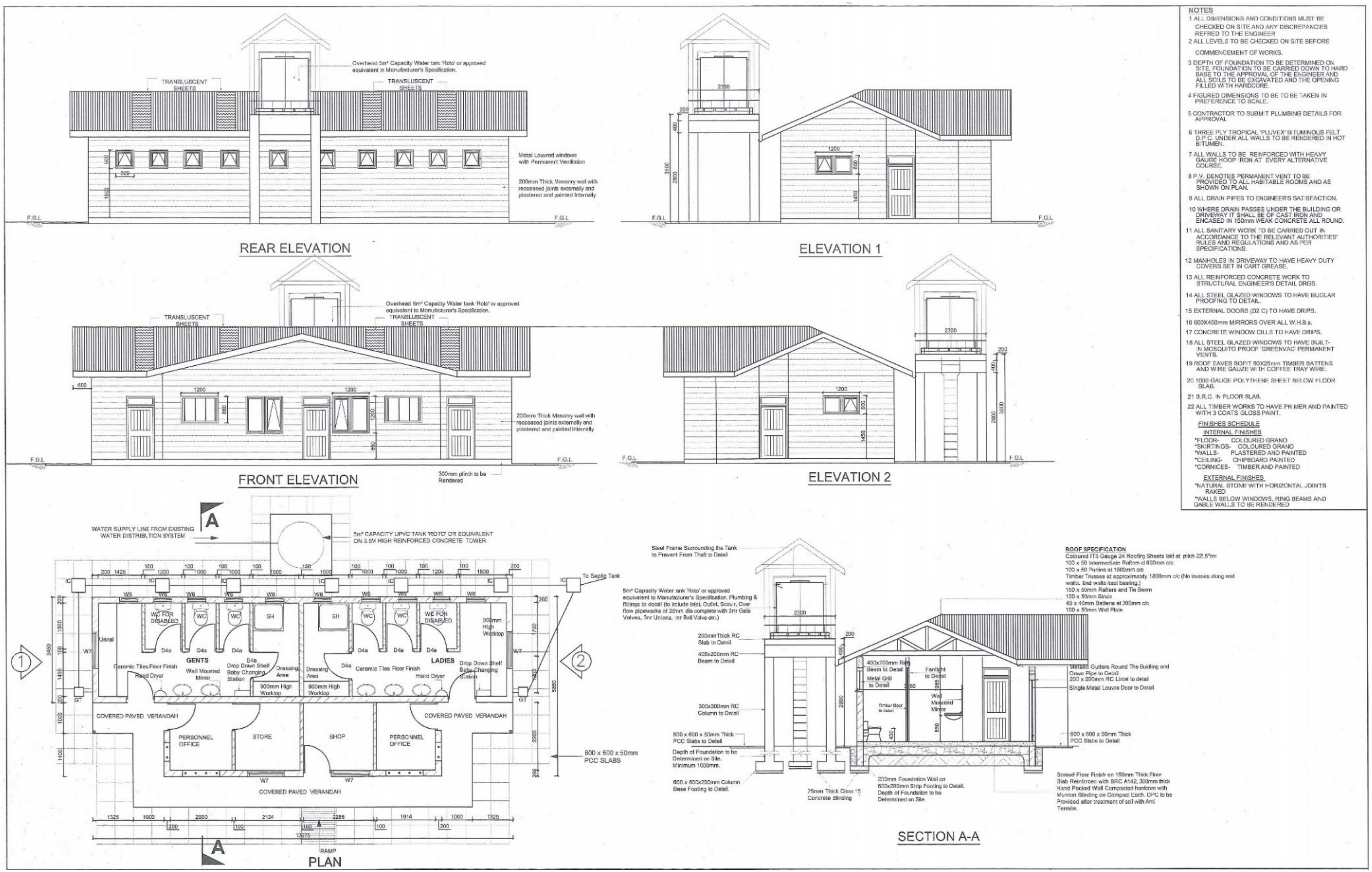


Figure 2.5: Typical Plan, Views and Sections of an Ablution Block

2.7.3 Sludge Handling Facility

A Sludge Handling Facility is a small-scale treatment plant for the treatment and safe disposal of septage from on-plot sanitation systems such as septic tanks or pit latrines. Septage from the on-plot sanitation systems is conveyed to the facility via an Exhaust Vacuum Tanker.

With exception of the Screens, Sludge Handling Facility relies on biological processes for the treatment of septage. This results to low capital investment requirement as well as Operations and Maintenance requirements (skills, complexity and labour costs), thus making it a suitable Immediate Sanitation Measure.

An ideal location for a Sludge Handling Facility is a site within economical distance to the service area but outside the residential zones and other socio-environmentally sensitive areas. At present, the Water Service Provider (MOWASSCO) has indicated availability of land for construction of this facility at Shimo la Tewa. This location is suitable for siting a Sludge Handling Facility.

The proposed Sludge Handling Facility will comprise of the following units;

a. Exhaust Vacuum Tanker Discharge Bay
b. Sludge Drying Lagoons
c. Septic Tanks complete with Soak Pits and French Drains
d. Associated Site and Ancillary Works, including Operator’s Office/ Guard House

Constructed wetlands are the alternative treatment unit to Septic Tanks for polishing of septage from Sludge Drying Beds / Lagoons. However, they require large footprint than the Septic Tanks and thus not suitable for urban areas like Mombasa Island and North Mainland where land is limited and the cost considerably high.

A Schematic Layout Plan showing the arrangement of the units for the Proposed Sludge Handling Facility is given in **Figures 2.6** on **Page 2-14.**

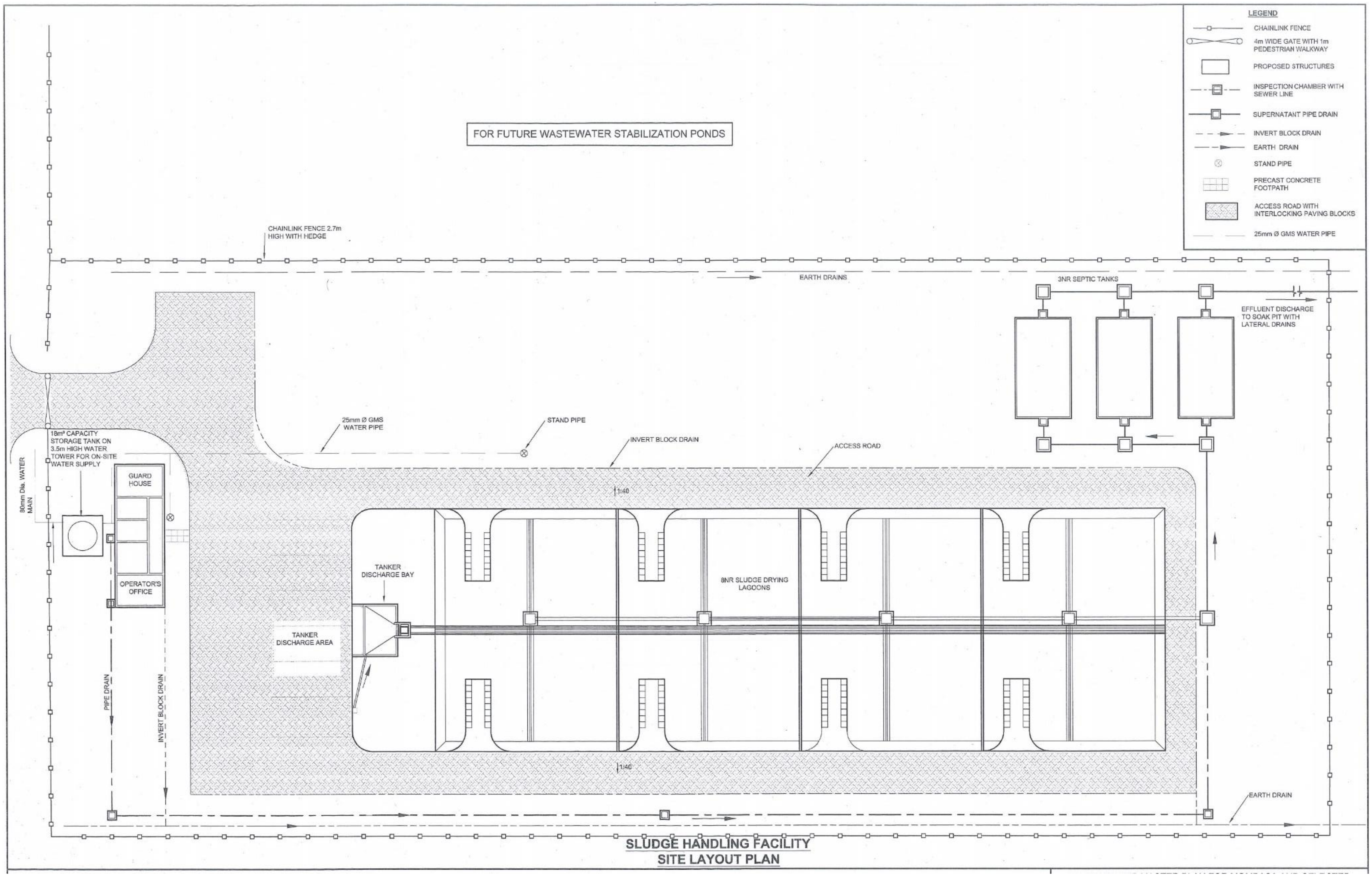


Figure 2.6: Schematic Layout Plan of the proposed Sludge Handling Facility

A brief description of the constituent treatment units in the proposed Sludge Handling Facility is given in the following sub-sections;

2.7.3.1 Exhaust Vacuum Tanker Discharge Bay

The Discharge Bay comprises of a septage discharge area which serves as the Inlet Works for the Sludge Handling Facility. An Exhaust Vacuum Tanker discharges septage at the Discharge Bay through Bar Screens into a Collection Chamber. The Discharge Bay is also provided with Hard-stand Washing Bay and Parking Space.

The discharged septage and wash water from the Washing Bay are pooled into the Collection Chamber and conveyed to the Sludge Drying Bed / Lagoons via an Open Channel to be provided with precast concrete cover slabs and guardrails for safety.

The Discharge Bay requires regularly cleaning for odour, flies and other disease-vectors control especially after each exhauster discharge session. A stand pipe will be provided to facilitate washing and flushing of septage once discharged.

2.7.3.2 Sludge Drying Lagoons / Beds

Septage is mostly liquid with small amounts of solids. Treatment of septage entails reducing sludge weight and volume with the aim of lowering the disposal costs of the residual sludge and reducing the potential health risks associated with septage.

Sludge Drying Lagoons are open areas on which the septage is spread for dewatering and air-drying. It comprises of filter media, perforated pipes at the beds and a Collection System. The filtrate from septage once directed into the Collection System is conveyed to Septic Tanks for further treatment and pathogen reduction.

The Sludge Drying Lagoons are made up of the following parts:

- Concrete Beds and Walls
- Sand and Gravel as Filter Media
- Splash Slab
- Under-drainage System
- Access Structures

A Sludge Drying Lagoon has intrinsic process reliability and flexibility. However, during wet season, the efficacy is hindered and longer drying periods are required.

For efficient operation of Sludge Drying Lagoons the following measures need to be undertaken;

a) Periodic unblocking of Collection System through the rodding chambers
b) Periodic monitoring and replacement of Filter Media when necessary
c) Maximum permissible sludge accumulation level to be observed for optimum operation
d) Proper drying of sludge once a bed is filled up
e) Careful removal of dried up sludge without scooping of filter media
f) Safe disposal of dried sludge to a landfill, agricultural use etc.

2.7.3.3 Septic Tank

A septic tank refers to a water-tight, covered, sub-surface receptacle for wastewater treatment. At the Sludge Handling Facility, Septic Tanks will be adopted for polishing of the filtrate from Sludge Drying Beds before discharge into the environment through soak pits French Drains.

Septic Tanks achieve polishing of septage filtrate by carrying out the following processes:

a) Separation of settleable and floating solids from the liquid
b) Digestion of organic matter by anaerobic bacterial action
c) Storage of digested solids during detention period
d) Allowing clarified liquids to discharge for final disposal

Septic tanks require periodic desludging after accumulation of solid sludge and disposal of residual sludge through burying or conversion into fertilizers.

2.7.3.4 Associated site and Ancillary works

To enhance access, proper drainage and security, the following site and ancillary works have been proposed at the Sludge Handling Facility;

i. Chain-link Fence and 4m wide Gate
ii. Access Roads paved with interlocking concrete blocks
iii. Operator's Office, Store, Washroom and Guard House
iv. Site drainage system
v. Onsite water supply

2.7.4 Design Criteria for Sludge Handling Facility

A summary of the Design Criteria adopted in the sizing of the proposed Sludge Handling Facility for Mombasa Island and North Mainland is given in **Table 2.5** below.

Table 2.5: Design Criteria - Sludge Handling Facility

Treatment Unit	Design Parameter	Value
Sludge Drying Bed	• Sludge accumulation rate	0.025 m^3/ca/yr
	• Sludge drying period	3 Months
	• Depth of media	300 mm
	• Sludge accumulation depth	150 mm
Septic Tank	• Aggregated Sewage generation factor	0.25*
	• Retention period	1 day
	• Sludge accumulation	0.04 m^3/capital/year

***Aggregated sewage generation factor of 25% is based on the distributive use of Septic Tanks and Pit Latrines by the respective Income Levels of the Population and sludge reduction in the On-Plot Sanitation Systems due to the anaerobic digestion during the period of storage by the on-plot sanitation systems*.**

2.7.5 Components of the Proposed Sludge Handling Facility

Considering that these Sanitation Measures for Mombasa Island and North Mainland are intended to serve the immediate needs, the Facility is designed to serve 20% of the estimated current population i.e. **10,000 persons**. This is because embracing of Sludge Handling Facility is expected to be gradual. Rigorous Public Health Campaigns are necessary for full usage to be experienced.

Details of the various components of the proposed Sludge Handling Facility in Mombasa Island and North Mainland are summarised in **Table 2.6** below

Table 2.6: Details of the Treatment Units at the Proposed Sludge Handling Facility

S/No.	Treatment Unit	Details
1.	Discharge Bay	• Bar Screens & Collection Chamber • Hard-stand Washing Bay & Parking
2.	Sludge Drying Lagoons / Beds	• 8 No. Beds; each 13 x 10 m • Sludge drying period: 3 months • Treatment zone media = 500 mm thick
3.	Septic Tanks	• 3Nr Twin-Tank; each 9.6 x 5.4 x 1.9 m (L x W x H) & capacity 98 m^3 • Desludging Interval = 0.2 years

Approximately **0.7Ha** of land is required for the construction of the proposed Sludge Handling Facility to serve the immediate sanitation needs of Mombasa Island and North Mainland**.**

Co-location of Sludge Handling Facility and Wastewater Treatment Plant is recommended for efficient land use and for shared use of common units and facilities. Therefore, the Shimo la Tewa site recommended for the development of Wastewater Treatment Plant under this Master Plan is an ideal location of the Sludge Handling Facility.

2.7.6 Implementation Cost for Immediate Measures

Engineer's Cost Estimate determined for the Immediate Measures for Improvement of Sanitation System in Mombasa Island and North Mainland based on the unit costs from recent contracts of similar scope and nature. Detailed Unit Costs and their derivations are discussed in **Chapter 8** of this Report.

A summary of the Implementation Costs is given in **Table 2.7** below.

Table 2.7: Implementation Costs for Immediate Measures

S/No.	Component	Number to be Provided	Cost, Kshs.	Cost, USD
1.	Rehabilitation Works	-	24,781,000	2,147,694
2.	Ablution Blocks	8	124,000,052	1,203,884
3.	Sludge Handling Facility	1	58,299,957	566,019

3.0 DEMOGRAPHY, LAND USE AND URBAN DEVELOPMENT

3.1 Demography and Population Dynamics

Demographic data from Central Bureau of Statistics (CBS), for the inter-censal periods between 1979 to 2009 have been analysed to establish trends in terms of population size and inter-censal growth rates, to develop future population projection patterns in Mombasa Island and North Mainland.

3.1.1 Previous Population Trend

From the analysis of the previous Kenya Population and Housing Census data, it is construed that between inter-censal periods, existing sub-locations are split to form new sub-locations and the areas covered by the sub-locations, in such cases, vary between the inter-censal period.

A summary of previous inter-censal population data for Mombasa Island and North Mainland is given in **Table 3.1** and **3.2** below.

Table 3.1: Inter-censal Population Data (1979 - 2009) for Mombasa Island

Sub-locations	(Census)											
	1979			1989			1999			2009		
	Pop.	Area (km²)	Pop. Density (person/km²)	Pop.	Area (km²)	Pop. Density (person/km²)	Pop.	Area (km²)	Pop. Density (person/km²)	Pop.	Area (km²)	Pop. Density (person/km²)
Ganjoni	11,366	2.0	5,683.0	10,761	4.0	2,690.25	11,626	2.1	5,536.19	10,418	2.2	4,735.45
Kizingo	11,654	2.0	5,827.0	5,534	4.0	1,383.50	7,165	2.2	3,256.82	7,163	2.2	3,255.91
Majengo	15,322.0	-	-	15,913	1.0	15,913.00	18,804	1.1	17,094.55	30,920	1.5	20,613.33
Mwembe Tayari	12,634.0	-	-	10,543	1.0	10,543.00	7,810	0.5	15,620.00	7,914	0.6	13,190.00
Makadara	11,705.0	-	-	8,000	0.4	20,000.00	10,129	0.4	25,322.50	8,656	0.4	21,640.00
Mji wa Kale	8,284.0	-	-	8,923	1.0	8,923.00	11,387	0.4	28,467.50	10,056	0.4	25,140.00
Railway	-	-	-	-	-	-	-	-	-	8,388	3.4	2,467.06
Bondeni	8,187.0	-	-	8,306	0.3	27,686.67	8,800	0.5	17,600.00	10,157	0.5	20,314.00
Tononoka	19,058.0	1.0	19,058.0	17,817	2.0	8,908.50	20,244	1.3	15,572.31	17,356	1.0	17,356.00
Tudor 4	9,219.0	1.0	9,219.0	11,401	2.0	5,700.50	13,148	1.4	9,391.43	14,470	1.7	8,511.76
Tudor Estate	7,937.0	-	-	7,902	1.0	7,902.00	14,077	0.7	20,110.00	17,630	0.8	22,037.50
Total	**115,366**	**6**	**19,227.67**	**105,100**	**17**	**6,293**	**123,190**	**11**	**11,622**	**143,128**	**15**	**9,737**

Table 3.2: Inter-censal Population Data (1979 - 2009) for Mombasa North Mainland

Sub-locations	(Census)											
	1979			1989			1999			2009		
	Pop.	Area (km²)	Pop. Density (person/km²)	Pop.	Area (km²)	Pop. Density (person/km²)	Pop.	Area (km²)	Pop. Density (person/km²)	Pop.	Area (km²)	Pop. Density (person/km²)
Bamburi	4,843	10.0	484.30	25,662	32	801.94	12,028	13.3	904.36	24,918	12.3	2,025.85
Maunguja	1,172	7.0	167.43				-	-		1,526	11.1	137.48
Mwakirunge	2,059	27.0	76.26	3,635	47	77.34	5,712	40.0	142.80	7,403	31.3	236.52
Mwembelengeza	-	-		-	-		18,324	11.3	1,621.59	28,803	11.1	2,594.86
Shanzu	6,766	7.0	966.57	-	-		9,230	6.5	1,420.00	9,264	7.2	1,286.67
Junda	0	0		-	-		13,564	9.0	1,507.11	39,432	7.5	5,257.60
Kisauni	20,420	13.0	1,570.77	71,997	31	2,322.48	51,250	8.2	6,250.00	79,811	8.1	9,853.21
Magogoni	-	-		-	-		53,075	6.6	8,041.67	82,718	8.3	9,966.02
Kongowea	29,333	13	2,256.38	52,030	16	3,251.88	49,156	8.0	6,144.50	63,993	8.4	7,618.21
Maweni	-	-		-	-		37,522	6.8	5,517.94	42,187	6.4	6,591.72
Total	**64,593**	**77**	**838.87**	**153,324**	**126**	**1216.86**	**249,861**	**110**	**2277.68**	380,055	**112**	**3402.46**

Population data is dependent on the coverage considered; for the same Town and time, a larger area would give a higher population. The use of population figures to establish inter-censal population growth rate in a sub-location with varying coverage areas between inter-censal period is inaccurate due to the variability of coverage area. It is therefore prudent to adopt the use of population density as a measure of demographic trend where sub-location coverage varies between inter-censal period, as is the case in Mombasa Island and North Mainland.

The inter-censal Annual Population growth rates based on the population densities for the sub-locations within the study area of Mombasa Island and North Mainland are given in **Table 3.3** and **3.4** below.

Table 3.3: Previous Inter-censal Annual Population Growth Rates in Mombasa Island

Sub-locations	Annual Growth Rates per inter-censal period		
	1979-1989	1989-1999	1999-2009
Ganjoni	-7.2%	7.5%	-1.6%
Kizingo	-13.4%	8.9%	0.0%
Majengo	0.0%	0.7%	1.9%
Mwembe Tayari	0.0%	4.0%	-1.7%
Makadara	0.0%	2.4%	-1.6%
Mji wa Kale	0.0%	12.3%	-1.2%
Railway	0.0%	0.0%	0.0%
Bondeni	0.0%	-4.4%	1.4%
Tononoka	-7.3%	5.7%	1.1%
Tudor 4	-4.7%	5.1%	-1.0%
Tudor Estate	0.0%	9.8%	0.9%
Total		**6.3%**	**-1.8%**

Table 3.4: Previous Inter-censal Annual Population Growth Rates in Mombasa North Mainland

Sub-locations	Annual Growth Rates per inter-censal period		
	1979-1989	1989-1999	1999-2009
Bamburi	5.17%	1.21%	8.40%
Maunguja	-	-	-
Mwakirunge	0.14%	6.32%	5.18%
Mwembelengeza	-	-	4.81%
Shanzu	-	-	-0.98%
Junda	-	-	13.31%
Kisauni	3.99%	10.41%	4.66%
Magogoni	-	-	2.17%
Kongowea	3.72%	6.57%	2.17%
Maweni	-	-	1.79%
Total	**3.79%**	**6.47%**	**4.10%**

From **Tables 3.3** and **3.4** above, on the analysis of previous Kenya Population and Housing Census data, the population of the study area of Mombasa Island and North Mainland in the Year 2009 are **143,128** and **380,055** respectively while their respective annual population growth rates in the last inter-censal period (1999- 2009) are **-1.8%** and **4.10%**.

The above population dynamic is mainly for the resident category. The non-resident category comprising of tourists / visitors is considered under the respective contributory Land-Use activities.

3.1.2 Population Growth Scenarios

Population trends are influenced by fertility, mortality and migration levels and patterns as well as the national socio-economic development momentum.

More rapid population growth is expected in Mombasa Island due to improved infrastructure development resulting in the planned development of more high storey residential apartments to replace the dominant single-detached dwellings. On the other hand, it is expected that North

Mainland will experience decrease in population growth rate due to development of other peri-urban areas e.g. Mtwapa as North Mainland becomes more saturated, cost of land increases and more commercial and industrial activities establish. The above population growth prediction has been done determined in corroboration with the Integrated Development Plan for Mombasa County.

Future populations of both Mombasa Island and North Mainland have been projected up to Year 2040 based on medium-growth rate scenario, with a constant annual population growth rate of 3% up to Year 2040. This is comparable to the average national growth rate of 3.19% for the period 1999 to 2009 as detailed in the 2009 Kenya Population and Housing Census.

In the last census (2009), it was established that the population within Mombasa Island is **143,128** and within Mombasa North Mainland is **380,055**. This gives a total population of **523,183.** To forecast the future population up to the design horizon (year 2040), the following factors have been considered:

- Percentage inter census global growth rates
- The dynamics of Land Use and Trends of development
- The correlation of water demand and income / type of housing, population density etc.
- Integrated Strategic Urban Development Plan for Mombasa County (Year 2015)

Three population growth rate scenarios have been formulated for the population projection in the study area based on the data obtained from Kenya National Bureau of Statistics, Census Reports and other relevant planning documents. These scenarios are briefly described below;

High Growth Rate: This growth rate scenario assumes that the resident population will grow at a higher growth rate than that reported in the last inter-censal period i.e. at **5.0%** up to the design horizon of year 2040. This can only happen if the overall natural growth of the resident population continues because of decreased mortality rates and increased life expectancy while immigration gradually increases due to intensive investments. Under this scenario, the projected population for Mombasa Island and North Mainland at year 2040 will be **2,374,225.**

Medium Growth Rate: This growth rate scenario assumes that the resident population will grow at a moderate growth rate increasing from **3.0%** up to the design horizon of year 2040. This is comparable to the average national growth rate of 3.19% for the period 1999 to 2009 as detailed in the 2009 Kenya Population and Housing Census. This scenario is possible if the natural growth of the population and influx from immigrants balances out with increased emigrants and mortality rate while growth limiting factors such as increased uptake of family planning practices, limited employment opportunities and growth of adjacent peri-urban areas take significance. Thus, the projected population at year 2040 under the assumed medium growth rate scenario is **1,308,000**.

Low Growth Rate: This scenario assumes that the population trend in the 1999 - 2009 inter-censal period will be experienced i.e. a decrease in Mombasa Island population by -1.8% and an increase in Mombasa North Mainland Population by 4.1% up to the design horizon of year 2040. In this scenario, the population in horizon year 2040 will be **757,268.** However, from an Urban Planning perspective, the trend of population growth in Mombasa Island is expected to be reversed due to the current improvements in infrastructure and conversion of single unit residential developments into multi-storey units. The trend of population growth in Mombasa North Mainland has been on the decline as land prices are prohibitive and the availability of suitable alternative development areas in the adjacent peri-urban area of Mtwapa. This trend is expected to continue.

Projected populations for the above population growth rate scenarios are given in **Figure 3.1** below;

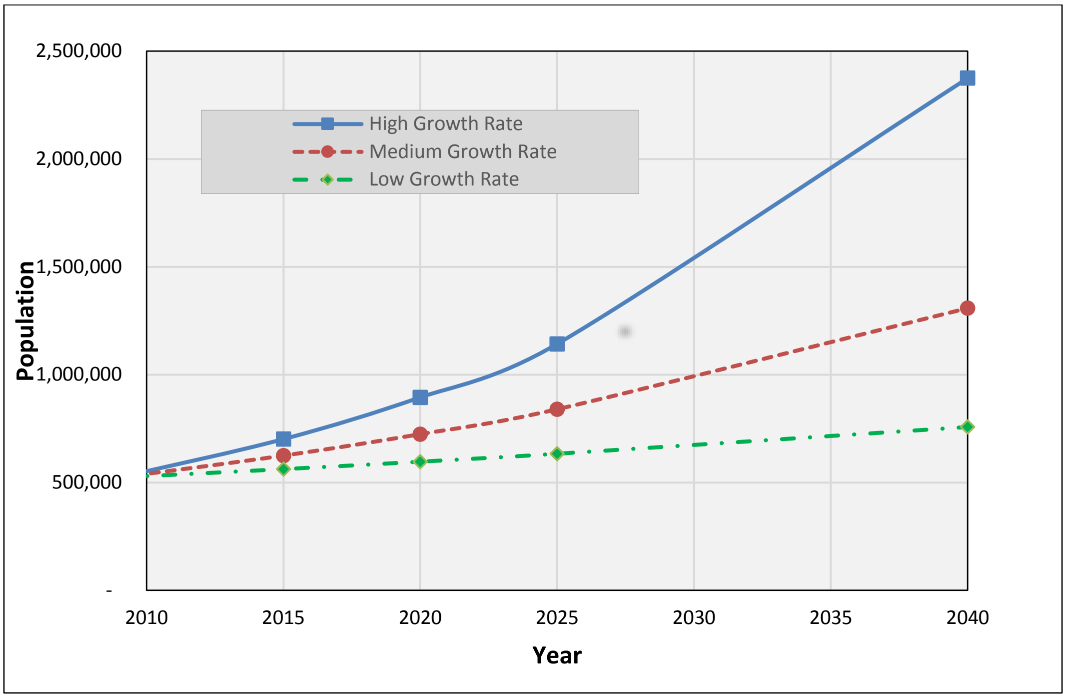


Figure 3.1: Projected Populations based on Growth Rate Scenarios

From Figure 3.1 above, it can be deduced that population forecast is highly sensitive to population growth rate; high growth scenario results to 81% additional population to the medium growth rate scenario while low growth rate scenario results to 42% less the medium growth rate scenario.

3.1.3 Projected Population for Mombasa Island and North Mainland

With the current improvements in infrastructure and the current emphasis of the County as the administrative centre under the new devolved structure of the Kenyan Government resulting in an increase in opportunities for employment, investments, population in and around Mombasa Island and North Mainland is set to grow.

Thus, **the medium growth rate scenario considered under the population growth scenario, is the most probable scenario for the future population projections of Mombasa Island and North Mainland Town up to the 2040 design year**. It considers the demographic dynamics with neighbouring Towns, possible trends in fertility, mortality and migration levels and patterns as well as the socio-economic development. Besides, it has the minimal risk associated under-utilization or over-investments as a result of the population growth deviating from the adopted.

Tables 3.5 and **3.6** on **Page 3-5** gives a summary of the projected population for Mombasa Island and North Mainland up to the design horizon of year 2040, based on the adopted medium growth rate scenario.

Table 3.5: Summary of the Projected Population for Mombasa Island

Sub-locations	2009	Projected population			
		2015	2020	2025	2040
Ganjoni	10,418	12,440	14,421	16,718	26,046
Kizingo	7,163	8,553	9,915	11,495	17,908
Majengo	30,920	36,920	42,801	49,618	77,302
Mwembe Tayari	7,914	9,450	10,955	12,700	19,786
Makadara	8,656	10,336	11,982	13,890	21,641
Mji wa Kale	10,056	12,007	13,920	16,137	25,141
Railway	8,388	10,016	11,611	13,460	20,971
Bondeni	10,157	12,128	14,060	16,299	25,393
Tononoka	17,356	20,724	24,025	27,851	43,391
Tudor 4	14,470	17,278	20,030	23,220	36,176
Tudor Estate	17,630	21,051	24,404	28,291	44,076
Total	**143,128**	**170,902**	**198,123**	**229,678**	**357,832**

Table 3.6: Summary of the Projected Population for Mombasa North Mainland

Sub-locations	2009	Projected population			
		2015	2020	2025	2040
Bamburi	24,918	29,753	34,492	39,986	62,297
Maunguja	1,526	1,822	2,112	2,449	3,815
Mwakirunge	7,403	8,840	10,247	11,880	18,508
Mwembe Lengeza	28,803	34,392	39,870	46,220	72,010
Shanzu	9,264	11,062	12,824	14,866	23,161
Junda	39,432	47,084	54,583	63,277	98,583
Kisauni	79,811	95,299	110,477	128,073	199,534
Magogoni	82,718	98,770	114,501	132,738	206,802
Kongowea	63,993	76,411	88,581	102,690	159,988
Maweni	42,187	50,373	58,397	67,698	105,471
Total	**380,055**	**453,806**	**526,085**	**609,877**	**950,168**

3.2 Land Use and Urban Development

3.2.1 Introduction

Mombasa began as a trading port in the 12th century as a key node in the complex Indian Ocean trading networks and has played a pivotal role in development of Kenya and East Africa.

The town's main planning efforts trace back as far as the early settlements of the native swahilis to the modern geometric planning of regular grids and urban blocks. The city lies within interesting geographic set up where it is located on an Island and sprawls to the surrounding mainlands.

Mombasa County has transformed from clustered traditional settlements in the colonial era to now a vibrant Coastal City. With this rapid urbanization, planning efforts have been superceeded by the development rates thus sprouting of informal settlements and un-planned developments.

This chapter analyzes Mombasa city in four zones borrowing the transport analysis concept of Uniform Analysis Zones (UAZ). The town is divided into three zones which are the southern zone, western, northern and island. The factors which have determined the town's zoning are: sublocations, administrative, physical features as well as the current development pattern of Mombasa town. The analysis is to inform on preparation of waste water management needs for period of year 2015 through the year 2040. Mombasa Island and North Mainland are analysed as seperate zones.

The Island is separated from the mainland by two creeks: Tudor Creek and Kilindini Harbour. It is connected to the mainland to the north by the Nyali Bridge, to the south by the Likoni Ferry, and to the west by the Makupa Causeway.

There have been several planning efforts for Mombasa County with the Mombasa district strategic plan for year 2005-2010. At that time the Town was at its initial stages of development thus its structure and form was not yet well established and its future growth pattern was uncertain. The First County Integrated Development Plan (year 2013-2017) is the most recent planning effort. It addresses major development challenges which include poor infrastructure, inadequate skilled labour, low agricultural productivity, environment and climate change, poverty, poor marketing system etc. The plan outlines development priorities, constraints and strategies in Infrastructure, Energy, ICT, Agriculture, Tourism, Trade, Health, Education, Administration, Socio-cultural issues, Gender, Environmental Protection, Water, Housing, Land Tenure and Mineral Resources.

3.2.2 Existing Land Use

The total area of Mombasa Island and North Mainland is approximately **9,640** ha.

The main types of land use evident in the Town are: residential, industrial, educational, recreational, public purpose, public utility, agriculture, hospitality and commercial. In Mombasa Island, the largest portion of land is residential covering an area of approximately 457 ha which represents 36.4% of the total land, followed by industrial land use which covers approximately 325ha which represents 25.9% of total land. In Mombasa North Mainland, undeveloped land and residential uses are predominant covering an area of approximately 3,045 ha and 3,047ha respectively which represents 36.4% and 36.3% of the total land.

Table 3.7 on **Page 3-7** shows a summary of existing Land Use of Mombasa Island and North Mainland.

The existing Land Use Plan for Mombasa Island and North Mainland is given in **Figure 3.2** and **3.3** on **Page 3-8** and **3-9** respectively.

Table 3.7: Summary of Existing Land Use

Land Use	Mombasa Island - Area Covered (Ha)	Coverage (%)	Mombasa North Mainland - Area Covered (Ha)	Coverage (%)
Agricultural	-	-	436	5.2
Commercial	112	8.9	238	2.8
Educational	102	8.1	206	2.5
Heavy Industry	178	14.2	38	0.5
Medium Industry	1	0.1	14	0.2
Light Industry	146	11.6	19	0.2
Public Purpose	97	7.7	451	5.4
Public Utility	21	1.7	128	1.5
Recreational	64	5.1	208	2.5
Residential High	144	11.5	2,006	23.9
Residential Low	240	19.1	843	10.1
Residential Medium	73	5.8	196	2.3
Undeveloped	31	2.5	3,047	36.3
Water Features/ Creek	41	3.3	8	0.1
Future Development	7	0.6	265	3.2
Forest	-	-	282	3.4
TOTAL	**1,257**	**100**	**8,385**	**100**

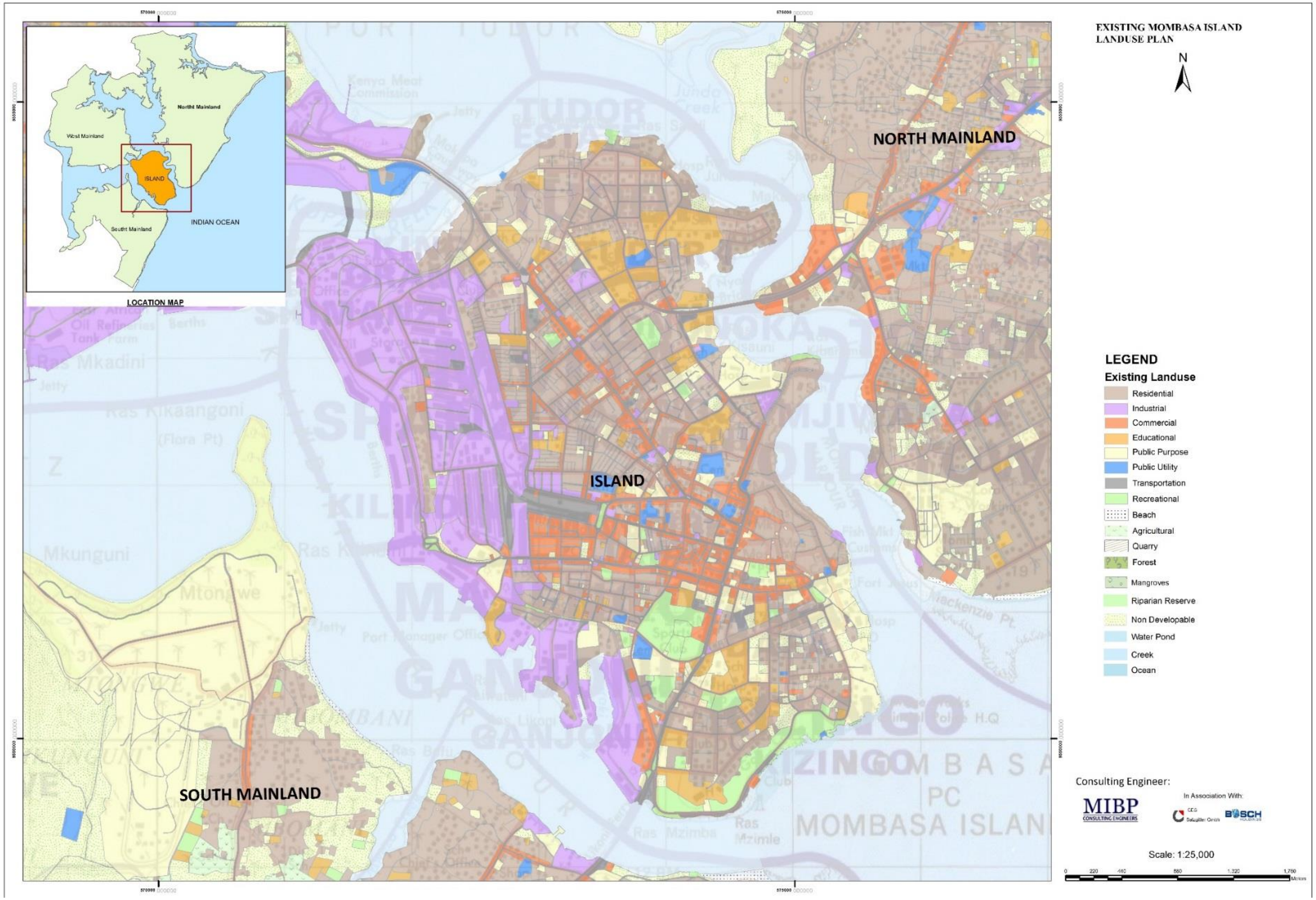


Figure 3.2: Existing Land Use for Mombasa Island

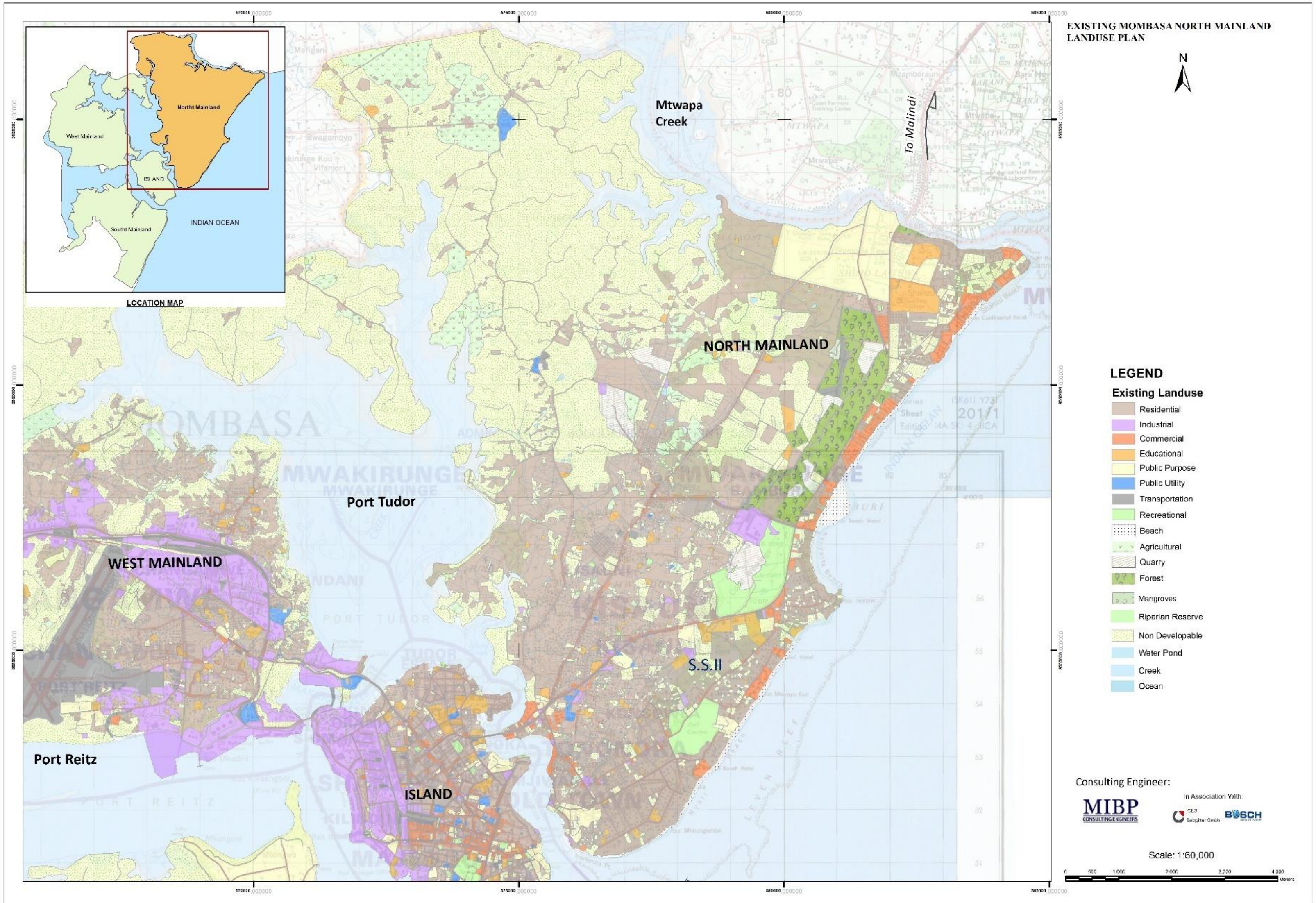


Figure 3.3: Existing Land Use for Mombasa North Mainland

The main drivers of Mombasa Island and North Mainland are as follows:

i) Tourism

Tourism is the most important economic activity in Mombasa Island and North Mainland with a variety of attractions including Fort Jesus, Old Town, white sandy beaches etc. Tourism creates employment opportunities to the local community. The coastline is characterised by resorts, hotels and other entertainment centres. It creates employment opportunities to the local community and in addition is the main source of Government Revenue.

ii) Standard Gauge Railway (SGR)

It's a flagship project under construction which revolutionize transport of people and goods through the East African region. The SGR is expected to connect Mombasa to Malaba. This will play a key role in achievement of Kenya's Vision 2030.

iii) Industries

Cement factories are a major industry in Mombasa due to abundance of limestone deposits. The cement factories create employment opportunities to the local community and is also among sources of government revenue.

iv) Agriculture

Agriculture in Mombasa North Mainland is an important source of food and livelihood to the local community, attracts investments into the town and is also a source of government revenue hence plays a key role in economic development.

3.2.3 Land Use Planning and Policy

All Land-Use activities depend on the regulations and practices that govern land ownership. Land allocation and ownership require proper planning for optimal utilisation.

Land-use planning encompasses the systematic social and economic assessment of land and water potential including the alternative land-uses for the selection and adoption of the best land-use options. It seeks to regulate land-use in efficient and ethical way and prevent land-use conflicts. Land-use planning is practiced to manage the development of land within jurisdictions, plan for the needs of the community and safe-guard the natural resources. Land-use planning often lead to land-use regulations, which typically encompasses zoning.

Zoning regulates the type of activities that can be accommodated on a piece of land, as well as the amount of space devoted to those activities and the ways that buildings may be situated and shaped. Conventional zoning does not regard the way buildings relate to one another or the public spaces around them, but rather provide a pragmatic system for mapping jurisdictions per permitted land use.

The primary purpose of zoning is to segregate uses that are thought to be incompatible. In practice, zoning is used to prevent new developments from interfering with the existing land-use activities and to preserve the "character" of an area. Zoning is commonly controlled by the local governments such as County Governments, though the nature of the zoning regime may be determined or limited by the national planning authorities or through enabling legislation.

Zoning may include regulation of the kinds of activities which will be acceptable on particular plots (such as Open Spaces, Residential, Agricultural, Commercial or Industrial), the densities at which those activities can be performed (from Low-Density Housing such as Single Family Homes to High-Density such as High-Rise Apartment Buildings), the height of the building etc.

The projected populations **1,308,000** in **Year 2040** (Refer to **Table 3.5 and 3.6** on **Page 3-5**) are proposed to be accommodated within the coverage of the study area. It is also proposed that the existing vacant land be utilised including the range lands where the slope is gentle for development to accommodate part of the projected population.

3.2.4 Land Use Requirement per Land Use Zone

Land requirement in zoning depends on projected population and proposed density.

The proposed population densities for each category of Residential Land-use have been worked out based on the projected population, land available for future development, the potential of the developed areas for densification and experience in Towns of similar nature and keeping sufficient room within the current planning boundary for future urban expansion i.e. beyond year 2040.

Details of existing Land use and projected land requirement for Mombasa Island and North Mainland are given in **Table 3.8** and **3.9** below and on **Page 3-12** respectively.

Table 3.8: Existing Land Use and Projected Land Requirement – Mombasa Island

Land Use	Existing Land Use 2015 (Area, ha)	Projected Land Use 2040 (Area, ha)
Agricultural	-	-
Commercial	112	113
Educational	102	102
Heavy Industry	178	178
Light Industry	146	146
Medium Industry	1	1
Public Purpose	97	97
Public Utility	21	25
Recreational	64	64
Residential High	144	150
Residential Low	240	251
Residential Medium	73	77
Undeveloped	31	4
Water Features	41	41
Future Development	7	7
TOTAL	**1,257**	**1,257**

Table 3.9: Existing Land Use and Projected Land Requirement - Mombasa North Mainland

Land Use	Existing Land Use 2015 (Area, ha)	Projected Land Use 2040 (Area, ha)
Agricultural	436	368
Commercial	238	352
Educational	206	313
Forest	282	341
Heavy Industry	38	38
Light Industry	19	20
Medium Industry	14	15
Public Purpose	451	552
Public Utility	128	118
Quarry		
Recreational	208	1,202
Residential High	2,006	2,979
Residential Low	843	1,252
Residential Medium	196	291
Transportation		
Undeveloped	3,047	271
Water Features	8	8
Future Development	265	265
TOTAL	**8,385**	**8,385**

The development pattern in Mombasa Island and North Mainland varies. In the proposed land use plan, Mombasa is expected to have sustainable urban development. Residential land use will be most dominant land use type with integrated education facilities for improved access to education.

Agricultural, undeveloped and future development land uses will be converted to accommodate development of residential and commercial developments. Population density in the residential areas will also increase. The industries are mainly the port and oil industries including the railway depots which are a key part of the economy of Mombasa. Mombasa North Mainland has plenty of undeveloped land which can be used for future residential and commercial developments.

With implementation of the Mombasa County ISUDP (Year 2015), the projected Land-use can be attained. The ISUDP should also aim at enforcing development control, establishing adequate, decent and affordable housing, conservation of the green spaces and the environment and also provide a road map for provision of services and facilities.

Layout Plans showing the Proposed Land Use for Mombasa Island and North Mainland are given in **Figure 3.4** and **3.5** on **Page 3-13 and 3-14** respectively**.**

Table 3.10 on **Page 3-15 to 3-18** shows a summary of adoptive standards for Urban Planning.

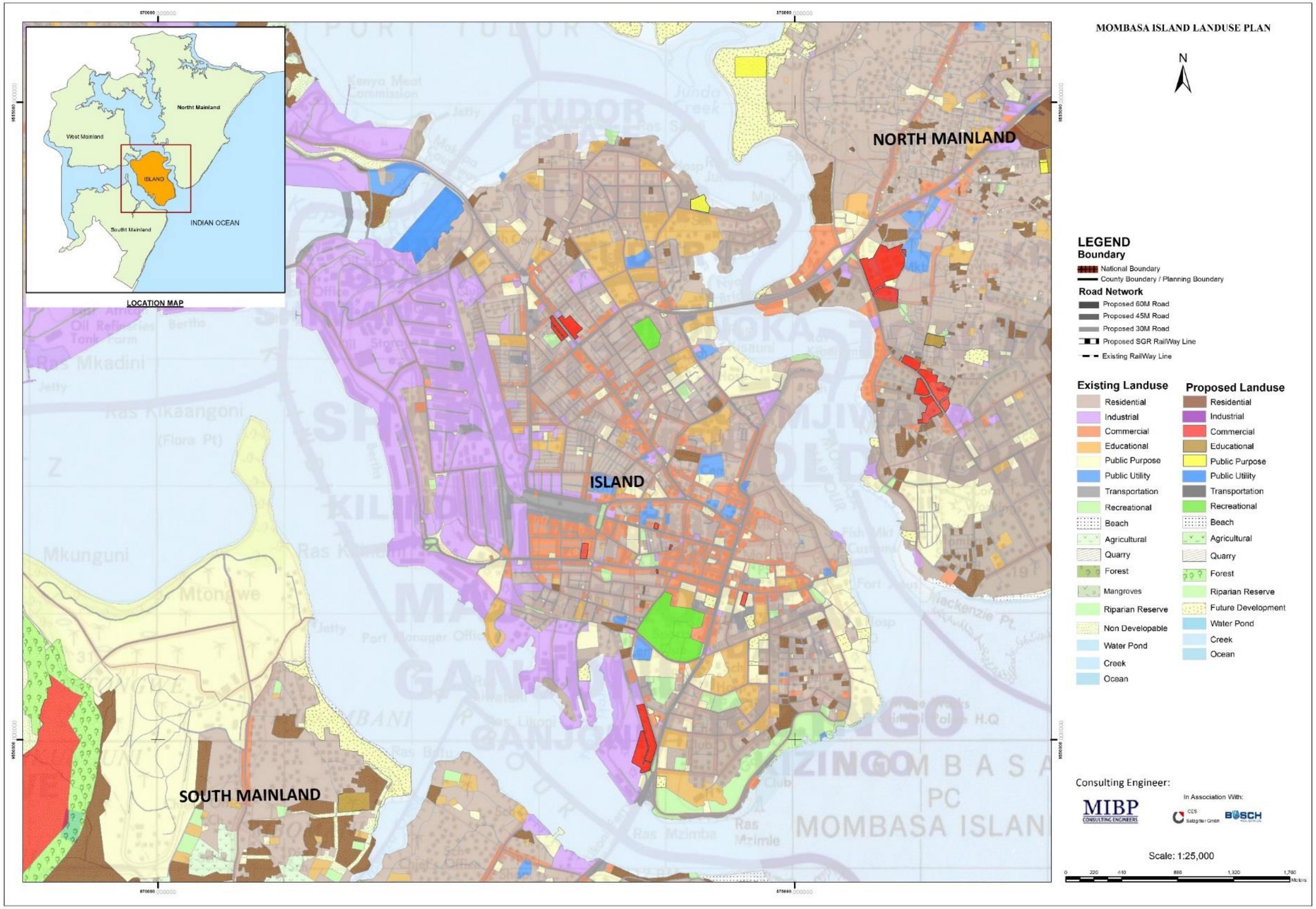


Figure 3.4: Land Use Plan for Mombasa Island (Year 2040)

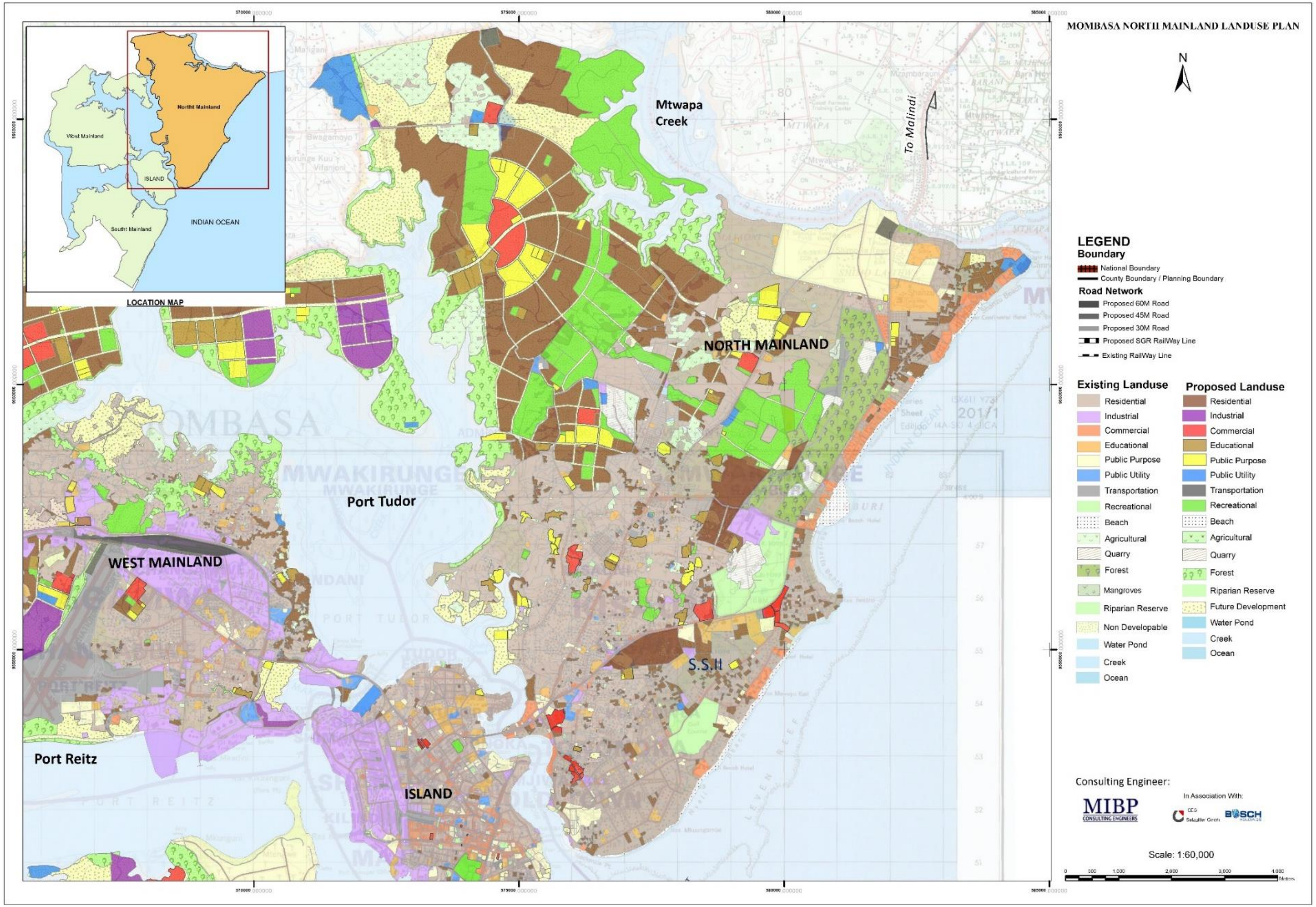


Figure 3.5: Land Use Plan for Mombasa North Mainland (Year 2040)

Table 3.10: Adoptive Standards for Urban Planning

Zone O: Residential								
Zone	**Proposed Land Use**	**Types of Development Allowed**	**BCR**	**PR**	**Min Plot Size**	**Density of Development**	**No. of Dwelling Units**	**Other Requirements**
0	Residential	Bungalows	35	25	0.4 Ha	Low Density	Single Dwelling Units	
	Residential	Bungalows	35	25	0.4 Ha	Low Density	Single Dwelling Units	Cottage industry may be practised
	Residential	Bungalows	35	25	0.4 Ha	Low Density	Single Dwelling Units	A Secondary School may be developed at an appropriate site
	Residential	Bungalows,	25	25	0.2 Ha	Medium density	Single Dwelling Units	
	Residential	Bungalows,	25	25	0.2 Ha	Medium density	Single Dwelling Units	
	Residential	Maisonettes Town houses Duplexes	50 50	50	0.1 Ha	Low Medium density	Two residential units allowed per plot	Shops allowed on plots fronting 9 m roads
	Residential	Maisonettes Town houses Duplexes	50 50	50	0.1 Ha	Low Medium density	Two residential units allowed per plot	Shops allowed on plots fronting 9 m roads
	Residential	Maisonettes Town houses Duplexes	50 50	50	0.1 Ha	Low Medium density	Two residential units allowed per plot	Shops allowed on plots fronting 9 m roads
	Mixed developments	Town houses Duplexes Swahili houses Guest/Boarding houses	65	65	0.03 - 0.045	High Density	Multiple residential units allowed	Shops allowed on plots fronting 9 m roads
	Mixed developments	Town houses Duplexes Swahili houses Guest/Boarding houses	65	65	0.045	High Density	Multiple residential units allowed	Shops allowed on plots fronting 9 m roads
	Mixed developments	Town houses Duplexes Flats Swahili houses Guest/Boarding	65	65	0.03 - 0.045	High Density	Mixed house types allowed	Upgrading areas

Zone 1: Industrial								
Zone	**Proposed Land Use**	**Types of Development Allowed**	**BCR**	**PR**	**Min Plot Size**	**Density of Development**	**No. of Dwelling Units**	**Other Requirements**
1	Industrial	Industrial plant	50	150	0.2	N/A	N/A	
	Light Industry	Repair Workshops, Hardware stores Furniture Makers small tin smiths, Re-use Industries	50	75	0.045	N/A	Garages, furniture and welding workshops allowed	
	Light Industry	Godowns, warehouse, hardware stores	50	75	0.045	N/A	Garages, furniture and welding workshops allowed	
Zone 2: Educational								
Zone	**Proposed Land Use**	**Types of Development Allowed**	**BCR**	**PR**	**Min Plot Size**	**Density of Development**	**No. of Dwelling Units**	**Other Requirements**
2	Educational	Classes, offices and dormitories Sanitation block	10	30	Nursery Sch. 0.1 Pri. school 4.0 Sec. School 4.5 College 10.2 University 50.0	N/A	N/A	Storeyed buildings recommended for effective use of space Sharing of recreational facilities recommended Institutional Housing allowed
Zone 3: Recreational								
Zone	**Proposed Land Use**	**Types of Development Allowed**	**BCR**	**PR**	**Min Plot Size**	**Density of Development**	**No. of Dwelling Units**	**Other Requirements**
3	Recreation	Conservation/ Green Park						
	Recreation	Conservation/ Green Park						
	Recreation	Conservation/ Green Park						

Zone 4: Public purpose								
Zone	Proposed Land Use	Types of Development Allowed	BCR	PR	Min Plot Size	Density of Development	No. of Dwelling Units	Other Requirements
4	Government Headquarters	Civic offices: - County government; local authorities, parastatals, trade unions, political party offices, library entertainment, etc.						Spatial compactness Public parking Accessibility
Zone 5: Commercial								
Zone	Proposed Land Use	Types of Development Allowed	BCR	PR	Min Plot Size	Density of Development	No. of Dwelling Units	Other Requirements
5	Commercial	Compatible mixed use	75	600	0.045	N/A	Commercial	Densification and diversification recommended Flats and high rise buildings recommended Future commercial core
Zone 6: Public Utilities								
Zone	Proposed Land Use	Types of Development Allowed	BCR	PR	Min Plot Size	Density of Development	No. of Dwelling Units	Other Requirements
6								
Zone 7: Transportation								
Zone	Proposed Land Use	Types of Development Allowed	BCR	PR	Min Plot Size	Density of Development	No. of Dwelling Units	Other Requirements
7	Lorry park		N/A	N/A	2	N/A	N/A	To be developed through public private partnership
	Bus park							To be developed by County Government

Zone 8: Hospitality Zone								
Zone	**Future Land Use**	**Types of Development Allowed**	**BCR**	**PR**	**Min Plot Size**	**Density of Development**	**No. of Dwelling Units**	**Other Requirements**
8								

Zone 9: Agriculture								
Zone	**Future Land Use**	**Types of Development Allowed**	**BCR**	**PR**	**Min Plot Size**	**Density of Development**	**No. of Dwelling Units**	**Other Requirements**
LD	Residential	Bungalows	35	25	0.4 Ha	Low Density	Single Dwelling Units	Agriculture may be practised
	Residential	Bungalows	35	25	0.4 Ha	Low Density	Single Dwelling Units	Agriculture may be practised
	Residential	Bungalows	35	25	0.4 Ha	Low Density	Single Dwelling Units	Agriculture may be practised
MLD	Residential	Bungalows,	25	25	0.2 Ha	Medium density	Single Dwelling Units	
	Residential	Bungalows,	25	25	0.2 Ha	Medium density	Single Dwelling Units	
	Residential	Bungalows,	25	25	0.2 Ha	Medium density	Single Dwelling Units	
	Residential	Maisonettes Town houses duplexes	50 50	50	0.1 Ha	Low Medium density	Two residential units allowed per plot	Shops allowed on plots fronting 9 m roads
	Residential	Maisonettes Town houses duplexes	50 50	50	0.1 Ha	Low Medium density	Two residential units allowed per plot	Shops allowed on plots fronting 9 m roads

4.0 WATER DEMAND FORECAST

Water demand is defined *as "the volume of water different categories of consumers can afford to consume in a context of unrestricted supply"*. The water demand of an area is dependent on the climate, economic considerations, sanitation facilities, industrial and commercial requirements.

$$\text{Water demand} = \textbf{Domestic demand} + \textbf{Institutional demand} + \textbf{Commercial demand} + \textbf{Industrial demand} + \textbf{Tourism Recreation demand}$$

For a more accurate determination of the Total Water Demand, it is important to adopt accurate water consumption rates for each of the water demand categories.

4.1 Analysis of Present Water Demand

The Design Manual for Water Supply in Kenya (MWI, 2008) gives guiding values of water consumption rates for the various categories of Water Demand. However, from individual studies and in consideration of various local conditions, several Consultants have adopted varied water consumption rates for the determination of Water Demand in Mombasa Island and North Mainland.

A summary of the Studies / Designs prepared by the various Consultants for Water Supply in Mombasa County and other Coast Towns is given below:

- Tahal Group and Bhundia Associates finalised the Water Supply Master Plan for Mombasa County and selected Towns in year 2013.
- Egis/bceom/Mangat JV finalised the Detailed Design of Rehabilitation and Expansion for Mombasa Water Supply and Sewerage System in year 2011.
- Gauff JBG/ TRAQ Consulting Engineers Detailed Design Report for Kilifi Water Service Provider, October 2010.
- Suereca / Mangat finalised Second Mombasa & Coastal Water Supply Project, Final Design Report, January 1998
- Kittelberger Consult GmbH Consulting Engineers Joint Venture with Mangat, I.B. Patel & Partners finalised Malindi Sanitation & Hygiene Education Feasibility Study in year 1994
- Norconsult A.S. Consulting Engineers finalised the Malindi Sewerage Master Plan and Preliminary Design Storm Water Feasibility Study, November 1978.

A comparison of water consumption rates adopted in the above Studies / Designs including those recommended in the Practice Manual for Water Supply Services in Kenya is given in **Table 4.1** on **Page 4-2**.

Table 4.1: Comparison of Water Consumption Rates

Consultant	Name of Report	Domestic Water consumption (l/c/day)			Institutions Water Consumption			Commercial Water Consumption (l/head/day)	Industrial Water Consumption (l/Ha/day)
		Low Density	Medium Density	High Density	Boarding Schools (l/head/day)	Day Schools with WC (l/head/day)	Regional Hospitals (l/bed/day)		
Tahal Group / Bhudia Associates	Water Supply Master Plan for Mombasa and other Towns - Aug 2013	250	150	75	-	-	-	-	-
Egis Bceom / Mangat	Rehabilitation & Expansion of Mombasa Water Supply & Sewerage Project - Final Design Report - July 2011	250	100	60	-	-	-	6	25.000
Gauff JBG / TRAQ	Detailed Design for Kilifi Water Service Provider – Oct 2010	200	120	60	100	20	365	83	30,000
Seureca / Mangat	Second Mombasa and Coastal Water Supply Project Final Design Report - January 1998	200	80	70	50	25	700	5	20,000
Kittelberger Consult GmbH Joint Venture with Mangat, I.B. Patel & Partners	Malindi Sanitation and Hygiene Education Feasibility Study - March 1994	300	150	75	50	25	400	25	29,400
Norconsult S.A Consulting Engineers	Malindi Sewerage Master Plan and Preliminary Design Storm Water Feasibility Study - November 1978	300	150	75	50	25	400	-	15,000
Ministry of Water & Irrigation	Practice Manual for Water Supply Services in Kenya	250	150	75	50	25	400	-	20,000

After analysis of these water consumption rates indicated in **Table 4.1** on **Page 4.2**, the water consumption rates adopted in this Study for the various consumer categories are described below:

a) Residential Water Demand

From the findings by different Consultants, it is evident that the type of housing and mode of water supply are relevant indicators for classifying domestic consumers.

Based on per capital demand observed in similar socio economic and climatic context but without restriction of water supply, the Consultant proposed to adopt the following consumption rates for each category of domestic consumer as summarised in **Table 4.2** below.

Table 4.2: Adopted Housing Categories & per Capita Water Consumption

Category	Description	Consumption Rate (l/c/d)
Low Density	Residential Houses and Maisonettes	200
Medium Density	Flats and Estates	120
High Density	Traditional Houses (Informal Settlements and Swahili houses	60

b) Institutional Water Demand

The institutional water demand was calculated based on the following commonly accepted demand criteria by type of institution:

- Boarding Schools - 50 l/head/day
- Day School with WC - 25 l/head/day
- Regional Hospital - 200 l/bed/day plus 5,000 l/day
- Dispensary and Health Centre - 5,000 l/day
- Administrative Offices - 25 l/head/day

c) Commercial Water Demand

The commercial water demand was calculated based on the following commonly accepted demand criteria by type of commercial facility:

- Shops - 100 l/day
- Bars - 500 l/day

d) Industrial Water Demand

The following criteria was adopted for the industrial water demand based on commonly accepted demand criteria: -

- Intensive industrial activity - 25,000 l/day/ha
- Small scale industrial activity - 600 l/day/ha

e) Tourism Water Demand

The following criteria was adopted for tourism demand based on commonly accepted demand criteria:

- Four and five star hotels - 600 l/occupied bed/ day
- Other hotels - 300 l/occupied bed/ day
- Tourist cottages complexes - 200 l/occupied bed/ day

4.2 Water Demand Projections

The water demand for Mombasa Island and North Mainland is expected to increase over the design period (up to 2040) due to the projected increase in population, commerce and industrialization. The major drivers for this development include the tourism industry, improved infrastructural network within the rest of the County and potential for new settlements.

The water demand by consumer category for the Design Horizons 2025 and 2040 has been calculated based on the projected population and proposed future land-use. A summary of the water demand by sub-location for Design Horizons Year 2025 and Year 2040 is given in **Tables 4.3** and **4.4** below.

Table 4.3: Projected Water Demand for Medium-Term Horizon - Year 2025

Service Area	Water Demand (m^3/d)						
	Domestic	Health	Education	Recreational	Commercial	Industrial	Total
Mombasa Island	21,275	1,553	1,274	172	110	3,136	27,521
North Mainland	61,699	457	581	89	58	5,168	68,051
Total	**82,974**	**2,010**	**1,855**	**261**	**168**	**8,304**	**95,572**

Table 4.4: Projected Water Demand for Long-Term Horizon - Year 2040

Service Area	Water Demand (m^3/d)						
	Domestic	Health	Education	Recreational	Commercial	Industrial	Total
Mombasa Island	33,146	2,305	1,851	268	172	4,886	42,628
North Mainland	96,124	711	905	139	90	8,052	106,021
Total	**129,270**	**3,016**	**2,756**	**407**	**262**	**12,938**	**148,649**

The water demand for Mombasa Island and North Mainland has been projected to increase within the design period as shown in **Figure 4.1** below.

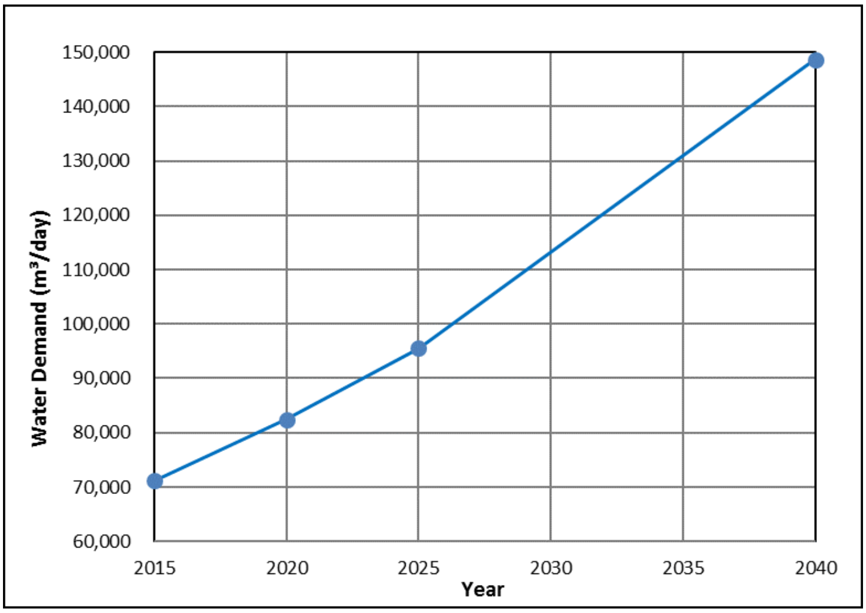


Figure 4.1: Combined Water Demand Projection

5.0 WASTEWATER FLOW PREDICTIONS

5.1 Design Criteria

The determination of the wastewater flows adopted in the design of the Sewers, Pumping Stations and Wastewater Treatment Plant for Mombasa Island and North Mainland has been guided and based on the Standard design criteria described in the following sub-sections;

5.1.1 Principal References

In Kenya, it is a standard practise to refer to the Design Manuals prepared by the Ministry of Water and Irrigation for the design of Sanitation Projects.

The principal References used to formulate the design criteria for Mombasa Island and North Mainland are as follows;

- Practice Manual for Sewerage & Sanitation Services in Kenya, December 2008 – Ministry of Water & Irrigation
- Selection and Design Criteria for Sewerage Project, Report No. 9 – World Health Organisation (WHO Report No. 9)
- Nairobi City Council – Sewer Design and Construction - Parameters for Adoptive Standards, 1974 (Nairobi City Council Manual)
- The Design of Small Bore Sewer Systems by Richard J. Otis and D, Duncan Mara (1985)
- Domestic Wastewater Treatment in Developing Countries by D. Duncan Mara (2003)

The Criteria outlined in these principal References have been evaluated in the context of the Consultants experience, knowledge and complemented with local and internationally accepted design standards.

5.1.2 Sewerage Collection System

As outlined in WHO Report No. 9, there are three forms of sewerage collection systems, namely;

- ***Separate Systems:*** Storm water and wastewater are collected and transported in two separate systems. Ideally, no storm water is allowed into the sanitary sewers
- ***Combined Systems:*** Storm water and wastewater from premises are collected and transported in one system. In this system, only one network of pipes is provided and those pipes are designed to carry both wastewater flows and storm water
- ***Partially Separate Systems:*** With these systems, the sewerage collection system is designed to carry all the wastewater together with some storm water. The bulk of the storm water is collected in an independent system of pipes and open drains

From the TOR ***"Neither CWSB nor the WSPs have the responsibility for the provision or maintenance of storm water drainage systems and so the study and review of those facilities is not included in this Wastewater Master Plan Study. All sewers shall be designed for separate systems."***

In line with the TOR, a separate sanitary sewer system has been proposed for the design of the Trunk and Secondary Sewers in Mombasa Island and North Mainland.

5.1.3 Sewage Generation

Wastewater collected in the Sewerage System is generated from;

- Domestic, institutional and Commercial consumers
- Industrial Effluent
- Infiltration and Inflow into the Sewerage System

5.1.3.1 Domestic and Commercial Consumers Sewage Contribution Factor

Not all the water supplied to a premise will reach the sewers as wastewater. The flow of wastewater leaving premises is dependent on following;

- Quantity of water supplied to the building
- Characteristics of the housing type
- Climate with higher losses associated with arid conditions
- Ground conditions with higher losses associated with high ground porosity

Sewage contribution factor varies from 75% to 85% of water supplied, depending on the different categories of consumers as outlined in WHO Report No.9 and summarised in **Table 5.1** below**.**

Table 5.1: Portion of Water Used that ends up as Wastewater

S/No.	Category	Wastewater generated as a Percentage of water supplied (%)
1	High Income Housing	75
2	Medium Income Housing	80
3	Low Income Housing	85
4	Communal ablution/ latrine block	85
5	Day schools, shops and offices	85
6	Other Institutions	80

<u>The Study adopts an overall figure of 80% for the sewage contribution factor in consideration that it has become a standard practice to adopt 80% in the design of Sewerage Systems for other Towns in Kenya.</u>

5.1.3.2 Industrial Effluent

Industrial effluent generation varies from industry to industry and therefore, each individual factory on a Sewerage System must be considered separately. <u>However, for areas designated for future industries whose type is not known, WHO Report No. 9 recommends a rate of 25,000 l/ha/day. This has been adopted in the Study.</u>

5.1.3.3 Infiltration and Inflow

The design of the sewers is based upon the concept of a separate Sewer System, i.e. sewers that are designed to carry only the anticipated sewage flows with only a nominal allowance in the pipe capacity for infiltration and storm-water inflow. If significant amounts of water from these other sources are allowed into the sewers, then the sewers will be ‘robbed’ of their carrying capacities, treatment plants of their process performance capabilities and the pumping costs will increase significantly. However, a small amount of water still enters the sewers from other sources, normally referred to as infiltration and inflow.

<u>Infiltration</u> is defined as the water entering a Sewer System from below ground level through such means as defective pipes, joints, connections or manholes.

The rate of infiltration into sewer pipes depends generally on the depth of the water table, sub-soil conditions, workmanship during construction, age and condition of the pipes and the frequency of occurrence of improper connections. Another significant factor can be the condition and depth of manholes, damaged or missing covers or where the ground surface level is above cover level, then surface water runoff can enter the sewer as inflow.

For the design of the sewers in Mombasa Island and North Mainland, it is intended to use an infiltration allowance that is based upon the area contributing to the sewer. This Study adopts the recommendation of Nairobi City Council manual of a <u>constant infiltration rate of 0.0025 l/s/ha within the design coverage area.</u>

Inflow/Splash is defined as the storm water discharged into a Sewer System from above ground from such sources as roofs/ yards through inspection chambers within premises, open/loose manhole covers, cross connections from storm drains, etc.

In addition to infiltration, Nairobi City Council Manual also recommends the use of a "Splash Allowance", which is in effect, make an allowance for unavoidable storm water entry and for authorised drainage of open industrial and commercial areas, i.e. "inflow". This allowance is taken as a percentage of the domestic wastewater flow and ranges from 5% to 30% depending upon the predominant housing type i.e.

- 30% for low income housing
- 15% for medium income housing
- 10% for high income housing

A conservative value of 5% of the total wastewater flow has been adopted in this Study for the determination of Splash flow contribution.

5.1.4 Peak Flow Factor and Sewer Capacity

A sewer should be designed to handle the peak sewage flows that occur due to daily, diurnal and seasonal fluctuations. A peak factor, which refers to an estimated ratio of maximum to average sewage flow, is applied on the average wastewater flow to determine the peak flow.

Sewers are normally designed to flow half full at peak flow, where peak dry weather flow is defined as:

$$\text{Peak Dry Weather Flow, PDWF} = \text{FR (DWF-I)} + \text{I}$$

Where:

PDWF	=	Peak Dry Weather Flow (l/s)
FR	=	Peak Factor
DWF	=	Dry Weather Flow (Design Flow) (l/s)
I	=	Infiltration Rate (l/s)

The Dry Weather Flow (Design Flow), which includes allowance for inflow and infiltration can be calculated from:

$$\text{DWF} = \text{SF}\left[\left(\frac{\text{P x G}}{86400}\right) \text{ x } \left(\frac{1+\text{SA}}{100}\right) + \frac{\text{E x A}_\text{E}}{86.4} + \text{I}_\text{R}\left(\text{A}_\text{P} + \text{A}_\text{E}\right)\right]$$

Where:

SF	=	Sewage Reduction Factor (%)
P	=	Population (no. of persons)
G	=	Water Consumption (litres per person per day)
SA	=	Inflow/Splash Allowance as % of P x G (litres per day)
E	=	Industrial Wastewater Flow (m^3/ha/day)
A_E	=	Industrial Drainage Area (Ha)
I_R	=	Infiltration Water Flow Rate (l/sec/ha)
A_P	=	Domestic Drainage Area (Ha)

The daily peak flow in a sewer is a function of the area contributing to the sewer, which, in turn, determines the contributing population and, hence, the size of the pipe. An increase in the contributing area results in a lower peak factor, hence large trunk sewers have lower peaks than small branch sewers.

Many methods and formulae are used to predict peak factors in sewers. The factors derived by Nairobi City Council in the 1960s, after a comprehensive survey of the Capital City's sewers, are shown in **Table 5.2** below.

Table 5.2: Nairobi City Council Manual Peak Flow Factors

DWF (litres/sec)	Peak Factor
< 6.0	7.5
< 12.0	6.6
< 60.0	5.5
< 120.0	5.0
< 600.0	3.8
> 600	3.1

These Peak Flow factors are considerably higher than those resulting from the empirical formulas commonly used. Some of the commonly used formulas are given in **Table 5.3** below.

Table 5.3: Common Formulas used to calculate Peak Flow Factor

Legg Formula, for population < 7,000 Persons	$Peak\ Factor = \frac{6.51}{Population^{0.38}}$
Babbit Formula, for population < 7,000 Persons	$Peak\ Factor = \frac{5}{Population^{0.2}}$
Harmon Formula, for population > 7,000 Persons	$Peak\ Factor = 1 + \frac{14}{4 + Population^{0.5}}$

Recent studies of the flow records in Nyeri Town carried out by the Nyeri Water & Sewerage Company indicate that the Babbitt Formula gives peak factors that more accurately correspond to the measured peaks in the Sewerage System.

The empirical formulas adopted in the computation of peak flows for Mombasa Island and North Mainland are as follows;

- Babbit formula for populations less than 7,000 persons
- Harmon Formula for populations greater than 7,000 persons

5.2 Projected Wastewater Flows

The total wastewater generated within a service area is determined by the drainage area from the water consumed (sewage generation factor of 80%), infiltration into the sewers and splash flows.

Based upon the above components and assuming a regular/unsuppressed water supply and full water distribution network, the projected wastewater generation for the sub-locations covered by the study area of Mombasa Island and North Mainland have been determined and are given in **Table 5.4** and **5.5** below;

Table 5.4: Projected Wastewater Generation up to Year 2040

Service Area	Dry Weather Flow (DWF), m³/day				
	2009	2015	2020	2025	2040
Mombasa Island	14,659	17,455	20,194	23,371	36,061
North Mainland	36,912	43,825	50,600	58,453	90,348
Total	**51,571**	**61,280**	**70,794**	**81,824**	**126,409**

However, achieving conditions of regular / unsuppressed water supply and full sewer connections in a Town with Sewerage System is nearly impossible. This is due to limited development of water resources to supply Mombasa Island and North Mainland, inadequate water distribution and sewerage networks and the use of on-plot sanitation systems due to topography, affordability, unplanned settlements, etc.

To consider the above situation, the factors of Sewer Connectivity and Water Supply, given in **Tables 5.5** and **5.6** below, have been adopted for the formulation of realistic wastewater generation projection for Mombasa Island and North Mainland.

Table 5.5: Sewer Connectivity adopted for Realistic Wastewater Generation Projection

Population Category Based on Income Levels	Sewer Connections	
	2021 – 2030	2031 - 2040
High Income	20%	80%
Medium Income	100%	100%
Low Income with Individual Water Connection	60%	80%
Low Income without Individual Water Connection	30%	40%

Table 5.6: Water Supply Status adopted for Realistic Wastewater Generation Projection

Population Category Based on Income Levels	Water Supply Status as a % of Regular Water Supply	
	2021 – 2030	2031 - 2040
High Income	50%	80%
Medium Income	50%	80%
Low Income with Individual Water Connection	50%	80%
Low Income without Individual Water Connection	50%	80%

Figure 5.1 below shows the projected wastewater flows up to Year 2040 for the ideal conditions of regular water supply and sewer connection condition (100% Sewer Connections) and the realistic conditions of suppressed water supply and gradual implementation of sewer connections;

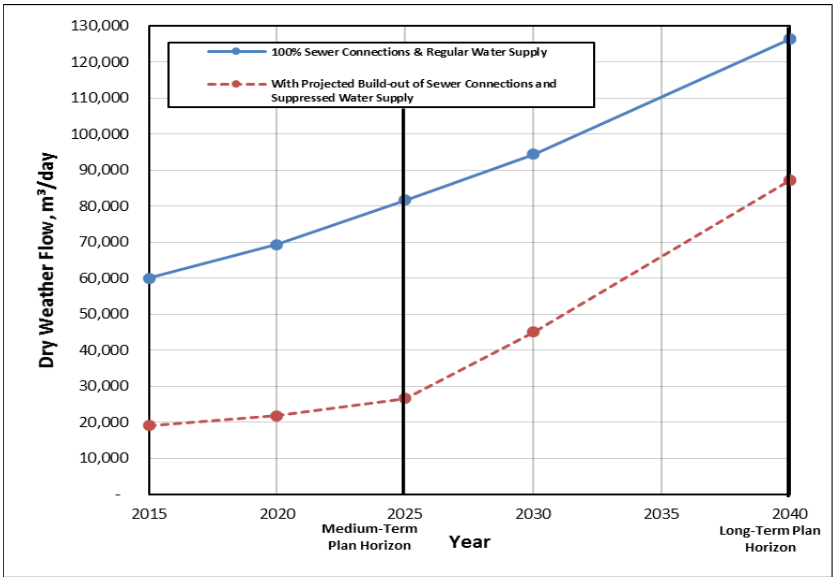


Figure 5.1: Comparative Projected Wastewater Flows up to Year 2040

From **Figure 5.1** above, the projected wastewater generation based on the realistic conditions of water supply and sewer connections at the Years 2025 and 2040 is 26,600 m^3/d and 87,200 m^3/d respectively.

The design of the Wastewater Treatment Plant and Sewerage System have been based on the wastewater flow generation determined from the realistic conditions of suppressed water supply and projected build-out of sewer connections.

6.0 DESIGN CRITERIA FOR SEWERAGE SYSTEM AND WASTEWATER TREATMENT PLANTS

6.1 Design of Sewers

6.1.1 Minimum Size of Sewer

Many sewer blockages in urban areas occur in the first length of small diameter sewer with less than five house connections. Because of this observation, Nairobi City Council Manual recommends a minimum diameter of 200mm for new sewers. Individual house connections of 150mm diameter is however sufficient.

This recommendation is comparable to that of WHO Report No. 9; 225mm minimum diameter for Trunk and Branch Sewers and 100mm – 150mm for Property Drains.

To reduce the tendency of blockages, 200mm diameter has been adopted as a minimum sewer size for Mombasa Island and North Mainland Sewerage System. However, at the upper ends of sewer lines, the expected flows would not achieve self-cleansing velocities except at rather steep sewer gradients. Thus, 150mm diameter sewers shall be adopted in the upper lengths of the sewers to alleviate this situation.

6.1.2 Hydraulic Design Criteria

The two most commonly used and recommended formulae for hydraulic design of sewers are:

- ***Colebrook-White Formula***: The Darcy Weisbach Formula, combined with the Colebrook White formulation of the friction factor, has long been regarded as the formula that closely relates both pipeline theory and observed pipeline losses. The main disadvantage is the cumbersome iterative calculations necessary for its solution. However, with the advent of computers and published Design Charts this limitation has been overcome and the formula universally used as the basis for most computer programs used in the design of sewers.

- ***Manning Equation:*** The Manning equation is widely used because of its simplicity. Although it is empirical, it gives an accurate answer, given the uncertainties associated with the flows generated (population projections, connected population, water consumption per person, etc.). The formula is as follows:

$$V = \left(\frac{R^{0.67} x\, S^{0.5}}{n}\right)$$

Where:

V	=	velocity of flow, (m/s)
n	=	pipe roughness coefficient
R	=	hydraulic radius, (m)
S	=	slope of the pipeline, (m/m)

Table 6.1 below shows the Manning's Pipe roughness coefficients for different pipe materials and diameters.

Table 6.1: Friction Factor for Manning's Formula

Pipe Material	Pipe Dia, mm	Friction Coefficient, n
Spun Concrete	<=300, <600	0.015
	>= 600	0.014
Cast Concrete	All sizes	0.018
uPVC	All sizes	0.013
Pitch Fibre	100 & 150	0.014

In this study, manning equation has been adopted for the design of gravity sewers. It has been complimented by Design Tables and Charts for the Colebrooke-White Equation, developed by the Hydraulic Research Station in UK.

6.1.3 Self-Cleansing Gradients and Velocities

The velocity of flow in a gravity sewer depends on its gradient; the steeper the gradient, the higher the velocity and for the same discharge volume, the shallower the depth of flow in the sewer.

A minimum velocity is required in a sewer to ensure settling of solids do not occur. A velocity of 0.75 m/s is considered as the 'self-cleansing' velocity that will keep solids including silt in suspension. It is important that this velocity is achieved at least once a day. This is ensured by laying sewers at a gradient that will give a velocity of 1.0 m/s at full bore flow. The Nairobi City Council's Adoptive Standards recommends that velocities in sewers should exceed 0.75m/s when flowing full.

Sewer velocity is more important in tropical climates such as in Mombasa Island and North Mainland Town since it has been noted that at high temperatures, increased biological activity rapidly reduces the dissolved oxygen content of the sewage and can result to build-up of hydrogen sulphide gas. Without oxygen, sulphate reducing bacteria break down the sulphates always present in sewage and hydrogen sulphide gas is produced which turns into sulphuric acid. Hydrogen sulphide gas is known to cause odour and corrosion problems. A velocity of 1.0 m/s is considered necessary in tropical climates, (WHO Sectorial Report No 9) to deal with this problem.

This requirement is more important for trunk sewers and is inappropriate for house connections or the secondary sewers for Mombasa Island and North Mainland Town where flows may be intermittent and retention times short. A minimum velocity of 0.75m/s has been adopted with exception of some critical circumstance where a velocity of 0.6m/s has been allowed.

In areas where ground slopes are flat, the adoption of a minimum velocity of 1.0m/s places a severe constraint on the design of the upper reaches of systems due to the steep gradients required. Thus, flatter gradients have been adopted to decrease the resultant sewer depths and to reduce the number of pumping stations. Regular flushing of sewers should be carried out at the flush manholes to be provided at the upper sewer sections to prevent silting.

The Ministry of Water & Irrigation Practice Manual for Sewerage and Sanitation Services in Kenya (December 2008) on Page 144 explains that the maximum flow velocities were previously specified in order to reduce the possibility of pipe erosion through scouring effects. Such effects were said to occur at flow velocities exceeding 4.0m/s but studies have shown that erosion effects observed at velocities greater than this threshold value are minimal and hence no upper limit of flow velocity is recommended.

The following velocity guidelines have been adopted in the design:

- Minimum velocity at peak flow 0.75 m/s
- Minimum velocity in exceptional circumstances 0.6 m/s
- Maximum velocity 3.0 m/s
- Maximum velocity in exceptional circumstances 6.0 m/s

6.1.4 Sulphide Generation

Hydrogen sulphide is the main source of corrosion in sewer pipes, particularly with high ambient temperatures and long retention times. Aerobic bacteria on the sewer walls above the sewage level oxidise the hydrogen sulphide gas to sulphuric acid which attacks the wall of sewer pipe and result to corrosion of ferrous and concrete walls causing their rapid deterioration.

The onset of Hydrogen sulphide attack depends upon many variables including;

- Sewage strength and sulphate content
- Dissolved oxygen concentration
- Velocity of flow – at low velocity, anaerobic conditions result through silt and sludge accumulation. Natural oxygen recovery from the atmosphere is also low at low velocities
- Temperature – sewer corrosion is more frequent and intensive in in warm climates as compared to temperate areas

A well-designed and constructed Sewerage System is the best way of preventing occurrence of sulphide attack. It is considered that the relatively short sewer lengths proposed in Mombasa Island and North Mainland Sewerage System, together with adequate gradients, make the onset of sulphide attack unlikely. HDPE/ uPVC pipes will be used as much as possible in flatter gradients.

In Pumping Mains, sewage retention time less than 30 minutes has been provided to avoid anaerobic conditions and generation of hydrogen sulphide. Injection of air into the main by a compressor is proposed where retention times exceed 30 minutes. Where there is high flow volume with turbulence and splashing, hydrogen sulphide will easily be generated. Proper design of gradient changes in manholes, especially back drop manholes should prevent this.

Flushing of sewers prevents hydrogen sulphide generation because sulphides generation result from slime and sewage deposits.

6.1.5 Ventilation of Sewers

Sewers must have adequate ventilation to:

- Remove odorous gases released from the sewage
- Remove explosive and poisonous gases produced in the sewage
- Maintain adequate supply of oxygen in sewers and prevent hydrogen sulphide generation

To ensure adequate ventilation, ventilation columns with extensions should be installed at all house connections, Pumping Stations and Manholes where pumping mains discharge. Manhole covers should also be provided with ventilation slots. Forced ventilation using compressors should be used where necessary.

6.1.6 Depth of Sewers

Sewers are designed to flow as much as possible in the direction of the natural ground slope. They should also be laid at depths that permit connection to the existing and future properties within the sewered area. Besides, adequate cover to the sewers is required to ensure protection against damages from live loads transiting on the overburden cover surface.

Nairobi City Council Manual recommends minimum depth of sewers of 1200mm in roads and 900mm in all other areas. Adopting this recommendation at the upstream sewer sections in flat areas lead to unnecessarily deep sewers. However, additional protection can be provided at the upstream section of sewers if shallow depths are adopted to limit sewer depths and result to savings from deep excavations of entire sewer length.

The minimum sewer depths and recommended pipe protection measures in the various circumstances are shown in **Table 6.2** below.

Table 6.2: Minimum Sewer Depths and Pipe Protection

	Depth Range	Pipe Protection
In Open Spaces	0 - 750 mm	Concrete bed & surround or granular bed & surround
	Over 750 mm	Protection governed by factors other than depth
In Roads	0 - 1200 mm	Concrete bed & surround
	Over 1200 mm	Protection governed by factors other than depth

The depth of sewers in Mombasa Island and North Mainland has been dictated by the constructability of soil conditions given the flat topography, loose sandy soils, depth of the water table and economic considerations.

Standard details for backfilling sewers and its surround have been provided to ensure protection of sewers from unnecessary damages and overburden.

6.1.7 Manhole Spacing and Sizes

Manholes permit the inspection and cleaning of sewers and the removal of blockages. They should be provided on sewers at all changes of direction, sewer change of gradient, at every junction, where pipe size changes and generally throughout the sewerage system at intervals sufficiently close to ease sewer cleaning.

Manhole spacing and size for the various sewer pipe diameters have been adopted based on the guidelines of the Nairobi City Council Manual as shown in **Table 6.3** below.

Table 6.3: Guideline to manhole diameter and spacing

Sewer Pipe Size (mm)	Manhole Spacing (m)	Manhole Diameter (mm)
225 - 375	60	1,050
450 - 600	80	1,200
675 – 900	100	1,500
Greater than 900	100	1,500

Most sewer blockages occur in the smaller diameter sewers. Thus, for pipe diameters smaller than 225 mm, it is proposed to reduce the manhole spacing to 40m for ease of cleaning and maintenance. The spacing of intermediate manholes in the Sewerage System for Mombasa Island and North Mainland Town has been guided by the proposed Sewer Layout Plan.

6.1.8 Pipe Materials

The choice of pipe material is influenced by:

- Hydraulic and structural design; in consideration of whether it is gravity or forced sewer
- Resistance to chemical and biological processes internally and externally e.g. Corrosion
- Physical properties of the pipe material i.e. strength (to prevent abrasion)
- Types of joints; in view of water tightness which affects infiltration
- Availability of required sewer diameters and necessary fittings
- Cost of materials and installations

Due to the various requirements in the Sewerage System for Mombasa Island and North Mainland Town, combination of various pipe materials, which are manufactured locally to internationally recognized standards, have been considered. These include;

i. Pre-cast Concrete Pipes

Spun concrete pipes are manufactured locally by several companies in Kenya. They are the most commonly used for sewer pipes.

Flexible jointed pipes are manufactured in sizes ranging from 150mm to 975mm diameter and are connected using rubber rings. They are vertically cast in vibrated moulds. They are the most commonly used type of concrete pipes.

Rigid jointed pipes are rarely used for sewers. They are connected using tarred hessian and cement mortar. Ogee jointed pipes, commonly used for surface water drainage systems, are available in sizes from 100 mm to 1525 mm diameter.

Concrete pipes are usually laid on a concrete bed and provided with a haunch and surround or reinforcement to meet the loading requirements.

Larger sizes and higher strength classes can be manufactured on order.

The disadvantages of using concrete pipes include their high friction coefficient and susceptibility to corrosion due to the generation of hydrogen sulphide gas especially at high ambient temperatures and long retention time.

ii. uPVC Pipes

Un-plasticised PVC pipes are manufactured in Kenya in metric sizes up to 450 mm diameter. The pipes are manufactured in accordance with KS 06-149 and both rubber ring jointed and cement jointed pipes are available.

Their main advantage is the low costs associated with the purchase, transportation, handling and laying. Most contractors are also experienced in handling uPVC pipes. In addition, uPVC pipes are resistant to attack from corrosive atmosphere, soils or wastewater conditions.

However, exposure to strong sunlight over a long period can cause brittleness of uPVC sewers. This is less common with modern pipes. There has also been reservation regarding the quality of the locally manufactured large diameter uPVC pipes and the ability of Contractors to lay these large dimeter pipes. Their use has therefore generally been limited to diameters less than 300 mm. Despite of the high cost, it is customary to specify the use of Class 41 uPVC pipes (with thicker walls) for sewers to provide the additional safeguard against corrosion attacks and overburden.

iii. HDPE Pipes

HDPE pipes are ideal for many different applications including municipal, industrial, energy, geothermal, landfill and more. HDPEs pipe are strong, durable, flexible and light weight. When fused together, HDPE has a zero-leak rate because the fusion process creates a monolithic HDPE system. HDPE pipes are also a more environmentally sustainable option as they are non-toxic, corrosion and chemical resistant, have long design life, and are ideal for trenchless installation methods owing to their flexibility.

With manufacture of HDPE Pipes gaining momentum in the country and considering its rapid use by most Water Service Providers, the benefits of using HDPE pipes in Sewerage Systems including reduction in the number of manholes required, ease of use in confined spaces and resistance to corrosion in the coastal towns, make HDPE Pipes the ideal sewer pipe material.

iv. Steel Pipes

Steel pipes are manufactured in Kenya. In the sewerage system, they are used for exposed locations such as river crossings or in pumping mains. However, protection against corrosion is required internally and externally. This is provided using bitumen sheathing with external sheathing reinforced and glass fibre windings. Alternatively, modern proprietary epoxy coatings can be used. Joints are bolted flanges, flexible couplings, or spigot and socket joints.

From field investigations, it has been found that when steel pipes are exposed to the strong sunlight, the external protective bitumen coating become brittle and crack, thus become susceptible to the atmosphere. There are also cases where the pipe couplings, and even the pipes, have been vandalised and stolen for recycling purposes. The high cost of steel pipes also discourages their use in other normal conditions.

All the foregoing four pipe materials have been used in the construction of the existing Sewerage Systems countrywide successfully.

Considering performance, cost and availability, HDPE and concrete pipes are the most appropriate pipes for use in large diameter sewer construction in Kenya. For smaller diameters, uPVC sewer pipes are more cost effective. Steel pipes are inevitable for aerial river crossings, pumping mains, high impact resistance and bridging ability; either spun iron or mild steel pipes can be used. Standardisation of pipe materials and fittings within the jurisdiction of MOWASSCO has also been considered.

The Gravity Sewers for Mombasa Island and North Mainland will consist of HDPE/ uPVC pipes and socket & spigot concrete pipes while Pumping Mains will comprise of Steel Pipes. Shallow sewer sections or those laid on road crossings shall consist of flexible jointed concrete pipes protected with reinforced concrete raft slab.

6.1.9 Property Connections

As the designed Sewer Network will comprise Trunk Sewers and Secondary Sewers, only those properties that are adjacent to the sewers will easily / directly connect. Other properties will need to be connected, either by MOWASSCO's tertiary sewers or by individual plot owners. It is not feasible at the construction stage to allow for all individual property connections, but, wherever, possible, 160 mm diameter Y-junctions shall be provided on the secondary sewers to facilitate connections.

6.2 Design of Sewage Pumping Stations

6.2.1 Sewage Pumps

The standardization of pumping stations and their equipment is very desirable. It simplifies design, maintenance and repair, and the training of operatives; it also reduces considerably the amount of spare parts which must be kept in store against breakdowns.

Sewage pumps commonly used in Kenya as observed in existing Sewerage Systems in Mombasa and as per the *Final Practice Manual for Sewerage and Sanitation Services in Kenya (MWI, 2008)* are:

i. Solids diverters
ii. Submersible pump-sets incorporating centrifugal pumps
iii. Centrifugal pumps
iv. Mixed-flow pumps
v. Screw Pumps (Sewage 'lift' stations)

Screw Pumps (sewage 'lift' stations) are suitable where the pump station can be located away from human settlements. Wherever electricity is available, it is recommended that pumps be driven by electric motors; elsewhere, diesel engines are considered the better alternative type of prime mover. Renewable energy e.g. Solar or wind power systems can also be used especially for smaller pumps.

Except solids diverters and screw pumps, it is recommended that all sewage and sludge pumps should be protected against blockage by screens; for the smallest pumps, 40 mm clear opening screens are required, but 100 mm openings are suitable for the larger centrifugal and mixed-flow pumps.

6.2.2 Sewage Pumping Stations

There are two basic types of sewage pumping stations, "lift" stations and stations which discharge into pumping mains. In the lift station, sewage is merely raised from a low to a higher level, for subsequent gravity flow.

The design of a pumping station is, considerable extent, dictated by the type of plant. Thus, a station for a screw pump simply houses the prime movers, and the buildings for ejectors or diverters are essentially partly-buried boxes giving access to the equipment and its control gear.

Roto-dynamic pumps require more sophisticated stations, which can be roughly categorized as either at Wet Well or Dry Well. Both types of station normally comprise a substructure below ground level and superstructure, containing special equipment mainly the electrical control panels, which could be damaged by flooding, above the ground surface.

Sewage pumping stations can be broadly classified as follows;

a) Wet Well Stations (Submersible Pumping Stations)
b) Dry Well Stations (Wet Well / Dry Well Pumping Stations)
c) Packaged Pumping Stations e.g. Screw Pumping Stations

Wet Well Stations

At such stations, the pumps are installed in the substructure or Wet Well which contains sewage. This arrangement ensures that the pumps are always primed. Usually, the prime movers are located in the superstructure and the drive is via cased shafting in case of vertical-shaft pumps.

In a Wet Well installation, pump maintenance, and especially the removal of blockages, is a constant problem as the pumps usually should be withdrawn to gain access. For this reason, new sewage pumping stations of this type are rarely constructed.

In recent years, several manufactures have started to produce watertight, submersible, portable pumping sets suitable for sewage, each comprising a centrifugal pump set (centrifugal pump and electrical motor). It is preferable to have the compact control equipment above ground level and the remaining unit lowered into underground chamber. This system considerably reduces capital costs and simplifies maintenance as within minutes, a standby unit can replace a faulty set, which can then be transported to a workshop for repair.

It is considered that such installations are suitable in Kenya, for pumping capacity within the range 450 – 2,500 l/min.

Dry Well Stations

The substructure of such stations comprises two compartments, a Dry Well to house the pumps and a sewage sump to store the sewage, sludge or effluent to be pumped.

The capital costs of such stations are more expensive than Wet Well stations of similar pumping capacity, but it is considered that the ease of maintenance provided by this arrangement compensates for the differences. It is recommended that all larger sewage pumping stations in Kenya (> 2,500 l/min) should be of this type.

Dry Well sewage pumping stations usually house centrifugal pumps (horizontal or vertical centrifugal pump sets). In general, horizontal centrifugal pumps are cheaper and easier to maintain than vertical pumps. However, vertical pump sets have advantage that the prime mover can be installed above ground level, so that it is protected from flooding caused by heavy rain or a burst on the pipeline. In such installations, the prime mover and pump are connected by shafting with universal joints. It is recommended that, when centrifugal pumps are used, vertical sets be adopted.

Reciprocating sludge pumping sets may also be installed in Dry Well Stations. These small sets, which include the prime mover, are usually located on the floors of the Dry wells to reduce the suction heads on the pump; otherwise the station resembles one housing a centrifugal pump.

Packaged Pumping Stations

These self-contained, factory-built units are recent development. They operate by electricity and are fully automated. Usually, a unit is installed underground and comprises pumping sets enclosed in a protected steel substructure. Most are designed as Dry Well stations except that electric motors are usually close-coupled to vertical pumps so that they are also at bottom.

6.2.3 Siting of Sewage Pumping Stations

The sewerage system dictates the approximate locations of all pumping stations. However, the sites for Sewage Pumping Stations should preferably be constructed away from residential property and should always be readily accessible.

Sewage Pumping Stations are mostly sited in low-lying areas, where flooding may be a risk. As a precaution, the floor of superstructure to the Pumping Station should always be elevated above the highest recorded flood level.

Electrical supply and mechanical failures are common occurrence at Sewage Pumping Stations. All Sewage Pumping Stations should therefore be so located that resulting sewage overflow causes minimum hazard to public health and environment. Where possible, a screened overflow pipe, for use only during emergencies should be provided to convey sewage by gravity to a retention ditch or pond.

6.2.4 Capacities of Sewage Pumping Stations Components

Pumping and Station Capacities

When a Sewage Pumping Station has roto-dynamic pumps, its total pumping capacity should be compatible with peak flows in the sewerage system it serves; if the sewers are not operating at their design capacities, then the installed pumping capacity should be correspondingly reduced.

It is relatively simple and inexpensive to change or add pumping sets, and thereby increase the pumping capacity of a station, if the building is sufficient for future installations. It is reasonable to install pump sets to serve for 5 to 10 years, depending upon the rate of increase of sewage generation in future. Buildings and other ancillary works should have design period of 20 years.

Sewage Pumping Stations with screw pumps or diverters cannot be designed in this way, as once initial installation is complete, the pumping capacities can only be increased by duplicating the installation. Where such types of stations are provided, it is considered reasonable to design them for either the maximum flow the sewerage system served can produce or 50 per cent more than the peak wet weather flows anticipated, whichever is lesser.

If, in the case of diverters, this formula results in design flows of 450 l/minute or more, then centrifugal pumps rather than diverters should be installed.

Stand-by Units

In the smallest sewage pumping stations, the pumping equipment should be duplicated and should be so sized that either one of the two pump sets, working alone, can deal with the peak inflow to the station; that is, there should be 100 % standby.

The percentage of standby may be reduced as the number of pump sets installed in a station increases; for example, for a station which should deal with a peak inflow of 1,800 l/min, it may prove cheaper to have three pump sets each rated at 900 l/min rather than two sets each with a capacity of 1,800 l/min; in this case, the provided standby is only 50 %.

It is recommended that the percentage standby never drops below 33 %; that is, the total number of pump sets in larger stations should be such that about three-quarters of pumps can deal with peak flows, with the remaining pump(s) held in stand-by.

Wet Wells and Sewage Sumps

The rate of inflow to Sewage Pumping Station normally varies throughout the day. As the installed pump-sets will each have finite capacities, rather than variable, a sewage sump providing storage is required to deal with the inflow fluctuations; in the case of Wet Well type of pumping station, the terms "Wet Well" and "Sewage Sump" are synonymous.

Effectively, the capacity of sewage sump is the volume between the highest level at which the pumps start and the lowest level at which they stop. Usually, the highest level will be just below the invert of lowest incoming sewer, to help prevent surcharging of the sewerage system.

A Sewage Sump's capacity should be related to the rate of inflow and the pump capacities, to reduce wear on the mechanical and electrical equipment in the station by minimizing the number of pump starts. Each pump should be limited to about six starts during any hour; the maximum number of starts occurs when the station inflows is equal to half the pumping capacity of one pump. On the other hand, if sewage sumps are too large, sewage will tend to become anaerobic during its retention.

It is recommended that the capacity of the sewage sump in a Pumping Station be calculated following the formula given below;

V =300Q

Where; V is the capacity of the sewage pump in litres
Q is the maximum rate of sewage inflow during dry weather in litres per second.

The capacity of the sewage sump given by the above formulae represent the sum of the capacities of the individual compartments if multiple sumps are provided at a Sewage Pumping Station.

At least two compartment of sewage sump is necessary, to facilitate cleaning of the wells and pipe work and repairs to pumps. These compartments should be interconnected by orifice through the dividing walls which can be closed by penstocks, when necessary, to isolate a compartment.

6.3 Design of Wastewater Treatment Plants

6.3.1 Selection Criteria for Treatment Process / Technology

Wastewater treatment technology has been selected after taking due consideration of the pertinent technical, operational and economic factors, limitations and constraints. In this regard, the technologies have been evaluated based on the following key factors:

i) **Nature and Strength of Wastewater**

The physical, chemical and biological treatment processes are primarily governed by the nature of pollutants to be removed and their strengths in the wastewater. The treatment technology selected has ensured the attainment of required pollutant removal efficiencies.

ii) **Cost**

The least cost treatment technology in terms of the both the capital and operation costs has been given preference.

To simplify the evaluation process for the various treatment technologies, the Consultant calculated the dynamic unit cost as average cost/m³ of wastewater treated for different treatment technologies as summarised in **Figure 6.1** below;

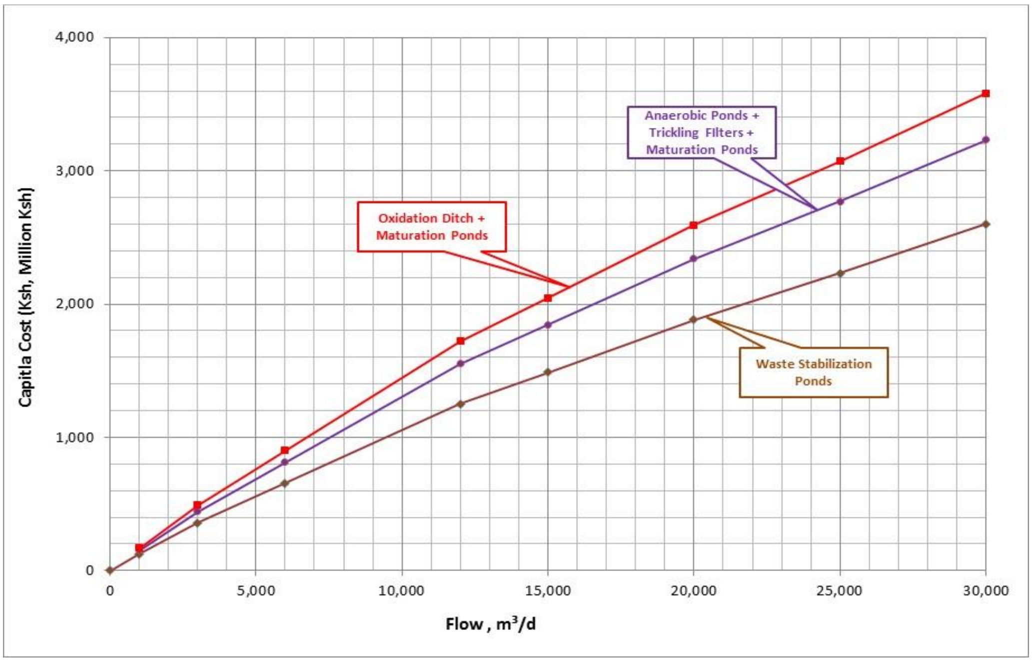


Figure 6.1: Capital cost for wastewater treatment technologies

iii) **Physical Constraints - Land**

Land required for installation of treatment plant is the principal physical constraint due to the availability and acquisition cost. Land available at the selected site in consideration of the site topography and terrain for the hydraulics at the WWTP has been assessed for adequacy for the selected treatment technology.

Figure 6.2 below shows the land requirements for the various treatment technologies.

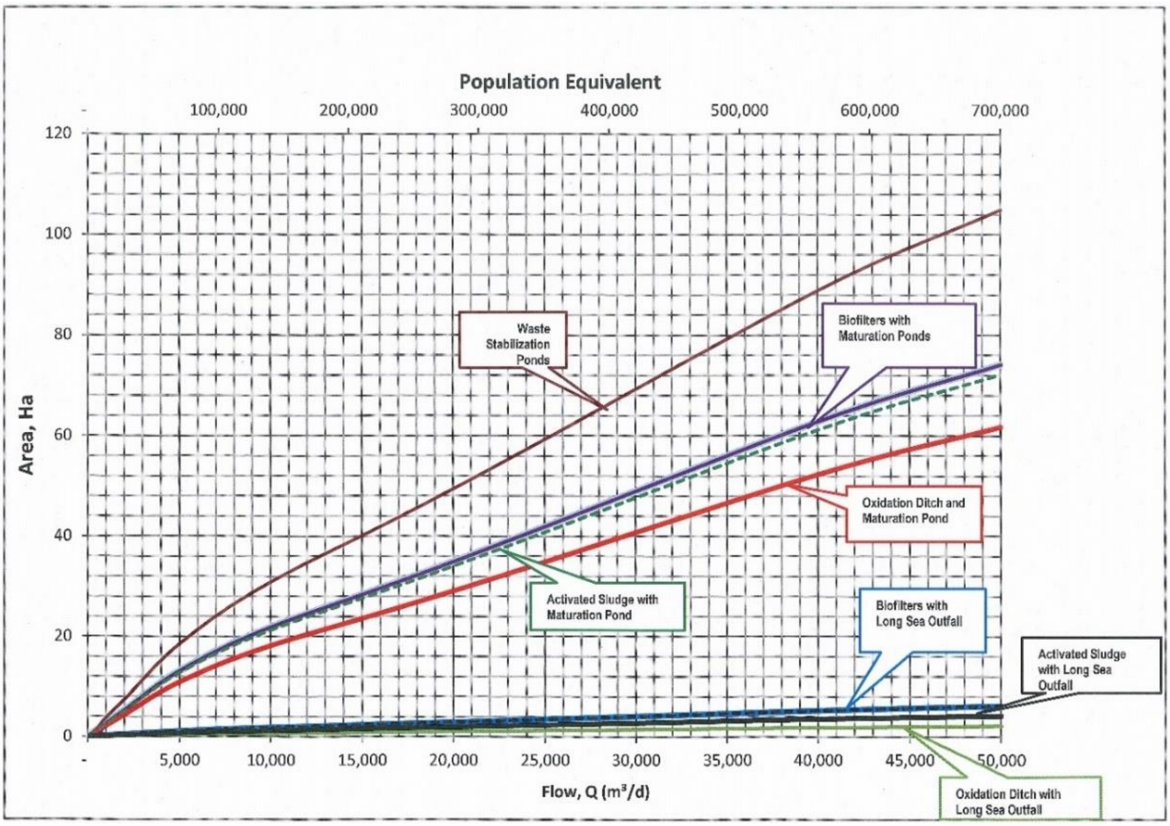


Figure 6.2: Land Requirements for wastewater treatment technologies

iv) **Operational Skills**

Treatment technologies whose skill requirement for operation and maintenance can be obtained locally, with minimum training of operators, has also been given preference.

v) **Sludge Production**

Different technologies generate varied amounts of sludge during wastewater treatment process. The amount of sludge generated and its disposal or reuse has a huge impact on the capital cost, operational cost and land requirement. The selection of wastewater treatment technology has considered minimal production of sludge and its safe disposal.

vi) **Energy Recovery**

Methane gas is usually generated during wastewater treatment process. Some technologies such as the Activated Sludge have dominant anaerobic digestion processes involving sludge which produces substantial amounts of methane. Energy production can also be achieved through direct incineration of sludge.

It is ideal to collect and utilize the produced methane gas for the generation of power and thereby reduce the cost of energy at the WWTP. However, this is only economically and financially viable for treatment technologies with high calorific value in sludge and methane gas.

vii) **Fertilizer Recovery**

The presence of nutrients such as nitrogen, phosphorous and potassium makes sludge a valuable fertilizer resource after stabilization. Natural and mechanical composting can be practised for conversion of sludge into fertilizer.

viii) **Sludge Handling**

In the absence of energy and fertilizer recovery, generated sludge (mostly liquid) must be disposed of in a safe and sound manner to the public and environment at the Sludge Dump Site. Dewatering of sludge by use of Sludge thickeners, Sludge Drying Beds, etc. prior to transportation is necessary. Some of these techniques are labour and land intensive and involve mechanical equipment.

ix) **Sludge / Solid Waste Dump Site**

After dewatering, solid sludge is easily transported to the Sludge Dump Site for final disposal. The sludge may also be combined with grits and screenings from the Plant for dumping. The Sludge Dump site shall preferably be developed near the Wastewater Treatment Plant site to reduce the hauling distance and to minimize cost of transportation. The dumped sludge is compacted with bulldozer and covered with a thick layer of clean soil to minimize nuisance through odour and flies.

Site evaluation and selection of the Sludge Dump Site have been carried out based on following key factors:

- Topography of the land and its potentials for erosion and runoff
- Soil Characteristics
- Soil depth to ground water
- Accessibility & proximity to critical areas

Availability of clean earth for covering the dumped sludge / solid waste have been considered to minimize hauling distance and transportation cost.

x) **Mechanical Equipment**

The selected system shall be such that minimum mechanical equipment needs to be provided. Unnecessary mechanical equipment has been avoided. The system has been designed such that maximum of the mechanical equipment is of local make.

xi) **Nuisance**

The degree of colour, odour and noise shall be below the nuisance thresh-hold, especially, regarding the proximity of the Wastewater Treatment Plant to the build-up areas.

6.3.2 Alternative Wastewater Treatment Processes / Technologies

The following biological Wastewater Treatment Technologies have been analysed in detail using the above criteria (*Sub-section 6.3.1*):

i) <u>Waste Stabilization Ponds</u>

Application Level:	Management Level:	Inputs: Blackwater Brownwater Greywater (Sludge)
Household Neighbourhood City	Household Shared Public	Outputs: Effluent Sludge

Waste Stabilization Ponds (WSPs) are large basins enclosed by earth embankments in which raw wastewater is treated by entirely natural processes involving algae and bacteria. Since these processes are unaided, the rate of oxidation is slower, and thus hydraulic retention times are longer than in conventional wastewater treatment. WSPs are the preferred method of wastewater treatment in developing countries where sufficient land is normally available and where the temperature is most favourable for their operation.

There are three principal types of WSP: anaerobic, facultative and maturation ponds which are linked in series. Anaerobic ponds and facultative ponds are designed for BOD (biochemical oxygen demand) removal, and maturation ponds are designed for faecal bacterial removal. Some removal of faecal bacteria (especially of *Vibrio cholerae*) occurs in anaerobic and facultative ponds, which are also responsible for most of the removal of helminth eggs; and some removal of BOD occurs in maturation ponds, which also remove some of the nutrients (N and P).

A typical layout of Waste Stabilization Pond is given in **Figure 6.3** below;

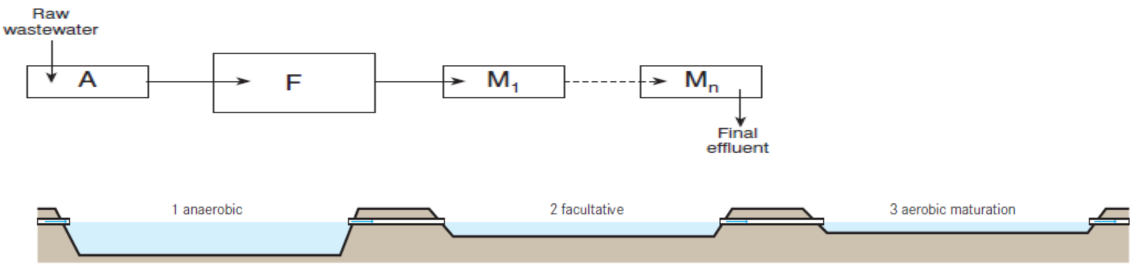


Figure 6.3: Layout of Waste Stabilization Ponds

The advantages of WSP are that they are simple, low-cost, highly efficient and robust. The disadvantages of WSP include high land requirements and odour release.

ii) Trickling Filters / Biofilter

Application Level:	Management Level:	Inputs: Effluent, Blackwater, Brownwater, Greywater
Household	Household	Outputs: Effluent, Sludge
★ Neighbourhood	Shared	
★★ City	★★ Public	

A trickling filter is a fixed-bed, biological reactor that operates under (mostly) aerobic conditions. Pre-settled wastewater is continuously ‘trickled’ or sprayed over the filter using sprinkler as shown in **Figure 6.4** below.

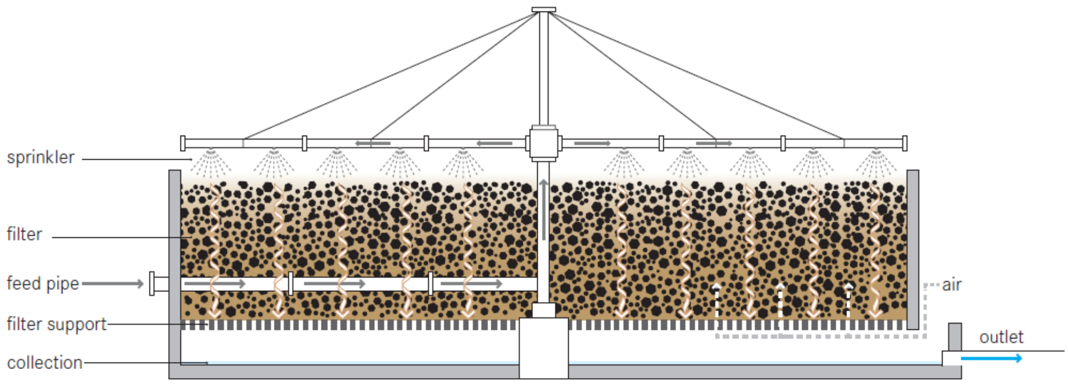


Figure 6.4: Sectional View of a Circular Biofilter

As the water migrates through the pores of the filter, organics are degraded by the biofilm covering the filter material. They produce high quality effluents (e.g. <20 mg BOD/l and <30 mg SS/l) without requiring large areas of land or consuming vast quantities of electricity. In many situations in developing countries they are much more appropriate than activated sludge. Trickling Filters comprise a 2-3 m deep bed of 50-100 mm rock.

The trickling filter is filled with a high specific surface area material, such as rocks, gravel, shredded PVC bottles, or special pre-formed plastic filter media. A high specific surface provides a large area for biofilm formation. Organisms that grow in the thin biofilm over the surface of the media oxidize the organic load in the wastewater to carbon dioxide and water, while generating new biomass.

The advantages of trickling filters are;

- High quality effluents at small footprint & less electricity
- Efficient nitrification
- Operation at a range of organic and hydraulic loading rates

The disadvantages include;

- High capital costs
- Skilled personnel for operation and maintenance,
- Constant source of electricity and wastewater flow
- Problems associated with flies and odour

iii) Oxidation Ditch / Extended Aeration

Application Level:	Management Level:	Inputs / Outputs
Household	Household	**Inputs:** Effluent, Blackwater, Brownwater, Greywater
★ Neighbourhood	Shared	**Outputs:** Effluent, Sludge
★★ City	★★ Public	

Oxidation ditches are a direct modification of conventional activated sludge. Their essential operational features are that they receive raw wastewater (after preliminary treatment) and provide longer retention times: the hydraulic retention time is commonly 0.5–1.5 days and that for the solids 20–30 days. The latter, achieved by recycling >95 per cent of the activated sludge, ensures minimal excess sludge production and a high degree of mineralization in the small amount of excess sludge that is produced. Sludge handling and treatment is almost negligible since the small amounts of waste sludge can be readily dewatered without odour on drying beds. The other major difference is in reactor shape: the oxidation ditch is a long continuous channel, usually oval in plan and 2–3 m deep.

The ditch liquor is aerated by several aerators, which impart a velocity to the ditch contents of 0.3–0.4 m/s to keep the activated sludge in suspension. The ditch effluent is discharged into a secondary sedimentation tank to permit solids separation and sludge return and to produce a settled effluent with low BOD and SS. Removals consistently >95 per cent are obtained for both BOD and SS.

Currently, there are few oxidation ditches in developing countries since Waste Stabilization Ponds are usually more favourable, both in terms of costs and faecal bacterial removal; although where there is a reliable electricity supply but insufficient land for ponds Oxidation Ditches are increasingly being used.

The advantages of Oxidation ditches include;

- Resistance to organic and hydraulic shock loads
- High reduction of BOD and pathogens (up to 99%)
- High nutrient removal possible

The limitations / disadvantages of using oxidation ditches include;

- High energy consumption
- Constant supply of energy
- High capital and operating costs
- Require operation and maintenance by skilled personnel

iv) Sequencing Batch Reactor (SBR)

Application Level:	Management Level:	Inputs: Effluent, Blackwater, Brownwater, Greywater
Household	Household	Outputs: Effluent, Sludge
Neighbourhood	Shared	
City	Public	

The Sequencing Batch Reactor (SBR) is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. The major difference between SBR and conventional continuous-flow activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems thus smaller footprint (see **Figure 6.5** below).

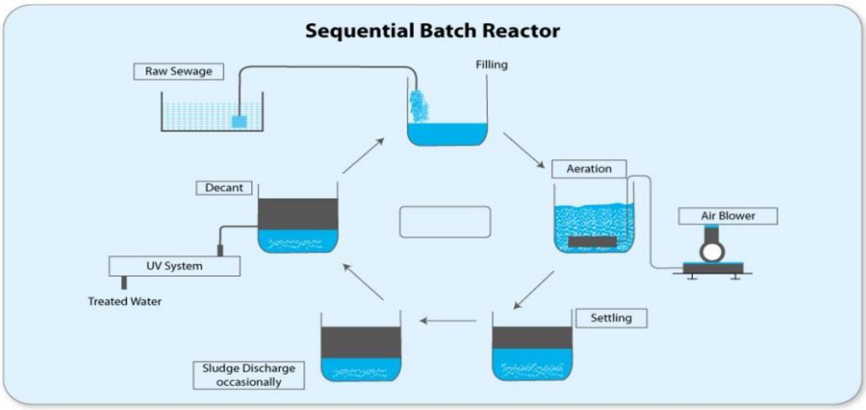


Figure 6.5: Schematic Showing SBR operational cycle

There is a degree of flexibility associated with working in a time rather than in a space sequence. The duration, oxygen concentration, and mixing in these periods could be altered per the needs of the Treatment Plant.

SBRs require controls to reduce energy consumption and enhance the selective pressures for BOD, nutrient removal, and control of filaments. This range from a simplified float and timer based system to a more complex PC based systems. An appropriately designed SBR process is a unique combination of equipment and software. Working with automated control reduces the number of operator skill and attention requirement.

SBRs does not include primary settling tanks; screening of solids and oil / grease removal should be accomplished prior to the activated-sludge process. Flow equalization is also critical where significant variations in flow rates and organic mass loadings are expected. A plant utilizing an influent equalization basin will be able to have a true batch reaction.

v) Sub-marine Outfall

This is a submarine pipeline or tunnel that discharges wastewater under the sea surface. In the case of municipal wastewater, effluent is often being discharged after having undergone no or only primary treatment, with the intention of using the assimilative capacity of the sea for further treatment.

The main advantages of marine outfalls for the discharge of wastewater include:

- Natural dilution and dispersion of organic matter, pathogens and other pollutant,
- Ability to keep the sewage field submerged due to deep discharge points
- Greater die-off rate of pathogens due to the greater distance they should travel to shore
- Less expensive than advanced Wastewater Treatment Plants i.e. not energy-intensive

For effective operation of outfall and its diffusers, preliminary treatment of wastewater is important. The combined capital and operation cost of preliminary treatment is about one tenth that of conventional biological treatment and require much less land.

However, sub-marine outfalls for partially treated or untreated wastewater remain controversial. The design calculation and computer models for pollution modelling have been criticized, arguing that dilution has been overemphasized and that other mechanisms work in the opposite direction, such as bioaccumulation of toxins, sedimentation of sludge particles and agglomeration of sewage particles with grease.

Outfall materials include polyethylene, stainless steel, carbon steel, glass-reinforced plastic, reinforced concrete, cast iron or tunnels through rock. Common installation methods for pipelines are float and sink, bottom pull and top pull.

For final polishing of treated effluent (pathogen reduction) before disposal into the environment, the following processes have been considered to formulate Wastewater Treatment Trains:

- Maturation Ponds
- Chlorination
- Sea outfall

<u>**Preliminary Treatment**</u>

Regardless of the Wastewater Treatment technology considered, it is important to have a preceding preliminary Treatment Process at the Wastewater Treatment Plant.

Wastewater contains large solids and grit that can interfere with treatment processes through accumulation of solids, frequent blockages, abrasion of mechanical parts and increased maintenance on wastewater treatment equipment. To minimize potential problems and extend the life of sanitation infrastructure, these materials require separate handling. Preliminary treatment removes these constituents from the influent wastewater.

Some of the preliminary treatment processes are briefly described below;

a) <u>Screening</u>

Screening is the first unit operation used at Wastewater Treatment Plants (WWTPs). It removes coarse objects such as rags, paper, plastics, and metals to prevent damage and clogging of downstream equipment, piping, and appurtenances. These screens can be cleaned either manually or mechanically.

Manually cleaned screens require little or no equipment maintenance and are suitable for small WWTPs with few screenings. However, they require frequent raking to avoid clogging and high backwater levels that cause build-up of solids mat on the screen. The increased raking frequency increases labour costs.

Mechanically cleaned screening systems are popular in modern WWTPs because they reduce labour costs and improve flow conditions resulting from screen capture. However, they have a high equipment maintenance costs. A screening compactor is usually situated close to the mechanically cleaned screen and compacted screenings are conveyed to a dumpster or disposal area. Plants utilizing mechanically cleaned screens should have a standby screen to put in operation when the primary screening device is out of service.

Coarse screens and fine screens are available for use at the WWTPs. Coarse screens remove large solids, rags, and debris from wastewater, and typically have openings of 6mm or larger. Fine screens are used to remove materials that may create operation and maintenance problems in downstream processes, particularly in systems that lack primary treatment. Typical opening sizes for fine screens are 1.5 to 6 mm.

b) <u>Grit Removal</u>

Grit includes sand, gravel, cinder, or other heavy solid materials that have higher specific gravities than the organic biodegradable solids in the wastewater. Removal of grit prevents unnecessary abrasion and wear of mechanical equipment, grit deposition in pipelines and channels, and accumulation of grit in anaerobic digesters and aeration basins. Removal of grit is carried out in a channel or chamber, where the velocity of the incoming wastewater is adjusted to allow settlement of sand and grit. Grit removal facilities typically precede primary clarification, and follow screening to prevent large solids from interfering with grit handling equipment. In secondary treatment plants without primary clarification, grit removal should precede aeration (Metcalf & Eddy, 1991).

Many types of grit removal systems exist, including;

- Aerated grit chambers
- Vortex-type (paddle or jet induced vortex) grit removal systems
- Detritus tanks (short-term sedimentation basins)
- Horizontal flow grit chambers (velocity-controlled channel)
- Hydrocyclones (cyclonic inertial separation)

Various factors must be taken into consideration when selecting a grit removal process, including the quantity and characteristics of grit, potential adverse effects on downstream processes, head loss requirements, space requirements, removal efficiency, organic content, and cost.

c) <u>Flow Control and Overflow</u>

Flow control requires that a flow control device be incorporated at the inlet works to restrict the forward flow to treatment i.e. to avoid hydraulic overloading of the subsequent treatment units.

A summary of the descriptive comparison of the above wastewater treatment technologies / processes is given in **Table 6.4** on **Page 6-17**.

Table 6.4: Descriptive Comparison of Wastewater Treatment Technologies / Processes

Treatment Process	Standard of Treatment	Process Reliability	Process Complexity	Operation & Maintenance Requirements	Land Requirements	Civil Construction Requirements	M & E Equipment	Sludge Production	Environmental Considerations
Waste Stabilisation Ponds	Good, except for nutrient removal	Very good, but climate dependent	Extremely simple. No skills needed	Very limited and simple	Large areas of land needed.	Very simple	Almost none, except, possibly, at the inlet works	Limited sludge production. Sludge is stable and requires no further treatment	High environmental acceptance.
Aerated Lagoons	Good, except for nutrient and bacterial removal.	Good, but partly subject to power outages and mechanical failure	Very simple. No skills needed.	Limited and straightforward	High land requirements, but not as large as WSPs	Very simple	Apart from the inlet works, only the surface aerators	Limited sludge production. Sludge is stable and requires no further treatment	Moderate environmental acceptance.
Biological Filters	Very good, except for nutrient and bacterial removal.	Good, but subject to power outages and mechanical failure	Simple. Limited skills required.	Moderate, but straightforward	Moderate land requirements	Complicated RC structural requirements.	Moderate degree of M&E plant needed.	Sludge from primary & secondary settlement needs treatment	Some aspects need further environmental consideration.
Activated Sludge	Very good, except for nutrient and bacterial removal.	Good, but subject to power outages and mechanical failure	Complex. Highly skilled manpower needed	High requirement for O&M and skilled staff	Minimum land requirements.	Very complicated RC structural requirements.	High input of M&E equipment needed	Sludge from primary & secondary settlement needs treatment	Many aspects need further environmental consideration.
Oxidation Ditch	Very good, except for nutrient and bacterial removal.	Good, but subject to power outages and mechanical failure	Simple. Limited skills required.	Moderate requirement for skilled O&M staff	Moderate land requirements.	Moderate construction requirements.	Moderate degree of M&E plant needed.	Limited sludge production. Sludge is stable and requires no further treatment	Some aspects need further environmental consideration.

Notes:

1. All treatment processes except waste stabilisation ponds will require additional treatment, such as sand filtration and disinfection or maturation ponds, to achieve bacteriological reduction.
2. All the treatment processes considered will require additional process units to achieve nutrient removal.
3. The activated sludge process and the oxidation ditch most easily lend themselves to nutrient reduction using the Modified Activated Sludge (MAS) process.

6.3.3 Identification of Site for Wastewater Treatment Plant (WWTP)

6.3.4 Identification of Site for the Wastewater Treatment Plant (WWTP)

The location of the proposed Wastewater Treatment Plant(s) is identified after the selection of wastewater treatment technology and determination of the land required for the installation of the various units of the WWTP. Possibilities of future extension of the WWTP is also considered.

The factors that have been considered to select appropriate location of the WWTP are:

6.3.4.1 Land-Use

In the Land-use Map, different areas of Mombasa Island and North Mainland have been assigned varied existing and proposed uses. Areas earmarked for residential, industries, agriculture, forests and social amenities are considered less suitable for the location of a Wastewater Treatment Plant (WWTP). On the other hand, public utility or undeveloped Agricultural Land located away from the sensitive residential areas are preferred.

6.3.4.2 Distance of Effluent Discharge Point

The distance from the WWTP site to the final receiving environment such as the river and ocean, is an important consideration in site selection. Preference is given to the sites that require shorter lengths of Outfall Sewers.

6.3.4.3 Topography of the Sewered Area

An ideal WWTP site should be located on a low-lying area of the sewerage system for gravity conveyance. Otherwise, pumping stations become necessary thereby increasing both capital cost and the operation and maintenance requirements of the sewerage system.

6.3.4.4 Topography of Site

The slope at an ideal site should permit the gravity flow within the WWTP without requiring excessive excavations for the structures. Slopes less than 1:20 are preferred.

6.3.4.5 Geological Conditions

A site with low water table and whose soils are impermeable is considered ideal with respect to geological considerations. For instance, silt or clay soils are suitable for pond construction.

More often, the geological formation within a Town is fairly similar. For instance, all the candidate sites in Mombasa Island and North Mainland comprise of a mixture of well drained, deep, dark red to reddish brown, friable, sandy clay loam to sandy clay, with top soil of loamy sand and well drained, very deep, yellowish red, very friable, fine sandy loam to fine sandy clay loam. These soils are suitable for WWTP (Waste Stabilization Ponds) construction.

6.3.4.6 Existing Infrastructure

Proximity to infrastructural systems such as roads, electricity and portable water is sought for while siting for a WWTP location. It reduces cost of construction and operation & maintenance requirements of the WWTP. Sites that are closer to existing infrastructure are preferred.

6.3.4.7 Potential for reuse of treated wastewater

Treated wastewater can be reused for beneficial purposes such as agricultural irrigation, industrial processes, ground water recharge, etc. Proximity to the potential re-use application and relative elevation difference (for gravity conveyance) is preferred in siting of WWTP. For instance, downstream arable land would make a WWTP site ideal for agricultural irrigation.

6.3.4.8 Land Acquisition

In this criterion, preference is given to sites owned by government agencies such as Ministries, County Governments, etc. This ensures that the project affected persons are kept to a minimal and reduces the cost of resettlement and compensation.

7.0 FORMULATION OF ALTERNATIVE DEVELOPMENT STRATEGIES

7.1 Justification of Study Area

It was proposed in the World Health Organisation (WHO) Report No. 9 that by the year 2000 all urban areas that have a population density greater than 124 persons per hectare should be connected to sewerage systems. This proposal aims to outline the extent to which the sewerage projects should be prioritized in the developing nations. The population pattern in Mombasa Island and North Mainland is distributed and dense settlement exists in dispersed areas. The effect of the sparse settlement on the overall population density is reductive.

The present population density for the Mombasa Island (year 2016) has been determined as 133 persons per hectare while the projected year 2040 mean population density is 271 persons per hectare. The highest projected population density in year 2040 is recorded in Mji wa Kale sub-location at approximatively 641 persons per hectare.

In Mombasa North Mainland, the present estimated mean population density (year 2016) has been determined as 53 persons per hectare while the projected year 2040 mean population density is 107 persons per hectare. The highest projected population density in year 2040 is recorded in Magogoni sub-location at approximatively 250 persons per hectare.

These estimated population densities have been adopted for the design of Sanitation System for the study area in consideration of the WHO recommendation.

7.2 Delineation of Drainage Areas

The Sewerage System for Mombasa Island and North Mainland has been developed based on drainage areas. A drainage area refers to a natural boundary within which the topography permits convergence of surface water flow to a single point at a lower elevation.

The total number of drainage areas formulated in Mombasa Island and North Mainland are twelve (13) and thirty-seven (37) drainage areas respectively.

Based on the projected land use, population and water demand (including suppressed conditions) as detailed in the previous Chapters, the sewage generated (Dry Weather Flow) at the various design horizons by Drainage area including BOD_5 is given in **Table 7.1** below for Mombasa Island and on **Table 7.2** on **Page 7-2** for Mombasa North Mainland.

Table 7.1: Summary of Sewage and BOD_5 Generated per Drainage Area – Mombasa Island

Drainage Area	Coverage (Ha)	Year 2025		Year 2040	
		DWF (m^3/d)	BOD_5 (mg/l)	DWF (m^3/d)	BOD_5 (mg/l)
1	135	69	650	160	572
2	171	101	688	258	573
3	323	161	733	336	661
4	43	41	779	100	697
5	4	15	953	38	931
6	11	18	970	42	956
7	27	99	785	295	643
8	67	31	752	61	684
9	16	20	867	47	812
10	30	34	763	88	670
11	168	332	1,017	1,112	650
12	138	146	855	441	617
13	529	2,415	1,036	8,376	654
Mean	**-**	-	**877**	-	**685**
Total	**2,479**	**6,136**	**-**	**19,916**	**-**

Table 7.2: Summary of Sewage and BOD_5 Generated per Drainage Area – North Mainland

Drainage Area	Coverage (Ha)	Year 2025		Year 2040	
		DWF (m^3/d)	BOD_5 (mg/l)	DWF (m^3/d)	BOD_5 (mg/l)
1	78	793	288	738	426
2	134	655	661	625	1,162
3	168	691	1,613	650	3,058
4	238	728	4,542	670	8,905
5	88	705	1,879	657	3,608
6	57	663	598	630	1,051
7	143	641	380	617	661
8	222	719	3,315	665	6,454
9	154	655	739	626	1,312
10	96	602	121	597	211
11	420	741	4,500	676	8,903
12	82	751	1,584	643	3,343
13	121	763	2,353	648	5,013
14	362	754	2,786	644	5,900
15	131	686	601	617	1,181
16	322	649	595	597	1,119
17	99	696	238	631	396
18	51	867	150	809	215
19	27	684	283	621	512
20	243	648	473	597	872
21	130	710	227	643	363
22	329	637	345	587	570
23	59	932	140	896	192
24	70	739	1,195	639	2,495
25	253	648	489	597	904
26	70	861	155	802	222
27	51	860	152	800	219
28	29	947	131	918	180
29	63	807	168	737	251
30	53	855	153	793	222
31	78	890	151	839	211
32	248	733	232	662	343
33	660	661	348	594	492
34	65	842	159	778	231
35	64	880	150	825	212
36	126	845	171	781	241
37	260	742	230	670	336
Mean	**-**	-	**753**	-	**696**
Total	**5,974**	**32,446**	**-**	**62,185**	**-**

The Projected Dry Weather Flow for the study area of Mombasa Island and North Mainland at the Design Horizon (Year 2040) is approximately **82,300 m^3/day**.

A layout Plan showing these drainage areas for Mombasa Island and North Mainland are given in **Figure 7.1** on **Page 7-3 and Figure 7-2 and** on **Page 7-4** respectively.

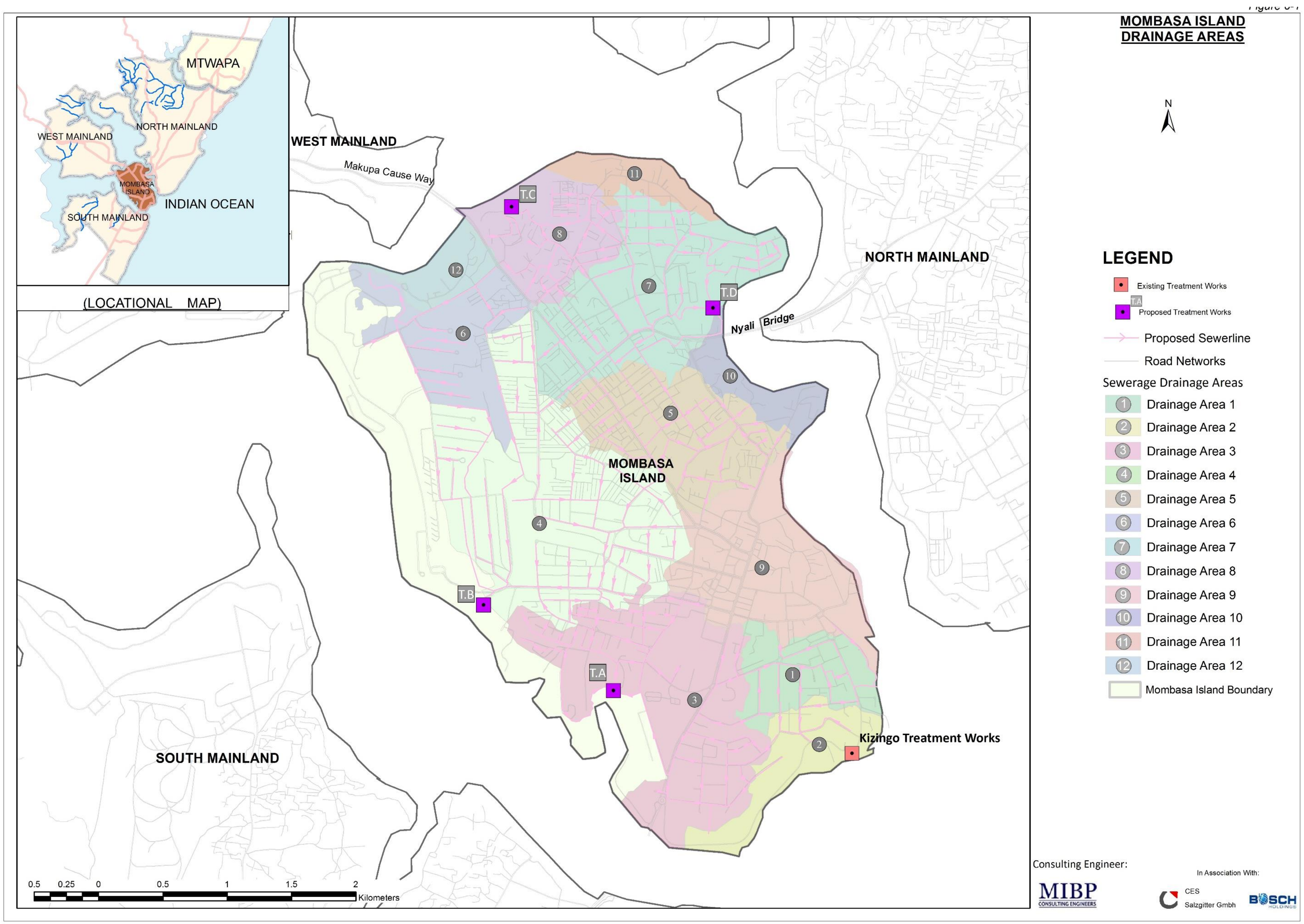


Figure 7.1: Proposed Drainage Areas – Mombasa Island

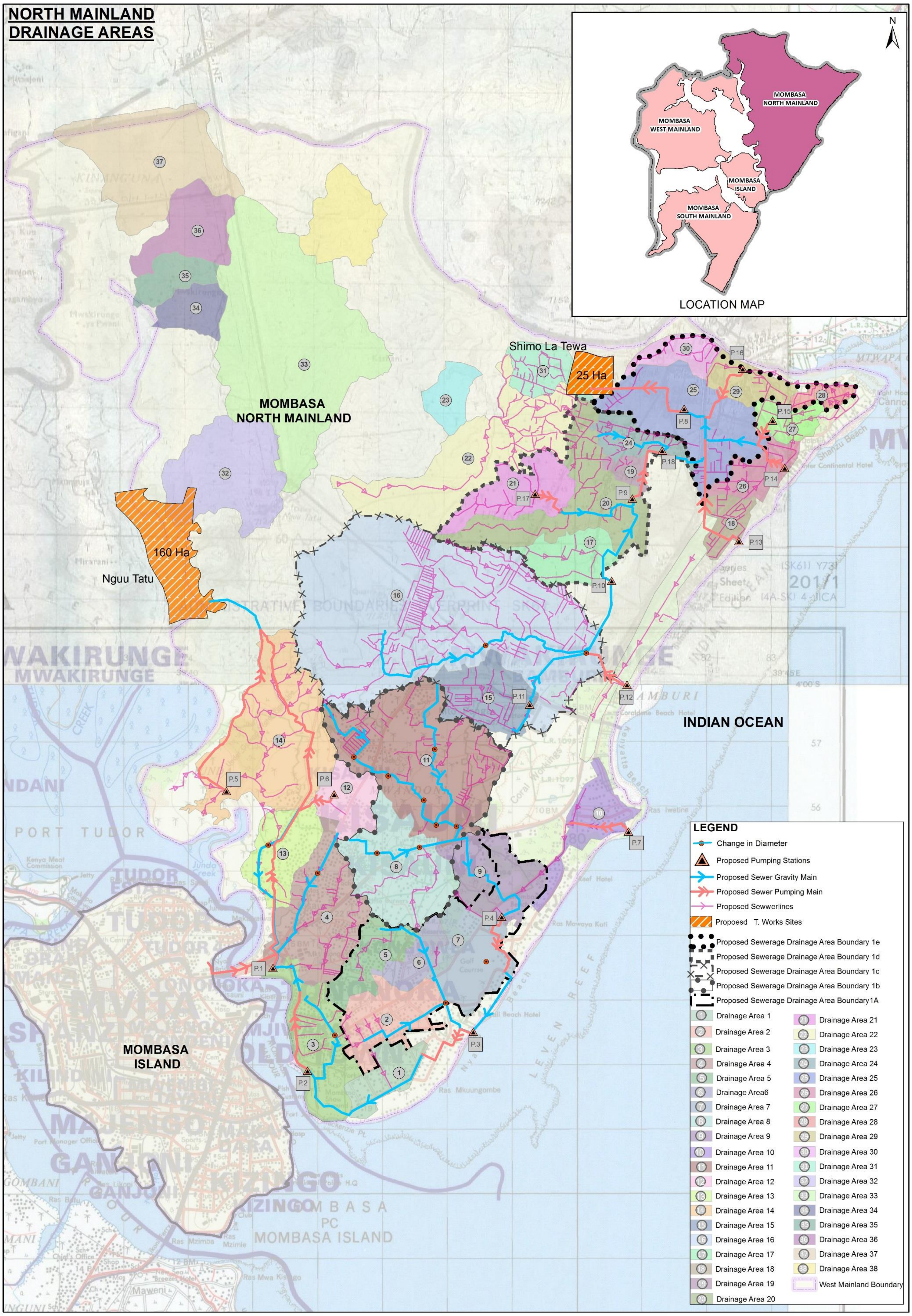


Figure 7.2: Proposed Drainage Areas – Mombasa North Mainland

7.3 Description of Alternative Wastewater Management Schemes

Three Alternative Wastewater Management Schemes have been formulated and evaluated to serve the sanitation needs of Mombasa Island and North Mainland up to Year 2040 as briefly described below;

i) Alternative 1: Long Sea Outfall for Mombasa Island at Kizingo and 2Nr Decentralized Wastewater Treatment Plants in North Mainland at Nguu Tatu and Shimo la Tewa

This alternative involves a decentralized wastewater management scheme to reduce conveyance distances.

Wastewater from Mombasa Island will be conveyed to the existing Kizingo WWTP for pre-treatment and disposal through the existing long sea outfall. This option requires extensive rehabilitation and expansion of existing Kizingo WWTP and long sea outfall to Ultimate design capacity 25,000 m^3/day. Due to the nature of topography in Mombasa Island, the wastewater will be conveyed to Kizingo WWTP via series of gravity and pumping mains. The 12Nr. proposed Pumping Stations will be located at strategic points of the Sewerage System with least pumping heads and shortest rising mains. The Preliminary Treatment will entail screening and grit removal, screening and grit removal only.

The main components of the Wastewater Treatment Plant include:

- Preliminary Treatment / Inlet Works
- Long Sea Outfall - 3.1 Km long
- Surge Chamber and Booster Pumping Station
- Staff Houses and Administration Buildings
- Site and Ancillary Works

Two (2) Wastewater Treatment Plants are proposed, one is located on reclaimed land at Nguu Tatu (Ultimate design capacity 52,300 m^3/day) and the other at Shimo la Tewa Prison compound (Ultimate design capacity 9,900m^3/day). Due to the topography of North Mainland, the wastewater will be conveyed to the WWTP via series of gravity and pumping mains involving a total of 17Nr pumps.

A full conventional Wastewater Treatment Plant, comprising of Waste Stabilization Ponds has been adopted considering availability of land, costs of land acquisition, capital costs and low operation and maintenance requirements.

The main components of the Wastewater Treatment Plant include:

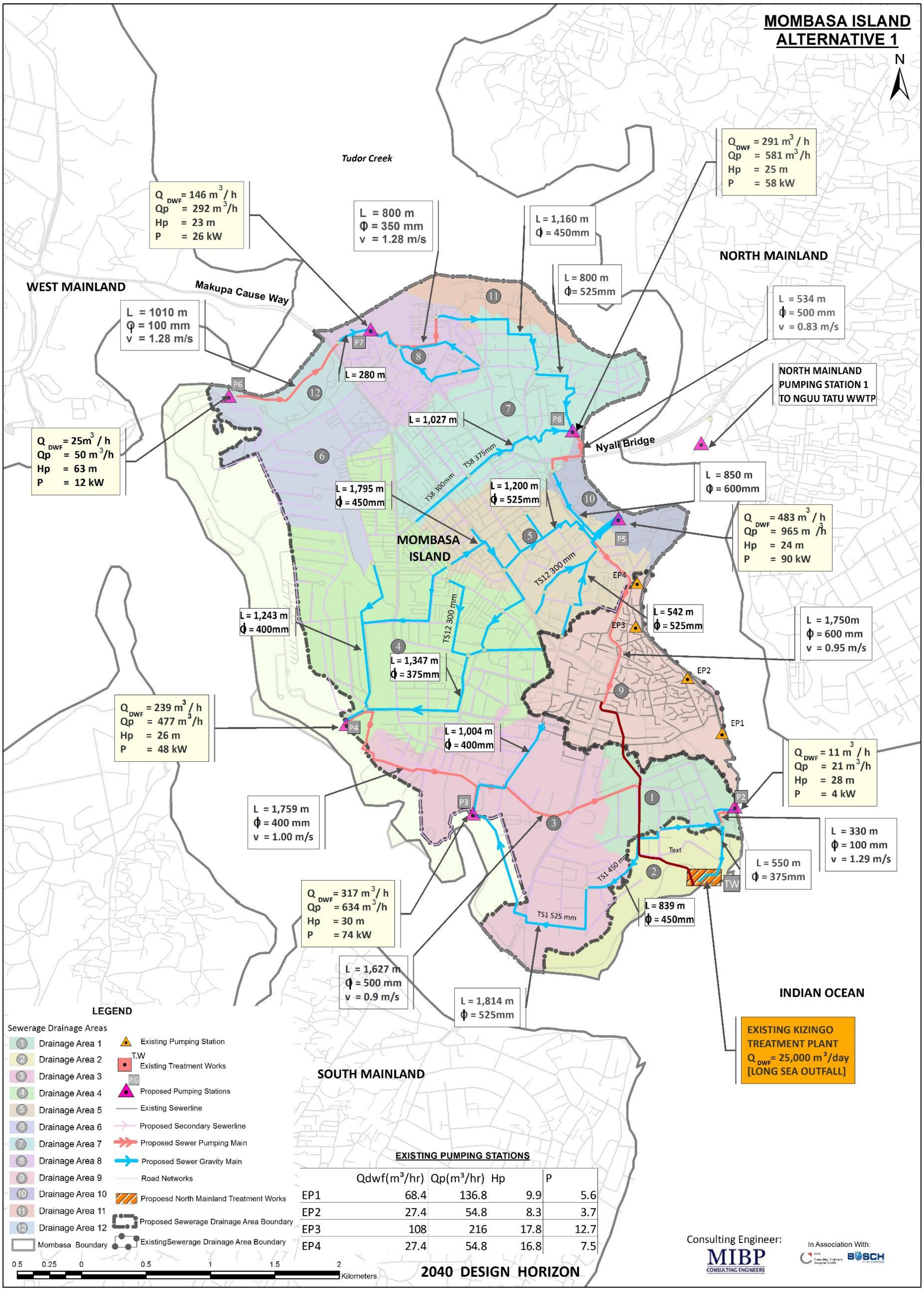
- Inlet Works
- Waste Stabilization Ponds - Anaerobic, Facultative and Maturation Ponds
- Sludge Drying Beds
- Staff Houses and Administration Buildings
- Site and Ancillary Works

A summary of the Sewerage Pumping Components and Treatment Technology in **Alternative 1** is given in **Table 7.3** on **Page 7-6** below.

Table 7.3: Alternative Scheme 1 - Pumping components and Treatment Technology

Rising mains		Pumping Stations				Wastewater Treatment Plants
Length (m)	**Dia. (mm)**	**Pumping Station Ref.**	**Design flow (m^3/h)**	**Pumping Head (m)**	**Power (kW)**	**WWTP**
MOMBASA ISLAND						Preliminary Treatment + Long Sea Outfall at Existing Kizingo WWTP Capacity 25,000 m^3/day
330	100	P2	21	28	4	
1,004	400	P3	634	30	74	
1,759	400	P4	477	26	48	
1,750	600	P5	965	24	90	
1,010	100	P6	50	63	12	
800	350	P7	292	23	26	
534	500	P8	581	25	58	
113	150	Existing P1	137	10	6	
200	150	Existing P2	55	4	8	
511	200	Existing P3	216	13	18	
150	150	Existing P4	55	8	17	
MOMBASA NORTH MAINLAND						Waste Stabilization Ponds at Nguu Tatu, Capacity 52,300m^3/d Area Required 115Ha
6,160	1000	P1	3750	62	898	
1,332	700	P2	2,237	23	196	
1,135	700	P3	1,946	25	186	
1,210	600	P4	1,407	23	125	
3,160	350	P5	492	77	147	
648	350	P6	279	15	16	
1,000	100	P7	18	57	16	
1,750	400	P8	763	34	100	Waste Stabilization Ponds at Shimo la Tewa, Ultimate Capacity 9,900 m^3/day Area Required 25Ha
1,194	400	P9	370	18	25	
-	-	P10	192	5	3	
-	-	P11	98	5	2	
825	100	P12	32	41	5	
2,020	100	P13	38	30	5	
668	100	P14	38	37	6	
365	100	P15	38	35	5	
1,112	150	P16	54	23	5	
555	100	P17	41	30	5	

A detailed Layout Plan for Alternative Scheme 1 for Mombasa Island and North Mainland are given in **Figure 7.3** on **Page 7-7 and Figure 7-4 and** on **Page 7-8** respectively**.**



	Qdwf(m³/hr)	Qp(m³/hr)	Hp	P
EP1	68.4	136.8	9.9	5.6
EP2	27.4	54.8	8.3	3.7
EP3	108	216	17.8	12.7
EP4	27.4	54.8	16.8	7.5

Figure 7.3: Alternative Scheme 1 - Mombasa Island

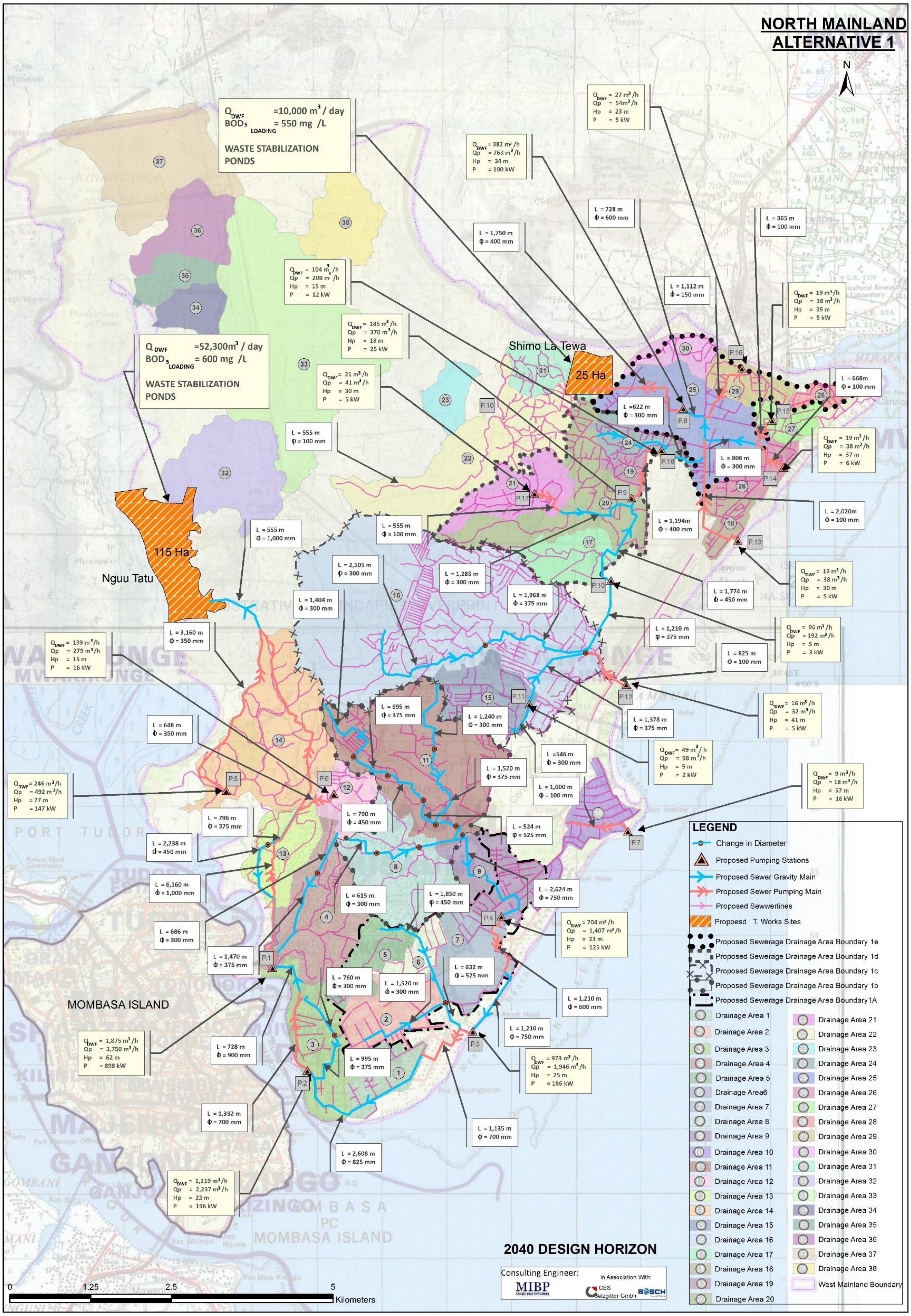


Figure 7.4: Alternative Scheme 1 – Mombasa North Mainland

ii) Alternative 2: Centralized Waste Water Treatment Plant in Mombasa North Mainland

This Alternative Scheme involves conveying wastewater generated within Mombasa Island and North Mainland to a centralized Waste Water Treatment Plant (ultimate design capacity - 87,300 m^3/day) on reclaimed land at Nguu Tatu. This site has been selected after an evaluation based on a check-list of pertinent considerations of physical, environmental and economic factors including the ease with which wastewater can be conveyed by minimal pumping to the site, land availability at the reclamation site, its safe distance from the built-up areas and proximity to a water body for discharge of effluent.

Due to the nature of topography of Mombasa Island and North Mainland, the wastewater will be conveyed to the proposed centralized Wastewater Treatment Plant via series of gravity and pumped sewers. The 29 Nr. Pumping Stations have been positioned at strategic locations to ensure least pumping heads and shortest rising mains, while serving the entire drainage area.

A full conventional Wastewater Treatment Plant, comprising of Trickling Filters and Maturation Ponds has been adopted considering availability of land, costs of land acquisition, capital costs and low operation and maintenance requirements.

The main components of the Wastewater Treatment Plant are as follows:

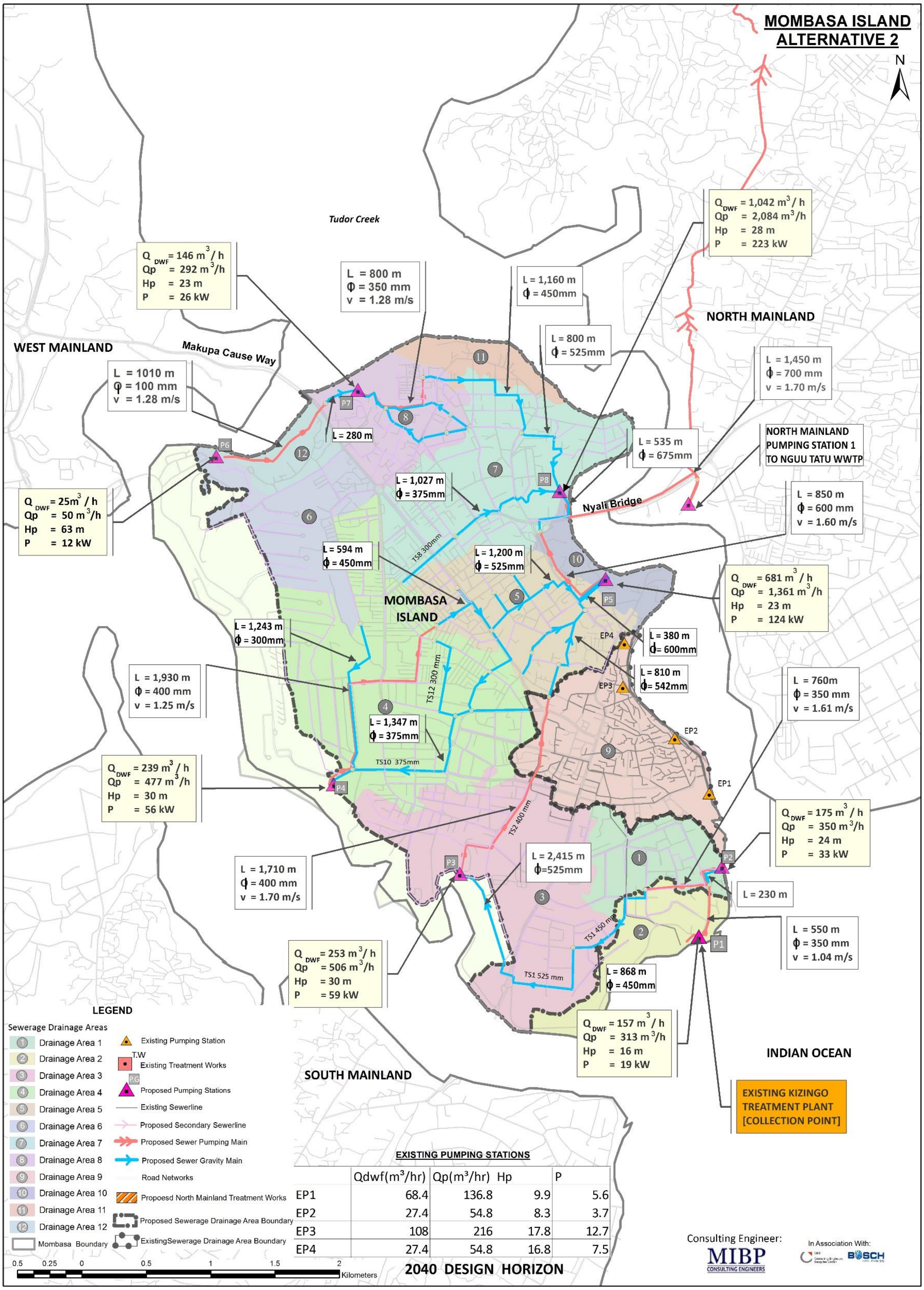
- Inlet Works
- Anaerobic Ponds, Trickling Filters/ Biofilters and Maturation Ponds
- Sludge Drying Beds
- Staff Houses and Administration Buildings
- Site and Ancillary Works

A summary of the Sewerage Pumping Components and Treatment Technology in **Alternative 2** is given in **Table 7.4** on **Page 7-10** below.

Table 7.4: Alternative Scheme 2 - Pumping components and Treatment Technology

Rising mains		Pumping Stations				Wastewater Treatment Plants
Length (m)	**Dia. (mm)**	**Pumping Station Ref.**	**Design flow (m^3/h)**	**Pumping Head (m)**	**Power (kW)**	**WWTP**
MOMBASA ISLAND						Waste Stabilization Ponds at Nguu Tatu, Capacity 87,300m^3/d Area Required 175Ha
550	350	P1	313	16	19	
760	350	P2	350	24	33	
1,710	400	P3	506	30	59	
1,930	400	P4	477	30	56	
850	600	P5	1,361	23	124	
1,010	100	P6	50	63	12	
800	350	P7	292	23	26	
1,450	700	P8	2,084	28	223	
113	150	Existing P1	137	10	6	
200	150	Existing P2	55	4	8	
511	200	Existing P3	216	13	18	
150	150	Existing P4	55	8	17	
MOMBASA NORTH MAINLAND						
6,160	1000	P1	3750	62	898	
1,332	700	P2	2,237	23	196	
1,135	700	P3	1,946	25	186	
1,210	600	P4	1,407	23	125	
3,160	350	P5	492	77	147	
648	350	P6	279	15	16	
1,000	100	P7	18	57	16	
1,750	400	P8	763	34	100	
1,194	400	P9	370	18	25	
-	-	P10	192	5	3	
-	-	P11	98	5	2	
825	100	P12	32	41	5	
2,020	100	P13	38	30	5	
668	100	P14	38	37	6	
365	100	P15	38	35	5	
1,112	150	P16	54	23	5	
555	100	P17	41	30	5	

A detailed Layout Plan for Alternative Scheme 1 for Mombasa Island and North Mainland are given in **Figure 7.5** on **Page 7-11 and Figure 7-6 and** on **Page 7-12** respectively**.**



	Qdwf(m³/hr)	Qp(m³/hr)	Hp	P
EP1	68.4	136.8	9.9	5.6
EP2	27.4	54.8	8.3	3.7
EP3	108	216	17.8	12.7
EP4	27.4	54.8	16.8	7.5

Figure 7.5: Alternative Scheme 2 – Mombasa Island

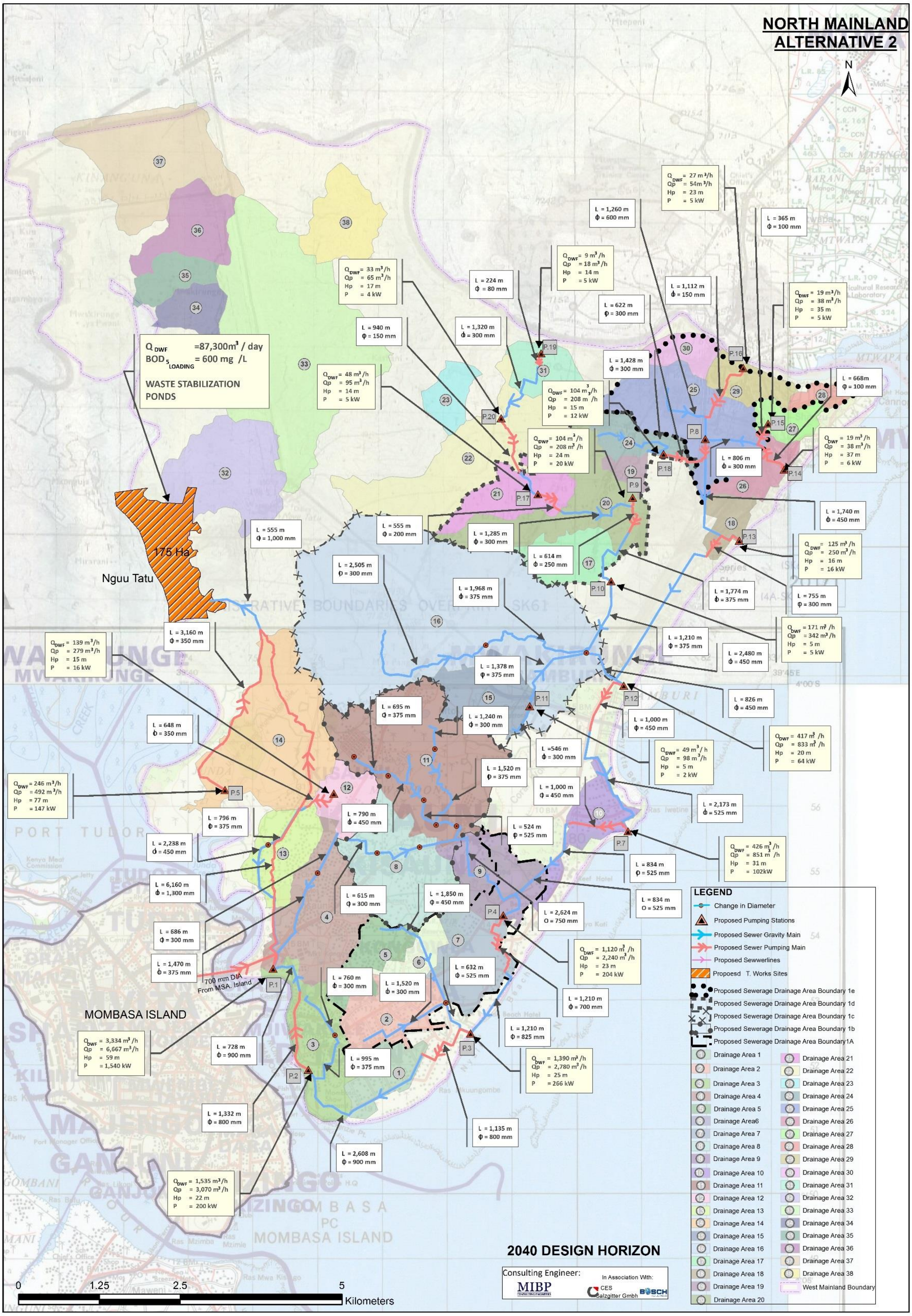


Figure 7.6: Alternative Scheme 2 – Mombasa North Mainland

iii) Alternative 3: 2Nr Decentralized Waste Water Treatment Plants in Mombasa North Mainland

This alternative involves a decentralized wastewater management scheme to reduce conveyance distances. Two Wastewater Treatment Plants are proposed, one on reclaimed land at Nguu Tatu which will treat wastewater generated within Mombasa Island and the southern part of North Mainland (ultimate design capacity - 77,300 m³/day) and acquired land at Shimo la Tewa prison for wastewater generated in the northern section of Mombasa North Mainland (ultimate design capacity - 9,9000 m³/day).

These sites have been selected after an evaluation based on a check-list of pertinent considerations of physical, environmental and economic factors including the ease with which wastewater can be conveyed by minimal pumping to the site, land availability, safe distance from the built-up areas and proximity to a water body for discharge of effluent.

Due to the nature of topography of Mombasa Island and North Mainland, the wastewater will be conveyed to the proposed centralized Wastewater Treatment Plant via series of gravity and pumped sewers. The 29 Nr. Pumping Stations have been positioned at strategic locations to ensure least pumping heads and shortest rising mains, while serving the entire drainage area.

A full conventional Wastewater Treatment Plant, comprising of Waste Stabilization Ponds has been adopted considering availability of land, costs of land acquisition, capital costs and low operation and maintenance requirements.

The main components of the Wastewater Treatment Plant include:

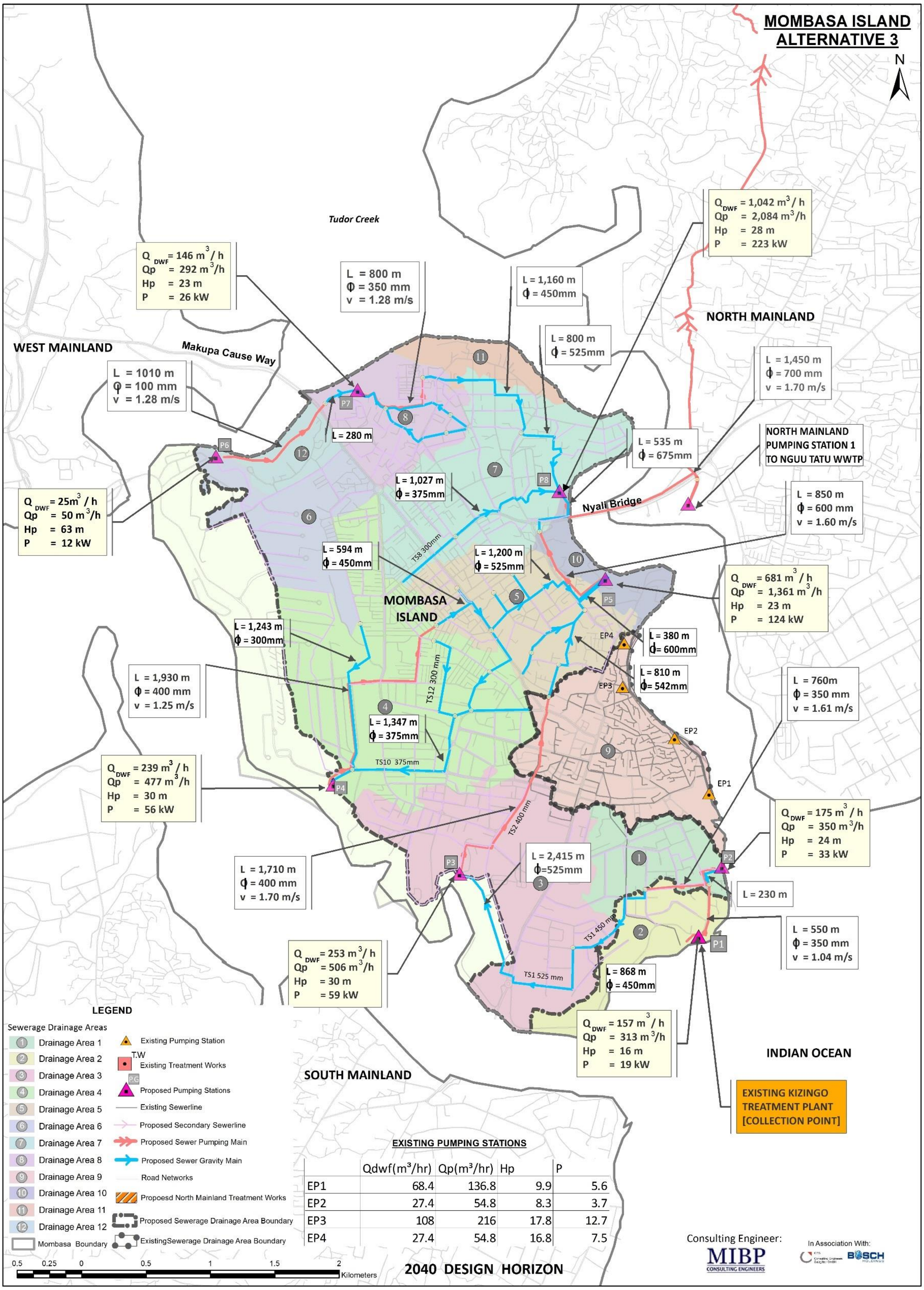
- Inlet Works
- Waste Stabilization Ponds - Anaerobic, Facultative and Maturation Ponds
- Sludge Drying Beds
- Staff Houses and Administration Buildings
- Site and Ancillary Works

A summary of the Sewerage Pumping Components and Treatment Technology in **Alternative 3** is given in **Table 7.5** on **Page 7-14** below.

Table 7.5: Alternative Scheme 3 - Pumping components and Treatment Technology

Rising mains		Pumping Stations				Wastewater Treatment Plants
Length (m)	Dia. (mm)	Pumping Station Ref.	Design flow (m^3/h)	Pumping Head (m)	Power (kW)	WWTP
MOMBASA ISLAND						Waste Stabilization Ponds at Nguu Tatu, Ultimate Capacity 77,300 m^3/day Area Required 160Ha
550	350	P1	313	16	19	
760	350	P2	350	24	33	
1,710	400	P3	506	30	59	
1,930	400	P4	477	30	56	
850	600	P5	1,361	23	124	
1,010	100	P6	50	63	12	
800	350	P7	292	23	26	
1,450	700	P8	2,084	28	223	
113	150	Existing P1	137	10	6	
200	150	Existing P2	55	4	8	
511	200	Existing P3	216	13	18	
150	150	Existing P4	55	8	17	
MOMBASA NORTH MAINLAND						
6,160	1,200	P1	5,833	64	1,380	
1,332	700	P2	2,237	23	196	
1,135	700	P3	1,946	25	186	
1,210	600	P4	1,407	23	125	
3,160	350	P5	492	77	147	
648	350	P6	279	15	16	
1,000	100	P7	18	57	16	
1,750	400	P8	763	34	100	Waste Stabilization Ponds at Shimo la Tewa, Ultimate Capacity 9,900 m^3/day Area Required 25Ha
1,194	400	P9	370	18	25	
-	-	P10	192	5	3	
-	-	P11	98	5	2	
825	100	P12	32	41	5	
2,020	100	P13	38	30	5	
668	100	P14	38	37	6	
365	100	P15	38	35	5	
1,112	150	P16	54	23	5	
555	100	P17	41	30	5	

A detailed Layout Plan for Alternative Scheme 3 for Mombasa Island and North Mainland are given in **Figure 7.7** on **Page 7-15 and Figure 7-8 and** on **Page 7-16** respectively**.**



EXISTING PUMPING STATIONS

	Qdwf(m³/hr)	Qp(m³/hr)	Hp	P
EP1	68.4	136.8	9.9	5.6
EP2	27.4	54.8	8.3	3.7
EP3	108	216	17.8	12.7
EP4	27.4	54.8	16.8	7.5

Figure 7.7: Alternative Scheme 3 – Mombasa Island

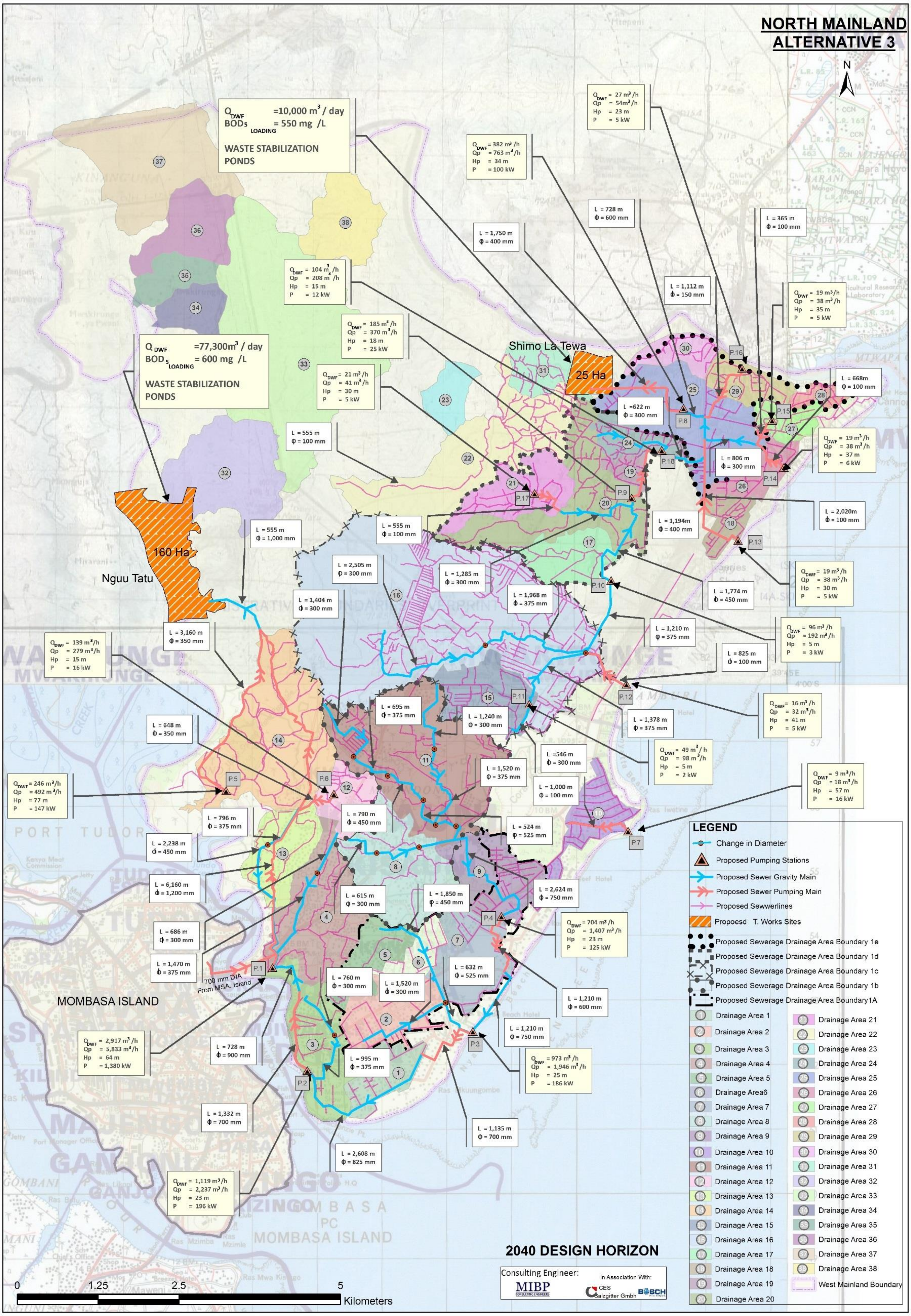


Figure 7.8: Alternative Scheme 3 – Mombasa North Mainland

7.4 Summary of Alternative Wastewater Management Schemes

A summary of the three proposed Alternative Wastewater Management Schemes for Mombasa Island and North Mainland is given in **Table 7.6** below.

Table 7.6: Summary of Alternative Wastewater Management Schemes

Alternative Scheme	Conveyance System		Wastewater Treatment Plants			
	Secondary and Trunk Sewers (km)	No. of Pumping Stations	Location	Design Capacity (m^3/day)	Treatment Technology	Land Required (Ha)
1	Mombasa Island 90 Km	Mombasa Island 12	Existing Kizingo	25,000	Long Sea Outfall	1.0
	North Mainland 250 Km	North Mainland 17	Nguu Tatu	52,300	Waste Stabilization Ponds	115
			Shimo la Tewa	9,900		25
2	Mombasa Island 90 Km North Mainland 250 Km	Mombasa Island 12 North Mainland 17	Nguu Tatu	87,300	Trickling Filters and Maturation Ponds	125
3	Mombasa Island 90 Km North Mainland 250 Km	Mombasa Island 12 North Mainland 17	Nguu Tatu	77,300	Waste Stabilization Ponds	160
			Shimo la Tewa	9,900		25

The locations of the Candidate Wastewater Treatment Sites considered in the considered Alternative Schemes are shown in **Figure 7.9** on **Page 7-18.**

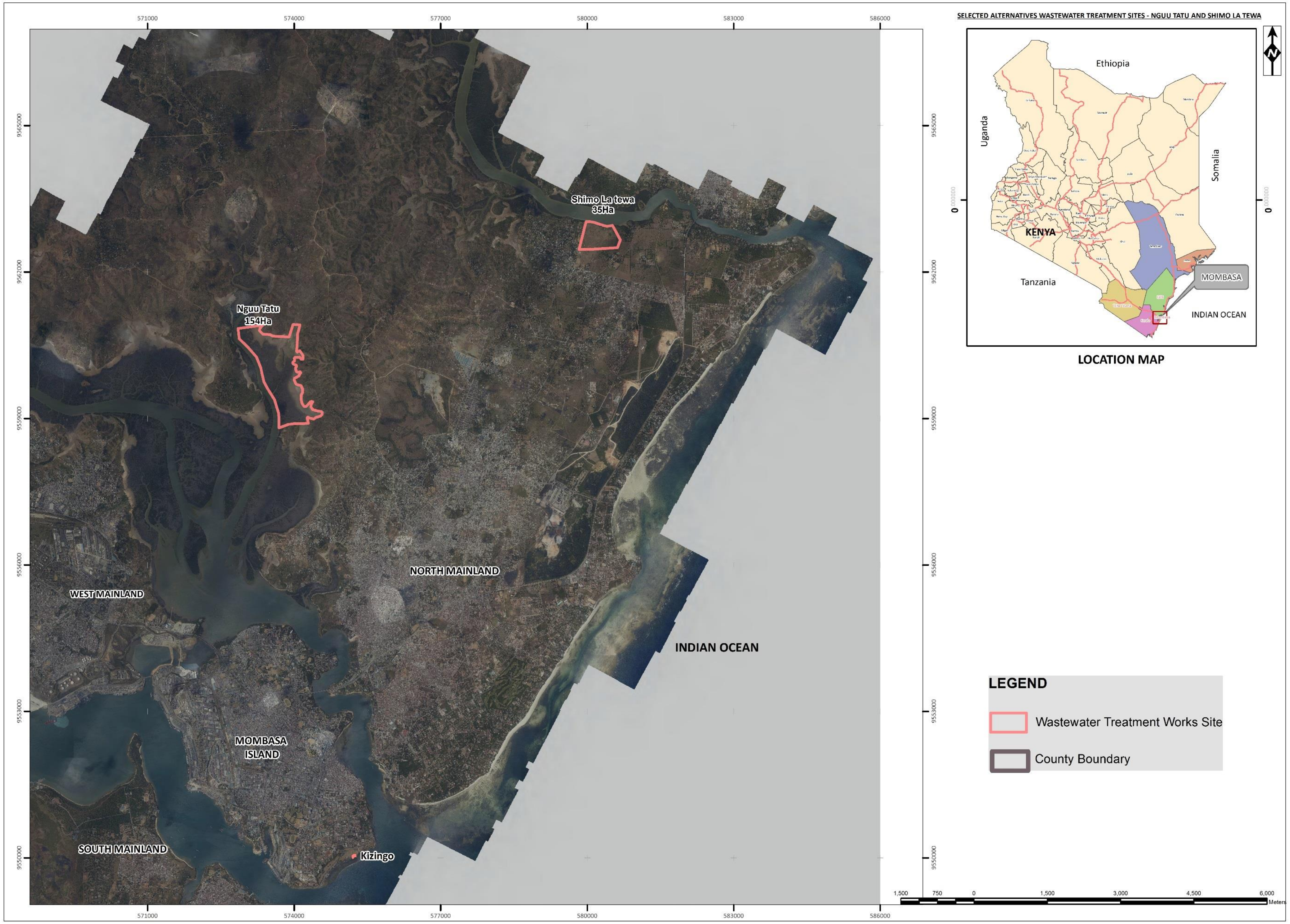


Figure 7.9: Locations of Candidate Sites for Wastewater Treatment Plant Sites

8.0 PROJECT COSTS OF THE ALTERNATIVE WASTEWATER MANAGEMENT SCHEMES

8.1 Introduction

This Chapter describes the Project Costs of the Alternative Wastewater Management Schemes formulated to serve the sanitation needs of Mombasa Island and North Mainland up to year 2040, including the methodology used to derive them.

The unit costs are based on recent contracts of similar nature in Kenya (2016), supplemented by quotations from various manufacturers and suppliers. All the unit costs are inclusive of relevant duties and taxes but not Preliminary and General Items, Contingencies and Consultancy Fees.

The accuracy of cost estimates is generally plus or minus 20%; which falls within the criteria for estimated costs based on Preliminary Design. However, larger variations are expected for individual works or items, or in places where average costs are used.

8.2 Unit Costs for Capital Investments

8.2.1 Basis of Cost Estimates

Capital costs represent the total expenditures incurred in the implementation of the infrastructural components of a Project. It includes the cost of land acquisition, construction and installation, construction contingencies, engineering services, legal and administrative services and financing expenses.

The unit costs of the construction and installation components have been determined from the market prices of the various material, labour costs, transport and Contractor's overhead and profit. The market prices of the materials have been obtained from various suppliers while labour rates have been obtained from the Joint Building Council of Kenya. All the rates derived have been compared with tender prices for other similar contracts implemented in the recent past. In general, the labour costs have been limited at 20% of the material costs while the Contractor's overhead and profit have been assumed to be 20% of the total costs (i.e. cost of material + labour cost).

In this Master Plan, it has been assumed that construction of sewers and the Wastewater Treatment Plant in an implementation phase will be included under a single contract for the benefits which result from the resulting economy of scale; this is more significant on items such as management and site supervision costs.

8.2.2 Land Acquisition

The cost of land at various locations within Mombasa Island and North Mainland depends on the proximity to services and market forces. The average costs of land adopted for the Wastewater Master Plan is **Kshs. 40,000,000** and **Kshs. 9,000,000** per Hectare for land acquisition and land reclamation respectively after comparison and assessment of the information of cost of land within the Town collected from the registered Land Valuers and recent land buyers**.**

As earlier described, the proposed sewer routes have been aligned with the public roads, easements or right-of-way and river wayleaves in some sections. Therefore, land acquisition will only apply in the few instances where sewer alignment goes beyond the easements into private lands.

In cases where encroachment of structures will be identified on the proposed sewer alignment within the public easements, demolishing of structures for passage of sewers shall be carried out without need for compensation or land acquisition.

8.2.3 Construction Cost

This cost includes cost of materials, equipment, labour and services necessary to construct the Sewerage System (Sewers, Manholes, Pumping Stations) and Wastewater Treatment Plant(s). It covers taxes and duties, and contractor's overhead and profit.

The unit costs for installation of new sewer lines comprises of the following components:

- Site Clearance and Excavation
- Supply of all materials to site
- Pipe lay, joint with rubber rings, granular bedding, test and backfill of trench for flexible-jointed Concrete Pipes
- Pipe lay, joint with rubber rings, granular bedding, test and backfill trench for Steel pipes
- Construction of manholes on the sewer lines
- Contractor's overheads and profits

Table 8.1 below shows the unit cost for different sizes of flexible jointed sewer lines, manholes and steel pipelines including taxes, duties and contractor's overheads and profit.

Table 8.1: Unit Costs for Sewer Lines and Manholes

	Item Description	Unit	Unit rate (Kshs)
A	***Flexible jointed precast concrete pipes excluding excavation***		
	-225mm dia. S&S	m	1,800
	-300mm dia. S&S	m	2,040
	- 375mm dia. S&S	m	2800
	- 450mm dia. S&S	m	4,900
	- 525mm dia. S&S	m	5800
	- 600mm dia. S&S	m	7,200
	- 750mm dia. S&S	m	10,500
B	***Steel Pipe – NP 10***		
	- 100mm nominal dia.	m	2,911
	- 150mm nominal dia.	m	4,426
	- 200mm nominal dia.	m	5,593
	- 250mm nominal dia.	m	9,966
	- 300mm nominal dia.	m	12,716
	- 350mm nominal dia.	m	14,090
	- 400mm nominal dia.	m	17,186
	- 450mm nominal dia.	m	18,552
	- 500mm nominal dia.	m	20,707
	- 600mm nominal dia.	m	26,456
	- 700mm nominal dia.	m	33,124
	- 800mm nominal dia.	m	41,104
	- 900mm nominal dia.	m	50,094
	- 1000mm nominal dia.	m	61,176
C	***Manholes - 1200mm dia. Precast rings with triangular heavy duty concrete filled mild steel covers***		
	- Depth n.e. 1.0m	Nr	104,000
	- Depth n.e. 2.0m	Nr	118,000
	- Depth n.e. 3.0m	Nr	148,000
	- Depth n.e. 4.0m	Nr	173,000
	- Depth n.e. 5.0m	Nr	198,000
	- Depth n.e. 6.0m	Nr	224,000

Since the depth of excavation for sewer lines varies considerably, depending on several factors like ground slopes, flow, velocity, etc., the cost of excavation has not been built in the above unit rates.

To consider the variation of trench excavation for different depths, the cost of excavation has been taken separately as shown in **Table 8.2** below. Cost for extra-over excavation in soft and hard rock has also been given.

Table 8.2: Unit Cost for Trench Excavations for Sewer Lines

Pipe Diameter (mm)	*Unit Rate (Kshs)*					
	Depth Not Exceeding					
	1.0m	*2.0m*	*3.0m*	*4.0m*	*5.0m*	*6.0m*
225	243	365	609	937	1205	1473
300	278	417	696	1071	1377	1683
375	313	469	782	1205	1549	1894
450	348	522	869	1339	1721	2104
525	383	574	956	1473	1894	2314
600	417	626	1043	1607	2066	2525
675	452	678	1130	1741	2238	2735
750	487	730	1217	1874	2410	2946
825	522	782	1304	2008	2582	3156
900	556	835	1391	2142	2754	3366

Hard rock – Kshs. 3,200/= per cubic metre
Soft rock – Kshs. 1,800/= per cubic metre

Figure 8.1 below shows variations of unit costs for sewer trench excavation for various diameters of sewers.

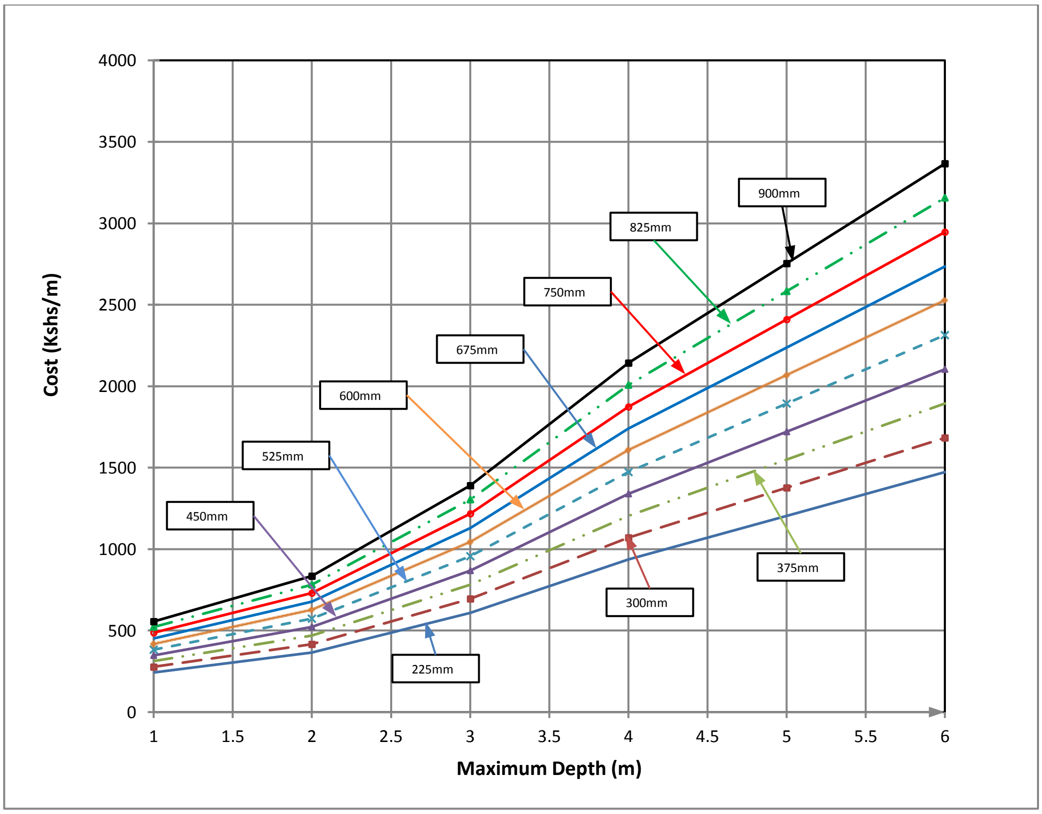


Figure 8.1: Unit cost for sewer excavation with Depth

Unit costs considered in the development of rate for Manholes or for any Pumping Station forming part of the Sewer Network are given in **Tables 8.3** to **8.9** below.

Table 8.3: Unit Cost for Earthworks

Item Description	Unit	Rate (Kshs)
Mass Excavation		
1) Excavate to spoil	m^3	297
2) Excavate and fill	m^3	320
3) Excavate in soft rock (E.O)	m^3	1800
4) excavate in hard rock (E.O)	m^3	3200
5) Imported fill	m^3	450

Table 8.4: Unit Cost for Concrete and Mortar

Design Mix	Unit	Rate (Kshs)
1. Grade 25 (1:1.5:3)	m^3	19,965
2. Grade 20 (1:2:4)	m^3	15,255
3. Grade 15 (1:3:6)	m^3	13,965
4. Blinding, 75mm	m^2	1,050

Table 8.5: Unit Cost for Formwork

Item	Unit	Rate (Kshs)
1. Wrought Formwork	m^2	1,750
2. Rough Formwork	m^2	1,200

Table 8.6: Unit Cost for Steel Reinforcement

Item	Unit	Rate (Kshs)
1. Mild Steel 12mm dia. and less	kg	125
2. Mild Steel 16mm dia. and less	kg	125
3. High Tensile Steel 12mm dia. and less	kg	125
4. High Tensile Steel 16mm dia. and over	kg	125
5. B.R.C Type A142 (2.22 kg/m^2)	m^2	750

Table 8.7: Unit Cost for Masonry and Block Walling

Item	Unit	Rate (Kshs)
Block Walling (Metric)		
90mm Blocks	m^2	1,940
140mm Blocks	m^2	2,400
190mm Blocks	m^2	2,800
240mm Blocks	m^2	3,200

Table 8.8: Unit Cost for Miscellaneous

Item	Unit	Rate (Kshs)
1. Staff Houses (High Grade)	m^2	28,000
2. Staff Houses (Medium Grade)	m^2	24,000
3. Staff Houses (Low Grade)	m^2	22,000
4. Main Electricity Supply Line	km	1,600,000
5. Chain link fencing on Concrete Poles (1.8m high)	m	3,250
6. Metal Gate (4.0m wide)	Nr	92,000
7. Access Road including side drain and footpath (5.5m wide bitumen standard, kerns, channels, etc.)	km	60,000,000
8. -Ditto- (double seal)	km	45,000,000

Table 8.9: Unit Cost for Electro-Mechanical Works

Treatment Technology	Cost of Electro-Mechanical Works as a % of Total Construction Cost
1. Waste Stabilization Ponds	5
2. Biofilters / Trickling Filters	20
3. Activated Sludge	35
4. Long Sea Outfalls	10
5. Activated Sludge	30

8.2.3.1 Pumping Stations

Pumping stations comprise of the three main components of urban schemes; (a) Civil Works (b) Electrical Works (c) Mechanical Components i.e. pumps, valves, etc.

The size of the pumping station depends on the designed flows and head and the type and specification of the pumps and motors to be installed.

For preliminary cost estimates, the unit cost of pumping stations has been based on contractor's rates of recent projects. Where possible, quotations obtained from renown suppliers have been used.

8.3 Unit Costs for Operation and Maintenance

8.3.1 General

The cost of Operation and Maintenance (O&M) of each viable alternative scheme is a very important factor in the selection of the recommended alternative. The component of the Operation and Maintenance costs includes:

1. Equipment maintenance and repairs e.g., pumps, motors, etc.
2. Power / Electricity charges,
3. Staff wages and salaries,
4. Cost of Chemicals.

8.3.2 Equipment Maintenance and Repairs

The cost of equipment maintenance and repairs can be estimated as a percentage of the initial capital costs. In the development of this Wastewater Master Plan, it is assumed that annual maintenance cost is 1% of the capital cost for Civil Works components and 5% of the capital cost for the Electro-mechanical Works components.

8.3.3 Power Charges

The cost of power consumed has been calculated using unit cost rate of Kshs. 18 per kilo watt-hour (kWh).

8.3.4 Chemical Costs

Where applicable, the cost of chemicals such as chlorine to be used at the Wastewater Treatment Plant has been calculated as a percentage of the overall operation and maintenance cost.

8.4 Capital and Operations & Maintenance Costs of the Alternative Schemes

8.4.1 Capital Costs

The Capital Costs of the three Alternative Schemes formulated for Mombasa Island and North Mainland have been worked out on the following basis;

a) Project Implementation planned to be carried out in two phases i.e. Medium-Term Plan (2020 -2025) and Long-Term Plan (2026 - 2040)

b) The Cost of Civil Works constitute the following fraction of the components total costs;
   - Wastewater Treatment Plant – 95%
   - Pumping Station – 60%
   - Sewers – 100%

A summary of the Capital Costs of the Alternative Schemes is given in **Table 8.10** below;

Table 8.10: Capital Costs of the Alternative Schemes

S/No.	Component	Alternative 1	Alternative 2	Alternative 3
1	**Land Acquisition (Kshs)**	**2,195,000,000**	**1,754,200,000**	**2,600,000,000**
2	**Civil Works (Kshs)**	**16,566,670,616**	**16,896,877,390**	**14,807,881,043**
2.1	Wastewater Treatment Plant (Kshs)	10,720,670,199	9,391,823,503	8,776,677,125
2.2	Pumping Stations (Kshs)	319,382,761	731,077,033	693,066,147
2.3	Sewers (Kshs)	5,526,617,656	6,773,976,854	5,338,137,771
3	**Electro-Mechanical Works (Kshs)**	**777,167,641**	**981,691,189**	**923,974,473**
3.1	Wastewater Treatment Plant (Kshs)	564,245,800	494,306,500	461,930,375
3.2	Pumping Stations (Kshs)	212,921,841	487,384,689	462,044,098
	Total Capital Cost (Kshs)	**19,538,838,257**	**19,632,768,578**	**18,331,855,516**
	Total Capital Cost (USD) [1]	**189,697,459**	**190,609,404**	**177,979,180**

8.4.2 Operations and Maintenance Costs

The Operations and Maintenance Costs of the three Alternative Schemes formulated have been worked out on the following basis;

a) Electricity Costs at the Pumping Stations has been assumed to increase annually at 3.0% p.a. (same as population) due to increased sewage flow from the increased connections

b) Annual Maintenance Costs of the Schemes have been calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works

c) Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule

A summary of the Annual Operations & Maintenance Costs of the Alternative Schemes in the first year of operation is given in **Table 8.11** below;

Table 8.11: Annual Operations & Maintenance Costs of the Alternative Schemes (Year 1)

S/No.	Component	Alternative 1	Alternative 2	Alternative 3
1	Maintenance Costs (Kshs)	204,525,088.20	218,053,333	185,437,155
2	Electricity Costs (Kshs)	184,451,892.78	139,511,141	120,784,521
3	Staff Costs (Kshs)	8,642,400	6,648,000	8,286,793
	Total O&M Cost (Kshs)	**397,619,381**	**364,212,475**	**314,508,469**
	Total O&M Cost (USD) [1]	**3,860,382**	**3,536,043**	**3,053,480**

[1] – Exchange Rate: 1 USD = 103 Kshs

8.5 Average Incremental costs of the Alternative Schemes

Net Present Value (NPV) is a one of the commonly used criteria for comparing economic viability of projects / Schemes. When the unit NPV of a scheme is derived for the unit of performance indicator, incremental cost (marginal cost) is obtained.

The Net Present Values of the Alternative Schemes have been worked out on the following basis;

- Discount Rate / Cost of Capital - 5%
- Economic Life of Scheme - 30 years
- 10 Years Asset Renewal Period for the Electro-Mechanical components
- Substantial completion of the scheme expected at the end of the 2nd year of Implementation of the Medium-Term Plan Works (2022) and thus, scheme operation to commence in the 3rd year (2023)

From the respective NPVs, Average Incremental Costs have been calculated in consideration of the following factors;

- Treated Wastewater to increase from 26,500 m^3/d in year 2025 to 87,300 m^3/d in year 2040
- BOD removal as the key performance indicator (kg/year)
- Average Influent BOD_5 of 500 mg/l and Effluent BOD_5 of 30 mg/l; thus, BOD_5 removal of 470 mg/l

Average Incremental Cost of BOD removal within the economic life of the Infrastructure is an alternative measure of economic viability.

The Net Present Values and the Average Increment Costs of BOD removal of the Alternative Schemes are given in **Table 8.12** below;

Table 8.12: Net Present Values and Average Incremental Cost of BOD Removal

Alternative Scheme	NPV (USD)	Average Incremental Cost of BOD Removal (USD / ton of BOD removed)
Alt Scheme 1	259,893,867	1,382
Alt Scheme 2	256,540,414	1,364
Alt Scheme 3	236,003,724	1,255

8.6 Sensitivity Analysis

To ascertain the susceptibility of the ranking of the Alternative Schemes based on the Net Present Values, sensitivity analyses of the Schemes has been carried out by varying the Capital Expenditures (CAPEX) and Operation Expenditures (OPEX).

A summary of the Sensitivity Analysis is given in **Table 8.13** below;

Table 8.13: Summary of Sensitivity Analysis of the Alternative Schemes

Alternative Scheme	NPV (USD)				
	No Variation in CAPEX & OPEX	Change in CAPEX (Capital Expenditures)		Change in OPEX (Operations Expenditures)	
		-20%	+20%	-20%	+20%
Alt Scheme 1	259,893,867	219,855,327	299,932,408	245,904,439	273,986,484
Alt Scheme 2	256,540,414	214,449,234	298,631,593	244,220,958	268,859,869
Alt Scheme 3	236,003,724	198,957,796	273,049,652	225,362,260	246,645,188

9.0 MULTI-CRITERIA ANALYSIS AND REVIEW OF DEVELOPMENT STRATEGIES

9.1 Introduction to the Adopted Criteria

Selection of an appropriate Wastewater Treatment Train and Wastewater Management Scheme is an important stage in the design of Wastewater Collection and Treatment System. Multi Criteria Decision Making (MCDM) techniques are generally enabled to structure the problem clearly and systematically for the decision makers' to easily examine and scale the problem in accordance with the priorities identified.

This chapter presents an application of the Analytical Hierarchy Process (AHP) for the selection of the most suitable Wastewater Treatment Train and Wastewater Management Scheme for the prevailing conditions in Mombasa Island and North Mainland.

The Analytical Hierarchy Process (AHP), has been adopted to perform the Multi Criteria Analysis because it permits objective focused discussion of the stakeholders' concerns. AHP is a system analysis technique introduced by Professor T.L.A. Saaty of the University of Pittsburgh, Pennsylvania, U.S.A.

9.1.1 Methodology of Analytical Hierarchy Process (AHP)

Traditionally the selection of the optimum treatment train or scheme from a number of alternatives is carried out by comparing objectively economical and technical parameters such as Capital Costs, Net Present Values, Dynamic Costs and Technical Considerations of the treatment train /schemes.

To carry out multi-criteria analysis in the development of Wastewater Master Plan for Mombasa Island and North Mainland, the economic, technical and environmental parameters of interest have been categorized for ease of comparison. These categories include Ease of Operation and Maintenance, Net Present Value, Environmental Impacts, Land Requirement and Institutional Strength.

AHP is a mathematical process which acts as a tool to simplify the various complex issues through a pairwise comparison of parameters and provides a rationale for ranking parameters thus prompting consensus on the selected alternative. The mathematical process is based on deriving weights for a set of parameters per importance.

A summary of the major steps in carrying out Multi Criteria Analysis by AHP Model is given below.

Step 1
A parameter matrix 'B' is constructed by the pairwise comparison of the relative importance of the parameter with respect to the principle objective of selecting the optimum alternative Wastewater Treatment Train.

The scale for the pairwise comparisons is given in **Table 9.1** on **Page 9-2**.

Step 2
A n x n decision matrix is constructed for each of the parameters. In the construction of each of the decision variable matrices, pairwise comparisons are carried out between the decision variables with respect to the parameter under consideration.

Table 9.1: Scale for Pairwise Comparison

Intensity of Relative Importance	Definitions	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement slightly favour one activity over the other
5	Essential or strong importance	Experience and judgement strongly favoured one activity over another
7	Demonstrated importance	An activity strongly favoured and its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed
Reciprocals of above non-zero numbers	If any activity has one of the above numbers (e.g. 3) compared with a second activity, the second activity has the reciprocal value (i.e. 1/3) when compared to the first	

Step 3

The priority vectors x_1, x_2, ...x_4 for the decision variable matrices are calculated. The priority vectors are taken as the column to form a composite matrix 'C' such that

$$C = (x_1\ x_2 \ldots \ldots x_4)$$

The composite priority vector x_c is obtained by multiplying the composite matrix C by the priority vector x_b of the parameter matrix i.e $x_c = c * x_b$.

From x_c, the relative weights of the decision variables i.e. Alternative Wastewater Treatment Train is obtained. The optimum alternative is the one with the highest weight.

9.2 Wastewater Treatment Train Selection

9.2.1 Objective Description

The principal objective of this study is to select the 'most suitable wastewater treatment train for Mombasa Island and North Mainland'. This is the core consideration in the formulation of the parameters used in AHP.

9.2.2 Parameters

To meet the principal objective, several parameters (subordinate objectives) have been formulated which must be fulfilled. These parameters are identified in the subsequent subsections with their influence on the Treatment Train selection and their characteristics briefly discussed.

9.2.2.1 Simplicity of Operations and Maintenance

This parameter defines the relationship between the level of operation and maintenance skills required and the capability of the local labour pool and service industry.

This factor is very important in consideration of the constraints in the availability of trained manpower, availability of spare parts and the need to prioritise the use of limited financial resources.

Decision variables that can be sustained with the use of affordable and locally available skills have been given higher weights.

9.2.2.2 Net Present Value (NPV)

This is an indicative parameter of the total monetary outlay required by a treatment train. It incorporates the Capital Costs and Operations & Maintenance Costs of the Project. A 20 year period has been used in the determination of NPV.

Using the scale for pairwise comparison of decision variables the treatment train with the lowest NPV is assigned the highest weight.

9.2.2.3 Environmental Impact

In the selection of the most suitable treatment train, it is important to analyse the effect on the environment. The degree of odour and noise from the treatment train should not exceed the nuisance threshold. This is achieved by such means including provision of a buffer zone planted with trees.

Lower weight is assigned to the treatment trains with greater negative impact.

9.2.2.4 Land Requirement

The Land requirement for the treatment train should include allowance for provision of future expansions works has been put into consideration under this parameter. Land requirement should also include a buffer zone between the location of the treatment train and adjacent lands.

A wastewater treatment train with the less land requirement have been given higher weight using the subjective scale of weighting.

9.2.2.5 Institutional Strength

The capacity of the utility provider such as manpower, requisite skill of staff, operation & maintenance equipment etc. should correspond to the treatment train adopted for efficient daily running of the treatment facility.

Alternatives which require a lower degree of management effort are weighted higher.

9.2.3 Alternative Wastewater Treatment Trains

Alternatives treatment trains considered in the AHP are listed below:

- Alternative 1 - Waste Stabilization Ponds
- Alternative 2 - Composite Biofilters (Trickling Filters) System (Anaerobic Ponds + Trickling Filters + Maturation Ponds)
- Alternative 3 - Composite Oxidation Ditch System (Oxidation Ditch + Maturation Ponds)
- Alternative 4 - Long Sea Outfall

9.2.4 Hierarchy Decision Model

The model of AHP developed in the Multi-Criteria Analysis is shown in **Figure 9.1** below.

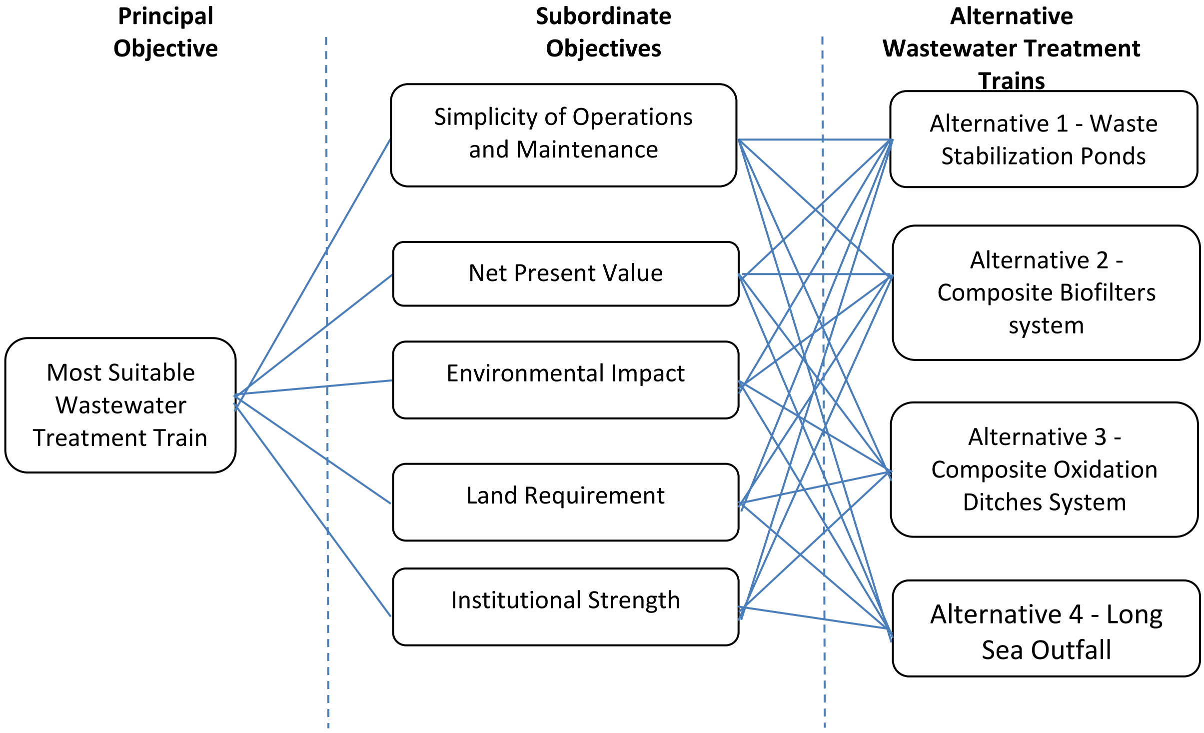


Figure 9.1: Hierarchy Decision Model used in the AHP

9.2.5 Parameter Matrix and Weighting

In accordance with the methodology, a pairwise comparison has been made on the parameters by addressing the question; "Which parameter /subordinate objective contribute more to the principal objective?"

The subordinate objectives which by cognizance pose greater importance have been assigned higher scales in the Intensity of Relative Importance.

A summary of the resulting matrix of the Parameters is given in **Table 9.2** below.

Table 9.2: Resultant Matrix of Parameters' Pairwise Comparison

	Simplicity of operation and Maintenance	*Net Present Value*	*Environmental Impacts*	*Land Requirement*	*Institutional Strength*
Simplicity of Operation and Maintenance	1	1	1/3	4	3
Net Present Value	1	1	1/3	4	2
Environmental Impacts	3	3	1	7	2
Land Requirement	1/4	1/4	1/7	1	1/5
Institutional Strength	1/3	1/2	1/2	5	1

To illustrate the interpretation of the scales of Intensity of Relative Importance, the weights of Simplicity of Operation and Maintenance against other parameters have been analyzed and summarized in **Table 9.3** below.

Table 9.3: Analysis of Simplicity of Operation & Maintenance Weights against other Parameters

Pairwise Comparison	Weighting	Explanation
Simplicity of Operation and Maintenance against NPV	1	Equal Importance
Simplicity of Operation and Maintenance against Environmental Impacts	1/3	Environmental Impacts is moderately more important Simplicity of Operation and Maintenance
Simplicity of Operation and Maintenance against Land Requirement	4	Simplicity of Operation and Maintenance is moderately more important than Land Requirement
Simplicity of Operation and Maintenance against Institutional Strength	3	Simplicity of Operation and Maintenance is moderately more important than Institutional Strength

A priority vector analyses the comparative weights of all the parameters for ranking purposes. A summary of the priority vectors and ranking for the parameters is given in **Table 9.4** below.

Table 9.4: A summary of the Priority Vectors for Parameter Matrix

Decision variable	Priority Vector	% Best	Ranking %
Simplicity of Operation and Maintenance	0.222	22%	2
Net Present Value	0.191	19%	3
Environmental Impacts	0.410	41%	1
Land Requirements	0.042	4%	5
Institutional Strength	0.135	13%	4

From **Table 9.4** above, it can be deduced that Environmental Impact is the most significant parameter in the selection of the most suitable wastewater treatment train. Simplicity of Operation & Maintenance and Net Present Values also have pronounced significance.

However, Land Requirement has least influence in the selection of most suitable treatment train.

Table 9.5 below gives a summary of the parameters' strengths against the alternative wastewater treatment trains.

Table 9.5: Summary of Parameter Weighting against Alternative Wastewater Treatment Trains

	Simplicity of Operations and Maintenance	*Net Present Value*	*Environmental Impacts*	*Land Requirement*	*Institutional Strength*
Waste Stabilization Ponds	Excellent	Excellent	Excellent	Poor	Good
Composite Biofilters	Fair	Good	Good	Fair	Fair
Composite Oxidation Ditches	Fair	Fair	Fair	Good	Fair
Long Sea Outfall	Good	Poor	Fair	Excellent	Good

Based on these strengths, decision variable matrices for each of the five parameters have been prepared.

The decision matrices for the significant parameters of Environmental Impact, Simplicity of Operations & Maintenance and Net Present Value are given in **Tables 9.6 to 9.8** on **Page 9-6.**

Detailed decision matrices for all the parameters is given in Volume 2 of this Report.

Table 9.6: Decision Variable Matrix based on Environmental Impact

	Waste Stabilization Ponds	*Composite Biofilters*	*Composite Oxidation Ditches*	*Long Sea Outfall*
Waste Stabilization Ponds	1	2	3	3
Composite Biofilters	1/2	1	2	2
Composite Oxidation Ditches	1/3	1/2	1	1
Long Sea Outfall	1/3	1/2	1	1

Table 9.7: Decision Variable Matrix based on Simplicity of Operation & Maintenance

	Waste Stabilization Ponds	*Composite Biofilters*	*Composite Oxidation Ditches*	*Long Sea Outfall*
Waste Stabilization Ponds	1	4	4	2
Composite Biofilters	1/4	1	1	1/3
Composite Oxidation Ditches	1/4	1	1	1/3
Long Sea Outfall	1/2	3	3	1

Table 9.8: Decision Variable Matrix based on Net Present Value

	Waste Stabilization Ponds	*Composite Biofilters*	*Composite Oxidation Ditches*	*Long Sea Outfall*
Waste Stabilization Ponds	1	3	4	5
Composite Biofilters	1/3	1	2	3
Composite Oxidation Ditches	1/4	1/2	1	2
Long Sea Outfall	1/5	1/3	1/2	1

9.2.6 Ranking of Alternatives Wastewater Treatment Trains

The composite matrices derived from decision variables when multiplied with the corresponding priority vectors result to weighted totals of the alternatives under consideration. A summary of the weighted totals for the alternative wastewater treatment trains is given in **Table 9.9** below.

Table 9.9: Weighted Totals for the alternative wastewater treatment trains

	Simplicity of Operations and Maintenance	*Net Present Value*	*Environmental Impacts*	*Land Requirement*	*Institutional Strength*	*Weighted Total*	*Rank*
Waste Stabilization Ponds	0.486	0.548	0.456	0.052	0.410	0.457	1
Composite Biofilters	0.11	0.23	0.26	0.09	0.13	0.198	3
Composite Oxidation Ditches	0.108	0.136	0.141	0.192	0.085	0.127	4
Long Sea Outfall	0.30	0.08	0.14	0.66	0.37	0.218	2

9.2.7 Recommendation for Wastewater Treatment Train

From the Multi-criteria Analysis, it has been found out that Environmental Impacts, Simplicity of Operations & Maintenance and Net Present Value are the main determinants in the selection of wastewater treatment train.

On this basis, Waste Stabilization Ponds System is the most suitable wastewater treatment train and is recommended for Mombasa Island and North Mainland Wastewater Management Scheme.

9.3 Site Identification and Selection

An ideal site for a Wastewater Treatment Plant (WWTP) is one with the minimal environmental effects and associated with low capital costs and operation & maintenance requirements.

Several parameters describe the requirements of such ideal WWTP sites and a systematic and unbiased analysis is necessary for an objective and robust site selection.

9.3.1 Criteria for Site Selection

Parameters considered in the site selection for WWTP in Mombasa Island and North Mainland are briefly described below;

9.3.1.1 Land-Use

In the Land-use Map, different areas of Mombasa Island and North Mainland have been assigned varied existing and proposed uses. Areas earmarked for residential, industries, agriculture, forests and social amenities are considered less suitable for the location of a Wastewater Treatment Plant (WWTP). On the other hand, public utility or undeveloped Agricultural Land located away from the sensitive residential areas are preferred.

9.3.1.2 Distance of Effluent Discharge Point

The distance from the WWTP site to the final receiving environment such as the river and ocean, is an important consideration in site selection. Preference is given to the sites that require shorter lengths of Outfall Sewers.

9.3.1.3 Topography of the Sewered Area

An ideal WWTP site should be located on a low-lying area of the sewerage system for gravity conveyance. Otherwise, pumping stations become necessary thereby increasing both capital cost and the operation and maintenance requirements of the sewerage system.

9.3.1.4 Topography of Site

The slope at an ideal site should permit the gravity flow within the WWTP without requiring excessive excavations for the structures. Slopes less than 1:20 are preferred.

9.3.1.5 Geological Conditions

A site with low water table and whose soils are impermeable is considered ideal with respect to geological considerations. For instance, silt or clay soils are suitable for pond construction.

More often, the geological formation within a Town is fairly similar. For instance, all the candidate sites in Mombasa Island and North Mainland comprise of a mixture of well drained, deep, dark red to reddish brown, friable, sandy clay loam to sandy clay, with top soil of loamy sand and well drained, very deep, yellowish red, very friable, fine sandy loam to fine sandy clay loam. These soils are suitable for WWTP (Waste Stabilization Ponds) construction.

9.3.1.6 Existing Infrastructure

Proximity to infrastructural systems such as roads, electricity and portable water is sought for while siting for a WWTP location. It reduces cost of construction and operation & maintenance requirements of the WWTP. Sites that are closer to existing infrastructure are preferred.

9.3.1.7 Potential for reuse of treated wastewater

Treated wastewater can be reused for beneficial purposes such as agricultural irrigation, industrial processes, ground water recharge, etc. Proximity to the potential re-use application and relative elevation difference (for gravity conveyance) is preferred in siting of WWTP. For instance, downstream arable land would make a WWTP site ideal for agricultural irrigation.

9.3.1.8 Land Acquisition

In this criterion, preference is given to sites owned by government agencies such as Ministries, County Governments, etc. This ensures that the project affected persons are kept to a minimal and reduces the cost of resettlement and compensation.

9.3.2 Candidate Sites

Two WWTP sites have been analysed and selected for the construction of WWTPs for Mombasa Island and North Mainland. A brief description of these sites is given below;

9.3.2.1 Nguu Tatu Site

The site is located on a low-lying land away from the tidal mark of the ocean as well as from the sensitive Mangroove forest, Sea grass, coral reefs and the sandy beaches

The site can be accessed from Kisauni or Bamburi using Kengeleni Road, the site faces Tudor Creek to the west. The site is accessible by road from the existing Mombasa Water and Sewerage Company reservoir tank located in Nguu Tatu. The land is privately owned and currently has coconut trees, mango trees and maize crops.

9.3.2.2 Shimo la Tewa Site

The Site is located in the Northern region of Mombasa Mainland within Kiembeni village.

The site can be accessed from Mtopanga on Old Malindi Road to Kiembeni Estate, the site was initially identified within the tidal zone of the Ocean within the lowland sand beach and mangrove forest, the site faces Mtwapa Creek to the North.

9.3.3 Evaluation of Candidate Sites

The above sites have been evaluated based on the listed criteria to determine the suitability ranking. A summary of the evaluation is given in **Table 9.10** below.

Table 9.10: Evaluation of Candidate Wastewater Treatment Plant Sites

	Land use	Distance of Effluent Discharge Point from the WWTP	Topography of Sewered Area	Topography of Site	Geological Conditions	Existing Infrastructure	Potential for Wastewater reuse	Project Affected Persons
Nguu Tatu	✓	✓	✓	✓	✓	×	✓	✓
Shimo la Tewa	✓	×	✓	✓	✓	✓	✓	✓

Multicriteria Analysis of the candidate sites has been incorporated in the analysis of the Alternative Schemes in the subsequent section.

9.4 Wastewater Management Scheme Selection Analysis

9.4.1 Objective Description

The principal objective of this study is to select the most suitable wastewater management scheme for Mombasa Island and North Mainland.

9.4.2 Parameters

To meet the principal objective, several parameters (subordinate objectives) must be fulfilled. These are listed below with brief description of their influence and characteristics.

9.4.2.1 Simplicity of Operations and Maintenance

This parameter defines the relationship between the level of operation and maintenance skills required and the capability of the local labour pool and service industry. It is an important parameter in consideration of constraints in the availability of trained manpower and spare parts and the need to prioritise the use of limited financial resources.

Decision variables that can be sustained by affordable and locally available skills have been given higher weights.

9.4.2.2 Net Present Value (NPV)

This is an indication of the total monetary outlay for scheme incorporating the capital cost and operation and maintenance requirements. A 20 year-period has been used for NPV calculation.

Using the scale for pairwise comparison, a decision variable with lower NPV has been assigned a higher weight.

9.4.2.3 Environmental Impact

Environmental impact of the scheme is important in the selection of the most suitable wastewater management scheme. The degree of odour and noise should not exceed nuisance threshold.

Lower weights are assigned to schemes with greater negative environmental impact.

9.4.2.4 Potential for Wastewater Reuse

Treated wastewater can be reused for beneficial purposes such as agricultural irrigation, industrial processes, ground water recharge, etc. Proximity to the potential re-use application and relative elevation difference (for gravity conveyance) is preferred in siting of WWTP. For instance, downstream arable land would give a scheme a higher ranking with respect to agricultural irrigation.

9.4.2.5 Land Acquisition

In this criterion, preference is given to schemes whose land requirements lie on sites owned by government agencies such as Ministries, County Governments, etc. This ensures that the project affected persons are kept to a minimum and reduces the cost of resettlement and compensation.

9.4.2.6 Land use

In the Land-use Map, different areas of Mombasa Island and North Mainland have been assigned varied existing and proposed uses. Areas earmarked for residential, industries, agriculture, forests and social amenities are considered less suitable for the location of a Wastewater Treatment Plant (WWTP). On the other hand, public utility or undeveloped Agricultural Land located away from the sensitive residential areas are preferred.

These have been considered in the selection of the wastewater management scheme.

9.4.3 Alternative Wastewater Management Schemes

Four alternatives Wastewater Management Schemes formulated for Mombasa Island and North Mainland are summarized in **Table 9.11** below:

Table 9.11: Alternative Wastewater Management Schemes

Alternative Scheme	Description
Alternative 1	De-Centralized Scheme with 1 Nr. Preliminary Treatment Plant and Long Sea Outfall at Kizingo comprising of a Long Sea Outfall with 12 Nr. Pumping Stations and 2 Nr. Wastewater Treatment Works at Nguu Tatu and Shimo la Tewa (ultimate capacity 52,300 and 9,900m³/d respectively), comprising of Waste Stabilization Ponds & 17 Nr. Pumping Stations
Alternative 2	Centralized Scheme with 1 Nr. Wastewater Treatment Plants at Nguu Tatu Site (ultimate capacity 87,300m³/d), comprising Trickling Filters and Maturation Ponds & 29 Nr. Pumping Stations
Alternative 3	De-Centralized Scheme with 2 Nr Wastewater Treatment Works at Nguu Tatu and Shimo la Tewa (ultimate capacity 77,300 and 9,900m³/d respectively), comprising of Waste Stabilization Ponds & 29 Nr. Pumping Stations

9.4.4 Parameter Matrix and Weighting

In accordance with the methodology, a pairwise comparison has been made on the parameters by addressing the question; "Which parameter /subordinate objective contribute more to the principal objective?"

The subordinate objectives which by cognizance pose greater importance have been assigned higher scales in the Intensity of Relative Importance.

A summary of the resulting matrix of the Parameters is given in **Table 9.12** below.

Table 9.12: Resultant Matrix of Parameters' Pairwise Comparison

	Simplicity of operation and Maintenance	*Net Present Value*	*Environmental Impacts*	*Potential for Wastewater Reuse*	*Land Acquisition*	*Land Use*
Simplicity of operation and Maintenance	1	2	1/2	3	1/2	2
Net Present Value	1/2	1	1/2	3	1/2	3
Environmental Impacts	2	2	1	4	2	3
Potential for Wastewater Reuse	1/3	1/3	1/4	1	1/4	1/3
Land Acquisition	2	2	1/2	4	1	2
Land Use	1/2	1/3	1/3	3	1/2	1

To illustrate the interpretation of the scales of Intensity of Relative Importance, the weights of Simplicity of Operation and Maintenance against other parameters have been analyzed and summarized in **Table 9.13** on **Page 9-11**.

Table 9.13: Analysis of Simplicity of Operation & Maintenance Weights against other parameters

Pairwise Comparison	Weighting	Explanation
Simplicity of Operation and Maintenance against NPV	2	Simplicity of Operation and Maintenance is slightly more important NPV
Simplicity of Operation and Maintenance against Environmental Impacts	1/2	Environmental Impacts is slightly more important Simplicity of Operation and Maintenance
Simplicity of Operation and Maintenance against Potential for Reuse	3	Simplicity of Operation and Maintenance is moderately more important than Potential for Reuse
Simplicity of Operation and Maintenance against Land Acquisition	1/2	Land Acquisition is slightly more important than Simplicity of Operation and Maintenance
Simplicity of Operation and Maintenance against Land Use	2	Simplicity of Operation and Maintenance is moderately more important than Land Use

A priority vector analyses the comparative weights of all the parameters for ranking purposes. A summary of the priority vectors and ranking for the parameters is given in **Table 9.14** below.

Table 9.14: A summary of the priority vectors for Parameter Matrix

Decision variable	Priority Vector	% Best	Ranking %
Simplicity of Operation and Maintenance	0.175	17.50%	3
Net Present Value	0.153	15.30%	4
Environmental Impacts	0.301	30.10%	1
Potential for Reuse	0.050	5.00%	6
Land Acquisition	0.227	22.70%	2
Land Use	0.094	9.40%	5

From **Table 9.14** above, it can be deduced that Environmental Impact is the most significant parameter in the selection of the most suitable Wastewater Management Scheme. Land Acquisition, Simplicity of Operation & Maintenance and Net Present Value also have pronounced significance.

However, Potential for Treated Wastewater Reuse and Land Use Pattern have the least influence in the selection of most suitable Wastewater Management Scheme.

Table 9.15 below gives a summary of the parameters' strengths against the alternative schemes.

Table 9.15: Summary of Parameter Weighting against alternative schemes

	Simplicity of Operations and Maintenance	*Net Present Value*	*Environmental Impacts*	*Potential for Reuse*	*Land Acquisition*	*Land Use*
Decentralized Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	Fair	Good	Poor	Fair	Good	Good
Centralized Scheme with 1Nr WSP Systems for both Island and North Mainland	Very Good	Poor	Fair	Good	Good	Very Good
Decentralized Scheme with 2Nr WSP Systems for both Island and North Mainland	Good	Good	Very Good	Poor	Fair	Fair

Based on these strengths, decision variable matrices for each of the five parameters have been prepared.
The decision matrices for the significant parameters of Environmental Impact, Land Acquisition, Simplicity of Operations & Maintenance and Net Present Value are given in **Tables 9.16 to 9.19** below.

Detailed decision matrices for all the parameters is given in **Volume 2 of this Report**.

Table 9.16: Decision Variable Matrix based on Environmental Impact

	Centralized Scheme with 1 Nr WSP System	*Decentralized Scheme with 2Nr WSP System*	*Centralized Scheme with Long Sea Outfall*
De-centralized Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	1	1/3	1/4
Centralized Scheme with 1Nr Trickling Filters and Maturation Ponds System for both Island and North Mainland	3	1	1/2
De-centralized Scheme with 2Nr WSP Systems for both Island and North Mainland	4	2	1

Table 9.17: Decision Variable Matrix based on Land Acquisition

	Centralized Scheme with 1 Nr WSP System	*Decentralized Scheme with 2Nr WSP System*	*Centralized Scheme with Long Sea Outfall*
De-centralized Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	1	1/3	1/2
Centralized Scheme with 1Nr Trickling Filters and Maturation Ponds System for both Island and North Mainland	3	1	2
De-centralized Scheme with 2Nr WSP Systems for both Island and North Mainland	2	1/2	1

Table 9.18: Decision Variable Matrix based on Simplicity of Operations & Maintenance

	Centralized Scheme with 1 Nr WSP System	*Decentralized Scheme with 2Nr WSP System*	*Centralized Scheme with Long Sea Outfall*
De-centralised Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	1	1/4	1/3
Centralized Scheme with 1Nr Trickling Filters and Maturation Ponds System for both Island and North Mainland	4	1	2
D-ecentralised Scheme with 2Nr WSP Systems for both Island and North Mainland	3	1/2	1

Table 9.19: Decision Variable Matrix based on Net Present Value

	Centralized Scheme with 1 Nr WSP System	*Decentralized Scheme with 2Nr WSP System*	*Centralized Scheme with Long Sea Outfall*
De-centralized Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	1	8	1
Centralized Scheme with 1Nr Trickling Filters and Maturation Ponds System for both Island and North Mainland	1/8	1	1/8
De-centralized Scheme with 2Nr WSP Systems for both Island and North Mainland	1	8	1

9.4.5 Ranking of Alternatives Wastewater Treatment Trains

The composite matrices derived from decision variables when multiplied with the corresponding priority vectors result to weighted totals of the alternatives under consideration. A summary of the weighted totals for the alternative schemes is given in **Table 9.20** below.

Table 9.20: Weighted Totals for the alternative schemes

	Simplicity of Operations and Maintenance	Net Present Value	Environmental Impacts	Potential for Reuse	Land Acquisition	Land Use	Weighted Totals	Rank
Decentralized Scheme with 1 Nr Long Sea Outfall for Island and 2 Nr. WSP System for North Mainland	0.12	0.47	0.12	0.12	0.16	0.31	0.20	3
Centralized Scheme with 1Nr Trickling Filters and Maturation Ponds System for both Island and North Mainland	0.56	0.06	0.32	0.18	0.54	0.58	0.39	2
Decentralized Scheme with 2Nr WSP Systems for both Island and North Mainland	0.32	0.47	0.56	0.69	0.30	0.11	0.41	1

9.4.6 Recommendation for Wastewater Treatment Train

From the Multi-Criteria Analysis, it has been found out that Environmental Impacts, Land Acquisition, Simplicity of Operations & Maintenance and Net Present Value are the main determinants in the selection of Wastewater Management Scheme.

On this basis, a de-centralized Wastewater Treatment Plants at Nguu Tatu and Shimo la Tewa Sites comprising of Waste Stabilization Ponds Systems is the most suitable Wastewater Management Scheme and is recommended for the Mombasa Island and North Mainland Sanitation Strategy.

10.0 PRELIMINARY DESIGN OF SELECTED STRATEGY

10.1 Introduction

At present, Mombasa Island has a Sewerage System that only covers the Old Town and a small part of the Central Business District. This sewerage system is non-functional and untreated sewage is disposed of at shallow depths in the Indian Ocean.

Mombasa North Mainland, on the other hand, has no sewerage system and effluent disposal is by means of pit latrines and septic tanks. These systems are inadequate to safeguard the health of the residents and the environment in general.

Based on the TOR, a new sanitation system is proposed for the study area (Mombasa Island and North Mainland) comprising of a Sewerage System and Wastewater Treatment Plant, to serve for a period of 20 years (2021 - 2040).

The Wastewater Management Scheme for Mombasa Island and North Mainland comprising of 2Nr Decentralized Waste Water Treatment Plants at Nguu Tatu and Shimo la Tewa which includes a conveyance system incorporating Trunk Sewers, Secondary Sewers and Pumping Stations has been analysed by the Multi-criteria analysis and found suitable.

Waste Stabilization Pond System has been selected as the most appropriate treatment technology at these proposed Waste Water Treatment Plants.

The main components of the proposed sanitation system include;

- Sewerage System comprising of Trunk Sewers and Secondary/Reticulation Sewerage Network connecting the Study area of Mombasa Island and North Mainland to the Wastewater Treatment Plant
- Wastewater Treatment Plant (WSPs) comprising of Inlet Works, Anaerobic Ponds, Facultative Ponds, Maturation Ponds & Sludge Drying Beds, Administration Building with Laboratory and Store, Guard House and Grade 9 Staff Houses, and Associated Ancillary Works e.g. Access roads, water reticulation, drainage etc.

10.2 Sewerage System

10.2.1 Aerial Photographic surveys

During the Study, aerial photographic surveys were carried out over the entire study area of Mombasa Island and North Mainland which produced aerial images at 15 cm resolution. A Digital Terrain Model was developed and contours generated.

A Digital Topographical Map was developed showing all topographical features such as contours, buildings, structures, roads, railways, vegetation cover, surface water bodies and drains, telephone and power lines, permanent structures etc.

Ground truthing was done through ground survey using a hand-held GPS receivers and place names, landmarks, road names etc. were captured and overlaid on the Digital Topographical Map.

10.2.2 Sewer Alignments

Proper design and construction of new sewers in a developed urban area such as Mombasa Island and North Mainland involves identification and overcoming the unique challenges associated with working in a confined urban area.

In the selection of sewer alignment, preference has been given to the road reserves where adequate space for construction can be obtained with ease and where minimum interference with existing services such as Water Mains, Permanent Structures, Powerlines, etc. is expected.

These locations also permit ease of access for future connections and maintenance. Minimum road crossings have been permitted along the proposed alignment at the necessary locations and preferably on roads without bitumen surfaces. At the road crossing, additional ground cover to the minimum requirement and concrete surrounds have been provided for pipe protection.

In circumstances where illegal structures were identified along the proposed sewer alignment and within the road reserves, provision for demolishing of such structures should be considered and associated costs included in the Bills of Quantities of the Final Design Stage.

The existing wayleave is shared with other public utilities such as telephone and electricity lines, communication cables, etc. therefore, it will be crucial to liaise with the relevant utility providers at the commencement of the project to help in identification and relocation of affected utilities.

The Utility Providers shall also be required to provide details and locations of their utility network within the Project Area to reduce accidental damages. Provisional items should be allowed in the Bills of Quantities for any requisite works for relocation of the existing utilities.

10.2.3 Sewerage Network Analysis Model

The analysis of the proposed Sewerage Network for Mombasa Island and North Mainland has been carried out using a Hydraulic Network Model developed by the Consultant on a Microsoft Excel platform.

The benefit of adopting a simplistic and universally recognized platform such as Microsoft Excel for the development of the Sewerage Network Analysis Model is the ease with which the analysis can be carried out by manipulation of design parameters without compromising the reliability of the output / results.

Microsoft Excel is a spreadsheet application that allows one to manipulate, manage and analyse data thereby assisting in design by making use of the inbuilt tools and methodologies. The advantages of Excel are wide and varied. The main advantages of this platform include:

- **Easy availability and Familiarity;** Ms Excel is part of Microsoft office which comes with most Personal Computers. It is easily available and requires no purchase. It is easy to install and can be run by most people owing to its familiarity of its commands. It is an all in one programme and does not need the addition of analysis subsets or scripts.
- **Powerful analysis of large amounts of data -** Recent upgrades to the Excel spreadsheet enhance analyse of large amounts of data. With powerful filtering, sorting and search tools one can quickly and easily narrow down the criteria that will assist in the analysis. This is in addition to the inbuilt formulas and other analysis tools available on Ms Excel.

Details of the Model is given in the subsequent sub-sections;

10.2.3.1 Model Structure / Mathematical Basis

This Hydraulic Network Model is a deterministic model. A deterministic model is one whose outcomes are precisely determined through known relationships among states and events, without any room for random variation. In deterministic models, a given input will always produce the same output. In comparison, stochastic models use ranges of values for variables in the form of probability distributions.

This Model has been prepared to design for critical parameters required for a sewer to convey peak wastewater flow generated between sections (manholes) of the sewer profile by gravity based on Manning's equation and other known relationships as briefly described below. All the quantities are entered in the indicated SI units.

- ***Manning Equation:*** It is widely used because of its simplicity. Although it is empirical, it gives an answer that is within the accuracy required, given the uncertainties associated with the flows generated (population, water consumption per person, etc.).

  The formula is as follows:

$$V = \left(\frac{R^{0.67} x S^{0.5}}{n}\right)$$

Where:

V	=	velocity of flow, (m/s)
n	=	pipe roughness coefficient
R	=	hydraulic radius, (m)
S	=	slope of the pipeline, (m/m)

- ***Discharge Formula***: Discharge through the pipe is determined by the equation;

$$Q = V x A$$

Where:

Q	=	Discharge (m^3/s)
A	=	Sectional area of flow (m^2)

Other standard formulae such as for determining peak factors (See ***sub-section 5.1.4)*** and other geometric formulae have also been incorporated in the Model.

The assumptions of this Model relate to the formulas on whose basis it is formulated. For instance, it is assumed that the pipe roughness will remain constant for the entire lifespan of the sewer and a fixed roughness co-efficient adopted. A conservative value for 'n' has been adopted to take care of anticipated deterioration of the pipe smoothness.

The Model evaluates the adequacy of sewer diameter and slope for the peak flow while meeting the requirements spelt out under the design criteria such as sewage flowing approximately half-bore and resulting velocities within the permissible range.

A summary of the adopted design criteria for Mombasa Island and North Mainland Sewerage System as detailed in **Section 6.1** is summarised in **Table 10.1** below.

Table 10.1: Adopted Design Criteria

Description	Adopted Criteria
Type of Sewerage System	Separate System
Sewage Contribution Factor	80% of the water supplied to consumers
Infiltration	Infiltration Rate of 0.0025 l/s/ha
Splash Allowance	5% of the wastewater flows
Peak Flow Factor	Based on Babbit and Harmon Formulas
Minimum Size of Sewer	200mm Diameter
Hydraulic Design Criteria	Manning's Equation with the following design parameters: • Pipe roughness coefficient, n 0.013 • Minimum velocity at peak flow 0.75 m/s • Minimum velocity in exceptional circumstances 0.6 m/s • Maximum velocity 3.0 m/s
Depth of Sewers	Depths range from 0.4m to 6.0m
Spacing of Manholes	60m maximum spacing between manholes
Pipe Materials	• HDPE/ uPVC Pipes • Socket and Spigot Concrete Pipes • Steel Pipes with internal and external epoxy coating

10.2.3.2 Model Parameters / Input Data Requirements

The input data required by the Model are explained below and in the indicated units;

i. Manhole Details

The location and number of manholes for each sewer line are determined based on the guidelines indicated in ***sub-section 6.1.7 – Manhole Spacing and Sizes*****.**

Each manhole is assigned a reference number and the chainage worked out from the last manhole. The manhole reference number, chainage and elevation are entered into the Model to determine length of sewer section being designed and the average ground slope.

ii. Population Equivalent (persons)

The population equivalent served by the sewer section is based on both the domestic wastewater contribution as well as that generated by the land-use activities within coverage area.

It has been assumed that the wastewater generated by one person is approximately *80 l/day***.**

iii. Wastewater flow (l/s)

This refers to the total wastewater flow generated within a given sewer section. It depends on the number of connections on the sewer and the quantities discharged by each premise/ connection.

The wastewater flow adopted in the sewerage analysis is based on the projections of wastewater flows (*See Section 5.2*).

iv. Proposed Sewer Slope (m/m)

The contours generated within the Study Area from the Digital Terrain Model have been used to generate sewer line profiles.

The slope of the sewers is determined by the natural ground slope and levels of adjoining sewers. The sewer slope is modified in the Model accordingly to ensure the outputs meet the adopted design criteria especially self-cleansing velocity.

v. Proposed Pipe Diameter (mm)

The model calculates the internal pipe diameter required for the flow of sewage at full bore conditions between a sewer section. The resultant diameters are not standards sizes and the designer is required to enter a standard pipe diameter of a larger dimension.

10.2.4 Model Output

This Model analyses the gravity conveyance of the indicated wastewater flow for the sewer section at Peak Flow and Dry Weather Flow Conditions. The output is checked against the adopted design criteria.

Some of the main output of this Model include;

i. Proportion of sewage flow to the full-bore capacity (Qp/Qfull),

Sewers are usually designed to flow half full or at worst at three-quarter depth for big diameter pipes (diameter > 500mm). This is a critical output which determines the pipe diameter selection at a given slope.

ii. Velocity of flow at full bore,

Velocity of flow in a sewer should not be less than 0.75 m/s to ensure attainment of self-cleansing conditions. On the other hand, the velocity should not exceed 3 m/s to reduce the abrasion effect of the contained solids.
Sewer Slope and diameter are adjusted accordingly to ensure velocity of sewage flow within this range.

10.2.5 Model Reliability

As earlier stated, this is a deterministic model whose output for similar conditions is constant. The formulas on whose basis it has been developed have been carefully entered and outputs run for known conditions.

Manual calculation of the sample condition (known situation with details of pipe diameter, slope, wastewater flow and the resulting velocities and fraction of sewage flow in the pipe) have been carried out to test the correctness of the outputs given by the Model.

The Model produces more precise outputs owing to the ability of Microsoft Excel to carry out computations to the highest accuracy possible.

10.2.6 Proposed Sewerage Network for Mombasa Island and North Mainland

Sewerage Analysis Model indicates that the range of diameter for the Sewers in Mombasa Island and North Mainland is 225 - 1,200 mm. The large diameter sewers are for the Trunk Sewers while the small diameter of 225 mm is used for the secondary sewers.

A Layout Plan of the proposed Sewerage Network for Mombasa Island and North Mainland is given in **Figure 10.1** and **10.2** on **Page 10-6 and 10-7**.

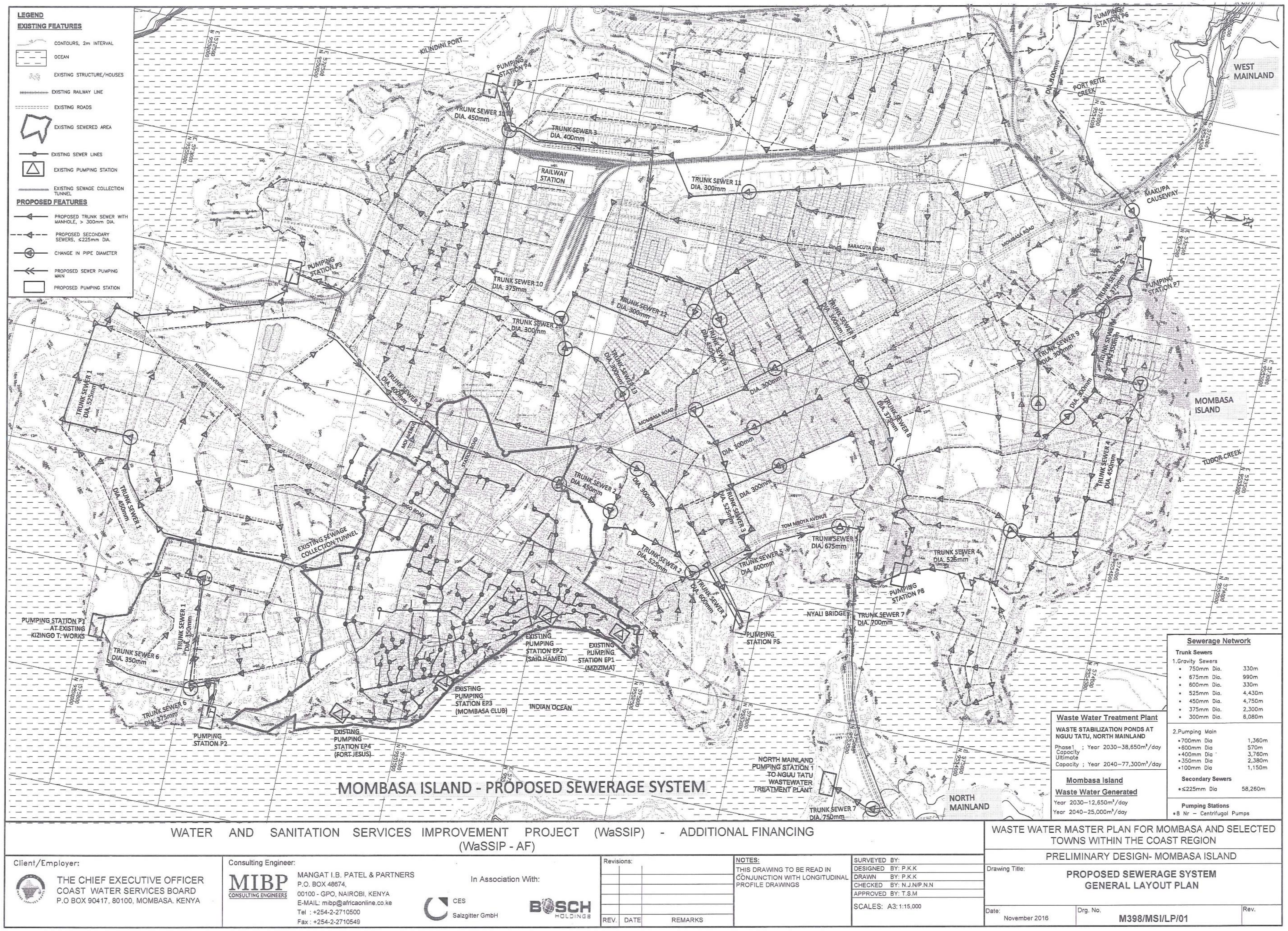


Figure 10.1: Detailed Layout of the Sewerage System – Mombasa Island

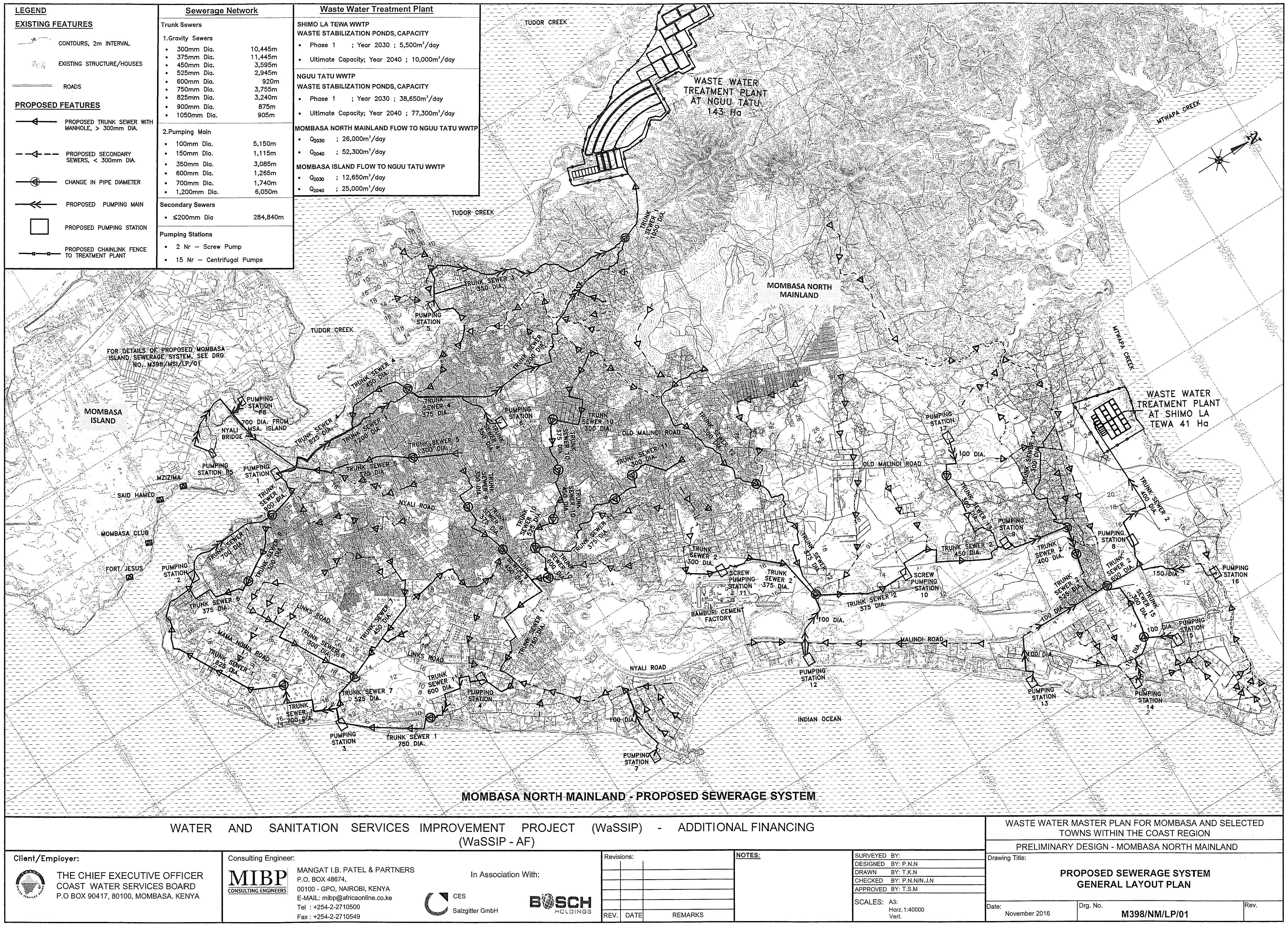


Figure 10.2: Detailed Layout of the Sewerage System – Mombasa North Mainland

10.2.7 Phased Investment Schedule for Sewerage Network

The Proposed Wastewater Management Strategy for Mombasa Island and North Mainland entails construction of new Wastewater Treatment Plants and Sewerage System comprising of Pumping Stations, Trunk and Secondary Sewers.

The Sewerage Network proposed for Mombasa Island and North Mainland Study Area has been studied with the aim of developing a Phased Investment Schedule.

Implementation phases of the Sewerage System has been formulated based on the following:

- Core Commercial Zone i.e. Central Business District,
- Population Densities – High Density and Medium Density Residential Zones, and
- Land-Use Plan – Water Intensive Activities i.e. Industrial Zones

Two implementation phases have been formulated as described below;

10.2.7.1 Phase 1 (2021 – 2025) – Medium Term Plan

The Sewerage system classified under Phase 1 comprises of the following;

- Trunk Sewer connecting the core sewage generating zones to the proposed WWTP site
- Secondary Sewers serving the core Central Business District (core Commercial Zones)
- Secondary Sewers serving Residential Zones with High Density and Medium Density Housing situated near the core CBD of Mombasa Island and North Mainland or adjacent to the WWTP
- Secondary Sewers serving Industrial Zones and other Water Intensive Land-Use Zones situated near the core CBD of Mombasa Island and North Mainland or adjacent to the WWTP

Summary of the Phase 1 Sewerage components in Mombasa Island and North Mainland is given in **Table 10.2** and **10.3** on **Page 10-9** and **Page 10-10** respectively.

Table 10.2: Schedule of Sewerage System - Phase 1 (Mombasa Island)

S/No	Sewer Line Reference No.	Dia. (mm)	Length (m)	Pipe Material
1	Trunk Sewer - TS1	525	1,300	Concrete S&S
2	-Ditto-	450	1,380	Concrete S&S
3	Trunk Sewer - TS2	450	740	Concrete S&S
4	-Ditto-	525	746	Concrete S&S
5	-Ditto-	600	330	Concrete S&S
6	Trunk Sewer - TS3	450	550	Concrete S&S
7	-Ditto-	525	1,409	Concrete S&S
8	Trunk Sewer - TS4	450	1,235	Concrete S&S
9	-Ditto-	525	975	Concrete S&S
10	Trunk Sewer - TS5	675	990	Concrete S&S
11	Trunk Sewer - TS6	375	267	Concrete S&S
12	Trunk Sewer - TS7	750	330	Concrete S&S
13	Trunk Sewer - TS8	300	985	Concrete S&S
14	-Ditto-	375	965	Concrete S&S
15	Trunk Sewer - TS9	375	287	Concrete S&S
16	-Ditto-	300	795	Concrete S&S
17	Trunk Sewer - TS10	450	845	Concrete S&S
18	-Ditto-	375	781	Concrete S&S
19	-Ditto-	300	630	Concrete S&S
20	Trunk Sewer - TS11	300	1,726	Concrete S&S
21	Trunk Sewer - TS12	300	1,100	Concrete S&S
22	Trunk Sewer - TS13	300	844	Concrete S&S
23	Pumping Main -PM1	350	827	Steel
24	Pumping Main -PM2	400	1,554	Steel
25	Pumping Main -PM3	400	2,206	Steel
26	Pumping Main -PM4	350	860	Steel
27	Pumping Main -PM5	600	570	Steel
28	Pumping Main -PM6	350	693	Steel
29	Pumping Main -PM7	700	1,360	Steel
30	Secondary Sewers - SS	225	58,260	HDPE / uPVC

Table 10.3: Schedule of Sewerage System - Phase 1 (North Mainland)

S/No	Sewer Line Reference No.	Dia. (mm)	Length (m)	Pipe Material
1	Trunk Sewer - TS1	1,050	904	Concrete S&S
2	-Ditto-	900	871	Concrete S&S
3	-Ditto-	825	3,240	Concrete S&S
4	-Ditto-	750	3,754	Concrete S&S
5	Trunk Sewer - TS2	300	530	Concrete S&S
6	-Ditto-	375	2,640	Concrete S&S
7	-Ditto-	600	580	Concrete S&S
8	Trunk Sewer - TS4	375	1,289	Concrete S&S
9	-Ditto-	450	828	Concrete S&S
10	-Ditto-	525	1,311	Concrete S&S
11	Trunk Sewer - TS5	375	1,459	Concrete S&S
12	-Ditto-	300	450	Concrete S&S
13	Trunk Sewer - TS6	300	1,470	Concrete S&S
14	Trunk Sewer - TS7	450	1,134	Concrete S&S
15	-Ditto-	525	666	Concrete S&S
16	Trunk Sewer - TS8	300	1,287	Concrete S&S
17	Trunk Sewer - TS9	300	600	Concrete S&S
18	-Ditto-	375	998	Concrete S&S
19	-Ditto-	450	350	Concrete S&S
20	Trunk Sewer - TS10	300	520	Concrete S&S
21	-Ditto-	375	1,118	Concrete S&S
22	-Ditto-	450	1,280	Concrete S&S
23	Trunk Sewer - TS11	300	1,410	Concrete S&S
24	-Ditto-	375	1,238	Concrete S&S
25	Trunk Sewer - TS12	300	1,000	Concrete S&S
26	-Ditto-	375	1,500	Concrete S&S
27	Trunk Sewer - TS13	300	1,285	Concrete S&S
28	Trunk Sewer - TS14	300	1,000	Concrete S&S
29	-Ditto-	375	1,200	Concrete S&S
30	Trunk Sewer - TS15	300	890	Concrete S&S
31	Pumping Main - PM 1	1,200	6,050	Steel
32	-Ditto-	700	1,736	Steel
33	-Ditto-	600	1,264	Steel
34	Pumping Main - PM 2	400	2705	Steel
35	-Ditto-	450	1700	Steel
36	-Ditto-	525	965	Steel
37	Pumping Main - PM 3	350	2740	Steel
38	Pumping Main - PM 4	350	232	Steel
39	Pumping Main - PM 15	100	4,600	Steel
40	Pumping Main - PM 5	150	1,110	Steel
41	Secondary Sewers - SS	225	200,000	HDPE / uPVC

10.2.7.2 Phase 2 (2026 – 2040) – Long Term Plan

The other parts of the study area with Low Density Housing or lacking Water Intensive Land-Use activities (Industrial or Commercial Zones) but are ear-marked for future utilization by these activities / settlement, have been proposed for Sewerage System Implementation under Long-Term Plan.

This comprise of parts of the remaining parts of North Mainland under the study but not sewered in Phase 1.

Summary of the Phase 2 Sewerage components is given in **Table 10.4** below.

Table 10.4: Schedule of Sewerage System - Phase 2 in Mombasa North Mainland

S/No	Sewer Line Reference No.	Dia. (mm)	Length (m)	Pipe Material
1	Pumping Main - PM 13	100	560	Steel
2	Secondary Sewer - SS	225	30,000	HDPE / uPVC

A Layout Plan of the proposed Sewerage Network for Mombasa Island and North Mainland showing each of the Sewerage Implementation Phases is given in **Figure 10.3** on **Page 10-11**.

Detailed calculation sheets for the proposed Trunk Sewers based on the Sewerage Network Analysis Model is given in **Volume 2: Master Plan Annexes – Section A1 (Trunk Sewers Design)**.

Layout Plans and Longitudinal Sections (Profiles) of the Trunk Sewers are given in **Volume 2: Master Plan Annexes – Section B (Engineering Drawings - Preliminary Design).**

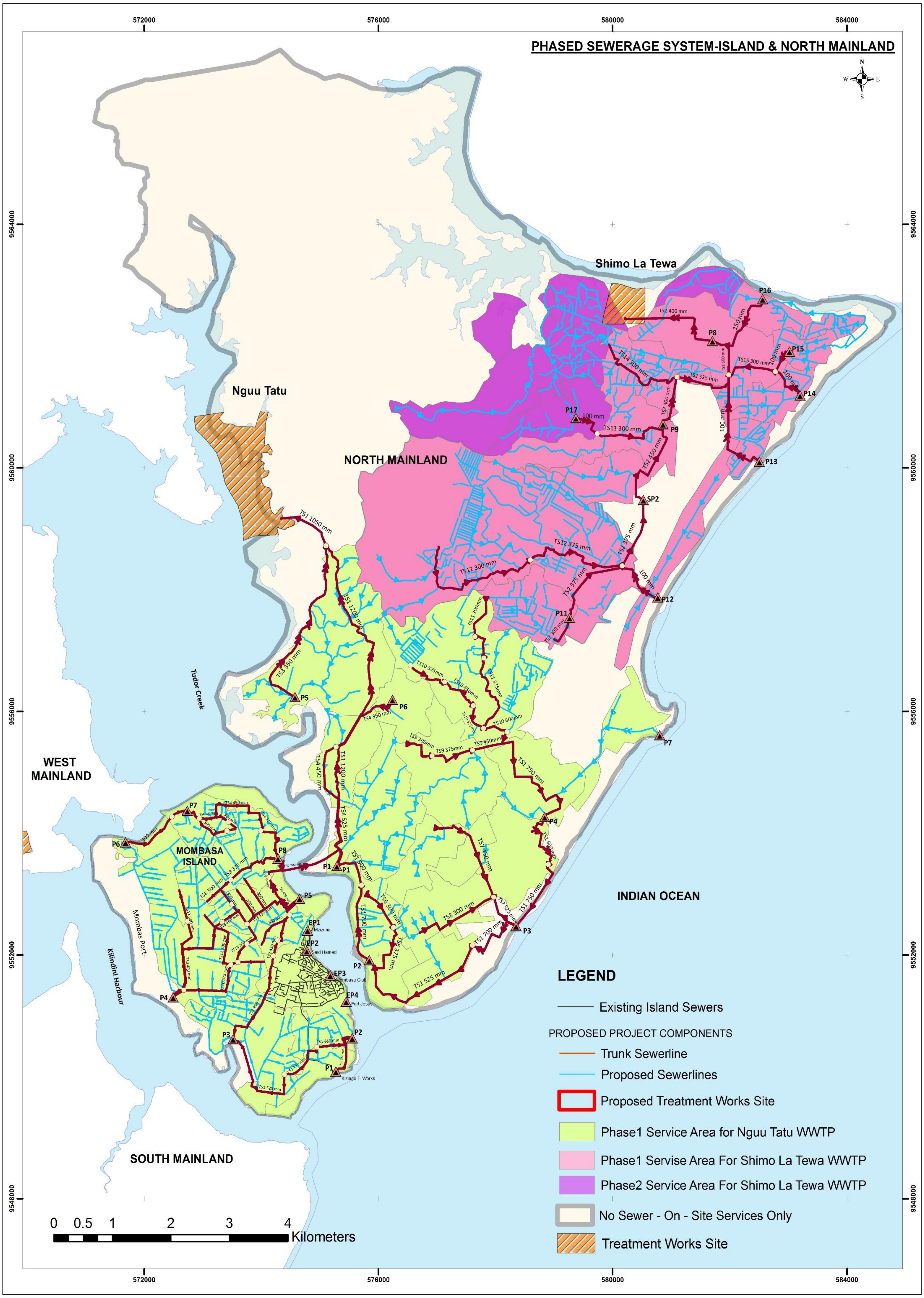


Figure 10.3: Layout Plan of the Phased Implementation of Sewerage System

10.3 Pumping Stations

10.3.1 Siting of Pumping Stations

The pumping stations for the Sewerage System for Mombasa Island and North Mainland have been necessitated by low-lying points along the sewage conveyance routes. Some proposed stations lie close to residential properties and as such mitigation measures have been incorporated to ensure minimum hazard to public health and environment, especially during periods of electrical or mechanical failures.

A provision has been made at each proposed pumping station to have a screened overflow pipe, for use only during emergencies leading to a nearby stream where available. In other circumstances, an overflow pipe will be installed from the pump sump to a septic tank within the pump station compound. The County's exhauster vehicle can then be used to transport the sewage to the treatment facility while repairs are in progress.

10.3.2 Pumping Station Details

Two types of Pumping Stations have been proposed for the Sewerage System of the study area, namely;

- Screw Pump Station (2 Nr)
- Dry Well Station type (27 Nr) with separate Sewage Sump

Screw Pump Stations have been adopted in circumstance where lifting of sewage is required within heads less than 10m and where topography of the Sewerage alignment permits construction of such station. Where Screw Pumps have been found to be unsuitable owing to topography or high boosting head requirement, Dry Well Station has been adopted. This type of pumping station has been adopted for the ease of operation and maintenance of the pumps.

In the Dry Well Station Type, the Sewage Sump is to be housed in the sub-structure of the Pumping Station while the Vertical Centrifugal Pump(s) and Motor(s) are to rest on the Super-structure including the control panels and the other associated equipment. Dry Well Stations have been adopted in lieu of Submersible pumps due to the ease of operation and maintenance of the pumps.

Each pumping station has been provided with a Preliminary Treatment Unit comprising of Screens and Grit Removal Structure. In addition, emergency overflow for use during pump failure has been incorporated from the Sewage Sump. A stand-by generator has also been provided in each Pumping Station.

It is proposed that the construction of Pumping Station be carried out in one phase i.e. with floor area adequate to house the ultimate number of pump-sets and multiple sumps required for the ultimate flows. The pump and motor plinths are to be constructed in the initial phase to allow for the installation of the additional pumps at later phases.

10.3.3 Pump Configurations

The pumping capacity for each pump-set has been designed compatible with the peak flows in the specific sewerage section. The percentage of stand-by unit in the proposed Pumping Stations vary depending on the economic analysis of the pump configuration. However, the reduction of the stand-by unit provision for the pumps in each Pumping Station at any implementation phase has been limited to 33%.

10.3.4 Schedule of Pumping Stations

In addition to the 4Nr Existing Pumping Stations which are planned for Replacement and Rehabilitation under the Immediate Urgent Works, the proposed Pumping Station for the Sewerage System have been designed based on the adopted criteria explained in ***sub-sections 6.2.1 to 6.2.4***.

Table 10.5 below and **Table 10.6** on **Page 10-15** gives summary of details of the Proposed Pumping Stations in Mombasa Island and North Mainland respectively.

Table 10.5: Summary of Details of the Sewage Pumping Stations – Mombasa Island

Pumping Station Ref. No.	Pumping Station Type	Pump Type	Pump Details			Implementation Phase	
			Design Flow, Q (m^3/h)	Pumping Head, H (m)	Power Requirement, P (kW)	2021 – 2025	2026 - 2040
P1	Dry Well	Vertical Centrifugal	313	16	19	✓	✓
P2	Dry Well	Vertical Centrifugal	350	24	33	✓	✓
P3	Dry Well	Vertical Centrifugal	506	30	59	✓	✓
P4	Dry Well	Vertical Centrifugal	477	30	56	✓	✓
P5	Dry Well	Vertical Centrifugal	1,361	23	124	✓	✓
P6	Dry Well	Vertical Centrifugal	50	63	12	✓	✓
P7	Dry Well	Vertical Centrifugal	292	23	26	✓	✓
P8	Dry Well	Vertical Centrifugal	2,084	28	223	✓	✓
EP1	Dry Well	Vertical Centrifugal	137	10	6	✓	✓
EP2	Dry Well	Vertical Centrifugal	55	4	8	✓	✓
EP3	Dry Well	Vertical Centrifugal	216	13	18	✓	✓
EP4	Dry Well	Vertical Centrifugal	55	8	17	✓	✓

Table 10.6: Summary of Details of the Sewage Pumping Stations – North Mainland

Pumping Station Ref. No.	Pumping Station Type	Pump Type	Pump Details			Implementation Phase	
			Design Flow, Q (m^3/h)	Pumping Head, H (m)	Power Requirement, P (kW)	2021 - 2025	2026 - 2040
P1	Dry Well	Vertical Centrifugal	5,833	64	1,380	✓	✓
P2	Dry Well	Vertical Centrifugal	2,237	23	196	✓	✓
P3	Dry Well	Vertical Centrifugal	1,946	25	186	✓	✓
P4	Dry Well	Vertical Centrifugal	1,407	23	125	✓	✓
P5	Dry Well	Vertical Centrifugal	492	77	147	✓	✓
P6	Dry Well	Vertical Centrifugal	279	15	16	✓	✓
P7	Dry Well	Vertical Centrifugal	18	57	16	✓	✓
P8	Dry Well	Vertical Centrifugal	763	34	100	✓	✓
P9	Dry Well	Vertical Centrifugal	370	18	25	✓	✓
P10	Screw	Screw	192	5	3	✓	✓
P11	Screw	Screw	98	5	2	✓	✓
P12	Dry Well	Vertical Centrifugal	32	41	5	✓	✓
P13	Dry Well	Vertical Centrifugal	38	30	5	✓	✓
P14	Dry Well	Vertical Centrifugal	38	37	6	✓	✓
P15	Dry Well	Vertical Centrifugal	38	35	5	✓	✓
P16	Dry Well	Vertical Centrifugal	54	23	5	✓	✓
P17	Dry Well	Vertical Centrifugal	41	30	5	×	✓

Figures 10.4 and **10.5** on **Pages 10-16** and **10-17** respectively show a Typical Layout Plan and Sections of a Screw Pumping Station and a Typical Layout Plan and Sections of a Centrifugal Pump Station.

Figures 10.3 on **Pages 10-12** shows the location of the proposed Pumping Stations in the Sewerage System.

Detailed calculation sheets for the Pumping Stations Components including the Sumps, Pumps and Motors are given in **Volume 2: Master Plan Annexes – Section A2 (Pumping Stations Design)**.

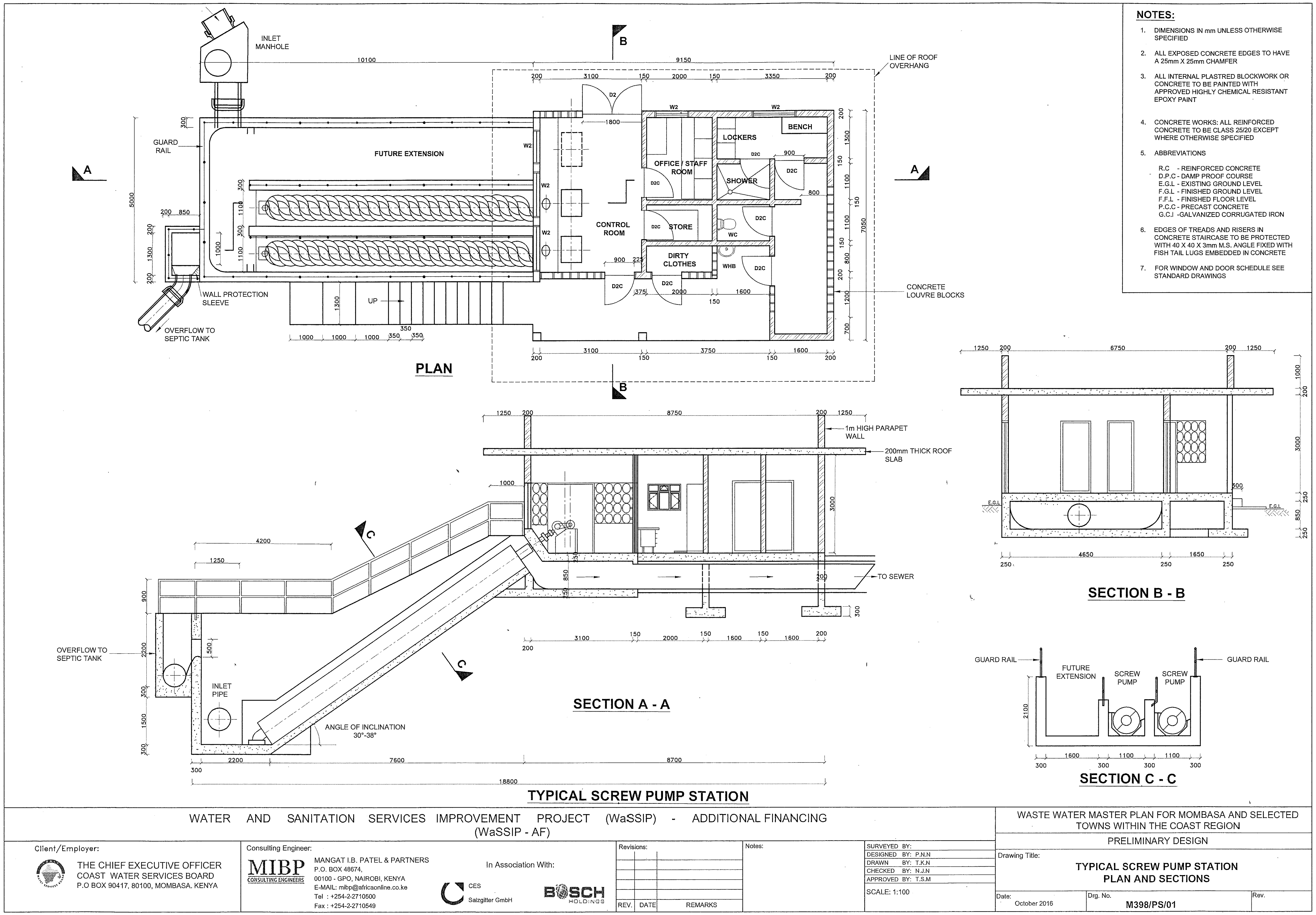


Figure 10.4: Typical Layout Plan and Sections of a Screw Pumping Station

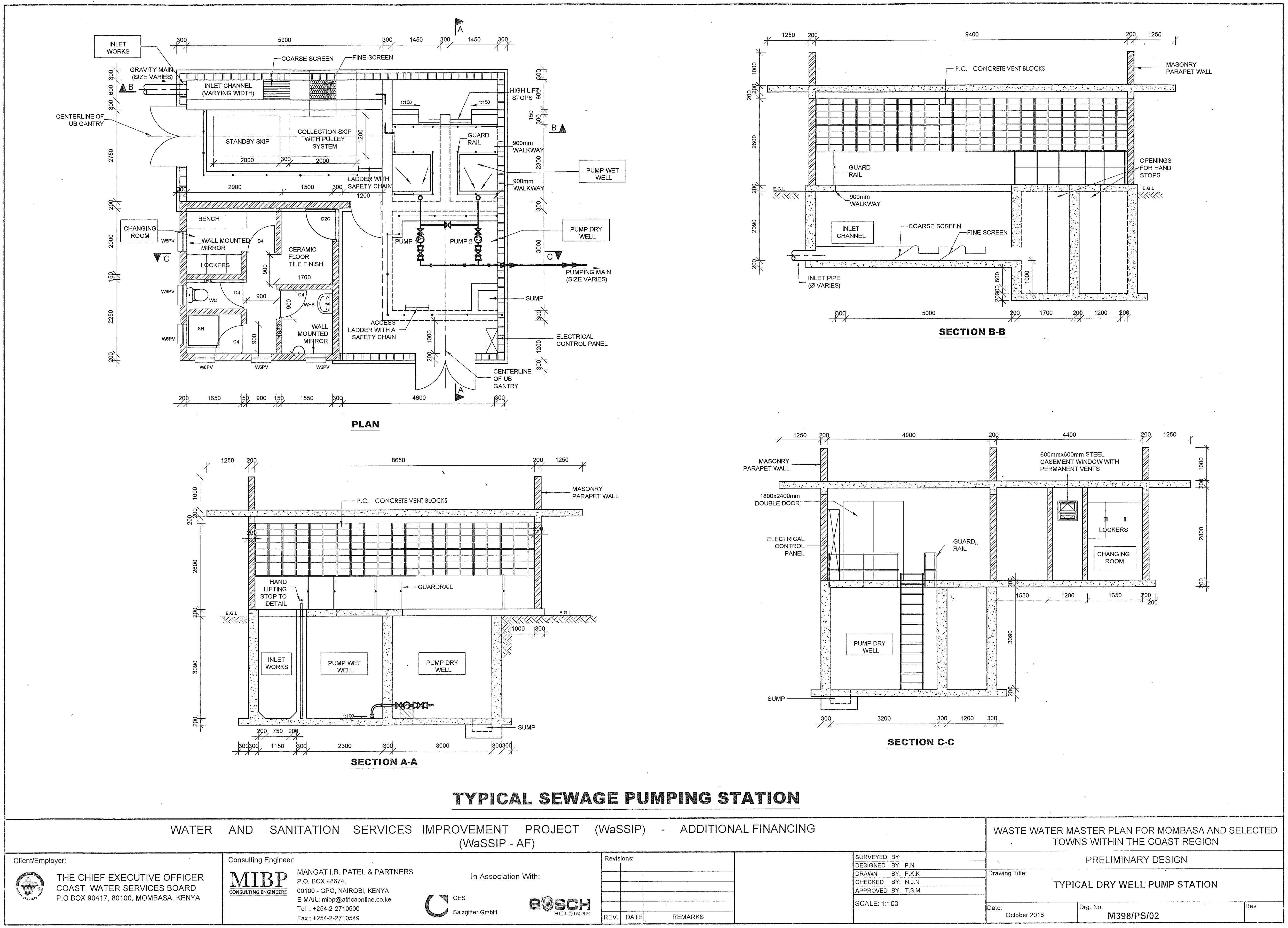


Figure 10.5: Typical Layout Plan and Sections of a Centrifugal Pumping Station

10.4 Wastewater Treatment Plants

10.4.1 Treatment Technology Selection

A summary of the comparison of the various locally available treatment technologies have been presented on **Table 6.4** on **Page 6-17** to establish the context of comparison of the available technologies and the re-affirm the conclusions reached.

Reference to the technologies comparison in Table 6.4 shows that the advantages of using Waste Stabilisation Ponds in Kenya over other technologies are so significant that they cannot be ignored. Their advantages can be summarised as follows:

- No mechanical and electrical equipment is needed, so no power is used in the process and little, or no, imported equipment is needed.
- The process takes place in simple lagoons and so the plant can be operated and maintained using only a small number of unskilled workers.
- Bacterial reduction and the removal of helminth eggs are superior to any other technology.
- Ability to absorb hydraulic and organic shock load - long retention times,
- Continuous sludge handling is not necessary. Facultative ponds need only be emptied every 15-20 years. The sludge is stable and requires no special treatment.
- Construction of the ponds is very simple and so the cost of construction is generally lower than other plants. Besides, land can easily be reinstated at the end of the plant's useful life.
- Pond systems can easily be upgraded by installing anaerobic ponds prior to the facultative ponds or by converting the ponds into aerated lagoons.
- Ponds usually provide minimal negative environmental impact.
- The ponds can be designed to provide a final effluent usable for agricultural irrigation.

The main handicap of Waste Stabilisation Ponds (WSPs) is the large land area requirement. However, the advantages of waste stabilisation ponds are so overwhelming that, wherever feasible, ponds should be the first choice where sufficient suitable land is available.

Besides, the high, year-round, ambient temperatures, availability of un-developed land within Mombasa Island and North Mainland and the simplicity of construction, render WSPs the most preferred wastewater treatment technology.

10.4.2 Treatment Plant Location

The recommended Waste Water Management Scheme entails 2Nr Waste Water Treatment Plants and sewage conveyance System to serve the sanitation needs of both Mombasa Island and North Mainland. These Waste Water Treatment Plants have been proposed at Nguu Tatu (574199 m E, 9559932 m N) and Shimo la Tewa (577473 m, 9562909 m N). The locations of these Waste Water Treatment Plants are shown on the Detailed Layout of the Sewerage System for North Mainland in **Figure 10.2** on **Page 10-7**.

The Site at Nguu Tatu requires land reclamation before development while Shimo la Tewa site is on a dry, un-developed Government-owned land.

These sites have been selected based on a check-list for site selection prepared in consideration of the pertinent physical, environmental and economic factors including the ease with which the wastewater generated in Mombasa Island and North Mainland can be conveyed to the sites by minimal pumping, land availability in these un-developed areas and the safe distance away from built-up areas.

Based on the recommended treatment technology (WSPs), ultimate projected wastewater flows based on the suppressed water supply and projected build-out of sewer connections (*Ultimate Combined Design Capacity - 87,300 m³/d; Refer to Subsection 5.2*) and availability of land at the two proposed sites, the land required for the construction of the WWTPs at Nguu Tatu and Shimo la Tewa to serve the sanitation needs of the study area (Mombasa Island and North Mainland) up to the ultimate horizon of year 2040, are approximately **160 Ha and 25 Ha** respectively**.**

Both sites are privately owned and Land Acquisition and Resettlement Action Plant (RAP) are required. In addition, land reclamation is required at Nguu Tatu site. They lie close to the creeks / shores of the Indian Ocean and the effluent can be discharged directly to the ocean through a short length of outfall sewer. They are also close to services such as water and electricity.

Both sites also site slope towards the ocean with sufficient slopes to permit an adequate hydraulic profile through the ponds without incurring excessive earthworks.

The proposed site at Nguu Tatu can be accessed from Kisauni or Bamburi using Kengeleni Road, the site faces Tudor Creek to the west. The site is accessible by road from the existing Mombasa Water and Sewerage Company reservoir tank located in Nguu Tatu. The proposed site at Shimo la Tewa is accessible using Bamburi - Mtwapa Road.

10.4.3 Design Considerations

Many different methods have been proposed for the design of Waste Stabilisation Ponds in hot climates. However, the most widely accepted standards and guidelines are those developed by G. V. Marais and D. D. Mara.

The design criteria and considerations that have been used for the design of WSPs for Mombasa Island and North Mainland is based on recommendations from D. D. Mara for use in Developing Countries.

The following is a summary of the main design criteria adopted in the design of the ponds:

a) Anaerobic Ponds

Anaerobic ponds are designed based on volumetric organic loading. The acceptable range of loadings is between 100 g/m³d and 300 g/m³d. The lower limit is to maintain anaerobic conditions while the upper limit is to control odour problems.

The loading is temperature dependent, as given in **Table 10.7** below:

Table 10.7: Design Values of Volumetric BOD Loadings at Various Temperature

Temperature, T(⁰C)	Volumetric Loading, λv (g/m³d)
T < 10 °C	100
10 °C < T >20 °C	20T-100
T > 20 °C	300

b) Facultative Ponds:

The design of a primary facultative pond is based upon the allowable organic surface loading that can be carried by the pond before failure (i.e. overloading) occurs.

The allowable surface loading in the primary pond is highly dependent upon the ambient temperature and it is common to use the mean temperature in the coldest month for design purposes.

The air temperatures in Mombasa Island and North Mainland are consistently moderately high throughout the year and a mean temperature in the coldest month of 24°C has been adopted. This mean temperature results to an allowable organic surface loading of 340 kg BOD/ha/day.

The depth of facultative ponds is based upon a compromise of being deep enough to prevent the emergence of weed growth, but without being too deep to allow anaerobic conditions to prevail. The ponds should also be deep enough to allow for a build-up of sludge over a period of years.

Depths are usually within 1.2 m and 2.0 m, with a commonly chosen depth of 1.5 metres.

c) Maturation Ponds:

The primary function of maturation ponds is the reduction of bacterial concentrations. However, efficient removal of the eggs of parasitic worms is also achieved. Bacteria are removed by providing a hostile environment that is unsuitable for their survival and helminth ova are removed by sedimentation. BOD is also removed in maturation ponds, but at a much slower rate than in anaerobic and facultative ponds.

The removal of bacteria in maturation ponds follows the laws of first order kinetics in a completely mixed reactor as suggested by Marais. The bacterial reduction in a single pond is given by the equation:

$$Ne = Ni/(1+k_T\theta)$$

Where,
- Ne = number of FC/100ml in the effluent
- Ni = number of FC/100ml in the influent
- k_T = first order rate constant for FC removal, d^{-1}
- θ = retention time, days

The rate constant is highly temperature dependent and for a temperature of 24.6 °C it has a value of 5.8 day^{-1}. The usual range of the faecal coliform concentration in raw sewage is 10^7-10^8 faecal coliforms per 100 ml. A conservative design value of $5x10^7$ FC per 100 ml has been adopted.

Maturation ponds are usually constructed as a series of ponds. The size and number of ponds provided is dependent on the required bacteriological quality of the final effluent. The minimum retention time for a maturations pond is three days.

Using the foregoing design values, the faecal coliform concentration in the effluent from a series of maturation ponds can be calculated and the number of ponds chosen to match the effluent quality requirements.

The adopted process design parameters for WSPs is given in **Table 10.8** below.

Table 10.8: Adopted Process Design Parameters

Design Parameter	Unit	Value
General:		
Raw Sewage BOD, Li	mg/l	600
Bacterial concentration of raw sewage	FC/100ml	$5x10^7$
Design Temperature	°C	24.6
First Order Rate Constant for FC Removal	days-1	5.8
Embankment side slopes	Embankment side slopes	
Freeboard allowance	m	0.5
Anaerobic Ponds:		
Volumetric Loading, λv	g/m3d	300
Depth of Anaerobic Pond	m	3.0
Retention Period	Days	≈ 3
Facultative Ponds:		
Organic Surface Loading, λs	kg/ha/day	342
Depth of Facultative Ponds	m	1.5
Retention time in Facultative Pond	Days	≈ 10
Maturation Ponds:		
Depth of Maturation Ponds	m	1.5
Retention in each Maturation Pond	Days	≈ 3

10.4.4 Wastewater Treatment Plant Details

The Waste Stabilization Pond system has been designed to serve the sanitation needs of Mombasa Island and North Mainland up to the design horizon - Year 2040.

Table 10.9 on **Page 10-22** shows a summary of details of the Wastewater Treatment Plants.

Table 10.9: Summary of Waste Water Treatment Plant Components – Year 2040

Design Parameter	Unit	Quantity	
		Nguu Tatu 77,300m³/day	**Shimo la Tewa 9,900m³/day**
Anaerobic Ponds:			
Number of Ponds	No.	4	4
Retention Period (Each Pond)	Days	2	2
Dimensions (Embankment)	m		66 (L) x 37 (B) x 3 (D)
Free-Board (All Ponds)	m	0.5	0.5
Embankment Slope (All Ponds)	-	1 in 2	1 in 2
Primary Facultative Ponds:			
Number of Ponds	No.	4	4
Retention Period (Each Pond)	Days	9	8
Dimensions (Embankment)	m		210 (L) x 70 (B) x 1.5 (D)
Secondary Facultative Ponds:			
Number of Ponds	No.	4	4
Retention Period (Each Pond)	Days	2	2
Dimensions (Embankment)	m		66 (L) x 60 (B) x 1.5 (D)
Maturation Ponds:			
Number of Ponds	No.	8	8
Retention Period (Each Pond)	Days	2	2
Dimensions	m		68 (L) x 60 (B) x 1.5 (D)
Sludge Drying Beds:			
Number of Beds	No.	8	4
Dimensions (Embankment)	m		70 (L) x 25 (B) x 1.5 (D)

The Site Layout Plan of the proposed Wastewater Treatment Plant is given in **Figure 10.6** and **10.7** on **Pages 10-22** and **10-23** respectively.

Typical details on the Inlet and Outlet Structures are also given in **Figure 10.8** on **Page 10-24.**

Detailed calculation sheets of the Wastewater Treatment Plants (Year 2030 and Year 2040) are given in **Volume 2: Master Plan Annexes – Section A3 (Wastewater Treatment Plant Design).**

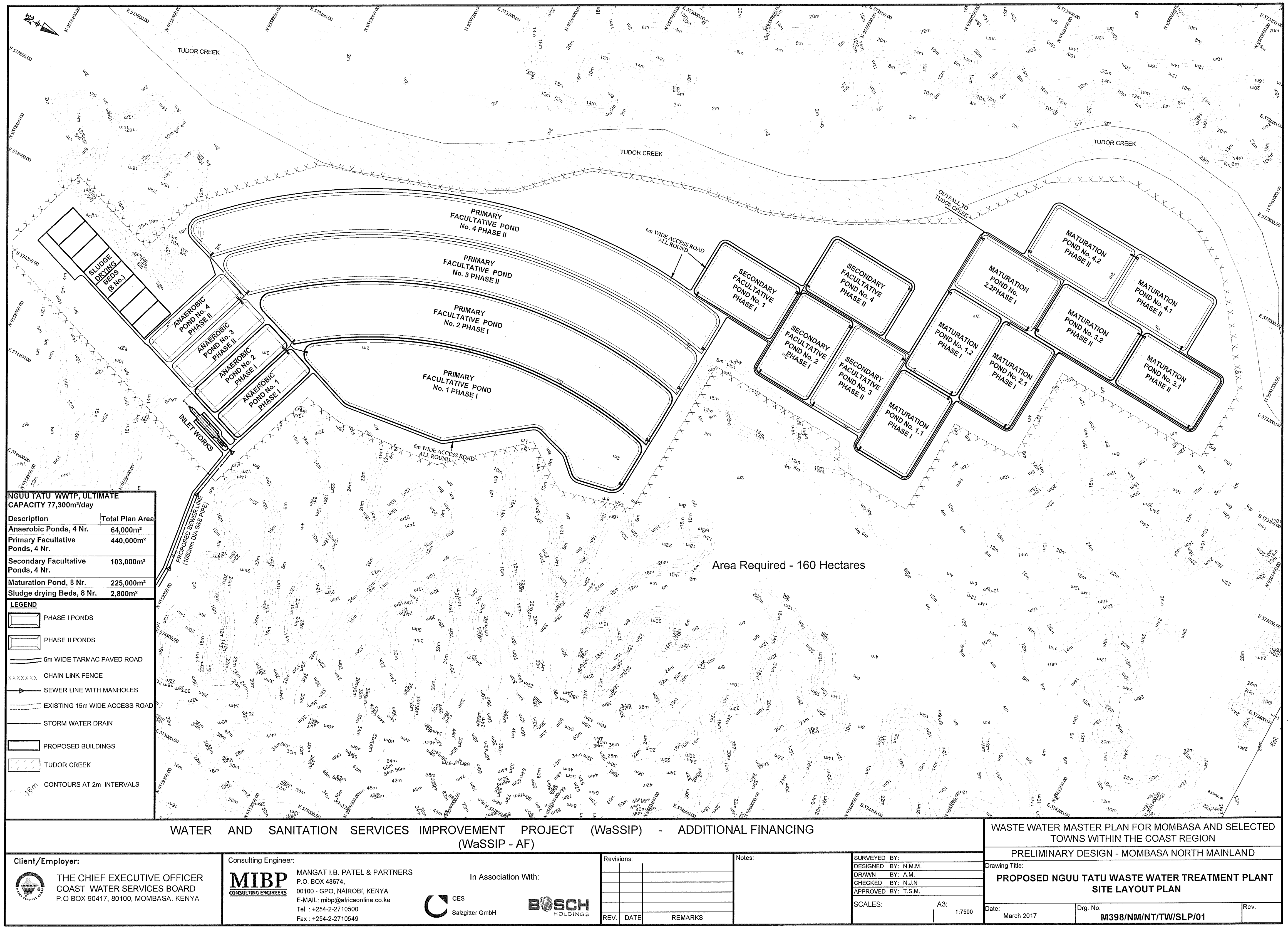


Figure 10.6: Site Layout Plan for Proposed Waste Water Treatment Plant – Nguu Tatu

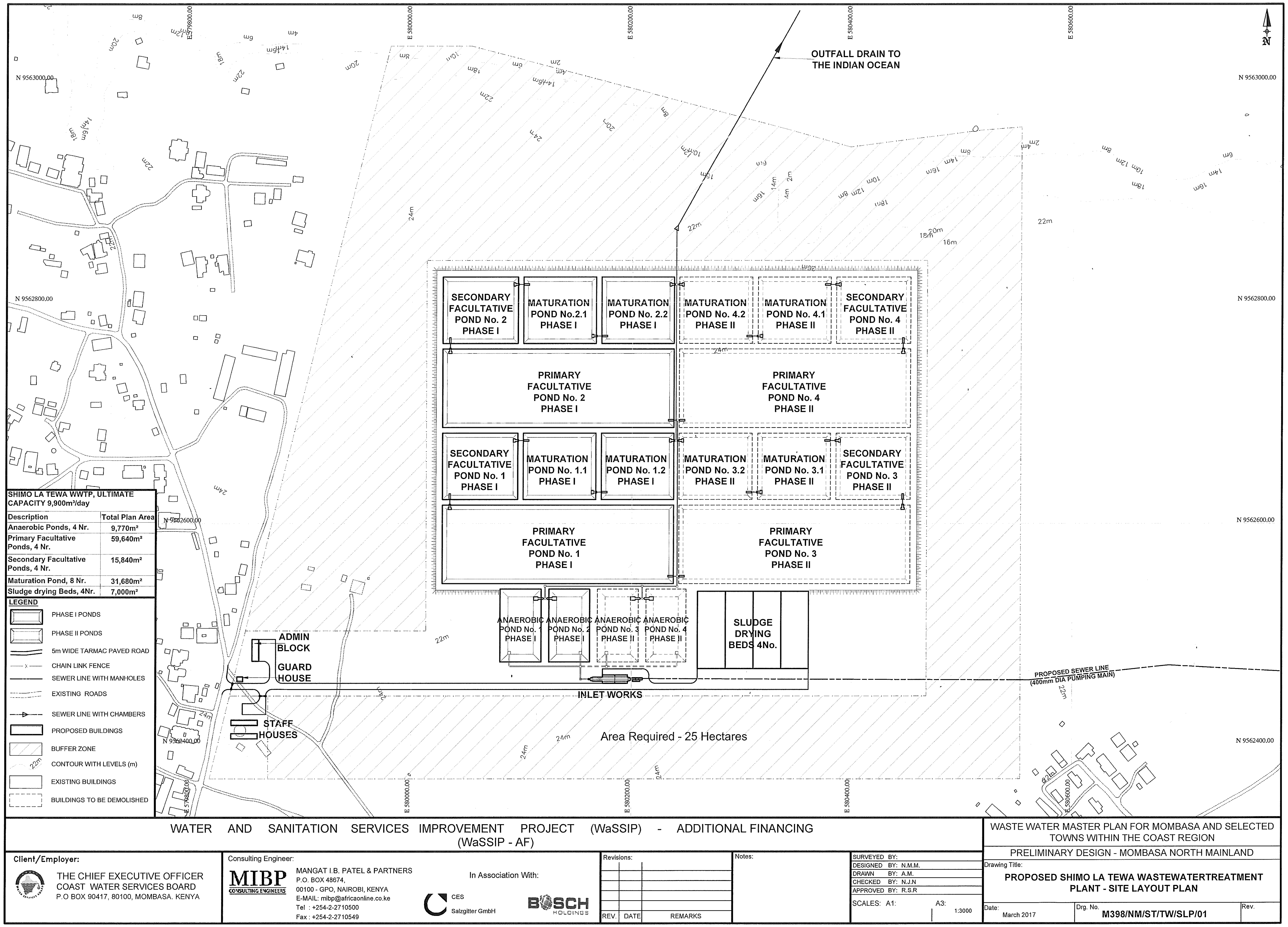


Figure 10.7: Site Layout Plan for Proposed Waste Water Treatment Plant - Shimo la Tewa

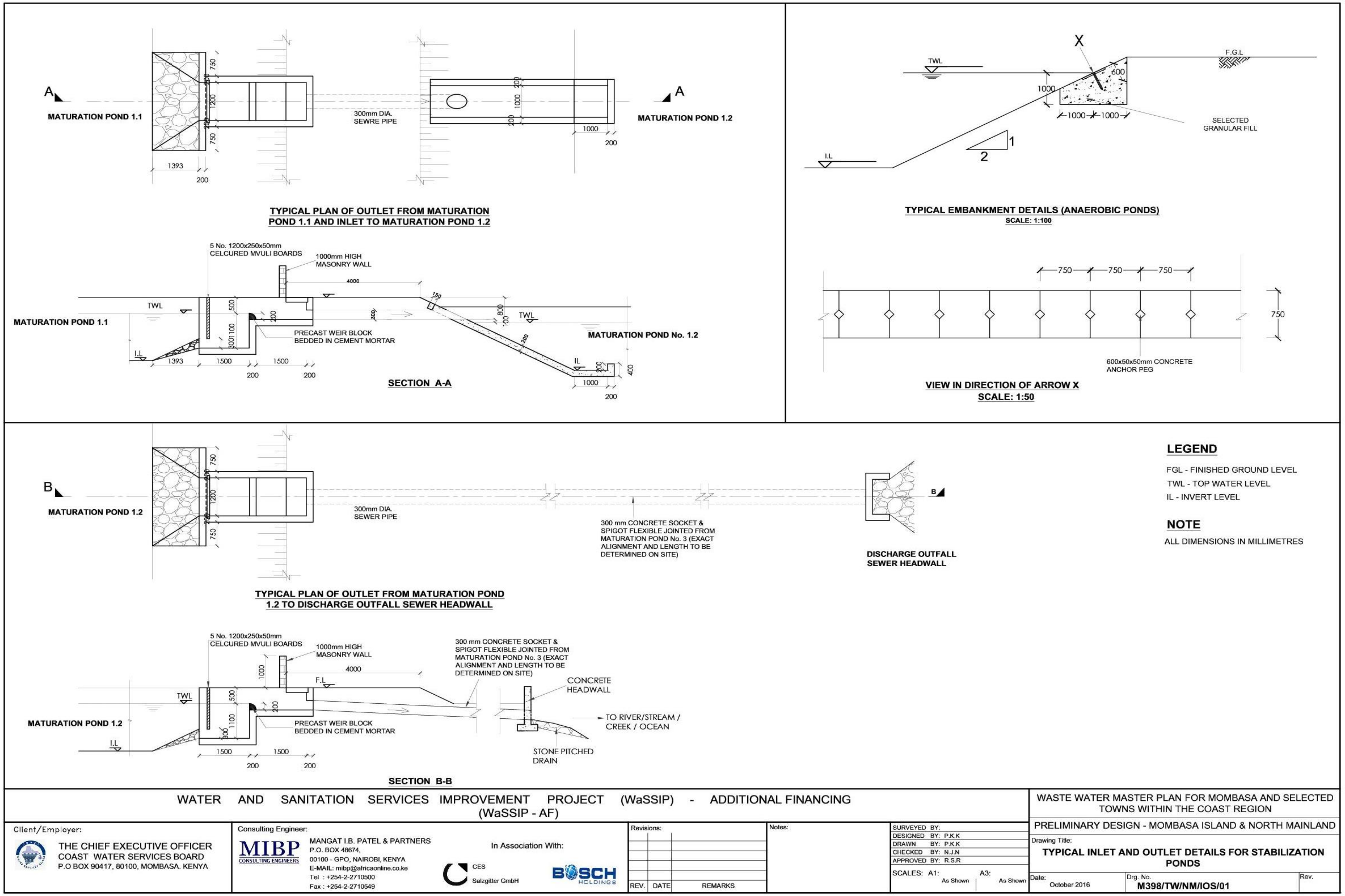


Figure 10.8: Typical Inlet and Outlet Structures for Waste Stabilization Ponds

10.4.5 Phased Investment Schedule for Waste Water Treatment Plant

Since wastewater generated within the study area is expected to increase with the population and land-use utilization, it is prudent to phase the implementation of the Waste Water Treatment Plant i.e. into Medium-Term and Long-Term Plan.

10.4.5.1 Medium Term Plan (2021 – 2025)

Medium Term Plan include construction of Waste Water Treatment Plants (WWTPs) to serve the sanitation needs of the study area up to year 2025. To ensure efficient operation of the WWTPs even during the implementation of the second phase (Long-Term Plan; 2025 - 2040), design capacity more than the projected wastewater generation of the sewered area in Year 2025, have been provided in the WWTPs under Medium-Term Plan.

For ease of phasing the WWTPs and to ensure additional capacity up to around year 2028, the ultimate design capacities of each WWTP have been divided equally into the two phases i.e. in the Medium-Term Plan, the design capacities at Nguu Tatu and Shimo la Tewa are 38,650 m³/d and 4,950 m³/d respectively.

Details of Waste Water Treatment Plants designed for implementation in the Medium-Term Plan at Nguu Tatu and Shimo la Tewa are given in **Table 10.10** below**.**

Table 10.10: Details of Waste Water Treatment Plants - Medium-Term Plan

Design Parameter	Unit	Quantity	
		Nguu Tatu 38,650m³/day	Shimo la Tewa 4,950m³/day
Anaerobic Ponds:			
Number of Ponds	No.	2	2
Retention Period (Each Pond)	Days	2	2
Dimensions (Embankment)	m		66 (L) x 37 (B) x 3 (D)
Free-Board (All Ponds)	m	0.5	0.5
Embankment Slope (All Ponds)	-	1 in 2	1 in 2
Primary Facultative Ponds:			
Number of Ponds	No.	2	2
Retention Period (Each Pond)	Days	9	8
Dimensions (Embankment)	m		210 (L) x 70 (B) x 1.5 (D)
Secondary Facultative Ponds:			
Number of Ponds	No.	2	2
Retention Period (Each Pond)	Days	2	2
Dimensions (Embankment)	m		66 (L) x 60 (B) x 1.5 (D)
Maturation Ponds:			
Number of Ponds	No.	4	4
Retention Period (Each Pond)	Days	2	2
Dimensions	m		68 (L) x 60 (B) x 1.5 (D)
Sludge Drying Beds:			
Number of Beds	No.	2	2
Dimensions (Embankment)	m		70 (L) x 25 (B) x 1.5 (D)

10.4.5.2 Long-Term Plan (2026 -2040)

The second phase of the implementation schedule involves construction of the additional units to augment the capacities of the Waste Water Treatment Plant to handle the ultimate wastewater generation of year 2040 i.e. 87,300m^3/day based on realistic conditions of water supply and sewer connections.

The details of the second Implementation Phase which is meant to provide the additional capacity at the Waste Water Treatment Works is given in **Table 10.9** below.

Table 10.11: Details of Additional Units at Waste Water Treatment Plants - Long-Term Plan

Design Parameter	Unit	Quantity	
		Nguu Tatu 38,650 m³/d	Shimo la Tewa 4,950 m³/d
Anaerobic Ponds:			
Number of Ponds	No.	2	2
Retention Period (Each Pond)	Days	2	2
Dimensions (Embankment)	m		66 (L) x 37 (B) x 3 (D)
Free-Board (All Ponds)	m	0.5	0.5
Embankment Slope (All Ponds)	-	1 in 2	1 in 2
Primary Facultative Ponds:			
Number of Ponds	No.	2	2
Retention Period (Each Pond)	Days	9	8
Dimensions (Embankment)	m		210 (L) x 70 (B) x 1.5 (D)
Secondary Facultative Ponds:			
Number of Ponds	No.	2	2
Retention Period (Each Pond)	Days	2	2
Dimensions (Embankment)	m		66 (L) x 60 (B) x 1.5 (D)
Maturation Ponds:			
Number of Ponds	No.	4	4
Retention Period (Each Pond)	Days	2	2
Dimensions	m		68 (L) x 60 (B) x 1.5 (D)
Sludge Drying Beds:			
Number of Beds	No.	2	2
Dimensions (Embankment)	m		70 (L) x 25 (B) x 1.5 (D)

10.5 Phased Implementation Costs

10.5.1 Land Acquisition Cost

Approximately 160 Ha and 25 Ha of land are required for the implementation of the proposed WWTPs at Nguu Tatu and Shimo la Tewa respectively. Considering the unit cost of land acquisition and land reclamation of **Kshs. 40,000,000** and **Kshs. 9,000,000** per Hectare respectively, the estimated total cost for land acquisition / reclamation to undertake the project (combined Wastewater Management Strategy for Mombasa Island and North Mainland) is **Kshs. 2,600,000,000.**

The requisite parcels of land should be acquired/ reclaimed in the Medium-Term Plan.

10.5.2 Implementation Costs for Phased Sewerage System

The estimated costs for each of the Implementation Phases is given in **Tables 10.12** and **10.13** below and **Table 10.14** on **Page 10-29**;

Table 10.12: Cost of Phase 1 Sewerage System, Medium Term Plan - Mombasa Island

S/No	Item Description	Cost (Kshs)	Cost (US$)
1	Trunk Sewers	303,081,730	2,942,541
2	Secondary Sewers	844,770,000	8,201,650
3	Pumping Mains	177,330,071	1,721,651
4	Pumping Stations	44,900,000	435,922
	Sub-Total 1	**1,370,081,801**	**13,301,765**
	Add 7.5% of Sub-Total 1 for Preliminary and General	102,756,135	997,632
	Sub-Total 2	**1,472,837,936**	**14,299,397**
	Add 10% of Sub-Total 2 for Physical Contingencies	147,283,794	1,429,940
	Sub-Total 3	**1,620,121,730**	**15,729,337**
	Add 10% of Sub-Total 3 for Price Contingencies	162,012,173	1,572,934
	Sub-Total 4	**1,782,133,903**	**17,302,271**
	Add 5% of Sub-Total 4 for Consultancy	89,106,695	865,114
	GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**1,871,240,598**	**18,167,384**

Table 10.13: Cost of Phase 1 Sewerage System, Medium Term Plan - North Mainland

S/No	Item Description	Cost (Kshs)	Cost (US$)
1	Trunk Sewers	595,682,126	5,783,322
2	Secondary Sewers	1,872,588,504	18,180,471
3	Pumping Mains	412,933,357	4,009,062
4	Pumping Stations	85,200,000	827,184
	Sub-Total 1	**2,966,403,987**	**28,800,039**
	Add 7.5% of Sub-Total 1 for Preliminary and General	222,480,299	2,160,003
	Sub-Total 2	**3,188,884,286**	**30,960,042**
	Add 10% of Sub-Total 2 for Physical Contingencies	318,888,429	3,096,004
	Sub-Total 3	**3,507,772,714**	**34,056,046**
	Add 10% of Sub-Total 3 for Price Contingencies	350,777,271	3,405,605
	Sub-Total 4	**3,858,549,986**	**37,461,650**
	Add 5% of Sub-Total 4 for Consultancy	192,927,499	1,873,083
	GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**4,051,477,485**	**39,334,733**

Table 10.14: Cost of Phase 2 Sewerage System, Long Term Plan - North Mainland

S/No	Item Description	Cost (Kshs)	Cost (US$)
1	Secondary Sewers	405,109,648	3,933,103
2	Pumping Mains	8,120,000	78,835
3	Pumping Stations	4,500,000	43,689
	Sub-Total 1	**417,729,648**	**4,055,628**
	Add 7.5% of Sub-Total 1 for Preliminary and General	31,329,724	304,172
	Sub-Total 2	**449,059,372**	**4,359,800**
	Add 10% of Sub-Total 2 for Physical Contingencies	44,905,937	435,980
	Sub-Total 3	**493,965,309**	**4,795,780**
	Add 10% of Sub-Total 3 for Price Contingencies	49,396,531	479,578
	Sub-Total 4	**543,361,840**	**5,275,358**
	Add 5% of Sub-Total 4 for Consultancy	27,168,092	263,768
	GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**570,529,932**	**5,539,126**

10.5.3 Implementation Costs for Phased Investment on Waste Water Treatment Plant

The estimated implementation costs for the Waste Water Treatment Plants (WWTPs) at Nguu Tatu and Shimo la Tewa, to serve the sanitation needs of the study area in the Medium-Term (Year 2021 – 2025) are summarized in **Tables 10.15 to 10.18** below and on **Page 10-31**.

Table 10.15: Implementation Cost for WWTP at Nguu Tatu: Medium-Term Plan

S/No.	Components	No.	Cost (Kshs)	Cost (US$)
1	Inlet Works	1	81,605,145	792,283
2	Anaerobic Ponds	2	863,729,959	8,385,728
3	Primary Facultative Ponds	2	831,739,961	8,075,145
4	Secondary Facultative Ponds	2	239,924,989	2,329,369
5	Maturation Ponds	4	479,849,977	4,658,738
6	Sludge Drying Beds	2	287,909,986	2,795,243
7	Administration Building	1	17,700,000	171,845
8	Staff Houses	4	18,000,000	174,757
9	Site and Ancillary Works	-	338,565,540	3,287,044
		Sub-Total 1	**3,159,025,557**	**30,670,151**
		Add 7.5% of Sub-Total 1 for Preliminary and General	236,926,917	2,300,261
		Sub-Total 2	**3,395,952,474**	**32,970,412**
		Add 10% of Sub-Total 2 for Physical Contingencies	339,595,247	3,297,041
		Sub-Total 3	**3,735,547,721**	**36,267,454**
		Add 10% of Sub-Total 3 for Price Contingencies	373,554,772	3,626,745
		Sub-Total 4	**4,109,102,493**	**39,894,199**
		Add 5% of Sub-Total 4 for Consultancy	205,455,125	1,994,710
		GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**4,314,557,618**	**41,888,909**

Table 10.16: Implementation Cost for WWTP at Shimo la Tewa: Medium-Term Plan

S/No.	Components	No.	Cost (Kshs)	Cost (US$)
1	Inlet Works	1	26,815,888	260,348
2	Anaerobic Ponds	2	105,885,343	1,028,013
3	Primary Facultative Ponds	2	101,649,929	986,893
4	Secondary Facultative Ponds	2	27,530,189	267,283
5	Maturation Ponds	4	55,060,378	534,567
6	Sludge Drying Beds	4	38,118,723	370,085
7	Administration Building	1	8,850,000	85,922
8	Staff Houses	2	4,500,000	43,689
9	Site and Ancillary Works	-	46,589,551	452,326
		Sub-Total 1	**415,000,001**	**4,029,126**
		Add 7.5% of Sub-Total 1 for Preliminary and General	31,125,000	302,184
		Sub-Total 2	**446,125,001**	**4,331,311**
		Add 10% of Sub-Total 2 for Physical Contingencies	44,612,500	433,131
		Sub-Total 3	**490,737,501**	**4,764,442**
		Add 10% of Sub-Total 3 for Price Contingencies	49,073,750	476,444
		Sub-Total 4	**539,811,251**	**5,240,886**
		Add 5% of Sub-Total 4 for Consultancy	26,990,563	262,044
		GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**566,801,814**	**5,502,930**

Table 10.17: Implementation Cost for Additional Units at Nguu Tatu WWTP: Long-Term Plan

S/No.	Components	No.	Cost (Kshs)	Cost (US$)
1	Anaerobic Ponds	2	863,729,959	8,385,728
2	Primary Facultative Ponds	2	831,739,961	8,075,145
3	Secondary Facultative Ponds	2	239,924,989	2,329,369
4	Maturation Ponds	4	479,849,977	4,658,738
5	Sludge Drying Beds	2	287,909,986	2,795,243
6	Site and Ancillary Works	-	138,916,195	1,348,701
		Sub-Total 1	**2,842,071,067**	**27,592,923**
		Add 7.5% of Sub-Total 1 for Preliminary and General	213,155,330	2,069,469
		Sub-Total 2	**3,055,226,397**	**29,662,392**
		Add 10% of Sub-Total 2 for Physical Contingencies	305,522,640	2,966,239
		Sub-Total 3	**3,360,749,037**	**32,628,631**
		Add 10% of Sub-Total 3 for Price Contingencies	336,074,904	3,262,863
		Sub-Total 4	**3,696,823,941**	**35,891,495**
		Add 10% of Sub-Total 4 for Consultancy	184,841,197	1,794,575
		GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**3,881,665,138**	**37,686,069**

Table 10.18: Implementation Cost for Additional Units at Shimo la TewaWWTP: Long-Term Plan

S/No.	Components	No.	Cost (Kshs)	Cost (US$)
1	Anaerobic Ponds	2	105,885,343	1,028,013
2	Primary Facultative Ponds	2	101,649,929	986,893
3	Secondary Facultative Ponds	2	27,530,189	267,283
4	Maturation Ponds	4	55,060,378	534,567
5	Sludge Drying Beds	2	38,118,723	370,085
6	Site and Ancillary Works	-	19,966,950	193,854
		Sub-Total 1	**348,211,512**	**3,380,694**
		Add 7.5% of Sub-Total 1 for Preliminary and General	26,115,863	253,552
		Sub-Total 2	**374,327,375**	**3,634,246**
		Add 10% of Sub-Total 2 for Physical Contingencies	37,432,738	363,425
		Sub-Total 3	**411,760,113**	**3,997,671**
		Add 10% of Sub-Total 3 for Price Contingencies	41,176,011	399,767
		Sub-Total 4	**452,936,124**	**4,397,438**
		Add 10% of Sub-Total 4 for Consultancy	22,646,806	219,872
		GRAND TOTAL INCLUDING PRELIMINARY AND GENERAL, CONTINGENCIES, DUTIES AND TAXES & CONSULTANCY FEES	**475,582,930**	**4,617,310**

10.6 Wastewater Reuse

10.6.1 Justification for Wastewater Reuse

The medium-term and long-term sanitation strategy for Mombasa Island and Mombasa North Mainland entails construction of a combined scheme comprising of a wastewater collection and conveyance systems from the two service areas to 2Nr Wastewater Treatment Plants in Mombasa North Mainland. These Wastewater Treatment Plants (WWTPs), comprising of Waste Stabilization Ponds Systems, are to be sited at Nguu Tatu and Shimo la Tewa and with respective ultimate design capacities (year 2040) of 77,300 m^3/day and 9,900 m^3/day.

Mombasa North Mainland where the Wastewater Treatment Plants are to be located has suppressed water supply considering the population borne and urbanization being experienced. Some of the water uses does not require water of potable standards making the cost incurred in treating water consumed by such uses unjustified. Besides, the implementation and operation of the proposed Wastewater Management Scheme in the Master Plan involves incurring of costs which would require further revenue collection to ease operation and give additional returns for investment. It has been considered that it was uneconomical to convey treated wastewater to Mombasa Island due to the associated high investment and running requirements.

Water reuse from Wastewater Treatment Plants is recommended for potable and non-potable applications if the water quality requirements are attained. It’s thus important to evaluate the feasibility of reusing wastewater in Mombasa North Mainland.

10.6.2 Types of Wastewater Reuse Applications

The main wastewater reuse applications are described below;

10.6.2.1 Agricultural Reuse

The Coastal region of Kenya is an important agro-ecological zone and a water-scarce area. The climatic conditions are of hot lowland humid tropics. The crops commonly cultivated in Mombasa North Mainland include; Mangoes, Cashew nuts, Coconuts, Copra, Cotton, Vegetables, Citrus Trees, Bananas, Macadamia Nuts, etc.

However, commercial farming is not viable mainly because of water scarcity, unproductive soils and to some extent, unfavourable terrains. With the increased water availability and nutrient benefits associated with treated wastewater reuse, it is expected that increased agricultural productivity can be realized.

10.6.2.2 Industrial Reuse

Where they exist, industries consume a significant fraction of bulk water supply. The industrial water demand depends on the scale of industry and the water-consuming processes i.e. whether an industry is water intensive or not.

For water-intensive industries, suppressed water supply limit productivity and increased production can only be attained if additional water supply is developed. This would result to increase in the cost of production.

In the recent past, industries have embraced water reuse in industrial applications such as process water, boiler feed water, cooling processes water, etc.

10.6.2.3 Urban Reuse

A significant portion of bulk water supply is consumed by non-potable water applications which does not necessarily require the enhanced water quality requirement of potable water. To reduce the cost incurred in treating bulk water for public supply, dual distribution systems comprising of separate pipes for potable water and non-potable water are utilized in some developed countries. This system contributes to the conservation of limited water resources.

Wastewater treated by secondary processes and followed by sand filtration and disinfection is commonly used for non-potable purposes such as car washing, garden watering, and firefighting.

Investing in infrastructure for urban water reuse application such as further treatment of wastewater and separate intensive distribution network is not cost effective owing to the inherent high Capital and Operation & Maintenance Expenditures. This would result to exorbitant tariffs on the users and consequently hinder embracement of urban wastewater reuse.

10.6.2.4 Environmental Reuse

Environmental water reuse includes natural/artificial streams augmentation, fountains, recreational features, forests, wetlands and ponds. With increased population and urbanization projected in Mombasa North Mainland, green spaces which serve as natural conservancies and groundwater recharge points get depleted. The reduction in green spaces and conservancies has resulted increased flooding owing to reduced infiltration and groundwater recharge.

Environmental water reuse is thus equally important for Mombasa North Mainland.

Compared to conventional surface water storage, aquifer recharge has negligible evaporation, little secondary contamination by animals, and no algal blooming. Aquifer recharge is also less costly because of minimal pipeline construction involved.

A figure showing three common types of aquifer recharge is given in **Figure 10.9** below.

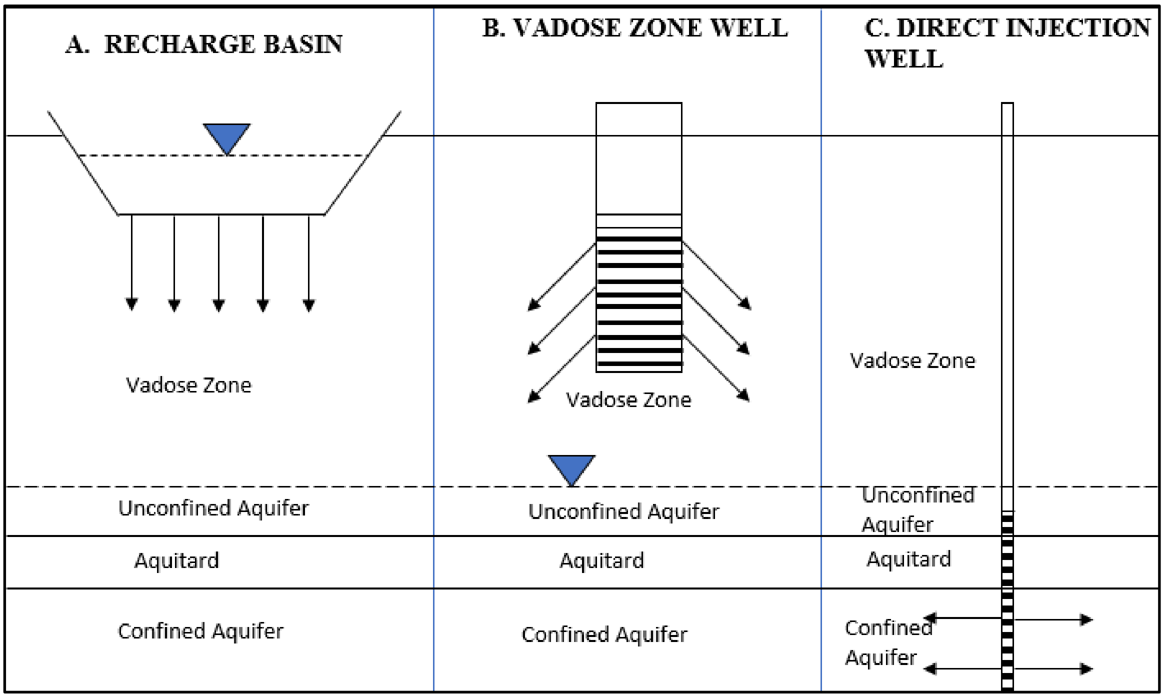


Figure 10.9: Types of Aquifer Recharge

The aquifer recharge types are briefly explained below:

a) Recharge Basin

This requires a wide area with permeable soil, an unconfined aquifer with transmissivity, and an unsaturated (or vadose) zone without restricting layers. With this system, the vadose zone and aquifer work as natural filters and remove suspended solids, organic substances, bacteria, viruses and other microorganisms. In addition, reduction of nitrogen, phosphorus and heavy metals can also be achieved. This process is called soil-aquifer treatment.

b) Direct Injection

This recharge type can access deeper aquifers through an injection well. Direct injection is utilized when aquifers are deep or separated from the surface by an impermeable layer. This method requires less land than the recharge basin methods, but it costs more to construct and maintain.

A well-wall is susceptible to clogging by suspended solids, biological activity or chemical impurities. In this method, the soil aquifer treatment effect is not observed. The method requires advanced pre-treatment of applied water, including sufficient disinfection. Without treatment, the injected wastewater may pollute the aquifer.

c) Vadose Zone Injection

This is an emerging technology that provides some of the advantages of both recharge basins and direct injection wells. It is used when a permeable layer is unavailable at a shallow depth, and a recharge well has relatively large diameter.

Aquifer recharge is important in Mombasa North Mainland for the prevention of groundwater level decline and preservation of the groundwater resource for future use. Besides, water reuse in aquifer recharge will protect groundwater from saltwater intrusion by barrier formation.

10.6.3 Fit-for-Purpose

The adopted wastewater treatment technology and level of treatment attained limits the type of reuse application. While reuse of treated wastewater poses additional financial, technical and institutional challenges, a range of treatment options are available such that any level of water quality required by any reuse application can be achieved.

A summary of levels of wastewater treatment and the appropriate reuse applications is summarized in **Table 10.10** below.

Figure 10.10: Level of wastewater quality

To optimize wastewater reuse and cost reduction potential, appropriate treatment technology and level of treatment should be selected.

The types of reuse technology appropriate for increasing levels of wastewater treatment are summarized in **Table 10.19** on **Page 10-35**

Table 10.19: Types of Reuse appropriate for Increasing Levels of Treatment

Description	Increasing Levels of Treatment →			
	Primary	**Secondary**	**Filtration and Disinfection**	**Advanced**
Level of Treatment	Sedimentation	Biological oxidation and disinfection	Chemical coagulation, biological or chemical nutrient removal, filtration, and disinfection	Activated carbon, reverse osmosis, advanced oxidation processes, soil aquifer treatment, etc.
End Use	No Uses Recommended	Surface irrigation of orchards and vineyards	Landscape and golf course irrigation	Indirect potable reuse including groundwater recharge of potable aquifer and surface water reservoir augmentation and potable reuse
		Non-food crop irrigation	Toilet flushing	
		Restricted landscape impoundments	Vehicle washing	
		Groundwater recharge of non-potable aquifer	Food crop irrigation	
		Wetlands, wildlife habitat, stream augmentation	Unrestricted recreational impoundment	
		Industrial cooling processes	Industrial systems	
Human Exposure	Increasing Acceptable Levels of Human Exposure →			
Cost	Increasing Levels of Cost →			

The wastewater treatment technology selected for the 2Nr Wastewater Treatment Plants in Mombasa North Mainland is the Waste Stabilization Ponds System (WSPs).

The functional units at the WWTP include the following;

a. Inlet works
b. Anaerobic Ponds
c. Facultative Ponds
d. Maturation Ponds
e. Sludge Drying Beds
f. Outfall sewer for discharge to receiving environment or Pumping Main to Treated Wastewater Storage Ponds for Reuse

The treatment processes involved in the WWTP provide treatment of wastewater up to secondary level.

From **Table 10.16** above the potential reuse applications for wastewater which has undergone secondary treatment include;

- Surface irrigation of orchards and vineyards
- Non-food crop irrigation
- Wetlands, wildlife habitat, stream augmentation
- Restricted landscape impoundments
- Groundwater recharge of non-potable aquifer
- Industrial Cooling Processes

10.6.4 Selection of Wastewater Reuse Applications

In the selection of the reuse application for Mombasa North Mainland, it is important to consider the proposed Land-use to guide on the proposed activities and their land allocations. This also helps in delineating the more feasible reuse applications based on proximity to the WWTP.

A layout plan showing the proposed land use for Mombasa North Mainland is given in **Figure 3.5** on **Page 3-14**.

Based on the proposed Land-Use and the quality of treated wastewater discharged from the proposed Wastewater Treatment Plants, three main wastewater reuse applications are feasible in Mombasa North Mainland, i.e., Agricultural, Industrial and Environmental applications.

Details of proposed area allocated for Agricultural, Industrial and Environmental land uses in the year 2040 for Mombasa North Mainland are given in **Table 10.20** below.

Table 10.20: Details of Land for Re-use Application (Year 2040).

	Land Use	Area Allocated (ha)
1.	Agricultural	328
2.	Industrial	44
3.	Environmental	1,551

Based on **Table 10.20** above, the following conclusion can be drawn:

- There exists significant land allocation for Agricultural use in Mombasa North Mainland which if utilized will be source of subsistence and contribute towards socio-economic development of Mombasa North Mainland. Since the agricultural practice is rainfall reliant (rain-fed), productivity can be greatly enhanced if farmers embrace wastewater reuse practice.
- Despite the significant land allocation for industrial use, the industries currently set-up in Mombasa North Mainland are not water intensive. They are also distributed such that implementing a conveyance system would be uneconomical. Besides, high concentration of Total Dissolved Solids (TDS) of wastewater treated by Waste Stabilization Ponds (WSPs) disqualifies the industrial cooling reuse applications based on the possibilities of scale formation and associated blockage effects on the conveyance conduits. Further, the high-water quality requirements for industrial applications such as for food processing, cleaning, etc. are more stringent and un-attainable from the WSPs.
- The areas planned for environmental uses comprises of Recreational, Forest and Water Pond Land Uses. Recreational Land uses in North Mainland is vast and concentrated along the beach. The Forest and Water Pond Land uses are scattered in the service area. Therefore, the Green Space in Mombasa North Mainland can be improved considerably if wastewater reuse for environmental purposes is adopted.

In conclusion, Agricultural and Environmental applications are the most suitable wastewater reuses considering the level of wastewater treatment by the Waste Stabilization Ponds and their land allocation in Mombasa North Mainland.

The volumetric water requirement for wastewater reuse will be determined by the type of crop grown in the service area among other factors.

A schedule of orchards grown in Mombasa North Mainland and their water requirements is given in **Table 10.21** below.

Table 10.21: Water requirements for Orchards

	Cash Crop	Water requirement (m^3/ha/day)
1.	Mango Trees	55
2.	Coconuts	360
3.	Cashew nuts	1545
4.	Citrus	35
5.	Cotton	55
6.	Vegetable	5
7.	Copra	80
8.	Macadamia nuts.	20
9.	Lawn Grass	175

Each of the proposed Wastewater Treatment Plants for Mombasa North Mainland has been analysed separately for suitable water reuse strategy. In each strategy, conveyance is limited to the central Storage Facility from which interested users will construct distribution canals / pipes. Description of the water reuse strategies are given in the following sub-sections;

10.6.5 Re-use for Wastewater Treatment Plant at Nguu Tatu

The wastewater Treatment Plant at Nguu Tatu is located adjacent to vast agricultural land. Therefore, agricultural land-use has been preferred for the wastewater reuse from the WWTP.

During site visits and investigations, it has been established that Mango is one of the predominant orchard type cultivated in the area.

To establish the potential irrigable land in Mombasa North Mainland, the following assumptions have been made;

a. The crop to be cultivated on the irrigated land is mango (water requirement of 55 m^3/ha/day)
b. Only the water requirement for the agricultural reuse application will be conveyed from the WWTP, the rest is to be discharge to the Tudor Creek.
c. Allowance has been made for increased agricultural land through change of land-use especially on the environmental land-use adjacent to proposed agricultural reuse site. It has been assumed that land equivalent to **20%** of the allocated agricultural land will be considered for agricultural reuse purposes from environmental use.
d. Only 80% of the treated wastewater will be available for agricultural reuse in consideration of the losses due to evaporation, seepage and transmission losses.

Thus, the Total Land available for agricultural reuse is given by;

Total Land Available (ha); = 328 ha x 1.2

= 394 ha (**Approx. 400 ha**)

The Net Water Available for agricultural reuse; = 55 m^3/ha/day x 400 ha

= 22,000 m^3/day

Gross Volume of treated Wastewater conveyed for Agricultural reuse is given by;

Volume, V_{AGR} (m^3/day); $= \frac{22{,}000\ m^3/day}{0.8}$

= 27,500 m^3/day

Therefore, it shall be considered that 27,500 m³/day of treated wastewater will be reused for agricultural applications from Nguu Tatu Wastewater Treatment Plant for an estimated 400 Ha.

A layout plan showing the proposed land which can be irrigated through wastewater reuse (400 ha) is shown in **Figure 10.9** on **Page 10-41.**

10.6.5.1 Conveyance and Storage System of wastewater for Reuse

To cover the potential irrigable area of **400 Ha,** the treated wastewater will be conveyed from the Nguu Tatu site, at an elevation of 2 m asl, to a Storage Facility at an elevation of 60 m asl by means of pumping. The distance between these points is approximately 9.0 km.

The Conveyance and Storage system shall comprise of the following components;

a) Pumping Station at the WWTP (Nguu Tatu)
   - Pump Discharge - 2,292 m^3/hr
   - Pumping Head - 102 m
   - Power requirement - 912 kW

b) Rising Main

- Pipe Material - Steel pipe
- Diameter – 700 mm
- Length – 9.0 Km.

c) Lined Storage Pond

- 1.5-m deep well compacted Earth Pond lined with Concrete Slabs (Capacity 22,000 m^3)
- Proposed site; co-ordinates 574564 m E, 9565645 m S
- Land requirement – **3 ha**

d) Overflow Sewer & Manholes

- To connect Lined Storage Pond to the Tudor Creek
- Pipe Details - 750-mm diameter concrete pipe
- Length - approximately 2.5 Km

A layout plan showing the Conveyance and Storage system is shown on **Figure 10.11** on **Page 10-40.**

10.6.5.2 Implementation Costs for the Agricultural Wastewater Reuse Scheme

Capital Cost

The Capital Costs for the Agricultural Reuse Schemes formulated for Nguu Tatu Wastewater Treatment Plant have been worked out on the following basis;

a) Project Implementation to be carried out within the 2040 design horizon
b) The Cost of Civil Works constitute the following fraction of the components total costs;
    - Pumping station – 60%
    - Rising main – 100%
    - Lined Pond (Reuse water reservoir) – 100%

A summary of the Capital Costs for the Agricultural Wastewater Reuse Scheme is given in **Table 10.22** below.

Table 10.22: Capital Cost for Agricultural Wastewater Reuse Scheme – Nguu Tatu Wastewater Treatment Plant

S/No.	Component	Cost, Kshs	Cost, USD
1	**Land Acquisition**	**19,383,333**	**188,188**
2	**Civil Works**	**826,795,377**	**8,027,140**
2.1	Pumping Station	89,021,961	864,291
2.2	Rising Main	363,854,865	3,532,572
2.3	Overflow Sewer & Manholes	151,418,551	1,470,083
2.4	Storage Pond	222,500,000	2,160,194
3	**Electro-Mechanical Works**	**59,347,974**	**576,194**
3.1	Pumping Stations	59,347,974	576,194
	Total Capital Cost	**905,526,685**	**8,791,521**

10.6.5.3 Operation and Maintenance Costs

The Operation and Maintenance Costs for the Scheme have been worked out on the following basis;

a) Electricity Costs at the Pumping Stations assumed to increase annually with increase sewer connections (same rate as population growth rate)
b) Annual Maintenance Costs of the Schemes calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works
c) Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule.

A summary of the Annual Operations & Maintenance Costs for the Scheme in the first year of operation is given in **Table 10.23**.

Table 10.23:Annual Operations & Maintenance Costs

S/No.	Component	Cost, Kshs	Cost, USD [1]
1	Maintenance Costs	14,652,231	142,255
2	Electricity Costs	29,524,461	286,645
3	Staff Costs	960,000	9,320
	Total O & M Cost	**45,136,692**	**438,220**

[1] – 1 USD = 103 Kshs

10.6.5.4 Net Present Value

Net Present Value (NPV) is one of the commonly used criteria for comparing economic viability of projects/Schemes. When the unit NPV of a scheme is derived for the unit of performance indicator, incremental cost (marginal cost) is obtained.

The Net Present Values of the Scheme has been worked out on the following basis;

a) Discount Rate/Cost of Capital – 5%
b) Economic Life of Scheme – 20 years
c) 10 Years Assent Renewal Period for the Electro-Mechanical components
d) Substantial completion of the scheme expected at the end of the 2nd year of implementation of the Medium-Term Plan Works (2023) and thus, scheme operation to commence in the 3rd year (2024)

The Net Present Value for the Agricultural Wastewater Reuse Scheme from Nguu Tatu Wastewater Treatment Plant is **Kshs. 1,643,843,815**.

10.6.5.5 Additional Cost for Wastewater Reuse Scheme

Treated wastewater from Nguu Tatu Wastewater Treatment Plant will be conveyed for agricultural reuse without any advanced tertiary treatment.

However, additional costs are to be incurred in the conveyance and storage.

The unit additional cost has been determined as follows;

- NPV of the Scheme for 20-year period = Ksh. 1,643,843,815
- Gross volume of reuse water pumped from the WWTP per day = 27,500 m^3/d
- Gross volume of reuse wastewater conveyed during 20-year period = 200,750,000 m^3
- Unit additional cost incurred during 20-year period $= \frac{1,643,843,815}{200,750,000}$

= Ksh 8.19 per m^3

Based on the information above, the additional Cost of Conveying and Storing treated wastewater from Nguu Tatu Wastewater Treatment Plant for Agricultural Reuse is; Ksh 8.19 per m^3.

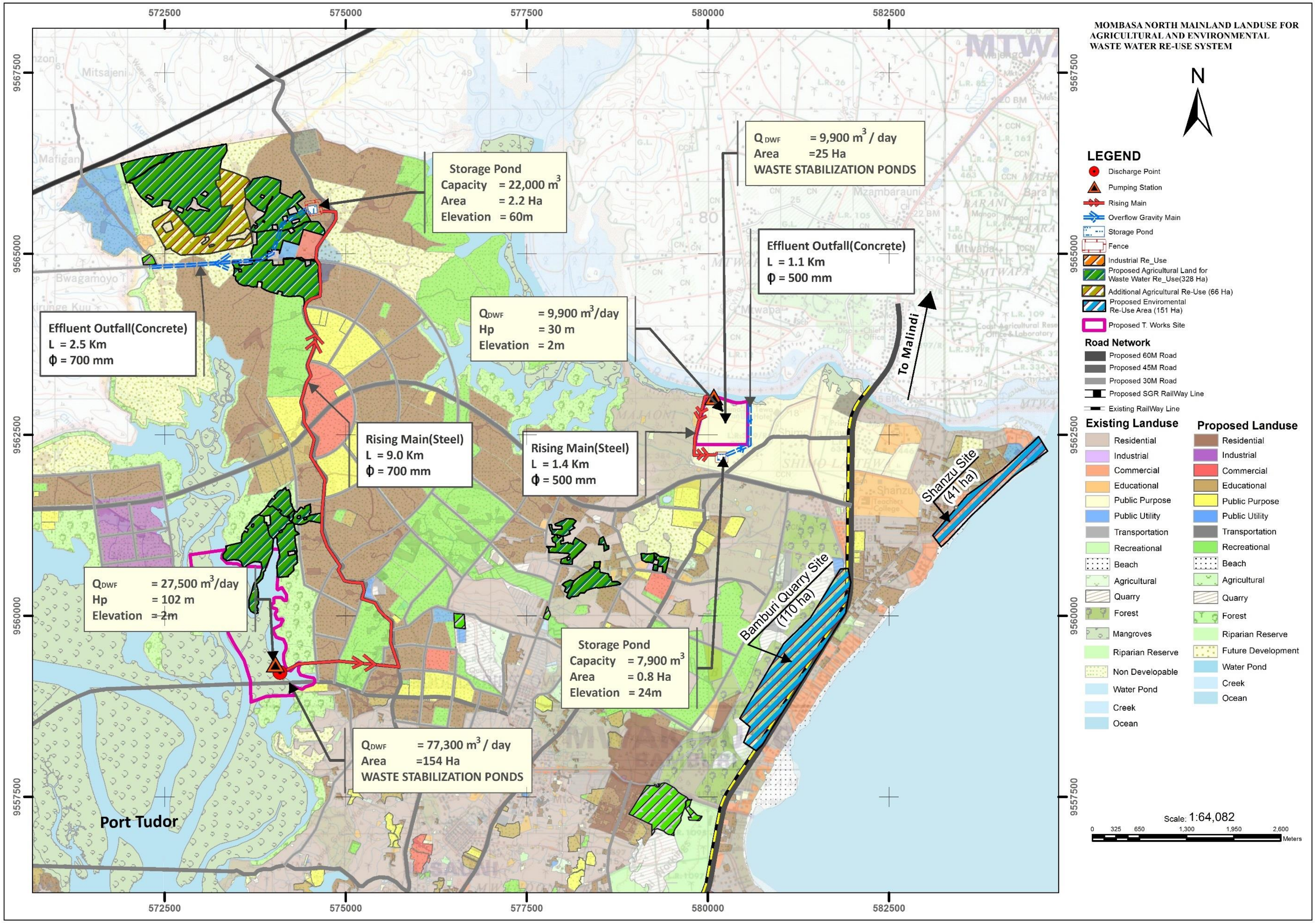


Figure 10.11: Layout Plan of the Conveyance and Storage System for Agricultural Wastewater Reuse – Mombasa North Mainland

10.6.6 Re-use of Wastewater Treatment Plant at Shimo la Tewa

Based on reconnaissance surveys of the Study Area, there exists numerous tourist resorts and a rehabilitated former quarry site (owned by Bamburi) within the proximity of the Proposed WWTP site at Shimo la Tewa (*Ultimate Capacity; 9,900 m³/day*). These sites required non-potable water for landscaping, tree irrigation among other uses. For economic conveyance, environmental reuse application is recommended for treated wastewater from Shimo la Tewa WWTP.

Based on **Table 10.21** on **Page 10-36,** Lawn Grass has been considered as the dominant use in landscaping application while citrus trees have been assumed suitable at the abandoned quarry site. Their water requirement are 175 m³/ha/day and 35 m³/ha/day, respectively.

Assuming equal coverage of the two crops, the average environmental water requirement to be adopted has been worked out as follows;

$$\text{Average Water Requirement for Environmental Reuse} = \frac{(175 + 35)\ m^3/\ ha/day}{2}$$

$$= 105\ m^3/ha/day$$

Consequently, the total land that can be covered by environmental re-use, considering 20% water losses is given by;

$$\text{Total Land Coverage for Environmental reuse} = \frac{(9{,}900\ x\ 0.8)\ m^3/day}{105\ m^3/\ ha/day}$$

$$= 75\ ha$$

The areas earmarked for Environmental wastewater reuse in the Study Area are shown on **Figure 10.11** on **Page 10-40** and a summary of their coverage given in **Table 10.24** below.

Table 10.24: Proposed area for Environmental wastewater re-use.

S/No.	Environmental Reuse Site	Area (ha)	Altitude (m)	Approx. Distance from Storage Pond (m)
1.	Abandoned Bamburi Cement Quarry	110	12	2.7
2.	Tourist Resorts along the Beach	41	6	3.9
	Total Area	**151**		

Thus, more land is available land for environmental re-use (**151 ha**).

10.6.6.1 Conveyance and Storage System of wastewater for Reuse

To cover the potential environmental area of **75 Ha**, the treated wastewater will be conveyed from the Shimo la Tewa WWTP site at an elevation of 2 m asl to a Storage Facility at an elevation of 24 m asl by pumping means. The distance between these points is approximately 1.0 km.

The Conveyance and Storage system shall comprise of the following components;

a) Pumping Station at the WWTP
- Pump Discharge – 825 m³/hr
- Pumping Head - 30 m
- Power requirement - 98 kW.

b) Rising Main
- Pipe Material - Steel pipe
- Diameter – 500 mm
- Length – 1.0 Km.

c) Lined Pond for storage
- 1.5-m deep well compacted Earth Pond and lined with Concrete Slabs (Capacity 7,900 m³)
- Proposed site; co-ordinates 580181 m E, 9562204 m S
- Land requirement – **0.8 ha**

d) Overflow Sewer & Manholes

- To connect Lined Pond to the Tudor Creek.
- Pipe Details - 525-mm diameter concrete pipe
- Length - approximately 1.2 Km

A layout plan showing the Conveyance & Storage system is shown on **Figure 10.11** on **Page 10-40**

10.6.6.2 Implementation Costs for the Agricultural Wastewater Reuse Scheme

Capital Cost

The Capital Costs for the Environmental Reuse Schemes formulated for Shimo la Tewa WWTP have been worked out on the following basis;

a) Project Implementation to be carried out within the 2040 design horizon
b) The Cost of Civil Works constitute the following fraction of the components total costs;
   - Pumping station – 60%
   - Rising main – 100%
   - Lined Pond (Reuse water reservoir) – 100%

A summary of the Capital Costs for the Environmental Wastewater Reuse Scheme is given in **Table 10.25** below.

Table 10.25: Capital Cost for Environmental Wastewater Reuse Scheme – Shimo la Tewa WWTP

S/No.	Component	Cost, Kshs	Cost, USD
1	**Land Acquisition**	**5,010,000**	**48,641**
2	**Civil Works**	**164,335,758**	**1,595,493**
2.1	Pumping Station	11,340,542	110,102
2.2	Rising Main	36,992,801	359,153
2.3	Overflow Sewer & Manholes	34,302,416	333,033
2.4	Storage Pond	81,700,000	793,204
3	**Electro-Mechanical Works**	**7,560,361**	**73,402**
3.1	Pumping Stations	7,560,361	73,402
	Total Capital Cost	**176,906,120**	**1,717,535**

10.6.6.3 Operation and Maintenance Costs

The Operation and Maintenance Costs for the Scheme have been worked out on the following basis;

a) Electricity Costs at the Pumping Stations assumed to increase annually with increase sewer connections (same rate as population growth rate)
b) Annual Maintenance Costs of the Schemes calculated as the sum of 1% of the Costs of the Civil Works and 5% of the Electro-Mechanical Works
c) Replacement of the Electro-Mechanical Items to be carried out every 10 Years with repair works planned for every intermediate 5 years between the replacement schedule.

A summary of the Annual Operations & Maintenance Costs for the Scheme in the first year of operation is given in **Table 10.26** below.

Table 10.26: Annual Operations & Maintenance Costs

S/No.	Component	Cost, Kshs	Cost, USD [1]
1	Maintenance Costs	2,330,997	22,631
2	Electricity Costs	3,158,060	30,661
3	Staff Costs	960,000	9,320
	Total O & M Cost	**6,449,057**	**62,612**

[1] – 1 USD = 103 Kshs

10.6.6.4 Net Present Value

Net Present Value (NPV) is one of the commonly used criteria for comparing economic viability of projects/Schemes. When the unit NPV of a scheme is derived for the unit of performance indicator, incremental cost (marginal cost) is obtained.

The Net Present Values of the Scheme has been worked out on the following basis;

a) Discount Rate/Cost of Capital – 5%
b) Economic Life of Scheme – 20 years
c) 10 Years Assent Renewal Period for the Electro-Mechanical components
d) Substantial completion of the scheme expected at the end of the 2nd year of implementation of the Medium-Term Plan Works (2023) and thus, scheme operation to commence in the 3rd year (2024)

The Net Present Value for the Environmental Wastewater Reuse Scheme from Shimo la Tewa Wastewater Treatment Plant is **Kshs. 270,555,940**.

10.6.6.5 Additional Cost for Wastewater Reuse Scheme

Treated wastewater for reuse in Mombasa North Mainland will be conveyed to the environmental reuse without any advanced tertiary treatment.

However, additional costs are to be incurred in the conveyance and storage.

The unit additional cost has been determined as follows;

- NPV of the Scheme for 20-year period = Ksh. 270,555,940
- Gross volume of reuse water pumped from the WWTP per day = 9,900 m^3/d
- Gross volume of reuse wastewater conveyed during 20-year period = 72,270,000 m^3
- Unit additional cost incurred during 20-year period $= \frac{270,555,940}{72,270,000}$

  = Ksh 1.35 per m^3

Based on the information above, the additional Cost of Conveying and Storing treated wastewater from Shimo la Tewa Wastewater Treatment Plant for Environmental reuse is; Ksh 1.35 per m^3.

10.6.7 Conclusion

The following conclusions are derived from the assessment of Wastewater Reuse in Mombasa North Mainland;

a) Agricultural and Environmental wastewater reuse applications are the most suitable for Mombasa North Mainland.

b) The wastewater reuse applications recommended for Wastewater Treatment Plants at Nguu Tatu and Shimo la Tewa are agricultural and environmental respectively.

c) Additional cost for conveyance and storage of Wastewater Reuse is lower than that of treating and conveying potable water in both cases as described below;
   i. Additional unit cost for conveyance and storage of Agricultural Wastewater Reuse from in Mombasa North Mainland is approximately **Ksh. 8.19 per m^3**
   ii. Additional unit cost for conveyance and storage of Environmental Wastewater Reuse in Mombasa North Mainland is approximately **Ksh. 1.35 per m^3**
   iii. Unit cost of abstracting, treating and conveying potable water is Ksh. **13.62 per m^3** (Feasibility Study for Kapsoya Treatment Work – 2015).

d) Detailed studies/research should be carried out to address the following salient issues;
   i. Tariffs for wastewater reuse;
      - Affordability of Agricultural Wastewater Reuse by farmers
      - Cost of irrigation systems and conveyance to the Farms
   ii. Establishment of reuse policy and qualitative guidelines
   iii. Awareness and cultural acceptance on wastewater reuse through public outreach and education programs.
   iv. Development of Agricultural Wastewater Reuse Management Plan which will include system assessment, quality control and monitoring.

e) Institutional arrangement is vital among CWSB, MOWASSCO, organized community groups and private sector for the success of the Agricultural Wastewater Reuse System.

11.0 FINANCIAL AND ECONOMIC ANALYSIS FOR SELECTED DEVELOPMENT STRATEGY

11.1 Background

This chapter provides results for financial, economic and social analysis for the investments associated with the Mombasa Island and North Mainland Wastewater Management Scheme (Project). The data used in the financial analysis has been sourced from the various studies undertaken in the development of this Master Plan and other relevant Reports.

11.1.1 Water and Sanitation Sector Organization Structure

11.1.1.1 Existing sector policies

Prior to 2002, the performance of the water and sanitation sector in Kenya faced various challenges. Some of the key challenges include;

- lack of a comprehensive policy, institutional and legal framework
- centralized decision making
- lack of adequate financing mechanism

Water Sector reforms were initiated to overcome these challenges and their implementation started in 2001. The reforms have been enforced through enactment of the Water Act 2002 which was done in March 2003.

The Water Act 2002 separated water resources management and water services provision; separated policy and regulation; and decentralized service provision with greater autonomy to the water sector institutions. It gave rise to the institutions such as Water Services Boards (WSBs), Water Service Providers (WSPs), Water Resources Management Authority (WRMA) and Water Services Regulatory Board (WASREB).

The institutional set up under the Water Act 2002 is shown in the **Figure 11.1** below:

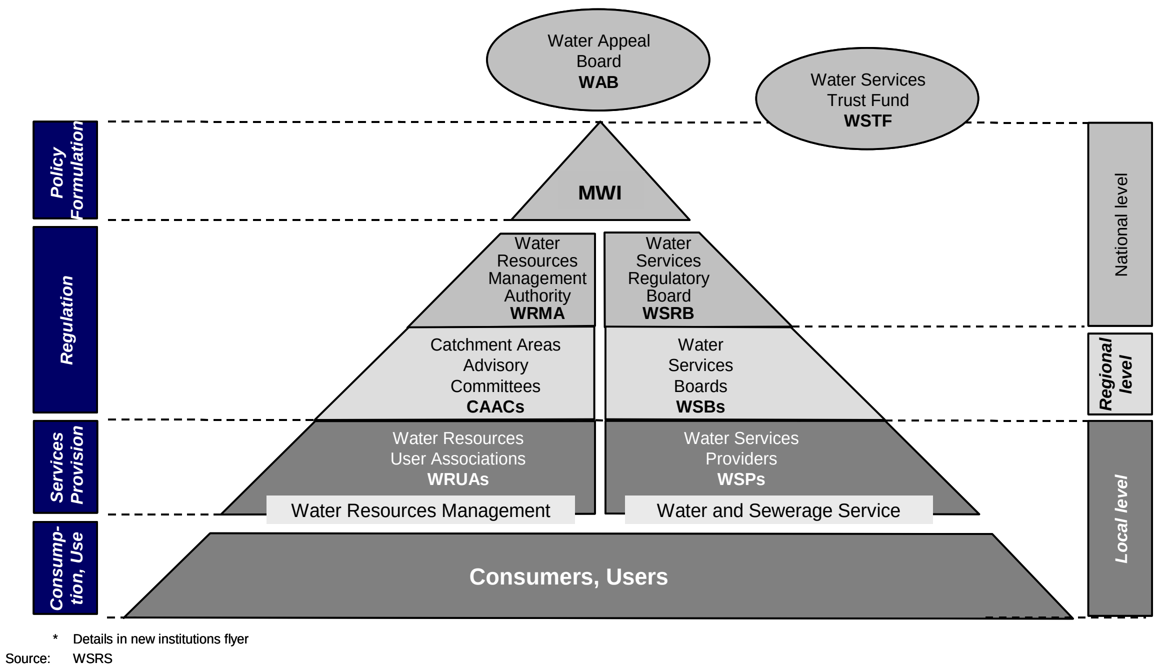


Figure 11.1: Institutional Set-up of Water Act 2002

In this set-up, the relationship between WSB and WASREB is governed through a license issued by WASREB while that between WSB and the WSPs is governed through a service provision agreement in which targets are set for the WSPs.

In the New Constitution dispensation (CoK 2010), water and sanitation services are part of the devolved functions of the 47 county governments. Thus, Water Act 2002 has been reviewed into a new legislation, as Water Act 2016, to be in accordance to the new constitution. Under the New Water Act 2016, Cabinet Secretary is empowered, in consultation with county governments to provide a national water sector investment and financing plan aggregated from the county government plans which shall provide details such as the time frames and the investment programs for the Plans.

The Act also requires the Water Service Boards to be transformed into Waterworks Development Agencies by notice in the Gazette by the Cabinet Secretary.

The powers and functions of the proposed Waterworks Development Agency include:

a) Undertaking the development, maintenance and management of the national public water works within its area of jurisdiction;
b) operating the waterworks and provide water services as a water service provider, until such a time as responsibility for the operation and management of the waterworks are handed over to a county government, joint committee, authority of county governments or water services provider within whose area of jurisdiction or supply the waterworks is located;
c) providing reserve capacity for purposes of providing water services where pursuant to section 103, the Regulatory Board orders the transfer of water services functions from a defaulting water services provider to another licensee;
d) Providing technical services and capacity building to such county governments and water services providers within its area as may be requested; and
e) Providing to the Cabinet Secretary technical support in the discharge of his or her functions under the Constitution and this Act.

11.1.1.2 Status of Water and Sanitation Coverage

Kenya is a water stressed country with a low per capita annual freshwater endowment. Access to water and sanitation is low because of limited water resources development and ageing/dilapidated infrastructure. Access to water and sanitation falls below the Sustainable Development Goal (SDG) targets of universal access. However, some parts of the Country have improved access than others.

Despite increased investments and improvements in levels of access in the last 5 years, the rapid population increase, urbanization and economic growth strain the existing water resources and infrastructure and hinder efforts towards achieving the sector SDGs. Furthermore, catchment degradation has increased the country's vulnerability to climate change with the high inter-annual and intra-annual rainfall variability resulting in frequent and severe droughts and floods. Water security is hence crucial to attainment of Vision 2030 aspirations and sustained economic development.

11.1.1.3 Sector Strategies

After enactment of Water Act 2002, the Ministry of Water and Irrigation (MWI) developed strategic objectives. These include:

i. Accelerating the implementation of water sector reforms
ii. Improving the sustainable management of water resources
iii. Improving the provision of water and sewerage services
iv. Improving utilization of land through irrigation and land reclamation
v. Strengthening institutions in the ministry and the water sector
vi. Mobilizing resources and promoting efficiency in their utilization
vii. Improving the management and access to water resources information

MWI also developed the Water Sector Strategic Plan (WSSP; 2010 – 2015) to ensure that water resources are protected, harnessed and sustainably managed for all competing uses and Strategic Plan (2013-2017) to increase access to clean, safe water and sanitation services.

In addition, the National Water Resources Management Strategy (NWRMS 2010-2016) aims to increase the per capita water storage levels in Kenya from 5.3m^3 to 25m^3 by 2030.

11.1.1.4 Regulation

Among the sector institutions, WASREB is mandated to set rules and enforce standards that guide the sector towards ensuring that consumers are protected and have access to adequate, efficient, affordable and sustainable services. They undertake tariff reviews to ensure cost-recovery for institutions to meet future demands. In efforts of promoting the commercialization of water service delivery, they have permitted private operators to run the urban water utilities.

WRMA issues water permits to the WSBs and monitors their compliance.

11.1.1.5 Coast Water Services Board

The Coast Water Services Board (CWSB) was established through a Gazette Notice No. 1328 of 27th February 2004 to undertake the mandate of WSB in the jurisdiction of the coastal area. CWSB has contracted the Mombasa Water Company (MOWASSCO), Kilifi-Mariakani Water Company (KIMAWASCO), Kwale Water Company (KWAWASCO), Malindi Water Company (MAWASCO), Lamu Water Company (LAWASCO), Taita-Taveta Voi Water Company (TAVEVO) and Tana Water and Sanitation Company (TAWASCO) with the dedicated mandate of water services provision in their respective areas.

The main responsibilities undertaken by CWSB include asset development and supervision of the WSPs. In addition to these, CWSB is currently operating the Bulk Water System while awaiting setting-up and operationalization of Bulk Water Company.

11.1.1.6 Mombasa Water and Sewerage Company Limited

Mombasa Water Supply & Sewerage Company Ltd (MOWASSCO) was established on 24th December 2004 as a limited liability company. At present, the company is owned by the Mombasa County Government.

The mandate of the company is to provide cost effective and affordable quality water and sanitation services in the area of jurisdiction. The Company's mandate includes;

a) Provide quality and economical water and sanitation services to consumers
b) Billing for water and sanitation services and ensure timely collection of revenues
c) Routinely maintain water and sanitation services infrastructure (depending on size of pipe)
d) Ensure compliance with standards and licensing requirements set by CWSB (as stipulated by Service Provision Agreement - SPA)

11.1.2 Tariffs

11.1.2.1 Introduction

Water Tariffs are identical for all the Water Service Providers under contract with CWSB. In cases where the tariff has been increased, approval by WASREB is mandatory. WASREB can also mandate WSB to formulate tariff adjustment.

In February 2010 water tariff adjustment was implemented. Where there is a sewer connection, a surcharge of 75% of the relevant water tariff applies. Other charges associated with tariff include meter rental, tanker water, septic tank evacuation etc.

11.1.2.2 Tariff Adjustments

It is the responsibility of the Water Service Boards (WSBs) and Water Service Providers (WSPs) to set / adjust tariffs in accordance with the costs of operation and maintenance. This is formulated in consideration of the commercial orientations, transparent accounting, long term investment programs, and social and equity aspects.

Tariff adjustments are crucial for full cost recovery of Projects and facilitation of long term infrastructure requirements as envisaged in the vision 2030 e.g. target water and sewer connections.

The tariff adjustment proposed for the WSP should also meet the objectives of economic efficiency, equity, fairness, resource conservation, ease of implementation and political acceptability.

There are three types of tariff adjustments, as described in the Tariff Guidelines:
(i) Regular Tariff Adjustments based on the WSP’s business plan
(ii) Extraordinary Tariff Adjustments when the cost structure undergoes significant changes
(iii) Automatic Tariff Adjustments every 12 months which might be part of a service provision agreement with a WSP

In 2008, an Extraordinary Tariff Adjustment was granted to all WSPs as an interim measure to assist them meet their operation and maintenance costs. Sewer Tariffs are part of the tariff adjustments and is aimed at ensuring full cost recovery for sewerage projects. However, full cost recovery tariffs result to higher sewer tariffs which make the service provision unaffordable for many households.

CWSB proposes a tariff adjustment in 2017 to cater for the increase in operations costs and to allow servicing of the loans used for implementing the infrastructure developments. A more conservative approach would be to increase the sewerage tariff to the level of the water tariff.

Table 11.1: Current and Proposed water and sewerage Tariffs – MOWASSCO

Current Tariff		Proposed Tariffs				
		[2023 – 2025]			[2026 – 2040]	
Consumption Block (m^3)	Water Tariff Kshs/m^3	Consumption Block (m^3)	Water Tariff Kshs/m^3	Sewer Tariff Kshs/m^3	Water Tariff Kshs/m^3	Sewer Tariff Kshs/m^3
Domestic/Residential						
0-6	55	0-6	78.00	62.40	86.67	69.34
7-20	75	7-20	90.29	72.23	130.00	104.00
21-50	97.5	21-50	130.00	104.00	169.00	135.20
51-100	120	51-100	159.34	127.47	208.00	166.40
101-300	165	101-300	185.89	148.71	260.00	208.00
>300	220	>300	200.00	150	280.00	224.00
Commercial/Industrial/Government Institutions						
0-6	55	0-50	75.00	56	83.34	66.67
7-20	75		85.00	64	122.38	97.91
21-50	97.5		105.00	79	136.50	109.20
51-100	120	51-100	140.00	105	182.75	146.20
101-300	165	101-200	180.00	135	251.76	201.41
>300	220	>200	200.00	150	280.00	224.00
Public Boarding Schools/Universities and Colleges						
0-600	40	0-600	85.00	63.75	94.45	75.56
600-1200	50	600-1200	100.00	75	143.98	115.18
>1200	90	>1200	240.00	180	312.00	249.60
Community Water Supply	35		150	112.5	195.81	156.65
Water Kiosks	35		35	26.25	48.95	39.16

Table 11.2: Other charges

Service	Charge in Kshs
Connection fee ½ to 1 inch	2,500
Connection fee 1.5 inch to 3 inches	7,500
Connection fee above 3 inches	15,000
Reconnection fee – normal	500.00 & double deposit for every default to a max of 2.5 time the bill
Reconnection fee – at mains	5,000 and double deposit or the cost of reconnection whichever is higher
Illegal connection-Commercial, Industry, Construction (Fraud)	30,000 and double deposit
Illegal connection (Fraud) – Domestic	15,000 and double deposit
Tanker – 8000 litres	2,500 per tanker supplied within the Mombasa Island and North Mainland
Replacement of stolen or damaged meters	100% of the market cost of the meter
Exhauster services	5,000 for other customers and 4,000 for informal settlements

11.1.3 Mombasa Island and North Mainland Wastewater Management Scheme Development Costs

11.1.3.1 Capital Development cost

The implementation costs of the proposed Wastewater Management Scheme include construction of sewerage system (sewers and pumping stations) and Wastewater Treatment Plants (Capacity at ultimate horizon of year 2040 - 87,300 m³/d). A summary of the capital development cost of the Project is given in **Table 11.3** below.

Table 11.3: Summary of Project Capital Development Costs

Component	Medium term (2021 – 2025), Kshs	Long-term (2026 – 2040), Kshs	Total, Kshs
Land	2,600,000,000	-	2,600,000,000
Sewerage System	5,922,718,083	570,529,932	6,493,248,016
Waste Water Treatment Plant	4,881,359,432	4,357,248,068	9,238,607,500
Total	**13,404,077,515**	**4,927,778,000**	**18,331,855,516**

The above costs include Physical and Price Escalation Contingencies, Taxes and Duties and Preliminary and General Items and Construction Supervision Fees. The total investment for the project is **Kshs. 18,331,855,516.**

11.1.3.2 Operation and maintenance Costs

The Operations and Maintenance costs comprise of Salaries / Wages, Replacement costs, and Electricity Charges. The Operation and Maintenance costs have been determined annually and includes annual increase due to increased sewer connections.

11.1.3.3 Annual Project Expenditures

Considering the Capital and Operations / Maintenance Costs of the Project, a schedule of Annual Project Expenditures has been formulated and is given in **Table 11.4** on **Page 11-6**.

Table 11.4: Schedule of Annual Project Expenditures

Year	Project Cost, Kshs	O&M, Kshs	Depreciation, Kshs	Total Cost, Kshs
2021	3,351,019,379	-	-	3,351,019,379
2022	3,351,019,379	-	259,902,168.21	3,610,921,547
2023	3,351,019,379	314,508,468.77	389,853,252.32	4,055,381,100
2024	3,351,019,379	318,132,004.40	519,804,336.43	4,188,955,720
2025	-	321,864,246.09	519,804,336.43	841,668,583
2026	492,777,800	325,708,455.04	542,269,971.14	1,360,756,226
2027	492,777,800	329,667,990.25	561,379,681.38	1,383,825,472
2028	492,777,800	333,746,311.52	580,489,391.62	1,407,013,503
2029	-	337,946,982.42	580,489,391.62	918,436,374
2030	739,166,700	342,273,673.46	609,153,956.99	1,690,594,331
2031	985,555,600	346,730,165.22	585,805,911.28	1,918,091,677
2032	1,231,944,500	351,320,351.74	572,012,720.70	2,155,277,573
2033	492,777,800	356,048,243.85	529,554,964.76	1,378,381,009
2034	-	360,917,972.73	467,987,498.58	828,905,471
2035	-	365,933,793.47	467,987,498.58	833,921,292
2036	-	371,100,088.83	455,577,887.12	826,677,976
2037	-	376,421,373.06	446,524,200.13	822,945,573
2038	-	381,902,295.81	437,470,513.15	819,372,809
2039	-	387,547,646.25	437,470,513.15	825,018,159
2040	-	393,362,357.20	423,889,982.67	817,252,340
2041	-	393,362,357.20	423,889,982.67	817,252,340
2042	-	393,362,357.20	423,889,982.67	817,252,340
2043	-	393,362,357.20	423,889,982.67	817,252,340
2044	-	393,362,357.20	423,889,982.67	817,252,340
2045		393,362,357.20	374,094,704.24	767,457,061
2046		393,362,357.20	374,094,704.24	767,457,061

11.2 Financial Analysis

11.2.1 Key Assumptions

The following assumptions have been made in the financial analysis:

- The project has an economic life of 30 years
- Two Phases of Implementation: Medium Term (2021 - 2025) and Long-Term (2026 - 2040)
- Project costs incurred based on a disbursement schedule (See Volume 2: Master Plan Annexes);
- Cost of capital (discount factor) assumed to be 5 %
- Main source of revenue is sewer billings
- Sewer connections will increase with the water connections
- 80% of water consumed is converted into wastewater
- Annual increase in Operations and Maintenance Costs throughout the project life
- Assumed Revenue collection efficiency of 90% throughout the period of analysis
- Annual population growth rate of 3.0% up to year 2040
- Average of 6 members per household
- About 60% of health expenditure in Mombasa Island and North Mainland is due to waterborne diseases
- Health expenditure per capita per year assumed to be USD 13 (Kshs. 975).

- By year 2040, the Wastewater Treatment Plant will have treated a cumulative volume of 452,114,504m^3
- Tourists and Visitors to Mombasa Island and North Mainland will increase by 0.1% and result to increase in revenue due to tourism by 0.1% of the current amount generated by tourist per annum.
- Investment comprises 82% civil works and 18% electromechanical.
- Depreciation is on straight line basis, with civil works having a useful life of 40 years and electromechanical 10 years' useful life.

11.2.2 Methodology for Financial Analysis

The financial analysis has been undertaken using project based financial model developed for modelling the financial performance of a Sewerage Project. The Microsoft excel based model incorporates all the important variables of financial performance and spans for a period of 26 years. Its main components include: Investment Cost, Revenue Generated, Operating and Maintenance Cost and other Economic Factors such as Projected Water Demand and Population.

The outputs for the model include the Project Financial Statements and Financial Ratios / Performance Indicators.

In determining the financial viability of the Mombasa Island and North Mainland Wastewater Management System the following activities were undertaken:

(i) identifying and quantifying the costs and revenues
(ii) calculating the project revenues
(iii) Estimating the average incremental financial cost, financial net present value and financial internal rate of return (FIRR)

FIRR is the rate of return at which the present value of the stream of incremental net flows in financial prices is zero. If the FIRR is equal to or greater than the financial opportunity cost of capital, the project is considered financially viable. Thus, financial benefit-cost analysis covers the profitability aspect of the project.

11.2.3 Project Revenues

The projects gross revenues are calculated as the total revenues from sewerage services less billings not recovered while net incomes are calculated as the difference between gross revenues and costs (capital development and O&M costs). A collection efficiency of 90% has been adopted in the analysis.

A summary of the Project Revenues is shown in **Table 11.5** below.

Table 11.5: Summary of Project Revenues

Year	Revenue Generated, Kshs	Collection Efficiency	Average Revenue, Kshs
2023	820,862,528.81	90%	738,776,276
2024	820,862,528.81	90%	738,776,276
2025	1,002,495,388.57	90%	902,245,850
2026	1,002,495,388.57	90%	902,245,850
2027	1,451,640,040.57	90%	1,306,476,037
2028	1,451,640,040.57	90%	1,306,476,037
2029	1,451,640,040.57	90%	1,306,476,037
2030	2,457,689,425.29	90%	2,211,920,483
2031	2,457,689,425.29	90%	2,211,920,483
2032	2,457,689,425.29	90%	2,211,920,483
2033	2,457,689,425.29	90%	2,211,920,483
2034	2,457,689,425.29	90%	2,211,920,483
2035	2,457,689,425.29	90%	2,211,920,483

Year	Revenue Generated, Kshs	Collection Efficiency	Average Revenue, Kshs
2036	2,457,689,425.29	90%	2,211,920,483
2037	2,457,689,425.29	90%	2,211,920,483
2038	2,457,689,425.29	90%	2,211,920,483
2039	2,457,689,425.29	90%	2,211,920,483
2040	4,750,348,173.53	90%	4,275,313,356
2041	4,750,348,173.53	90%	4,275,313,356
2042	4,750,348,173.53	90%	4,275,313,356
2043	4,750,348,173.53	90%	4,275,313,356
2044	4,750,348,173.53	90%	4,275,313,356
2045	4,750,348,173.53	90%	4,275,313,356
2046	4,750,348,173.53	90%	4,275,313,356

11.2.4 Project Financial Statement

The projected Income and expenditure statement for the project is summarized in **Table 11.6** below.

Table 11.6: **Projected Financial Statement of the Project**

Project Income and expenditure Financial statement (Kshs)								
Year	Total Project Revenue	Billings Not Recovered	Net Project Revenue	Operations & Maintenance	Annual Depreciation	Total Expenditure	Net Revenue
2023	820,862,529	82,086,253	738,776,276	314,508,469	389,853,252	704,361,734	34,414,542
2024	820,862,529	82,086,253	738,776,276	318,132,004	519,804,336	837,936,354	-99,160,078
2025	1,002,495,389	100,249,539	902,245,850	321,864,246	519,804,336	841,668,596	60,577,254
2026	1,451,640,041	145,164,004	1,306,476,037	325,708,455	542,269,971	867,978,440	438,497,597
2027	1,451,640,041	145,164,004	1,306,476,037	329,667,990	561,379,681	891,047,686	415,428,351
2028	1,451,640,041	145,164,004	1,306,476,037	333,746,312	580,489,392	914,235,718	392,240,319
2029	1,451,640,041	145,164,004	1,306,476,037	337,946,982	580,489,392	918,436,389	388,039,648
2030	2,457,689,425	245,768,943	2,211,920,483	342,273,673	609,153,957	951,427,646	1,260,492,837
2031	2,457,689,425	245,768,943	2,211,920,483	346,730,165	585,805,911	932,536,092	1,279,384,391
2032	2,457,689,425	245,768,943	2,211,920,483	351,320,352	572,012,721	923,333,088	1,288,587,394
2033	2,457,689,425	245,768,943	2,211,920,483	356,048,244	529,554,965	885,603,225	1,326,317,258
2034	2,457,689,425	245,768,943	2,211,920,483	360,917,973	467,987,499	828,905,488	1,383,014,995
2035	2,457,689,425	245,768,943	2,211,920,483	365,933,793	467,987,499	833,921,309	1,377,999,173
2036	2,457,689,425	245,768,943	2,211,920,483	371,100,089	455,577,887	826,677,994	1,385,242,489
2037	2,457,689,425	245,768,943	2,211,920,483	376,421,373	446,524,200	822,945,591	1,388,974,891
2038	2,457,689,425	245,768,943	2,211,920,483	381,902,296	437,470,513	819,372,828	1,392,547,655
2039	2,457,689,425	245,768,943	2,211,920,483	387,547,646	437,470,513	825,018,178	1,386,902,304
2040	4,750,348,174	475,034,817	4,275,313,356	393,362,357	423,889,983	817,252,359	3,458,060,997
2041	4,750,348,174	475,034,817	4,275,313,356	393,362,357	405,782,609	799,144,986	3,476,168,370
2042	4,750,348,174	475,034,817	4,275,313,356	393,362,357	383,148,391	776,510,769	3,498,802,587
2043	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,082	3,507,856,274
2044	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,083	3,507,856,273
2045	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,084	3,507,856,273
2046	4,750,348,174	475,034,817	4,275,313,356	393,362,357	374,094,704	767,457,084	3,507,856,272

The Key outputs of the Financial Analysis Model include the Benefit Cost (BC) ratio and Discounted Measures such as Net Present Value (NPV) and Financial Internal Rate of Return (FIRR).

A summary of these key outputs is described in the subsequent sub-sections while the detailed results for the analysis are presented in **Volume 2: Master Plan Annexes**.

11.2.5 Cost Benefit Analysis

The benefit cost (BC) ratio of the project was computed using the following formula:

BC Ratio = present value of the project revenues/ project investment cost

From the analysis, the BC ratio for the project is **1.47** with an assumed discounting rate of 5%. However, at discounting rates of 8%, the resulting BCs are **1.14.** These BC ratios are greater than 1 and indicate that the project is financially viable at a cost of capital less than 10%

11.2.6 The Net Present Value (NPV)

From the Financial Analysis, the NPV values for the project are **Ksh7,611,825,333** at 5% cost of capital and **Kshs 1,758,548,750** at 8% cost of capital. The positive NPVs suggest that the project is financially viable at a cost of capital less than 10%.

11.2.7 Financial Internal Rate of Return

The Financial Internal Rate of Return (FIRR) for the project is **9.70%** This FIRR is greater than the assumed cost of capital of 5% and confirm project viability.

11.2.8 Sensitivity Analysis

The project's financial ratios have been subjected to sensitivity analysis as follows:

Scenario 1: 20% shocks

- 20% increase in investment cost
- 20 % decrease in revenues
- 20% increase in operation and maintenance costs

Scenario 2: 10% shocks

- 10% increase in investment cost
- 10 % decrease in revenues
- 10% increase in operation and maintenance costs

A summary of the Sensitivity Analysis is given in **Table 11.7** below

Table 11.7: Summary of Sensitivity Analysis

Type of Variation	NPV (KSHS)	FIRR (%)
20 % shocks		
Increasing the project cost by 20%	-1,947,461,430	8%
Reducing the total net income by 20%	-2,289,557,926	7%
Increasing O&M cost by 20%	-1,088,492,087	9%
10 % shocks		
Increasing the project cost by 10%	-1,090,355,644	9%
Reducing net income by 10%	-1,261,403,892	8%
Increasing O&M cost by 10%	-641,433,649	9%

The results on **Table 11.7** above show that the project's viability is affected when subjected to variations of 10% and of 20% in increase in project cost, reduction in net income and increase in O&M cost.

11.2.9 Conclusion of Financial Analysis

The results of the cost-benefit analysis confirm that the project has favourable BC ratios of between **1.14** to **1.47** The financial analysis confirms that the project has positive NPV of **Kshs 7,611,825,333** at 5% cost of capital and **Kshs 1,758,548,750** at 8% cost of capital and Financial Internal Rates of Return (FIRR) of **9.70%.**

Sensitivity analyses also indicate that the project viability is susceptible to shocks of 10% and 20% increase in O&M and project costs and reduction in net income.

It can therefore be concluded that the Project is financially viable.

11.3 Economic Analysis

11.3.1 General

This sub-section presents the economic analysis of the selected Wastewater Management Scheme for Mombasa Island and North Mainland. It is envisaged that the goal of the Project comprises of improved health and living conditions, reduction of poverty, increased productivity and economic growth of the Project Area.

The purpose of the economic analysis of projects is to inform a better allocation of scarce resources. Detailed results of the analysis of the analysis are given in Volume 2 of this Report.

11.3.2 Methodology

The assessment is based on the analysis of the economic impacts and returns in the conventional cost benefit approach i.e. the Capital and Operational and Maintenance Costs in economic terms over the project life are compared to the Economic Benefits of increased Sanitation Services.

To assess the economic viability of the project, the following steps have been undertaken:

i. Costs and benefits were identified and quantified (in physical terms).
ii. Costs and benefits were valued to the extent feasible, in monetary terms; and
iii. Economic Internal Rate of Return (EIRR) or Economic Net Present Value (NPV) discounted at Economic Opportunity Cost of Capital (EOCC) of 5%, 10% and 12% by comparing benefits with the costs

The EIRR is the rate of return for which the present value of the net benefit stream becomes zero, or at which the present value of the benefit stream is equal to the present value of the cost stream. For a project to be acceptable, the EIRR should be greater than the EOCC.

The weighted average cost of capital for the CWSB area is approximately 3%. The analysis has adopted 5% as the minimum rate of return since the projects are assumed to have considerable non-quantifiable benefits.

11.3.3 Key Assumptions

The assumptions considered under Financial Analysis applies for the Economic Analysis (Refer to **Sub-section 11.2.1**).

11.3.4 Capital Development Cost

The capital development costs adopted in the economic analysis are summarized in **Table 11.8** below:

Table 11.8: Schedule of Capital Development Costs

Implementation Period	Distribution of Investments	Percentage of Disbursement	Sewerage system	Waste Water Treatment plant	Land
2021	Medium Term Investment	25%	1,480,679,520.86	1,220,339,857.95	650,000,000.00
2022		25%	1,480,679,520.86	1,220,339,857.95	650,000,000.00
2023		25%	1,480,679,520.86	1,220,339,857.95	650,000,000.00
2024		25%	1,480,679,520.86	1,220,339,857.95	650,000,000.00
2026	Long Term Investment	10%	57,052,993.22	435,724,806.83	-
2027		10%	57,052,993.22	435,724,806.83	-
2028		10%	57,052,993.22	435,724,806.83	-
2030		15%	85,579,489.83	653,587,210.24	-
2031		20%	114,105,986.44	871,449,613.65	-
2032		25%	142,632,483.06	1,089,312,017.07	-
2033		10%	57,052,993.22	435,724,806.83	-
Total		**18,331,855,515.72**	**6,493,248,015.64**	**9,238,607,500.08**	**2,600,000,000.00**

11.3.5 Project Expenditures

The annual cash flows for the capital and O&M cost is summarized in **Table 11.9** below.

Table 11.9: Schedule of Project Expenditures

	Costs (Ksh)		
Year	**Capital Cost**	**O & M costs**	**Total cost**
2021	3,351,019,379	-	3,351,019,379
2022	3,351,019,379	-	3,351,019,379
2023	3,351,019,379	318,132,004	3,669,151,383
2024	3,351,019,379	321,864,246	3,672,883,625
2025	-	325,708,455	325,708,455
2026	492,777,800	329,667,990	822,445,790
2027	492,777,800	333,746,312	826,524,112
2028	492,777,800	337,946,982	830,724,782
2029	-	342,273,673	342,273,673
2030	739,166,700	346,730,165	1,085,896,865
2031	985,555,600	351,320,352	1,336,875,952
2032	1,231,944,500	356,048,244	1,587,992,744
2033	492,777,800	360,917,973	853,695,773
2034	-	365,933,793	365,933,793
2035	-	371,100,089	371,100,089
2036	-	376,421,373	376,421,373
2037	-	381,902,296	381,902,296
2038	-	387,547,646	387,547,646
2039	-	393,362,357	393,362,357
2040	-	393,362,357	393,362,357
2041	-	393,362,357	393,362,357
2042	-	393,362,357	393,362,357
2043	-	393,362,357	393,362,357
2044	-	393,362,357	393,362,357
2045	-	393,362,357	393,362,357
2046	-	393,362,357	393,362,357

11.3.6 Conversion to Economic Prices

The capital cost has been converted to their economic prices in real 2016 price terms. This excludes: Sunk Costs, Working Capital, Transfer payments such as Taxes, duties and subsidies, External Costs and Depreciation.

11.3.7 Water and Wastewater projections

Table 11.10 on **Page 11-12** shows the projections of water demand and supply, and wastewater generation under both ideal and realistic situations of water supply and sewer connections.

Table 11.10: Projected Water and Wastewater conditions

Scenario	2009	2015	2020	2025	2030	2040
	m^3/d					
Projected Water Demand	86,951	68,905	79,880	94,509	109,562	147,242
Projected Water Supply	32,004	20,766	24,069	29,726	51,640	101,578
Wastewater Generation with Regular Water Supply & 100% Sewer Connections	75,314	59,997	69,302	81,703	94,464	126,409
Wastewater Generation with projected build-out of Sewer Connections and Suppressed Water Supply	-	19,019	21,799	26,623	45,074	87,121

In the Economic Analysis, the projected wastewater generation with the projected build-out of Sewer Connections and Suppressed Water Supply has been adopted.

11.3.8 Future without project situation

Mombasa Island and North Mainland currently lacks a functional water-borne sewerage system. If the proposed wastewater management strategy is not implemented, the service area will continue to rely on the on-plot sanitation systems such as septic tanks and latrines. These systems are unsustainable and pose hazard to both the public health and the environment resulting to pollution of water bodies (ocean and rivers) and increased occurrence of water-borne diseases.

11.3.9 Valuation of benefits

11.3.9.1 Improvement of water bodies (non-use value)

Tourism is the main economic activity in Mombasa Island and North Mainland. At present, raw sewage is released into the environment including water bodies such as the ocean beaches. The implementation of the proposed wastewater management system will ensure proper treatment and disposal of wastewater and result to clean and more attractive beaches with the effect of boosting the economy of Mombasa Island and North Mainland through increased number of visiting tourists and investors.

It has been assumed that the tourists and visitors to Mombasa Island and North Mainland will increase by 0.1% and increase the revenue for the beaches by 0.1% of the tourist spend per annum.

The resulting benefits have been calculated based on the following variables & their assumed values;

- Number of Tourists and Visitors Per Month (N) - 50,000
- Average expenditure per day in in USD - 200
- Exchange rate USD to Kshs (E) - 101
- Number of Month in a year (M) - 12
- Percentage contribution - 0.10%

Total expenditure by tourists & visitors = (50,000*200*101*12) *0.1% = **Ksh. 12,120,000** p.a.

11.3.9.2 Health Benefits

Improved sanitation systems are expected to generate significant health benefits to be measured by the reduction in waterborne sickness and thereby reduced household expenditure in health, reduced work day losses from sickness or by having to care for the sick family members.

In the economic analysis, it has been assumed that about 60% of health expenditure in Mombasa Island and North Mainland results from waterborne diseases and health expenditure per capita per year is USD 13 (Kshs. 975).

11.3.10 Results of Economic Analysis

The Key outputs of the model are the Cost Benefit Cash Flow, Net Present Value and Economic Internal Rate of Return (EIRR). Details of these outputs are given in following sub-sections.

11.3.10.1 Cost Benefit Cash Flow Summary

Results of Cost and Benefit Cash Flows are presented in **Table 11.11** on **Page 11-13.**

Table 11.11: Summary of Cost Benefit Cashflow

Year	Investment Costs (Kshs)			Monetary value of Benefits (Kshs)						Population Served
	Sewerage Capital Cost	O & M costs	Total cost	Incremental Revenue	Improvement of water bodies (non-use value)	Cost Savings in terms of Health Benefits	Total Benefit	Net economic benefits 12%	Net economic benefits 10%	
2021	3,351,019,379	-	3,351,019,379	-	12,120,000	354,775,061	366,895,061	-2,984,124,317	-2,984,124,317	606,453
2022	3,351,019,379	-	3,351,019,379	768,327,327	12,120,000	365,418,313	1,145,865,640	-2,519,662,207	-2,519,662,207	624,647
2023	3,351,019,379	318,132,004	3,669,151,383	768,327,327	12,120,000	376,380,863	1,156,828,190	-2,512,323,194	-2,512,323,194	643,386
2024	3,351,019,379	321,864,246	3,672,883,625	938,335,684	12,120,000	387,672,288	1,338,127,972	-2,334,755,653	-2,334,755,653	662,688
2025	-	325,708,455	325,708,455	1,358,735,078	12,120,000	399,302,457	1,770,157,535	1,444,449,080	1,444,449,080	682,568
2026	492,777,800	329,667,990	822,445,790	1,358,735,078	12,120,000	411,281,531	1,782,136,609	959,690,818	959,690,818	703,045
2027	492,777,800	333,746,312	826,524,112	1,358,735,078	12,120,000	423,619,977	1,794,475,055	967,950,943	967,950,943	724,137
2028	492,777,800	337,946,982	830,724,782	1,358,735,078	12,120,000	436,328,576	1,807,183,654	976,458,872	976,458,872	745,861
2029	-	342,273,673	342,273,673	2,300,397,302	12,120,000	449,418,433	2,761,935,735	2,419,662,062	2,419,662,062	768,237
2030	739,166,700	346,730,165	1,085,896,865	2,300,397,302	12,120,000	462,900,986	2,775,418,288	1,689,521,423	1,689,521,423	791,284
2031	985,555,600	351,320,352	1,336,875,952	2,300,397,302	12,120,000	476,788,016	2,789,305,318	1,452,429,366	1,452,429,366	815,022
2032	1,231,944,500	356,048,244	1,587,992,744	2,300,397,302	12,120,000	491,091,656	2,803,608,958	1,215,616,214	1,215,616,214	839,473
2033	492,777,800	360,917,973	853,695,773	2,300,397,302	12,120,000	505,824,406	2,818,341,708	1,964,645,935	1,964,645,935	864,657
2034	-	365,933,793	365,933,793	2,300,397,302	12,120,000	520,999,138	2,833,516,440	2,467,582,647	2,467,582,647	890,597
2035	-	371,100,089	371,100,089	2,300,397,302	12,120,000	536,629,112	2,849,146,414	2,478,046,326	2,478,046,326	917,315
2036	-	376,421,373	376,421,373	2,300,397,302	12,120,000	552,727,986	2,865,245,288	2,488,823,915	2,488,823,915	944,834
2037	-	381,902,296	381,902,296	2,300,397,302	12,120,000	569,309,825	2,881,827,127	2,499,924,832	2,499,924,832	973,179
2038	-	387,547,646	387,547,646	2,300,397,302	12,120,000	586,389,120	2,898,906,422	2,511,358,776	2,511,358,776	1,002,375
2039	-	393,362,357	393,362,357	4,446,325,890	12,120,000	603,980,794	5,062,426,684	4,669,064,327	4,669,064,327	1,032,446
2040	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
2041	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
2042	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
2043	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
2044	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
2045	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
2046	-	393,362,357	393,362,357	4,446,325,890	12,120,000	622,100,217	5,080,546,108	4,687,183,751	4,687,183,751	1,063,419
							NPV	**1,188,043,219**	**3,061,239,678**	
							ERR	**14%**	**14%**	

11.3.10.2 The Net Present Value (NPV)

The NPV values for the project with resource savings (economic benefits included) at 10% and 12% cost of capital are **Kshs 3,061,239,678** and **Kshs 1,188,043,219** respectively. These suggest that the project is economically viable.

11.3.10.3 Economic Internal Rate of Return

Economic Internal Rate of Return (EIRR) for the project while considering the resource savings results to an economic rate of return (EIRR) of **14%** for both 12% and 10% discount rates. These confirm that the project is economically viable.

11.3.11 Conclusion of Economic Analysis

The results of the economic analysis after including other economic benefits showed that the project have a **positive NPV of Kshs 3,061,239,678** and **EIRR of 14% at 10% cost of capital.**

These indicators confirm that the project is economically viable.

12.0 RECEIVING ENVIRONMENT AND MONITORING PROGRAM

12.1 Introduction

The proposed combined Wastewater Management Scheme for Mombasa Island and Mombasa North Mainland involves wastewater collection and conveyance system from the service areas and 2 Nr Decentralized Wastewater Treatment Plants at Nguu Tatu and Shimo la Tewa Areas. These locations of the Wastewater Treatment Plants have been selected in consideration of the proximity of effluent discharge to natural water courses among other factors. Thus, the effluent discharge from Nguu Tatu and Shimo la Tewa sites are to be conveyed ultimately to adjacent creeks of Tudor, Makupa and Mtwapa, which form the future receiving environments of the proposed Wastewater Treatment Plants (WWTPs).

The aims of this Chapter include to:

- Describe the background condition of waterways in the receiving environment, including a description of key 'background' (i.e. without impacts from the proposed discharges) water quality characteristics
- Describe the environmental values (EVs) and water quality objectives (WQOs) with respect to NEMA Standards of the receiving environment
- Identify and describe the extent of any adverse environmental impacts to local environmental values
- Monitor any changes in the receiving water

Many processes in a Wastewater Treatment Plant are designed to mimic the natural treatment processes that occur in the environment, whether that environment is a natural water body or the ground. If not overloaded, bacteria in the environment will consume organic contaminants, although this will reduce the levels of oxygen in the water and may significantly change the overall ecology of the receiving water. Native bacterial populations feed on the organic contaminants, and the numbers of disease-causing microorganisms are reduced by natural environmental conditions such as predation or exposure to ultraviolet radiation. Consequently, in cases where the receiving environment provides a high level of dilution, a high degree of wastewater treatment may not be required. However, recent evidence has demonstrated that very low levels of specific contaminants in wastewater, including hormones and synthetic materials such as phthalates that mimic hormones in their action, can have an unpredictable adverse impact on the natural biota and potentially on humans if the water is re-used for drinking water.

In addition, Wastewater Treatment Plants can have multiple effects on nutrient levels in the water that the treated wastewater flows into. These nutrients can have large effects on the biological life in the water in contact with the effluent.

12.2 Preliminary Environmental Values and Water Quality Objectives

The list of preliminary environmental values (EVs) that apply to the receiving environment include the following:

- Aquatic ecosystem (slightly to moderately disturbed)
- Stock watering
- Drinking water
- Primary, secondary and visual recreation
- Cultural and spiritual values

Confirmation of the EVs for the receiving environment will be sought during the Detailed Environment and Social Impact Assessment Studies. However, during the implementation and o operation phases of the proposed strategy, monitoring of the receiving environment is important.

12.3 Background Water Quality

Background water quality is critical in the monitoring of the receiving environment and in the assessment of the impacts of the effluent discharge from the proposed Wastewater Treatment Plants over time.

The most recent surveys of these receiving environments were undertaken as a part of the Preliminary Environmental and Social Impact Assessment (ESIA). The ESIA involved survey of the Alternative Wastewater Treatment Plant sites and the receiving waters for aquatic habitat, water quality, macrophytes, and fish.

The data collected during the ESIA was corroborated with those obtained from the relevant government agencies charged with the responsibility of analysing and monitoring the water bodies which form the receiving environment of this Wastewater Management Scheme.

The location of the proposed Wastewater Treatment Plants and the sampling stations of the receiving environment within the creeks of Tudor, Makupa and Mtwapa are shown on **Figure 12.1 on Page 12-3.**

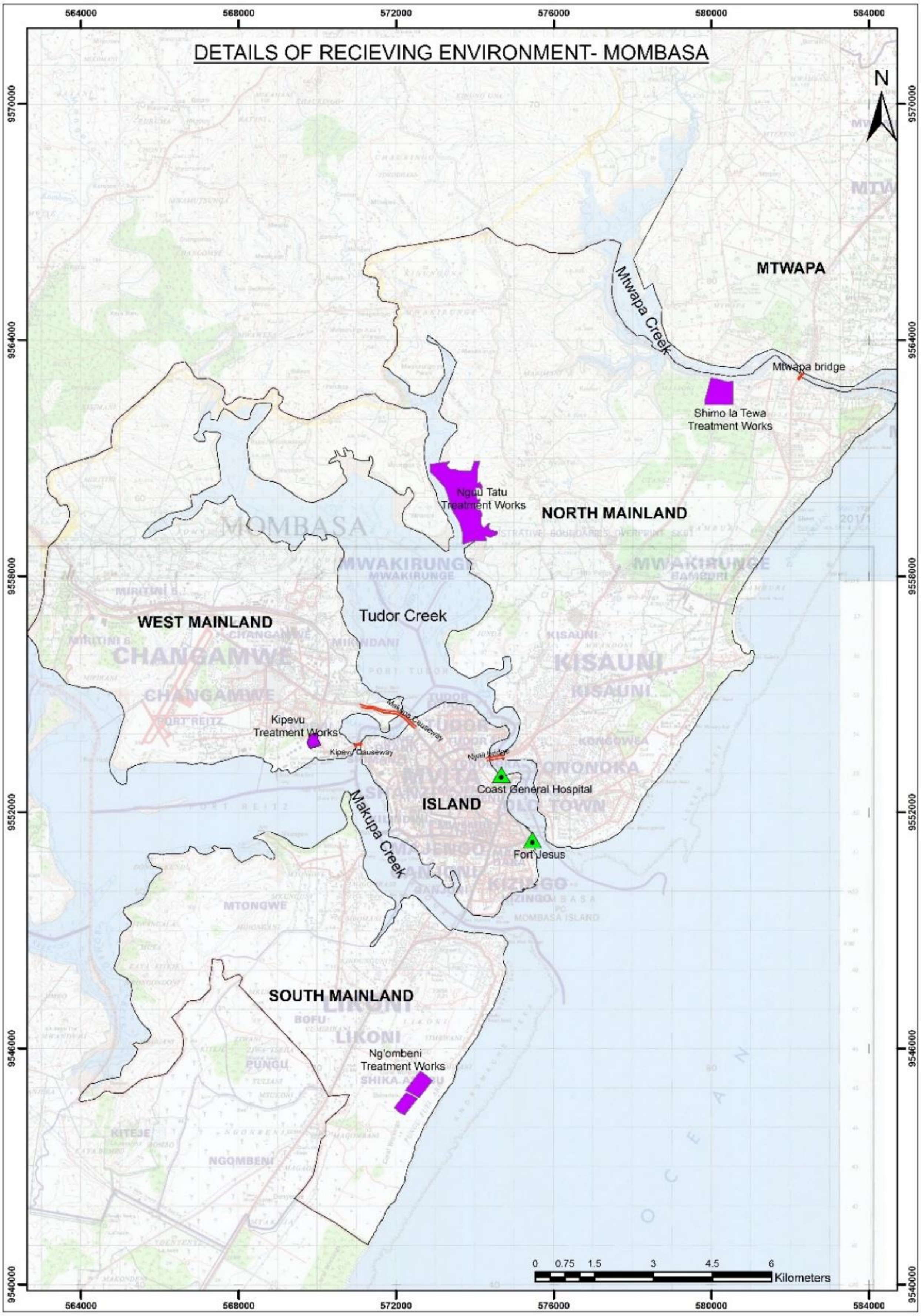


Figure 12.1: Locations of proposed WWTP and sampling stations for receiving environment

Summaries of the water quality at the sampling stations within the Creeks of Mtwapa, Tudor and Makupa are given in **Table 12.1** below, **Table 12.2** on **Pages 12-5** and **12-6** and **Table 12.3** on **Page 12-7** respectively.

Table 12.1: Background Water Quality – Mtwapa Creek

Station	variable/Year	2009		2010		2011		2013		2014	
		Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV	Mean	STDEV
Mtwapa Mouth	Water temp			25				30		26.23	1.570
	Sal PSU)			35							
	Secchi(m)			4.1	0.794			12.65	1.202	3.533	1.762
	DO mg/L	6.25	0.354	5.559	0.329	4.117	0.126	4.1		6.773	0.360
	BOD5-mg/L	3.973	0.654	3.673	0.648	4.240	0.445	3.28		3.147	0.720
	TSS (mg/l)	0.004	0.000	28.83	7.679	32.00	0.000	31.7		0.034	0.004
	Chl-a (mg/l)	1.726	0.105	5.181	4.714	0.221	0.000	3.9			
	Ammonia (mg/l)	0.011	0.004	0.018	0.014	0.007	0.008	0.0404	0.000	22.95	34.31
	Nitrate& Nitrite (mg/l)	0.014	0.005	0.037	0.033	0.003	0.000	0.0050	0.000	58.39	61.97
	Phosphate (mg/l)	0.012	0.008	0.018	0.019	0.055	0.008	0.1391	0.005	38.62	73.15
	pH									8.250	0.115
	OM mg/L									0.007	0.000
Mtwapa Bridge	Water temp			26.17	0.289			30		26.27	1.206
	Sal PSU)			34.33	1.155						
	Secchi (m)			1.833	0.289			2.975	0.318	1.080	0.823
	DO mg/L	6.3	0.2646	5.382	0.350			4.3		6.080	0.429
	BOD5-mg/L	5.1733	1.1238	4.253	0.462			3.44		2.880	0.429
	TSS (mg/l)	0.0027	0.0006	36.67	20.29			37.2		0.163	0.199
	Chl-a (mg/l)	1.4213	0.3416	6.477	3.753			5.2			
	Ammonia (mg/l)	0.0115	0.0053	0.013	0.010	0.0110	0.0025	0.040	0.000	24.93	37.40
	Nitrate& Nitrite (mg/l)	0.0524	0.0185	0.057	0.035	0.0106	0.0015	0.0078	0.000	73.61	71.99
	Phosphate (mg/l)	0.0116	0.0048	0.020	0.019	0.0185	0.0242	0.1331	0.004	27.58	25.23
	pH									8.130	0.114
	OM mg/L									0.316	0.007
Mtwapa Prison	Water temp			25	0			30		26.13	1.026
	Sal PSU)			30.67	4.933						
	Secchi(m)			0.950	0.910			3.225	0.389	1.200	1.015
	DO mg/L	5.9667	0.4041	5.910	0.543	3.7	0.1803	3.9		5.520	0.644
	BOD5-mg/L	4.4800	0.5769	4.573	0.680	4.533	0.0462	3.04		2.320	0.683
	TSS (mg/l)	0.0020	0.0000	36.33	9.626	49.00		32		0.268	0.365
	Chl-a (mg/l)	1.9192	0.1270	4.958	4.496	0.9156		5.8			
	Ammonia (mg/l)	0.5979	1.1206	0.018	0.016	0.0098	0.0056	0.0482	0.000	28.84	42.99
	Nitrate& Nitrite (mg/l)	0.1509	0.1780	0.056	0.032	0.0093	0.0004	0.0085	0.000	81.83	83.12
	Phosphate (mg/l)	0.2967	0.5158	0.110	0.211	0.0079	0.0063	0.1339	0.003	203.9	547.6
	pH									8.147	0.118
	OM mg/L									0.620	0.184
Mtwapa Ferry	Water temp	25.667	0.577	25.67	0.577			30		26.57	1.358
	Sal PSU)	34.000	1.000	34.00	1.000						
	Secchi(m)	1.233	0.208	1.233	0.208			3	0.141	1.100	1.082
	DO mg/L	6.481	0.238	6.481	0.238			4.2		5.920	0.624
	BOD5-mg/L	4.493	0.366	4.493	0.366			3.28		2.453	0.503
	TSS (mg/l)	35.000	11.367	35.00	11.37			42.8		0.244	0.328
	Chl-a (mg/l)	6.628	4.888	6.628	4.888	0.000	0.000	6.3			
	Ammonia (mg/l)	0.015	0.026	0.015	0.026	0.012	0.004	0.0398	0.001	27.94	41.83
	Nitrate& Nitrite (mg/l)	0.041	0.015	0.041	0.015	0.011	0.002	0.0066	0.001	54.35	54.79
	Phosphate (mg/l)	0.020	0.017	0.020	0.017	0.007	0.002	0.1301	0.004	22.94	23.53
	pH									8.117	0.112
	OM mg/L									0.567	0.118

Table 12.2: Background Water Quality – Tudor Creek

Station	Variable/Year	2009	STDEV	2010	STDEV	2011	STDEV	2013	STDEV	2014	STDEV
		Mean		Mean		Mean		Mean		Mean	
Fort Jesus	Water temp			27.00				29.50		26.07	0.945
	Sal PSU)			35.00							
	Secchi (m)							7.655	0.771	3.193	1.700
	DO mg/L			6.646	1.175	4.283	0.058	4.600		6.827	0.360
	BOD5-mg/L			4.867	0.587	5.147	0.281	3.600		2.747	0.765
	TSS (mg/l)			32.83	9.968	35.00		35.50		0.058	0.045
	Chl-a (mg/l)			5.751	5.617	3.502		3.200			
	Ammonia (mg/l)			0.016	0.017	0.048	0.009	0.040	0.001	15.09	26.03
	Nitrate& Nitrite (mg/l)			0.095	0.098	0.027	0.015	0.006	0.000	26.12	22.67
	Phosphate (mg/l)			0.012	0.006	0.005	0.003	0.120	0.000	25.73	20.47
	pH									8.133	0.015
	OM mg/L									0.012	0.009
Madobeni	Water temp			28.00				29.50		26.03	0.929
	Sal PSU)			35.00							
	Secchi (m)			0.300				6.800	0.424	2.100	1.273
	DO mg/L			7.009	1.276	4.450	0.265	3.000		6.133	0.413
	BOD5-mg/L			5.520	0.933	5.227	0.395	4.400		3.440	1.102
	TSS (mg/l)			37.83	7.935	53.00		37.60		0.039	0.009
	Chl-a (mg/l)			5.254	4.773	1.529		10.60			
	Ammonia (mg/l)			0.346	0.490	0.177	0.022	0.040	0.001	23.36	34.85
	Nitrate& Nitrite (mg/l)			0.409	0.415	0.009	0.004	0.006	0.000	39.43	38.22
	Phosphate (mg/l)			0.195	0.287	0.033	0.008	0.135	0.006	38.56	34.40
	pH									8.183	0.047
	OM mg/L									0.009	0.003
Coast General	Water temp			27.50				30.00		26.13	1.002
	Sal PSU)			32.00							
	Secchi(m)			2.60				6.90	0.283	2.30	2.26
	DO mg/L			6.861	1.253	4.17	0.076	4.10		5.87	0.83
	BOD5-mg/L			5.000	0.793	4.96	0.288	3.92		2.85	0.91
	TSS (mg/l)			30.50	8.264	37.00		22.10		0.04	0.02
	Chl-a (mg/l)			6.504	6.805	1.07		4.40			
	Ammonia (mg/l)			0.183	0.273	0.08	0.004	0.04	0.002	35.15	52.75
	Nitrate& Nitrite (mg/l))			0.297	0.331	0.06	0.007	0.01	0.000	87.12	67.98
	Phosphate (mg/l)			0.073	0.068	0.01	0.002	0.12	0.001	128.05	256.79
	pH									8.13	0.06
	OM mg/L									0.01	0.00
Nyali Bridge	Water temp			28.00				29.50		26.07	1.10
	Sal PSU)			33.00							
	Secchi (m)			50.00				4.050	0.919	4.875	5.834
	DO mg/L			6.726	1.465	4.383	0.153	4.100		5.667	0.691
	BOD5-mg/L			5.627	0.939	5.147	0.411	3.600		2.227	1.112
	TSS (mg/l)			28.83	6.646	90.00		28.70		0.034	0.017
	Chl-a (mg/l)			7.401	7.046	0.883		5.400			
	Ammonia (mg/l)			0.086	0.085	0.103	0.022	0.046	0.003	28.66	43.65
	Nitrate& Nitrite (mg/l)			0.163	0.079	0.068	0.018	0.018	0.001	57.30	59.91
	Phosphate (mg/l)			0.036	0.026	0.115	0.005	0.273	0.011	25.74	21.72
	pH									8.150	0.069
	OM mg/L									0.005	0.000
KMC	Water temp			29.000				30.00		27.50	1.114
	Sal PSU)			30.000							
	Secchi(m)			0.600				5.650	0.778	1.097	0.205
	DO mg/L			6.972	1.115	4.200	0.132	4.200		5.600	0.716
	BOD5-mg/L			5.147	0.983	4.693	0.642	3.920		2.240	1.136

Station	Variable/Year	2009 Mean	STDEV	2010 Mean	STDEV	2011 Mean	STDEV	2013 Mean	STDEV	2014 Mean	STDEV
	TSS (mg/l)			35.17	6.178	68.00		19.70		0.038	0.007
	Chl-a (mg/l)			6.076	5.368	0.883		3.700			
	Ammonia (mg/l)			0.124	0.154	0.068	0.007	0.039	0.001	28.57	42.78
	Nitrate& Nitrite (mg/l)			0.053	0.049	0.023	0.030	0.006	0.000	59.25	62.20
	Phosphate (mg/l)			0.097	0.151	0.022	0.003	0.132	0.000	19.78	23.18
	pH									8.090	0.137
	OM mg/L									0.007	0.002
Mikindani	**Water temp**			28.00				31.00		26.67	1.701
	Sal PSU)			29.00							
	Secchi(m)			0.20				3.175	0.672	0.697	0.170
	DO mg/L			7.122	1.026	4.350	0.100	4.300		5.387	0.676
	BOD5-mg/L			5.240	1.048	4.960	0.277	4.880		1.760	0.744
	TSS (mg/l)			33.15	17.90			36.60		0.051	0.012
	Chl-a (mg/l)			5.252	4.19			6.400			
	Ammonia (mg/l)			0.080	0.070	0.092	0.017	0.039	0.001	29.60	44.10
	Nitrate& Nitrite (mg/l)			0.094	0.053	0.007	0.001	0.014	0.012	69.51	67.19
	Phosphate (mg/l)			0.035	0.008	0.020	0.010	0.134	0.007	23.77	21.42
	pH									7.973	0.122
	OM mg/L									0.004	0.001

Table 12.3: Background Water Quality – Makupa Creek

Station	variable/Year	2010		2011		2014	
		Mean	STDEV	Mean	STDEV	Mean	STDEV
Makupa Dumpsite	Water temp	29.00				28.10	0.141
	Sal PSU)	32.00					
	Secchi(m)	0.370				1.250	0.354
	DO mg/L	6.352	0.756	4.083	0.076	6.440	0.046
	BOD5-mg/L	4.680	0.822	4.960	0.604	3.240	0.046
	TSS (mg/l)	30.17	6.585	90.000		0.036	0.005
	Chl-a (mg/l)	10.46	7.252	1.309			
	Ammonia (mg/l)	0.063	0.051	0.024	0.004	36.04	40.18
	Nitrate& Nitrite (mg/l)	0.135	0.170	0.008	0.000	83.13	54.91
	Phosphate (mg/l)	0.061	0.016	0.023	0.004	47.21	66.33
	pH					8.215	0.120
	OM mg/L						
Makupa Mangroves	Water temp					27.33	0.551
	Sal PSU)						
	Secchi(m)					1.267	0.702
	DO mg/L	5.546	1.031	5.546	1.031	6.440	0.067
	BOD5-mg/L	4.704	0.594	4.704	0.594	3.000	0.407
	TSS (mg/l)	33.00	7.000	33.00	7.000	0.046	0.013
	Chl-a (mg/l)	10.41	9.505	10.414	9.505		
	Ammonia (mg/l)	0.135	0.127	0.135	0.127	19.39	29.44
	Nitrate& Nitrite (mg/l)	0.228	0.126	0.228	0.126	68.74	62.54
	Phosphate (mg/l)	0.061	0.016	0.061	0.016	35.82	36.39
	pH					8.150	0.161
	OM mg/L					0.007	0.000
Makupa Channel	Water temp	27.00				27.63	0.404
	Sal PSU)	33.00					
	Secchi(m)	1.560				1.083	0.202
	DO mg/L	6.483	0.532			6.453	0.083
	BOD5-mg/L	4.933	0.449			2.720	0.379
	TSS (mg/l)	35.83	9.065			0.077	0.053
	Chl-a (mg/l)	14.83	14.33				
	Ammonia (mg/l)	0.018	0.008			21.47	32.02
	Nitrate& Nitrite (mg/l)	0.068	0.053			64.83	56.39
	Phosphate (mg/l)	0.025	0.010			33.79	41.25
	pH					8.177	0.115
	OM mg/L						
Makupa Causeway	Water temp	28.50				28.60	1.682
	Sal PSU)	31.00					
	Secchi(m)	0.690				0.400	0.173
	DO mg/L	6.806	1.251	4.633	0.126	5.427	0.502
	BOD5-mg/L	5.107	1.102	5.973	0.333	2.520	1.557
	TSS (mg/l)	32.17	4.355			0.049	0.008
	Chl-a (mg/l)	11.25	6.494	4.132	4.014		
	Ammonia (mg/l)	0.049	0.023	0.032	0.012	26.01	41.78
	Nitrate& Nitrite (mg/l)	0.139	0.096	0.009	0.000	148.2	110.1
	Phosphate (mg/l)	0.052	0.014	0.023	0.004	175.7	243.6
	pH					8.090	0.100
	OM mg/L					0.010	0.001

12.4 Monitoring Program Design

It is recommended that the sampling stations within the Creeks of Mtwapa, Makupa and Tudor as shown on **Figure 12.1** on **Page 12-2** be used during the Receiving Environment Monitoring Program (REMP). Flows, bank stability, water quality, sediment quality, macrophytes and fish will be the key indicators for monitoring.

12.4.1 Water Flows

The volume of water released from the Wastewater Treatment Plants at Nguu Tatu and Shimo la Tewa Sites to the receiving environment including the creeks need to be measured and recorded. This should exclude the volume conveyed to the Wastewater Reuse Storage Ponds if the proposed wastewater reuse strategies are implemented. Thus, the flow measurement devices should be installed on the Outfall Sewer from the Proposed Wastewater Treatment Plants.

12.4.2 Bank Stability

It is recommended that the Outfall Sewers conveying the treated wastewater to the receiving environment be installed to discharge below low-tidal mark.

Where applicable, bank stability at the discharge points will be monitored twice per year at the discharge point (notionally in the wet season and post-wet season), by physical inspection to determine whether significant erosion has occurred or bank stability compromised.

The assessment will include characterization of the following parameters at the proposed wastewater discharge point:

- Bank shape
- Bank stability
- Bed stability
- Artificial bank protection measures
- Factors affecting bank stability
- Valley shape
- Channel shape
- Channel and stream width

12.4.3 Water Quality

Water quality at the receiving environment and background site will be monitored throughout the duration of the REMP. It is intended that sampling for water quality analysis be carried out twice per year in the wet season at the proposed monitoring locations (notionally in the wet season and post-wet season). Two replicate samples will be collected per location.

Analysis of water quality will only be carried out for the parameters that are consistent with the NEMA Guidelines.

At each location and during each sampling event, physical water quality measurements will be collected *in situ* using a hand-held water quality meter. The following variables will be recorded at the three locations at 30 cm depth:

- Water temperature (°C)
- pH
- Conductivity (µS/cm)
- Dissolved oxygen (DO, mg/L),
- Turbidity (NTU).

In addition, two replicate water samples will be collected from each location for analysis of the following parameters in accordance with the indicators currently monitored by NEMA:

- Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) (mg/L)
- Water hardness (mg/L)

- Major Cations (Ca, K, Mg, Na) and Anions (Cl, SO4, alkalinity) (mg/L)
- Carbonate, bicarbonate and hydroxide (m/L)
- Fluoride (mg/L)
- Nutrients (total nitrogen and total phosphorus (unfiltered) and ammonia (as N), nitrate (as N), nitrite (as N) (filtered) and filterable reactive phosphorus (FRP) (as P)) (mg/L)
- Metals and metalloids (Al, As, Ba, Be, Cd, Cr, Cu, Fe, Hg, Pb, Ni, Zn, B, Co, Mn, Mo, Se, Ag, U, V) (dissolved (filtered) and total (unfiltered) in µg/L)
- Chlorophyll-a (µg/L)
- Blue green algae (cyanobacteria) (cells/mL)
- Organochloride and organophosphate pesticides (OCPs and OPPs) (µg/L)
- Total petroleum hydrocarbons (TPH), benzene, toluene, ethylene and xylene (BTEX) and polyaromatic hydrocarbons (PAHs) (µg/L)
- Sodium absorption ratio (SAR) (mg/L)
- Colour (Hazen units)
- Silicon (mg/L)
- Faecal coliforms / e-coli (CFU/mL), and
- Methylene blue (MBAS) (mg/L).

Grab samples will be collected at each of these locations, 30 cm below the water's surface, by hand or by a sampling pole with clamp if required for safety reasons.

Two samples will be collected for analysis of nutrients and metals and metalloids. The first sample will be un-filtered and will be used for analysis of total nitrogen, total phosphorus and total metals. The second sample will be filtered in the field through a 0.45 µm filter, and will be used for the analysis of ammonia, nitrate, nitrite and dissolved metals.

Sediment Quality

Sediment quality will be monitored in conjunction with water quality monitoring.

Two replicate sediment samples from the creek bed will be collected and analysed for the parameters currently monitored by NEMA and other relevant government agencies.

The following parameters will be monitored;

- particle size distribution (sieve and hydrometer)
- pH
- major cations (Ca, K, Mg, Na) and anions (Cl, SO4, alkalinity) (mg/kg)
- sodium absorption ratio (SAR)
- fluoride (mg/kg)
- nutrients (total nitrogen, total phosphorus, ammonia (as N), nitrate (as N) nitrite (as N)) (mg/kg)
- total metals and metalloids (Al, As, Ba, Be, Cd, Cr, Cu, Fe, Hg, Pb, Ni, Zn, B, Co, Mn, Mo, Se, Ag, U, V) (mg/kg)
- organochloride and organophosphate pesticides (OCPs and OPPs)
- silicon (mg/kg), and
- cyanide (total) mg/kg.

Where the water is shallow (<0.5 m deep), replicate sediment samples will be collected from the top 0.30 m of sediment on the bed using a stainless-steel trowel, with the sediments transferred directly into the sampling jar provided by the analytical laboratory.

Where the water is deep or the sediment is too soft to walk in, surface sediment from the bed (top 0.30 m depth) will be collected using a stainless-steel corer. The sample will be emptied into a bucket or other intermediate container, which has been thoroughly washed with ambient site water, and the sediment mixed and placed into the sample jar using a stainless-steel trowel.

Macrophytes

Macrophyte communities and algae abundance will be monitored twice per year: notionally in the pre-wet season and the post-wet season at the proposed monitoring locations.

At each site, macrophytes and algae will be surveyed along three 50 m by 1 m belt transects. The percent cover of floating, emergent and submerged macrophytes will be visually estimated by species, noting listed threatened and exotic (and declared noxious) species.

Fish

Fish communities will be monitored twice per year: notionally in the wet season and the post-wet season at the proposed monitoring sites.

Fish communities will be surveyed using a combination of backpack or boat electrofishing (depending on the nature of the waterway being sampled), seine and set nets, baited traps and dip nets. At each site, the species present and the abundance of each species by life history stage (juvenile, intermediate, adult), the length, frequency distribution for each species, and the apparent health of individuals will be recorded.

Onsite Observations

General physical observations will be recorded at each site during each sampling event, to provide an 'early warning' of potential adverse impacts. In particular, algal blooms, unusual deposits of sediment and floating objects (debris, oil and grease), dense growth of attached plants and insects, any evidence of chemical precipitation, any evidence of erosion and the presence of dead aquatic fauna (odour) will be recorded. If these are detected, this will trigger further investigations of recent releases, and of water and sediment quality results.

12.5 Data Analysis and Reporting

Interim reports will be provided after each survey event, and will provide a preliminary comparison of the results to relevant NEMA and other standards, and a preliminary discussion of potential impacts to the receiving environment.

Annual reports will also be prepared, and will include comparison to the relevant NEMA and other standards, and an assessment of potential impacts to the receiving environment.

13.0 PRELIMINARY ENVIRONMENT IMPACTS AND RESETTLEMENT ACTION

13.1 Introduction

This Chapter focuses on the potential environment and social impacts that are likely to be triggered during implementation of the proposed Wastewater Management Systems for Mombasa Island and North Mainland. The social safeguards in this context include Project resettlement impacts.

The implementation of the proposed Wastewater Management Schemes entails construction of the following components;

- Wastewater Treatment Plant (Waste Stabilization Ponds - WSPs) at an identified site in Nguu Tatu Village
- Wastewater Treatment Plant (Waste Stabilization Ponds - WSPs) at an identified site in Shimo la Tewa Area on Parcels Nos. IMN/12561 and IMN/4491, IMN/5141 belonging to the Kenya Prisons Department
- Trunk, Secondary and Tertiary Sewers within Mombasa Island and North Mainland
- 12 Nr Sewage Pumping Stations at designated locations within Mombasa Island and 17 Nr within Mombasa North Mainland

Once commissioned, the schemes, hereafter referred to as the Project, will provide sustainable water-borne sanitation system to Mombasa Island and North Mainland as an improvement to the existing on-plot sanitation systems comprising of pit latrines and septic tanks.

13.1.1 Environment Screening

This process is critical in the assessment of environment for a project as it ensures early management of environmental risks through identification of potential environmental impacts and proposal of mitigation measures. The process also helps in establishment of Project's Environmental Assessment (EA) Category (A, B, C or FI) as required by the World Bank OP 4.01 and ranking of Project (high, medium and low risks) as required by Environmental Management and Co-ordination Act (EMCA) 1999 amended in 2015.

The environmental components of the Project have been determined and appropriate mitigation measures proposed. The environment components assessed include;

- Natural environment (air, water, land)
- Human health and safety
- Physical cultural resources
- Social issues which include involuntary resettlement

This Project has been classified based on the type, location, sensitivity, nature and reversibility of environmental impacts identified at screening stage as Category A and High Risk as per OP 4.01 and EMCA 1999 respectively.

This implies that the adverse environmental impacts associated with the Project are broad, diverse, beyond local site and trigger resettlement. Thus; a full Environmental and Social Impact Assessment (ESIA) should be carried especially at the Detailed Design Stage.

13.1.2 Screening for Resettlement Impacts

The purpose of this stage / process is to identify social and resettlement risks and propose appropriate measures to manage the risks.

The Project has a potential of triggering Resettlement impacts. Thus, the Land Act 2012 and the World Bank Operational Policy OP 4.12 have been adopted as the main policy documents to guide on mechanisms for preparation of Resettlement Action Plan.

The main principles of the Policy include:

- To prevent or minimize involuntary displacement whenever possible;
- To design and implement resettlement as a sustainable development program;
- To pay for lost assets at replacement cost;
- To restore peoples' capacity to earn a living and their community ties;
- Components necessary to realize project objectives are covered regardless of the source of financing;
- Resettlement costs are considered part of project costs.

The Project components are expected to result to significant resettlement of persons since the proposed site for the Wastewater Treatment Plant (Nguu Tatu Area) on land parcel (No.829/II/MN) is privately owned.

However, the land parcels (No. IMN/12651, IMN/4491 and IMN/5141) in Shimo la Tewa are owned by the National Government and is in the possession / allocation of Kenya Prisons Department.

The Project has potential effects on assets and sources of livelihood through;

- Loss of private land at the proposed site for establishment of WWTP (WSPs) at Nguu Tatu and Pumping Stations. Shimo La Tewa site will not trigger land acquisition due to the fact that the land belongs to Kenya Government under the Kenya Prisons Department
- Loss of structures lying along the sewer alignments and its wayleave and at the proposed WWTP site during construction period
- Loss of crops and trees lying along the sewer alignments and its wayleave and at the proposed WWTP site during construction period

13.2 Guiding Legislation and Policy

Based on the scope, EMCA 1999 requires that Project activities under the proposed Wastewater Master Plan for Mombasa Island and North Mainland be subjected to an Environmental and Social Impact Assessment (ESIA).

The World Bank under Operation Policy OP 4.01 also requires that Environmental Assessment (EA) be carried out for Projects of such magnitude.

The development of such Infrastructural Projects require compliance to the guiding legislations, guidelines and policies, both under the Kenyan context and the World Bank. These have been dealt with under several laws, by-laws, regulations and Acts of parliament, as well as policy documents. The relevant guidelines are summarized in the following sub-sections;

13.2.1 Kenyan Legislations

- The Environmental Management and Coordination Act (EMCA), 1999 and subsequent regulations
- Coast Development Authority Act (Cap 449)
- Forest Act 2005
- Marine Zones Act Cap 371 of 1989
- Water Act 2016
- County Government Act No. 17 of 2012
- Physical Planning Act 1996 (286)
- Occupational Safety and Health Act (OSHA 2007)
- The Public Health Act (Cap.242)

13.2.2 World Bank Policies and Guidelines

The Project has been assessed against the following Safeguards Policies;

- Environmental Assessment OP 4.01
- Involuntary Resettlement (OP 4.12)
- Forestry (OP4.36, GP4.36)
- OP/BP 4.04 (Natural Habitats)
- Physical Cultural Resources(OP/BP4.11)
- World Bank Group Environmental Health and Safety Guidelines on Water and Sanitation

13.3 Scoping for Environmental and Social Impacts

The process of scoping for environmental and social impacts has been undertaken on all components of the proposed Project. The purpose of scoping is to identify significant environmental and social risks that are likely to be triggered by the Project.

The process enabled determination of the appropriate issues within the scope and extent of the Project. The aspects considered during scoping include;

a. Relevant issues to be considered in an ESIA
b. Appropriate time and space boundaries of the ESIA
c. Information necessary for decision-making
d. Significant effects and factors to be studied in detail

13.3.1 Alternative Sites

The scoping for environment and social impacts has been carried out for all the alternative WWTP sites considered in the Master Plan. A summary of the finding for the alternative sites based on the scoping is presented in **Tables 13.1** to **13.3** and **Figures 13.1 to 13.3 on Pages 13-3 to 13-4.**

Table 13.1: Site Description – Nguu Tatu

Site Name	Environment and Social Parameters	Remark
Nguu Tatu	• No anticipated significant impact to natural environment • No significant impact to Health and Safety of the community • No significant impact to social environment, however OP 4.12 is triggered due to isolated households undertaking farming activities on site.	• Detailed ESIA required at detailed design • Full RAP required detailed design • Site ideal for establishment of the WWTP from an Environment and Social perspective

Figure 13.1: Nguu Tatu Site

Table 13.2: Site Description – Shimo la Tewa

Site Name	Environment and Social Parameters	Remark
Shimo la Tewa	• No anticipated significant impact to natural environment • No significant impact to Health and Safety of the community • No significant impact to social environment, however OP 4.12 is triggered due to isolated households undertaking farming activities on site	• Detailed ESIA required at detailed design • Full RAP required detailed design • Site ideal for establishment of the WWTP from an Environment and Social perspective

Figure 13.2: Shimo la Tewa

13.3.2 Selected Site

In consideration of the evaluated environmental and social factors, the most appropriate sites for development of the Wastewater Treatment Plants are Nguu Tatu and Shimo la Tewa Sites.

They present the least significant environment and social risks which can be mitigated by undertaking an Environment Assessment and Resettlement Action Plan.

The subsequent sub-section summarizes the Environmental and Social Impact, Resettlement Impacts and their proposed mitigation measure with respect to developing Wastewater Treatment Plant at the selected site and implementing the selected Wastewater Management Strategy in general.

13.4 Environment and Social Impact Scoring and Rating Criteria

In carrying out the environmental and social assessment, a standard impact rating criteria has been adopted for the evaluation of the significance of environment and social impacts associated with the proposed Project components (both during construction and operation).

The impacts have been analysed based on their severity, scope and duration as summarized in **Table 13.3** on **Page 13-5**.

Table 13.3: Environment Impact Scoring and Rating Criteria

Severity of Impact	Rating	Scoring
Insignificant / non-harmful/less beneficial	-1/+1	Very Low
Small/ Potentially harmful / Potentially beneficial	-2/+2	Low
Significant / slightly harmful / significantly beneficial	-3/+3	Medium
Great/ harmful / beneficial	-4/+4	High
Disastrous/ extremely harmful / extremely beneficial	-5/+5	Very high
Spatial Scope of the Impact	**Rating**	**Scoring**
Activity specific	-1/+1	Very Low
Right of way specific	-2/+2	Low
Within Project area 5km radius	-3/+3	Medium
Regional / County	-4/+4	High
National	-5/+5	Very high
Duration of Impact	**Rating**	**Scoring**
one day to one month	-1/+1	Very Low
one month to one years	-2/+2	Low
Within Project construction period	-3/+3	Medium
within the Project life	-4/+4	High
at decommissioning	-5/+5	Very high

Example of Cumulative Impact Scoring

1. +3,+2,+5,+4, +4,+1=+4 (the weight that occurs more becomes the overall rating)
2. +2,+2,+5,+4, +4,+1=+3 (if two scores or more tie, then an average of the scores shall be adopted)

13.5 Positive Impacts During the Construction Phase

13.5.1 Creation of Employment and Business Opportunities

It is anticipated that the Project construction will create new employment opportunities in the form of skilled and unskilled labour, Suppliers and Sub-Contractors, etc. This will reduce unemployment, improve income status of the local workers' household and increase revenue.

The Impact Rating for Creation of Employment and Business Opportunities is given in **Table 13.4** below.

Table 13.4: Impact Rating for Creation of Employment

Severity of Impact	+4
Spatial Scope of the Impact	+3
Duration of Impact	+3
Overall score	**+3**
Impact Rating	**Medium – Beneficial**

13.6 Positive Impacts During Operation Phase

13.6.1 Increased Water Availability through Re-Use

Treated effluent from the Wastewater Treatment Plant is a potential source of re-charge to the water bodies. If found economically viable at a later stage, the effluent from the Wastewater Treatment Plant can be re-used for farm irrigation and other non-potable uses.

The impact rating for increased water availability is presented in **Table 13.5** below.

Table 13.5: Impact Rating for Increased Water Availability

Severity of Impact	+3
Spatial Scope of the Impact	+3
Duration of Impact	+4
Overall score	**+3**
Impact Rating	**Medium – Beneficial**

13.6.2 Reduction of Terrestrial and Marine Pollution

Once commissioned, it is expected that the Project will reduce both terrestrial and marine pollution caused by discharge of untreated sewage into the mangrove swamps, Sea grass bed and coral reefs. Pollution of open storm water drains and water resources within Mombasa Island and North Mainland due to improper disposal of wastewater will also be minimized.

The impact rating for reduction of pollution is presented in **Table 13.6** below.

Table 13.6: Impact Rating for Elimination of Pollution

Severity of Impact	+5
Spatial Scope of the Impact	+4
Duration of Impact	+4
Overall score	**+4**
Impact Rating	**High – Beneficial**

13.6.3 Improved Hygiene and Sanitation in the Project Areas

Good Hygiene and Sanitation Standards are linked to provision of sanitation infrastructure. Mombasa Island and North Mainland will benefit from improved hygiene and sanitation from the Wastewater Management Scheme if implemented.

The impact rating for improved Hygiene and Sanitation in the Project Area is summarized in **Table 13.7** below.

Table 13.7: Impact Rating for Improved Hygiene and Sanitation

Severity of Impact	+4
Spatial Scope of the Impact	+3
Duration of Impact	+4
Overall score	**+4**
Impact Rating	**High – Beneficial**

13.6.4 Reduced Cases of Water Related Diseases

Cases of water borne disease in Mombasa Island and North Mainland are likely to reduce with improved sanitation infrastructure. This will effectively reduce related medical expenses among the residents with extended long term increased social productivity.

The impact rating for reduced water borne related diseases in the Project Area are summarized in **Table 13.8** below.

Table 13.8: Impact Rating for Reduced Water Related Diseases

Severity of Impact	+4
Spatial Scope of the Impact	+3
Duration of Impact	+4
Overall score	**+4**
Impact Rating	**High – Beneficial**

13.6.5 Reduced Water and Sanitation Burden to Women

The socio-economic survey undertaken in the Project Area found that the burden of collecting water and solving sanitation problems in a household is mainly the responsibility of women. The same applies to caring for the sick who suffer from water related illness. Improved sanitation system will lessen this burden and ensure enhanced family health.

The impact rating for reduced burden to women due to improved water and sanitation system is shown in **Table 13.9** below.

Table 13.9: Impact Rating for Reduced Burden to Women

Severity of Impact	+3
Spatial Scope of the Impact	+3
Duration of Impact	+4
Overall score	**+3**
Impact Rating	**Medium – Beneficial**

13.6.6 Increased Land Values in the Project Area

Provision of the sanitation infrastructure to Mombasa Island and North Mainland will result to appreciation of land value due to improved access to proper sanitation facilities.

The impact rating for increased land values is shown in **Table 13.10** below.

Table 13.10: Impact Rating for Increased Land Values

Severity of Impact	+3
Spatial Scope of the Impact	+3
Duration of Impact	+4
Overall score	**+3**
Impact Rating	**Medium – Beneficial**

13.7 Negative Impacts and Mitigation Measures during the Construction Phase

13.7.1 Negative Impacts to the Biophysical Environment and Mitigation Measures

(i) Destruction of Vegetation in areas covered by the Project Components

From site visit, it has been realized that most parts of the Mombasa Island and North Mainland are less vegetated except for isolated coastal vegetation. Therefore, less significant impact of the Project to vegetation is anticipated.

The impact rating for destruction of vegetation cover is shown in **Table 13.11** below.

Table 13.11: Impact Scoring for Destruction of Vegetation Cover

Severity of Impact	-3
Spatial Scope of the Impact	-2
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Low Negative**

Mitigation Measures

- Site clearance and construction activities will be limited within the Project dimension to minimize destruction to vegetation cover
- Reinstatement of the Project sites to their original state once construction works are completed to allow vegetation growth
- Vegetation and trees damaged during construction to be replaced / reinstated if possible, after completion of the Works

(ii) Contamination of Water Resources

The proposed Wastewater Management Scheme entails collection of wastewater within the drainage area of Mombasa Island and North Mainland, conveyance to the proposed WWTP for treatment and discharge of treated effluent to Indian Ocean.

During the construction period, effluents from construction plant and equipment (oils, grease, hydro-carbonates) are potential point pollutants of water resources. These effluents originate from activities such as cleaning, repair of the equipment as well as through leakages during normal operation. As a result of surface run-off, these effluents will be conveyed to the Ocean through natural drains, streams and rivers, resulting to contamination of water resources.

The impact rating of contamination of water resources is shown in **Table 13.12** below.

Table 13.12: Impact Rating for Contamination of Water Resources

Severity of Impact	-2
Spatial Scope of the Impact	-1
Duration of Impact	-3
Overall score	**-2**
Impact Rating	**Low – Negative**

Mitigation Measures

- Risk of water resources pollution by discharges from Construction Equipment is low; however, it will be further minimized by ensuring Construction Equipment is well maintained and serviced per manufacturer's specifications to prevent oil leaks.
- Cleaning / repair of Construction Plant and Equipment to be carried out at designated yards and the Contractor to have designated storage areas for oils, fuels etc. that is protected from rain water and away from nearby surface water courses.

(iii) Soil Erosion Resulting to Loss of Top Soil

Site clearance, excavation and ground levelling activities during construction of the Project Components loosen the top soil and make it susceptible to erosion agents (wind and water).

The impact rating for soil erosion is shown in **Table 13.13** below.

Table 13.13: Impact Rating for Soil Erosion

Severity of Impact	-2
Spatial Scope of the Impact	-2
Duration of Impact	-3
Overall score	**-2**
Impact Rating	**Low – Negative**

Mitigation Measures

The risk of soil erosion is low as the design of the sanitation infrastructure has incorporated measures to minimize this risk through provision of erosion prevention structures i.e. gabions, scour checks, etc. in areas susceptible to soil erosion such as river banks.

(iv) Solid Wastes Pollution (Construction Activities)

Construction activities and Contractor's Camps will generate solid wastes such as plastics, used tires, metal parts, biodegradable materials, etc. Such wastes if poorly disposed of can lead to pollution of nearby water courses and blockage of drainage and sewerage systems.

The impact rating for pollution by solid wastes is shown in **Table 13.14** on **Page 13-9**.

Table 13.14: Impact Rating for Pollution by Solid Wastes

Severity of Impact	-3
Spatial Scope of the Impact	-2
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Medium – Negative**

Mitigation Measures

- Construction wastes (residual earth, debris and scrap materials) to be collected at designated points and Contractor to dispose to designated Solid Waste Dumping Sites approved by the Local Authority.
- Environmental Management, Health and Safety Training Programmes to be conducted for Contractor's Staff to create awareness on proper solid wastes management

(v) Air Pollution and Dust Generation

Air Pollution will result from dusts and emissions from Construction Plant, Equipment and Vehicles. Dusty conditions result due to unpaved roads and tracks, exposed and non-vegetated surfaces, etc. Project borrow pits and quarries are also potential sources of dust.

Impact rating for air pollution and dust generation is shown in **Table 13.15** below.

Table 13.15: Impact Scoring for Air Pollution and Dust Generation

Severity of Impact	-3
Spatial Scope of the Impact	-2
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Medium – Negative**

Mitigation Measures

- Contractor to comply with the provisions of EMCA 1999 (Air Quality Regulations 2014)
- Workers to be trained on management of air pollution from vehicles and machinery and construction machinery maintained and serviced in accordance to manufacturer's specifications
- Removal of vegetation to be avoided until clearance is required and exposed surfaces re-vegetated or stabilized as soon as possible
- The Contractor shall not carry out dust generating activities (excavation, handling and transport of soils) during times of strong winds
- Vehicles delivering construction materials and vehicles hauling excavated materials shall be covered to reduce spills and windblown dust
- Water sprays shall be used on all earthworks areas within 200 metres of human settlement especially during the dry season.

13.7.2 Negative Impacts to the Socio-Economic Environment and Mitigation Measures

(i) Land Acquisition and Impacts to Assets and Sources of Livelihood

The Project implementation will result to land acquisition for the proposed WWTP at Nguu Tatu on Lr Parcel No. 829/II/MN and the 25 Nr Pumping Stations within Mombasa Island and North Mainland, which are privately owned.

This triggers application of World Bank OP 4.12, which requires that a Resettlement Action Plan (RAP) be prepared at the Detailed Design Stage.

Table 13.16 below presents a summary of Resettlement Impacts identified for Nguu Tatu site;

Table 13.16: Resettlement Impacts – Nguu Tatu Site

Site Name	Category of Loss identified	Extent and Magnitude of Loss	Ownership of Land
Nguu Tatu	• Loss of Land • Loss of structures • Loss of crops and trees	Land requirement approximately 160 Ha	Thathini Development

The Impact Rating for Resettlement Impacts is shown in **Table 13.17** below.

Table 13.17: Impact Scoring for Resettlement Impacts

Severity of Impact	-4
Spatial Scope of the Impact	-2
Duration of Impact	-3
Overall score	**-4**
Impact Rating	**High – Negative**

Mitigation Measures

- A Resettlement Action Plan (RAP) need to be prepared and implemented prior to commencement of construction activities.

(ii) Disruption of Public Utilities

The proposed Project will affect other public utility infrastructure including existing data cables, plot access culvers, existing water and sewerage infrastructure, access roads and storm water drainage channels. This impact will be more significant during the construction of sewers which are located along road reserves.

Impact rating for disruption of public utilities is shown in **Table 13.18** below.

Table 13.18: Impact Rating for Disruption to Public Utilities

Severity of Impact	-3
Spatial Scope of the Impact	-2
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Medium - Negative**

Mitigation Measures

- Contractor to carry out piloting to locate services such as pipes and cables along the Pipeline Route before commencing excavation works.
- Relevant Services Providers and Agencies (KeNHA, KURA, KeRRA, Kenya Power, etc.) to be notified prior to commencement of Works so that any relocation works can be carried out before commencement of the pipeline construction.

(iii) Increased Transmission of HIV/AIDS

The Project is expected to attract new people to the Project area seeking employment during the construction period. This has a potential of increasing transmission of HIV/AIDS and other sexually transmitted diseases (STDs).

Impact rating for increased transmission of HIV/AIDS is as shown in **Table 13.19** below.

Table 13.19: Impact Rating for Increased Transmission of HIV/AIDS

Severity of Impact	-2
Spatial Scope of the Impact	-3
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Medium - Negative**

Mitigation Measures

- HIV/AIDS Awareness Program to be instituted and implemented as part of the Contractor's Health and Safety Management Plan to be enforced by the Supervisor. This will involve periodic HIV/AIDS Awareness Workshops for Contractor's Staff
- Access to Contractor's Workforce Camps by outsiders to be controlled
- Contractor to provide standard quality condoms to personnel on site

13.7.3 Negative Impacts on Occupational Health and Safety and Mitigation Measures

(i) Noise and Excessive Vibrations

Noise and excessive vibrations are caused by operation of construction plant and equipment and activities during excavation and rock breaking. This impact poses a health and safety risk to the communities living in the Project area and construction workers.

Impact rating for noise and excessive vibrations is shown in **Table 13.20** below.

Table 13.20: Impact Rating for Noise and Excessive Vibrations

Severity of Impact	-3
Spatial Scope of the Impact	-1
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Medium - Negative**

Mitigation Measures

- Contractor to comply with provisions of EMCA 1999 (Noise and Excessive Vibrations Regulations of 2009)
- Contractor to keep noise level within acceptable limits (60 Decibels during the day and 35 Decibels during the night) and construction activities shall, where possible, be confined to normal working hours in the residential areas
- Hospitals and other noise sensitive areas such as schools shall be notified by the Contractor at least 5 days before construction is due to commence in their vicinity
- Complaints received by the Contractor regarding noise to be recorded and communicated to the Supervising Engineer for appropriate action

(ii) Risk of Accidents at Work Sites

Most accidents during construction result due to failure to use Personal Protective Equipment (PPE) by workers on site and unrestricted access to the sites by members of public; resulting to injuries or death.

Impact rating for risk of accidents at work sites is shown in **Table 13.21** below.

Table 13.21: Impact Rating for Risk of Accidents at Work Sites

Severity of Impact	-4
Spatial Scope of the Impact	-3
Duration of Impact	-3
Overall score	**-3**
Impact Rating	**Medium - Negative**

Mitigation Measures

- Construction Workers and the Supervising Team to be provided with Personal Protective Equipment including gloves, gum boots, overalls and helmets. Use of PPE to be enforced by the Supervising Engineer
- Fully stocked First Aid Kits to be provided at the Sites, Camps and in all Project Vehicles
- Contractor to provide a Healthy and Safety Plan prior to the commencement of works to be approved by the Supervising Engineer.
- Camps and Work Sites to be fenced off and Security Guards tasked to restrict access by members of the public.

13.8 Negative Impacts During Operation

The Project once commissioned has the potential of triggering negative impacts associated with operation and maintenance as summarized in **Table 13.22** below.

Table 13.22: Environment and Social Risk during Project Operation

Impact	Summary of Mitigation
Risk of environmental pollution and eutrophication by effluent from the Wastewater Treatment Plant.	• Routine sampling & analysis of effluent to ensure compliance to the requirements of the Third Schedule (Standards for Effluent Discharge into the Environment) of the Water Quality Regulations of 2006. • Routine inspection of the Wastewater Treatment Plant for any blockages or overflow of raw sewerage into the environment. • Repair and maintenance of mechanical installations at the inlet works of the Wastewater Treatment Plant
Risk of pollution and eutrophication of environment by leachates from sludge drying beds	• De-sludging of ponds be undertaken as indicated in O&M Manuals • Adequate drying of sludge to create a pathogen and odour free product. • Avoid de sludging the ponds during rainy seasons to limit the risks of leachates flowing into the environment • Sludge shall be tested for chemical quality with aim of establishing possibility of re-use on farms
Risk of encroachment and construction of structures on sewer wayleaves	• Mapping and installation of beacons which illustrate the width of the pipeline reserve • Regular inspection of the pipeline corridor for encroachment. • Prosecution of encroachers as required by county by laws on way leaves and road reserves maintenance.
Risk of illegal connection to the sewer pipeline	• Conduct public sensitization programs on importance of not interfering with the sewer pipeline and the need to seek official sewer connection from Mombasa Water and Sanitation Company (MOWASSCO).
Risk of Sewer blockage and overflows to the environment	• Awareness rising among community members not to dump solids in manholes and to report any blockages to MOWASSCO • Regular cleaning of grit chambers and sewer lines to remove grease, grit, and other debris that may lead to sewer backups • Design manhole covers to withstand anticipated loads and ensure that the covers can be readily replaced if broken to minimize entry of garbage and silt into the system • Ensure sufficient hydraulic capacity to accommodate peak flows and adequate slope in gravity mains to prevent build-up of solids and hydrogen sulphide generation
Risk of invasion of birds, rodents, mammals and associated reptiles to Wastewater Treatment Plant	• Keep the WWTP clean to limit the attraction of birds which scavenge for insects and maggots from the ponds and sludge beds • WWTP should be protected from wildlife encroachments by providing secure barriers. • The quality of treated effluent before discharge into the river be an important parameter for the control of the river eutrophication. • Continuous generation and sharing of sewage quality data on pre-scheduled monitoring programmes will be necessary
Risk of Vandalism of the infrastructure (Manhole covers and man hole step irons)	• Manhole covers and step irons where made of steel become prone to vandalism and pilferage • Manhole covers and manhole step bars should be made of alternative materials such as high density plastic which has low scrap resell value.
Air pollution from odour from WWTP	• Plant trees especially bamboos and eco-friendly indigenous trees around WWTP for odour control and breaking wind. • Ensure appropriate covering/ventilation of the pre-treatment unit;

Impact	Summary of Mitigation
	• Ensure appropriate handling and removal of grit/grease; • Ensure proper sizing and alignment of the lagoons • Ensure scum is appropriately disposed of or properly stabilized; • Ensure that the pond series have adequate water flow and aeration to reduce the potential of odour formation; • Construct roof over Sludge Drying Beds to protect drying sludge from precipitation • Appropriate disposal to reduce odour emanating from wet sludge
Land and Soil Contamination	• MOWASSCO to attend to sewer bursts promptly; • Provide high risk areas with appropriate drainage for effective channelling of burst sewage spills; • Encourage land owners along sewers to maintain vegetated belts along the pipeline to control any overflows flows and trap soil. This should include protection of sewers; • Install marker posts along the pipeline alignment for ease of identification and protection by the adjacent landowners

13.9 Project Resettlement Impacts

This section presents preliminary Resettlement Action Plan (RAP) for Project-Affected Persons (PAPs) in the Project Area (PA) who will be affected by the planned implementation of Project components presented in the Wastewater Master Plan for Mombasa Island and North Mainland.

The Project components involved include;

- Waste Stabilization Ponds (WSP) at Nguu Tatu and Shimo la Tewa
- Trunk, secondary and tertiary sewers
- Pumping Stations

13.9.1 Objectives of RAP

The RAP aims to ensure that all affected parties are compensated and assisted in restoring their livelihood.

The main objectives of the Preliminary RAP are:

(a) To identify PAPs and their properties and determine the extent of involuntary resettlement/displacements and restricted access impacts associated with the Project implementation and put in place measures to minimise and/or mitigate such impacts;

(b) To set out strategies for the preparation of detailed RAP and implementation of the RAP, including the process through which to acquire the necessary land and easements for the implementation of the Project activities;

(c) To carry out consultations with community members and other stakeholders, including PAPs, and make them aware of the project and to obtain their concerns regarding the economic and social impacts of the proposed Project and mitigation measures.

This Preliminary RAP defines the procedures and methodology for identifying the PAPs and spells out the compensation entitlements for PAPs, the socio-economic profiles of the Project areas, the legal and institutional framework that impacts on resettlement and compensation.

13.9.2 Guiding Legislations and Policies

The assessment identified that both community land and private land will be acquired either as easement or permanently for construction of the Project. Land acquisition will be carried out as stipulated in the Land Act 2012, Land Registration Act 2012, National Land Commission Act 2012 as well as the World Bank Operation Safeguard Policy OP 4.12 on Involuntary Resettlement as presented below;

- World Bank OP 4.12
- Land Act 2012
- Land Registration Act 2012
- Valuation Act
- National Land Commission Act
- The Constitution of Kenya

13.9.3 Identified Project Resettlement Impacts

In general, the assessment determined that the Project will result to the following impacts:

- Land acquisition for establishment of the proposed Projects Components
- Potential Project Impacts on people's assets and sources of livelihood
- Potential Project Impacts on the environment

A summary of preliminary Project impacts in terms of type, nature and ownership of potential assets to be affected for the Master Plan is given in **Table 13.23** below.

Table 13.23: Project Resettlement Impacts for Master Plan Projects

Project Component	Category of Loss	Land Requirement (Ha)	WWTP Land Ownership
Waste Stabilization Pond (WSP) – Nguu Tatu	• Land acquisition anticipated • Loss residential structures • Loss of crops and trees	160	LR Parcel No. 829/II/MN Thathini Development
Waste Stabilization Pond (WSP) – Shimo la Tewa	• No land acquisition • Loss residential structures • Loss of crops and trees	25	LR Parcel No. IMN/12561, IMN/4491 & IMN/5141 – Kenya Prisons Department
Trunk, Secondary and Tertiary Sewers	• Loss business structures • Loss of crops and trees	N/A	Road reserves land and river riparian land
Pumping Stations	• Land acquisition required • Loss business structures • Loss of crops and trees	5	Varied locations; Public / Private land

13.9.4 Eligibility for Compensation and 'Cut-Off' Date

The affected persons, irrespective of their status, are eligible to some form of assistance if they occupied the land or engaged in any livelihood income-generating activity at the affected sites before the entitlement 'cut-off date'. This date will be determined at detailed RAP stage for each of the identified Project in the Master Plan.

The following categories will be eligible for compensation under the RAP;

- People who own land at the identified sites for the Projects
- People whose houses/structures (commercial or residential) will be affected by acquisition of land for the Project
- People who rent structures (tenants) and are doing business and whose structures are to be temporarily removed or relocated
- Mobile traders within the identified Project sites
- People whose crops and trees will be affected by acquisition of Project or the physical project activity implementation

13.9.5 Livelihood Restoration

Livelihood restoration is an important aspect in ensuring that the PAPs livelihood is totally restored even after compensation is done. In a bid to ensure that livelihoods are improved and restored to full replacement levels, the Preliminary RAP has made provisions which will be fully determined at detailed RAP stage. This will be achieved through the following:

- Determination of average monthly income and compensation for loss of income for a period of three months to cushion PAPS during transition period before source of income is restored
- Payment of compensation cash to the PAPs prior to implementation of Project activities
- Compensation for structures, crops and trees has incorporate disturbance allowance of 15% the value of structure and right of salvage
- Sensitization of PAPs on the impacts of the project to their assets / sources of livelihood and mitigation measures put in place;
- Provision of ample time for affected person to remove and reconstruct structures away from the Project route and sites prior to commencement of construction work
- Implementation of a monitoring programme to ensure that the PAPs have well re-established their structures and business away from Project routes and sites
- The RAP implementation team at CWSB will ensure that the spouses of affected asset owners are included in the RAP implementation process in a bid to enhance safeguard of the family’s livelihood upon compensation
- A grievance redress mechanism will be established to provide the PAPs with a system to channel their complaints and seek redress during compensation and re-establishment phase. This measure will be ensured by the GRM committees identified in this RAP
- Implementation of a Financial Management Training to be provided to the PAPs prior to disbursement of cash compensation. This Training will be outsourced by CWSB to a suitable Financial Training Organization. The Financial Training Organization will develop a suitable Training Curriculum and deliver the Training to PAPs under supervision of CWSB

13.9.6 Vulnerable Groups

The preliminary RAP recognizes that there are vulnerable groups among the PAPs. These are social and distinct groups of people who might suffer disproportionately or face the risk of being marginalized as a result of resettlement compensation and specifically:

a. Female-and child-headed households
b. Disabled household heads
c. Households where the head is unemployed
d. Households headed by elderly persons with no means of support.

The list of properties and owners (PAPs) will be identified at detailed RAP stage. These categories of PAPs will be entitled to adequate compensation as presented in the Entitlement Matrix on **Table 13.24** on **Page 13-16**.

Table 13.24: Entitlement Matrix

	Type of Loss	Unit of Entitlement persons	Entitlements
A.	**Loss of Residential/Commercial/Industrial Land**		
1	Partial loss of land but residual is viable	a) Titleholder	• 100% Cash compensation for loss at replacement cost • 15% cash top up in compulsory acquisition • Cash compensation for standing assets • Administrative charges, title fees, or other legal transaction costs • Money Management training
		b) Tenant c) Lease holder	• Cash compensation for standing assets • Administrative charges or other legal transaction costs • One month notice to vacate • Money Management training
		d) Informal Settlers	• Cash compensation for standing assets • One month notice to vacate • Money Management training
2	Entire loss of land or partial loss where residual is not viable	a) Owners	• 100% Cash compensation for entire land holding at replacement cost • Replacement cost for standing assets erected by the Land Owner • 15% cash top-up in compulsory acquisition • Administrative charges, title fees, or other legal transaction costs • Money Management training
		b) Tenant (either residential or business) c) Lease holders	• Replacement cost for standing assets • Administrative charges or other legal transaction costs for registered leases • One month notice to vacate • Money Management training • Relocation assistance
		d) Informal Settler	• Replacement cost for standing assets • Land grant where possible alongside relocation and assistance with livelihood restoration • One month notice to vacate • Money Management training
B.	**Loss of Structures**		
3	Partial loss but residual viable	a) Legal User with valid titles	• Cash compensation at replacement cost calculated on market value without depreciation • Repair costs for unaffected structure or cash equivalent to 25% of the compensation • Right to salvage material plus relocation costs.
		b) Owner without titles	• Cash compensation at replacement cost based on market value without depreciation • Repair costs for unaffected structure or cash equivalent to 25% of the compensation • Right to salvage material plus relocation costs

	Type of Loss	Unit of Entitlement persons	Entitlements
		c) Informal user of building	• Cash compensation at replacement cost based on market value without factoring depreciation • Repair costs for unaffected structure at 25% compensation • Right to salvage material plus relocation costs • Where possible suggest and/or provide alternative business areas
4	Fully affected/part affected and remaining structure is non-viable	a) Land owner with valid title	• Cash compensation at replacement cost of the affected unit based in market value without depreciation plus a house building allowance at 25% of compensation • Right to salvage materials without deduction from the compensation package • One month notice to vacate • Relocation assistance
		b) Tenant/Lease Holder	• Cash compensation for remaining lease/deposits • Right to salvage materials • One month notice to vacate • Relocation assistance
C. Movable / Mobile structures			
5		Kiosks or Stalls	• Cash Compensation of comparable replacement sites • Cash Compensation of replacing improvements (such as foundations), and relocation expenses or other transaction costs.
D. Loss of Crops and Trees			
6	Trees and crops	Trees and crops owners	• Cash compensation for lost trees and crops at full replacement cost valued at market rate • Allowed adequate time to harvest the crop and trees. • 3-month notice to the PAPs of intention to use the site
E. Loss of Business / Income			
		Business operators	• Cash compensation based on a calculated average loss of income over an appropriate period (normally 3 months) • Livelihood restoration measures as identified in section 5.3 (above)
		Landlords	• Cash compensation based on average loss of income over an appropriate period (3 months)
		Employees	• Compensation as per national legal provisions (formal employees) • Informal employees: one month minimum wage • Casual, day to day labourers will receive advance notice that businesses will be removed
F. Loss of Community Proprietary Resources		Local Community	• In kind replacement for affected community resources/property
G. Assistance to Vulnerable Groups		Vulnerable Groups	• CWSB to consider other assistance over and above compensation package to cushion them against impact. To be treated on merit basis
H. Graves		Individual graves	• Negotiated reimbursement for translocation costs including option for physical translocation
		Communal graveyards	• Negotiation of available options

13.9.7 Grievance Management

The Project provides for simple and accessible extra judicial mechanism for managing grievance and disputes based on explanation and mediation by third parties. Each of the affected parties will be able to trigger this mechanism while still being able to resort to the judicial system

- The Grievance management provides for two tiers of amicable review and settlement, with the first tier at the site level[1]
- The second level will integrate a mediation committee in case the grievance cannot be solved at first level.
- Finally, there will be an option for each of the complainant to resort to the Court of Law (third level) in case there is no resolution of the grievance with the mechanism

Detailed Grievance redress mechanism is provided in the Preliminary RAP Report prepared as a separate assessment under this Consultancy.

13.9.8 RAP implementation Arrangements

All PAPs will be compensated before their structures are demolished, implying that compensation will be paid before project works start at a specific site/in a specific area as per the contractor's work schedule. Coast Water Services Board (CWSB) will be the lead agency in the RAP implementation and will work together with the County and The National Lands Commission (NLC) to implement the RAP.

In this Project, CWSB will establish a RAP Implementation Unit (RIU)), to implement this RAP. The unit will be responsible for ensuring that PAPs promptly access their compensation entitlements and that their livelihoods are restored after resettlement. The RAP implementation team will be responsible for:

- Liaison with National Lands Commission (NLC) on matters related to RAP implementation
- Delivery of the RAP compensation and rehabilitation measures to identified PAPS

The RAP Implementation Team and NLC will develop the schedule for the implementation of RAP activities which will include:

- Target dates for the start and completion of compensation payments
- Timetables for and the place of compensation payments
- Target dates for fulfilling the prerequisites for compensation payments and other legal requirements by PAPs
- The time table for special assistance to vulnerable groups
- Dates for vacant possession of the acquired land from the PAPs (this date must be after the payment of all compensation)
- The link between the RAP activities to the implementation of the overall sub-project components

[1]A site in this context implies areas where the PAPs are concentrated under various Project components.

13.9.9 RAP Monitoring and Evaluation

The purpose of monitoring and evaluation is to report on the effectiveness of the implementation of the RAP and the outcomes and impact of compensation on the PAPs in relation to the purpose and goals of the RAP. The general objective of the M&E system is to provide a basis for assessing the overall success and effectiveness of the implementation of the resettlement and compensation processes and measures.

Several Objectively Verifiable Indicators (OVIs) will be used to monitor the impacts of the compensation and resettlement activities. These indicators will be targeted at quantitatively measuring the physical and socio-economic status of the PAPs to determine and guide improvement in their social wellbeing.

The M&E will be undertaken at two levels:

- Internal monitoring: undertaken regularly by the RIU/Monitoring Officer
- External evaluations (or end-time of RAP implementation): Evaluations will be undertaken by an independent consulting firm hired by CWSB. Evaluation will be necessary to ascertain whether the livelihood and income restoration goals and objectives have been realised

Details of RAP monitoring indicators during and after Compensation Payments is presented in **Table 13.25** below.

Table 13.25: Monitoring Indictors During and After Compensation Payments

Resettlement Compensation Payment Period	Post-resettlement Compensation Payment Period
• Number of PAPs compensated • Number of PAPs who have acquired legal papers to new property • Number of PAPs who have restored their livelihood enterprises • Number of PAPs who have registered grievances with the GO • Number of PAPs whose grievances have been resolved • Number of vulnerable PAPs or groups identified and assisted during compensation payments	• Number of PAPs with successfully restored livelihoods and assets, • Number of PAPs who have maintained social and cultural ties, • No of PAPs whose grievances have been resolved or otherwise, • Number of vulnerable groups assisted and restored livelihood enterprise and assets.

Detailed RAP process has been provided in a separate Report presented as **D8: Preliminary Environmental and Social Impact Assessment (ESIA) & Preliminary Resettlement Action Plan (RAP) for the Preferred Development Strategy.**

14.0 ASSETS MANAGEMENT PLAN

14.1 Introduction to Asset Management Planning

This Chapter describes the purpose and requirements of an Asset Management Plan for a Wastewater Management Infrastructure based on current international best practice that is applicable to CWSB and MOWASSCO.

Asset Management is described as:
"*The combination of management, financial, economic, engineering and other practices, applied to physical assets with the objective of providing the required level of service in the most cost effective manner*".

It can also be described as: "maintaining a desired level of service provided by assets at the lowest life cycle cost." Lowest lifecycle cost refers to the best appropriate cost for rehabilitating, repairing or replacing an asset. Asset Management is implemented through an asset management programme that usually includes a living document in a written Asset Management Plan (AMP). In summary, an AMP identifies the assets that owned by the entity, presents the whole life cost of managing those assets to a specified level of service and allows the entity to more effectively meet its objectives.

The challenges faced by a Water Services Provider includes:

- Determining the best (or optimal) time to rehabilitate / repair aging assets
- Increasing demand for services
- Overcoming resistance to increasing tariffs
- Diminishing resources
- Rising expectations of customers/ consumers
- Increasingly stringent regulatory requirements
- Responding to emergencies due to asset failure
- Protecting assets

The benefits that result from the practice of Asset Management are:

- Prolonged asset life and aid in the rehabilitation/ replacement decisions through efficient, focussed and planned operation and maintenance
- Meeting consumer demands with a focus on system sustainability
- Setting tariff rates based on sound operational and financial planning
- Budgeting focused on activities critical to sustained performance
- Meeting service expectations and regulatory requirements
- Improving response to emergencies
- Improving security and safety of assets

There are five core aspects that need to be considered in implementing asset management. These aspects are illustrated in **Figure 14.1** on **Page 14-2.**

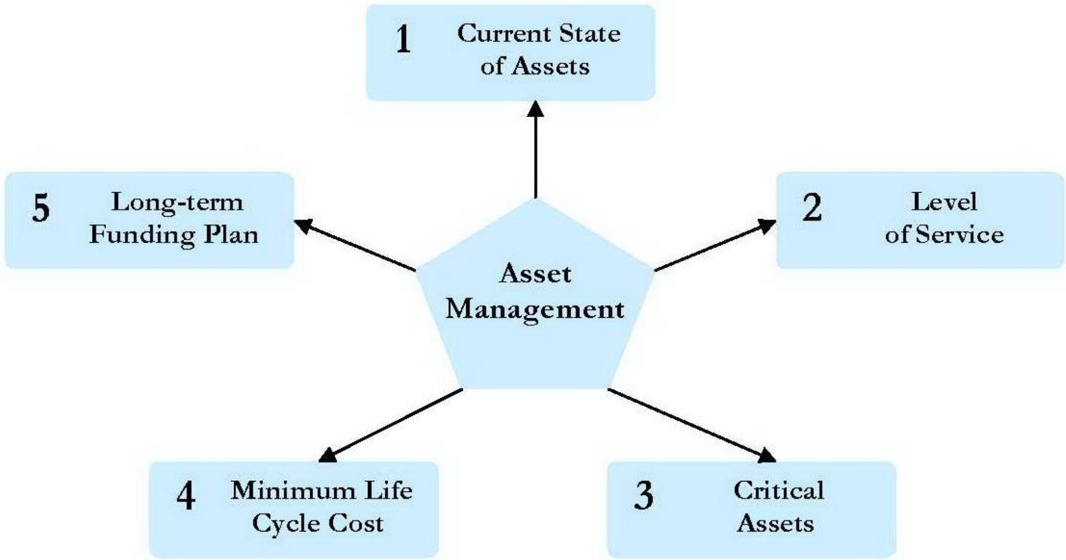


Figure 14.1: Core Aspects of Asset Management Framework

This framework covers all the major activities associated with asset management and can be implemented with a level of sophistication applicable to any given water supply system and situation. These five core framework aspects provide the foundation for asset management.

14.2 Asset Inventory

The first step in Asset Management is having an inventory of assets, knowing their current state and remaining useful life. Asset inventories need to be regularly updated to reflect on the status at the time and allow for assets that are rehabilitated, repaired, added or removed from service. An Asset Inventory includes information such as: ownership, location, age/ condition, useful life and value (original cost, depreciated value and replacement value) with assets grouped and subdivided into components and elements with similar base lives. Each component or element should be allocated a unique Identity (ID) in the Asset Inventory.

International best practices on Asset Inventory include:

- Recording the details and physical location of each asset in the asset database that is categorised in a manner which can be easily searched and manipulated e.g. by type, location, condition etc.
- Mapping the system with spatial data stored in a GIS with multiple levels and layers showing the different components
- Developing a condition assessment and rating system for all assets
- Assessing the remaining useful life of assets through projected useful life tables and asset decay curves, and determining asset values and replacement costs.

14.3 Levels of Service

Knowing the required level of "sustainable" service helps in the implementation of an Asset Management Programme and to communicate the AMP objectives with stakeholders. It is a defined service standard driven by legislation and regulation and customer expectations and against which service performance can be measured. Quality, reliability and environmental standards are all elements that define the level of service and associated performance goals for a sanitation system, both short-term and long- term.

Defining level of service requirements can be carried out based on the use of information about customer demand, from MOWASSCO and CWSB reports and stakeholders involved in the service provision and consumption.

The sustainable level of service needs need to be updated periodically to account for changes due to future growth in supply and demand, regulatory requirements and technology improvements.

Questions that need to be answered in determining the level of service cover include:

- What level do stakeholders and customers demand?
- What are the regulatory needs of the environmental agencies?
- What is the actual system performance?
- What are the physical capabilities of the assets?

Best practices undertaken in addressing the above questions include:

- Analysing current and anticipated customer demand and satisfaction with the system
- Allowing for the current and anticipated regulatory requirements
- Writing and communicating to the public, a level of service "Agreement" that sets out the systems performance
- Using level of service standards to track system performance over time

14.4 Critical Assets

It is necessary to determine which assets are critical to the sustainable performance of the system. Because assets fail, how are the consequences of failure best managed? Not every asset presents the same risk of failure, or is equally critical to the wastewater management system's performance. Critical assets are those that are classified as having a high risk of failing (through being old, in poor condition etc.) and which have major consequences if they do fail (major expense, system failure, safety concerns etc.). This type of analysis is also carried out in the vulnerability assessment.

Aspects for determining critical assets threshold are covered by addressing the following concerns:

- How can assets fail
- How do assets fail
- What are the likelihoods (probabilities) and consequences of asset failure?
- What is the cost of repair or replacement?
- What are the other costs (social, environmental etc.) associated with asset failure?

Best practices in the analysis of critical assets include:

- Listing assets in the inventory in accordance to how crucial they are to system operations
- Conducting a failure analysis root cause analysis, failure mode analysis
- Analysing failure risk and consequences
- Using asset decay curves to determine their economic life
- Reviewing and updating the systems vulnerability assessment

14.5 Asset Life Cycle Costs

Asset Management enables a system to determine the lowest cost options for providing the highest level of service over time. Typically for Utility Companies (WSPs) responsible for the wastewater management, the expenses for operation and maintenance, personnel and capital budget make up around 85% of annual expenses. An appropriate Asset Management Programme helps to make risk-based decisions for choosing the priority projects based on a time schedule and sound reasons.

Important issues to be addressed include:

- What alternative strategies exist for managing O&M, personnel and capital budget accounts?

- What strategies are most feasible?
- What are the costs of rehabilitation, repair and replacement for critical assets?

Best practices include:

- Applying predictive maintenance rather than reactive maintenance
- Knowing the costs and benefits of rehabilitation compared to replacement
- Applying lifecycle cost analysis, especially for critical assets
- Allocating resources based on asset conditions
- Analysing the cause of asset failure to develop specific response plans

Lifecycle Asset Management focuses on management and strategies considering all relevant economic and physical consequences from initial planning through to disposal, as are depicted in Figure **14.2** below.

Figure 14.2: Life Cycle Asset Management

14.6 Long-Term Funding and Classifying Expenditure

Sound financial decisions and developing an effective long-term funding strategy are critical to the implementation of an AMP. Knowing the full financial costs and revenues generated by the wastewater management system enables managers to produce reliable forecasts and budgets, which helps to decide changes needed for the long-term funding strategy to meet the AMP. The funding plan shows the relative magnitude of the different expenditure categories, which are usually broadly divided into operating and capital expenditure.

Annual expenditure can further be classified into the following categories:

14.6.1 Operational Expenditure

This is expenditure associated with the day to day running of the assets. They are those that generally consume resources such as manpower, energy and materials.

14.6.2 Maintenance Expenditure

This is expenditure required for maintaining an asset to achieve its design life. Maintenance expenditure can be planned (proactive/predictive) or unplanned (reactive). This cost excludes asset rehabilitation or renewal. The application of regular and timely maintenance can have a significant effect on the performance and life of the asset.

14.6.2.1 Renewal Expenditure

Expenditure associated with works for the rehabilitation or replacement of existing assets with those of equivalent capacity or performance. Having provisions for this type of expenditure is crucial for all facilities including new ones and is typically planned for 5 – 10 years after the construction or installation of the assets.

Deterioration curves or asset decay curves are used to calculate the life of an asset and decide the appropriate time for asset renewal instead of spending increasing amounts on annual maintenance and repair.

14.6.2.2 Capital Expenditure

Expenditure used to create new assets, or to increase the capacity of existing assets beyond their original design capacity or service is classified as capital expenditure.

14.7 Funding Plan

The preparation of accurate budgets and forecasts in a funding plan show whether the entity has sufficient funding to maintain the assets to the required level of service, and ultimately are the tariffs sufficient to meet the long-term needs.

Strategies to consider to meet this objective include:

- Revising the tariff structure
- Funding a dedicated asset renewal reserve fund from current revenue to provide for future needs (creating an asset annuity)
- Financing asset rehabilitation, repair and replacement through borrowing or other financial assistance.

14.8 Asset Management Plan Implementation

An AMP is a “living document” that constantly requires updating and revision by managers to accommodate changes to the asset inventory resulting from the rehabilitation, replacement and addition of assets. Deficiencies in AMP can be detailed in the improvement programme through its updates.

Where AMP fits into the operational, facilities’’ management and strategic sectors of the entity is as shown in the **Figure 14.3** on **Page 14-6**.

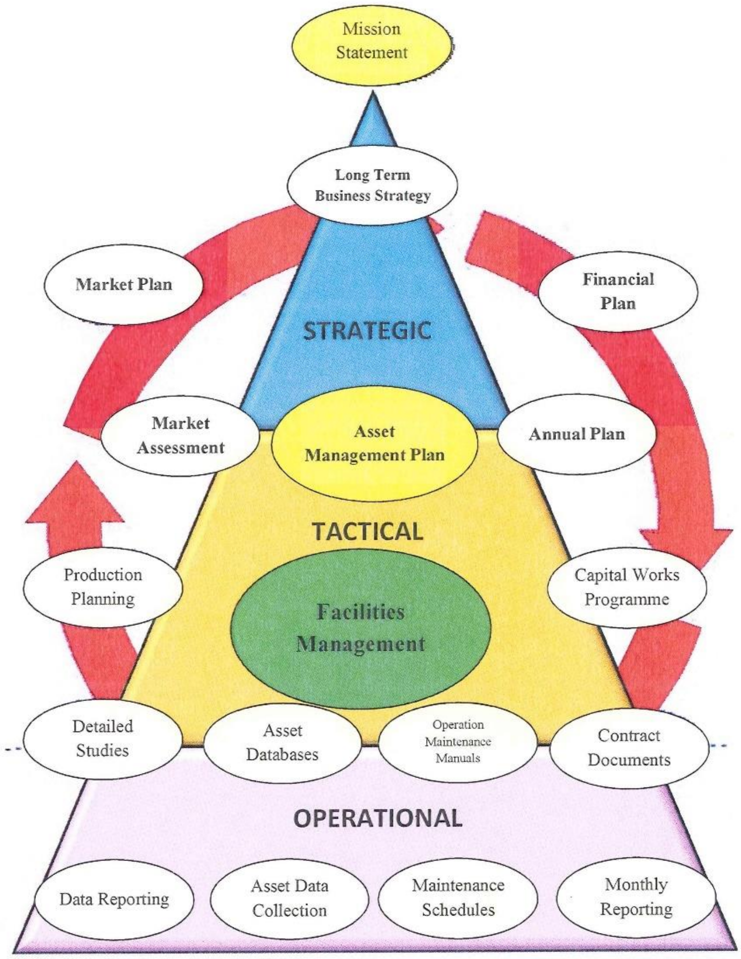


Figure 14.3: Where the AMP Fits In

14.9 CWSB Asset Management Plan Situation

Currently CWSB or MOWASSCO does not have a comprehensive Asset Management Plan in place along the lines of the AMP structure described above. There is thus an urgent need to prepare an Asset Management Plan for MOWASSCO with respect to water and sanitation services

The main aspects that need to be addressed while developing an AMP include;

- Define sustainable levels of service to customers
- More specifically determine critical assets and asset life cycle costs
- Define O&M, asset rehabilitation and renewal costs with a long-term funding strategy for the AMP
- Define the resources needed for implementing the AMP in terms of manpower, equipment, spare parts, training, outsourcing, etc.
- Define the process of incorporating the AMP into the business plan and operational procedures of AWSB and WSPs and procedures for the regular updating and modification of the AMP in the future as needs and infrastructure changes.

15.0 RISK MANAGEMENT

15.1 Introduction

Risk management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. Risk management's objective is to assure uncertainty does not deflect the endeavour from the project goals.

Risk management in Water Supply and Sanitation Systems is crucial.

Water is a finite and vulnerable environmental resource essential for life, social and economic good. The allocation of scarce water resources among competing uses has fundamental effects on the ecosystems and national economic development in terms of employment and the generation and distribution of income and poverty alleviation. Such policies can also have a significant impact on land use planning and the movement of population from rural to urban areas. The access to suitable amounts of water for basic human needs is therefore essential to be incorporated in the formulation and implementation of economic policies for resource development and allocation. Decreasing availability of usable water supplies, coupled with increases in demand can potentially lead to the inefficient and unsustainable use of water resources with significant economic, social, and environmental consequences.

Wastewater handling, treatment, disposal and re-use (where applicable) is important in determining the quality of the environment, water resources and public health.

Therefore, the environment and water natural resources should be safeguarded from all risks including monitoring the quality of effluent from Wastewater Treatment Plants which is normally discharged into natural water courses.

A risk is considered as an uncertain event or condition that, if or when it occurs, has a positive or negative effect on a project's objectives or outcome. Risks are inevitable and a component of any Project. Project managers should regularly assess risks as standard practice and develop or modify plans to address them.

The active Project level risk management plans should include an analysis of potential risks, including those with both high and low impact, as well as proposed mitigation strategies to help in counteracting negative consequences should problems arise.

Risk Management Plans should be periodically reviewed (preferably every 5 years, if not more frequently) by the Project team to avoid having the analysis becoming stale and not reflective of actual potential Project risks. In practice, the levels of risk involved in a specific course of action are compared to expected benefits to provide evidence for decision making.

Hazards and risks can be more elaborately defined as follows in **Table 15.1 on Page 15-2.**

Table 15.1: Definition of Project Hazards and Risks

Hazard	A situation or biological, chemical or physical agent that may lead to harm or cause adverse effects.
Risk	The potential consequence(s) of a hazard combined with their likelihoods/probabilities. The likelihood or probability of an adverse outcome or event.
Risk Assessment	The process of evaluating the consequences of hazards and their likelihoods or probabilities. For example, the failure of a technology may result in economic loss and associated risks. Environmental Risk Assessment is a process that evaluates the likelihood or probability that adverse effects may occur to environmental functions, as a result of human activities. Risk assessment provides a mechanism for communicating forecasted risks associated with decisions to the public and the stakeholders.
Risk Management	The process of appraising options for responding to risk and deciding which to implement. Risk management require periodic /continual re-assessment.
Environmental Value	An aspect of the environment that is important because of its ecological, economic or social significance to an ecosystem, the potential consequences of its loss, and/or its economic or social importance, including for example the ability of the environment to support agriculture, and to support tourism, or the human health hazards associated with deterioration in environmental services.

Risks are complex and may result from a variety of factors, including uncertainty in financial markets, project or business failures, legal liabilities, credit risk, accidents, and natural causes or disasters. Importantly, risks may also derive from unintended or unrecognised consequences of developments associated with individual projects, not necessarily directly connected to the programme under consideration, and from the cumulative impacts of a variety of factors.

Assessing a risk involves an analysis of the consequences and likelihood of a potential hazard being realised. In decision-making, low-consequence or low-probability risks are typically perceived as acceptable and therefore only require monitoring. In contrast, high-consequence or high-probability risks are perceived as unacceptable and a strategy is required to manage the risk.

A strategy would include structured risk assessment to better understand the features that contribute most to the risk, and to assist with the development of countermeasures. In the long-term, education and training in risk assessment and management should be considered for managers dealing with the wastewater management sectors. Furthermore, the precautionary principle should be adopted when considering and assessing risks, particularly where hazards have long environmental lifetimes or accumulative or irreversible consequences.

In the wake of the recent global economic problems, risk management is increasingly seen as an important executive-level issue and a process that needs to be incorporated in day-to-day decision making for long-term profitability and competitive advantage.

In general, risk management is considered to include the following elements:

1. Identify, categorise and assess potential threats.
2. Assess the vulnerability of critical components or assets to specific threats or to combinations of different threats.
3. Determine the risk and consequences of specific threats.
4. Identify mechanisms whereby those risks may be reduced.
5. Prioritise risk reduction measures, and include regular reviews of all threats as an integral component of programme management, ensuring that risk management is dynamic and responsive to change.

Potential hazards or risks can be categorised as either environmental or economic risks even though inevitable overlaps and linkages exist.

15.2 Environmental Risks

A range of potential environmental risks are expected in the construction and operation phases of the Wastewater Management Scheme such as from the effluent discharge into the natural water courses from the proposed Wastewater Treatment Plants.

The expected environmental and socio-economic impacts result from:

a. Resettlement and compensation,
b. Construction of Sewerage System (Sewers & Sewage Pumping Stations),
c. Construction of Wastewater Treatment Plants,
d. Operation of the Constructed Sanitation Systems.

Potential categories of risks include:

- Changes in precipitation and temperature as a result of climate change
- Hazards resulting from construction of the project components. Risk management procedures need to be incorporated in the detailed designs and operating procedures.
- Discharge of inadequately treated effluent to natural water course may result to increased health risks for downstream communities or households.
- Changes in local groundwater regime as a result of increased downstream flows after discharge of treated effluent.
- Hazards and risks encountered during the operation of the sewerage system.

Environmental impacts resulting from construction are considered as short-term impacts and can be managed with the adoption of recommended mitigation measures.

15.2.1 Climate Change

Global climate is predicted to change substantially, with changes in temperature, precipitation and frequency of storms, and with subsequent effects on hydrology especially in the drier areas. A global rapid rise in temperatures in the likely range of 1.1 to 6.4°C is expected. Precipitation patterns are expected to change significantly, and extreme weather events (severe storms, floods, droughts, and heat waves) are expected to become more intense and frequent. From the sanitation (public health) and environment (water resources) perspective, the increased incidence of drought periods represents a potential critical risk.

Agricultural output is predicted to be impacted by increased temperatures and changes in precipitation and runoff. It is considered that many countries in Africa may suffer productivity losses of more than 25 percent (World Bank, 2011)[2]. Such losses are projected to be acute in the Sahel, the Horn of Africa, and in East and South-West Africa – areas that are projected to experience significant decreases in precipitation and increases in temperature. Further work focussed on Kenya also confirms that global warming will have adverse effects on agriculture (Kabubo-Mariara and Karanja, 2007)[3]. Thus, the ability to provide water for downstream environments and for irrigation purposes is likely to be of increasing importance, especially when coupled with the increasing food requirements of an increasing urban population.

Most models confirm projected changes in precipitation and temperature. Whilst the actual extent of changes in precipitation are currently uncertain, models do indicate that changes will occur. This will have inevitable implications for water and food security.

[2] World Bank (2011). *Africa's Water Resources in a Changing Climate: Toward an Operational Perspective. Summary Report.* Africa Region, Sustainable Development Department, The World Bank.

[3] Kabubo-Mariara, J. and Karanja, F.K. (2007). *The Economic Impact of Climate Change on Kenyan Crop Agriculture: A Ricardian Approach*. World Bank, Policy Research Working Paper 4334.

The risks from climate change can therefore be summarized as follows:

- Most parts of East Africa are projected to experience an increase in consecutive dry days
- There will be an increase in temperatures
- Water demands are expected to increase. Crop water requirements are expected to be higher for both rain-fed and irrigated crops as temperatures rise. Similarly, livestock are likely to require more water.
- Water-related public health could also be compromised by climate change. Hydrologic and temperature change may modify the natural habitat boundaries of disease vectors such as mosquitoes, and other water borne diseases.

Given the difficulties of averting global warming, adaptation to climate change is considered essential to counter the expected impacts of long-term climate change. Improved management and conservation of available water resources, protection of the water sources from potential pollutants, water harvesting and recycling of wastewater are likely to play important roles.

Risk Management procedures need to include a regular assessment of the current climatic situation and water and sanitation related issues (public health).

15.2.2 Risks from Construction

Potential negative impacts expected from construction of the project components, are detailed in the Preliminary ESIA for the Selected Wastewater Management Schemes.

In general, the impacts related to such construction activities are minor, can be understood and planned for and mitigated against. The major risks would therefore result from pre-construction phase and construction phase environmental management plans not being fully prepared in advance and not being followed and activities monitored in detail.

An important component of risk management in the pre-construction phase will be to set up a series of important long-term monitoring systems that will provide the important information required during the construction phase and during the subsequent operational phase.

At construction, the disposal of excavated material represents a potential hazard if not planned and carried out to result in minimal social, economic and environmental impact. It is recommended that instead of considering the excavated material as “spoil” requiring disposal, it should be used as raw material for a range of activities such as road repair and construction, and for use as building material, including the making of bricks for buildings.

15.2.3 Public Health Risks

Public health depends on factors including the quality / quantity of water supply and sanitation systems adopted in an area. Proper sanitation entails safe handling of wastewater and proper disposal of the treated effluent and sludge.

The quality of the raw water in potential water resources should be good enough to produce domestic water supplies of a safe and acceptable standard when treated. These sources should be consistent in terms of quantity and quality. In many cases, it is cheaper to protect the water resources from pollution than to provide requisite treatment after contamination to ensure achieve acceptable standards. Contaminated and poorly managed water resources contain chemical, microbiological or radiological hazards which are health hazard.

The preventive measures that should be incorporated in risk management procedures include:

- Regular and comprehensive monitoring, to decide if and where contamination of the water is occurring especially when contamination of the water sources is most likely. Ideally, monitoring should be 200m downstream of effluent discharge point and 200m upstream.

- Proper operation and maintenance of the Wastewater Management Schemes to ensure proper conveyance and treatment of sewage including safe disposal of sludge
- Detailed knowledge of where the catchment (surface water) or re-charge zones (groundwater) of the water sources are, and the nature of the land and all the land use and/or land cover in these areas.
- Identifying protection zones for the sources, so that possible sources of contamination that require to be managed can be identified. This could for example, include the legal establishment of a series of Nitrate Vulnerable Zones (NVZs) within the watersheds.

As an integral component of risk management procedures, water quality data of the water resources need to be analysed and made available on a regular basis to all authorities involved in the management of water resources and related issues.

15.2.4 Operational Hazards

Several hazards are inevitable during the operation of the Wastewater Management Scheme System such as:

- Blockages of sewers
- Sewer leakages and bursts; leading to ground infiltration
- Microbiological contamination of water sources and natural water courses from raw sewage or unpolished effluents
- Contamination of drainage channels and downstream water sources as a result of poorly or inadequately treated wastewater.

Risk management plans will need to take account of such operational hazards and incorporate risk reduction strategies.

15.3 Economic Risks

The use of pricing policies and other economic instruments are essential for the effective and equitable allocation of resource considering social and economic criteria as well as basic human needs. Economic evaluations need to consider positive and negative impacts on health, human and ecosystems. Inadequate economic policies have often contributed to the poor performance of wastewater utilities thus decreasing their ability to attract financial resources from the public and private sector as well as the international community.

While the public sector has traditionally played a major role in financing wastewater utilities development, there is an increasing recognition of the need to involve other stakeholders (private sector and community based organisations) for financial sustainability.

Financial support for the collection, processing and dissemination of timely, reliable and demand-oriented information is essential to the effective management of wastewater management schemes.

15.3.1 Multicriteria Evaluation and Risk Analysis of Proposed Investment Scenarios

The Least Cost Analysis for the economic evaluation of alternative schemes of satisfying the sanitation needs of Mombasa Island and North Mainland up to year 2040, considered the capital and operational costs and their investment schedules.

The Least Cost Analysis determined the most economically efficient means of providing Wastewater Management System to meet the projected demand, through a normalisation process allowing for the options different configurations, to show the Average Incremental cost of BOD_5 Removal (AIC) for each option expressed as US$/m^3 of BOD_5 removed. Sensitivity analysis to test the effect of changes in the key parameters – capital costs, O&M costs, and discount rate was also carried out.

Following the Least Cost Analysis, a Multicriteria Analysis was carried out (***See Chapter 9***) considering six key sustainability issues taking account of natural resources, economic performance, technical issues, environmental issues and social sustainability. Each aspect was scored and weighed according to its importance and the overall score used to determine the best option and strategy.

The Multicriteria Analysis allowed for other factors affecting the risk and sustainability of the development option that were not fully reflected in the economic Least Cost Analysis which uses the monetised capital and O&M costs. Risks were accommodated in the Multicriteria Analysis by considering several factors, particularly on the operation and maintenance, schemes technical complexity and number of management entities involved; susceptibility to prioritisation and; multiplicity of the Wastewater Treatment Plant (Phasing).

The results of the Multicriteria Analysis reflect the preferred option and strategy for meeting future water demand that is best suited to manage the potential risks.

15.3.2 Key Issues and Recommended Actions

a. Wastewater Management Scheme must be integrated into the national economy, recognising it as a social and economic good, vital for ecosystem functioning and applying economic instruments in its management. As such, economic policies must consider "intangibles" such as social and environmental values of dealing with wastewater as well as the special conditions in non-monetary sector economies.

b. Actions should be oriented towards applying demand based management approach taking into account the notion of users' willingness and ability to pay. Resources must help in the collection, dissemination and transfer of international experiences in economic evaluation and financial management of wastewater schemes. Where possible, support should be provided to strengthen private sector, community based participation as well as the development of appropriate and low cost technologies. Also, assistance should continue in favour of public institutions in improving their role.

c. Efficiency, transparency and accountability are keys to sustainable financial management of wastewater management schemes. For these, information should be made public including; performance indicators, procurement procedures, pricing policies and components, cost estimates and revenues. Determination and allocation of subsidies, cross-subsidies, and charges should be transparent in order to maintain confidence and improve investment revenues in the sector. Instruments such as auditing could help achieve this goal.

d. Integrated wastewater management requires closed partnership between public and private sectors. As such, a clear definition and distinction should be made of the role of both central and county governments, the private sector and other stakeholders, where appropriate to local situations. This is expected to create more conducive institutional and legal environment for private sector investment and the emergence of local water service providers. Particular attention has to be given to financial and economic risk assessment.

e. Regardless of policies, financial sustainability is a prerequisite for sustainable integrated wastewater management. Therefore, it is a necessity to facilitate a gradual transition towards full cost recovery, criteria for financial burden sharing and the development of financial and regulatory instruments. Also, measures needed include adapted financial policies for the poor and rural areas who might not have access to the water-borne sanitation system when carrying tariff studies. Emphasis should be placed on participation of users, training of local entrepreneurs and the diversification of sources of funding. Furthermore, a strong link should be made with the de-centralisation process.

f. At the same time, it is important to ensure adequate financing of the wastewater management schemes. Related issues in this case concern the adequacy of absorptive capacity and availability of financial resources within the sector, the lack of political awareness and will to implement strategies aimed at recovering costs as well as the requirements of external funding sources which limit the flows of resources to the sector. Thus, actions should be aimed at improving donor-recipient dialogue on financing, the creation of national fund for financial resources mobilisation and allocation in the water resources sector. The international community and Governments (donors and recipients alike) should be urged to maintain and be encouraged to increase their assistance to the water resources sector in a predictable manner and targeted to solve specific problems. Value can be added by improving communication and co-operation among sources of financing as well as the mobilisation of largely untapped community financing resources and through the provision of credit mechanisms which foster self-help efforts by individuals. This includes the mobilisation of innovative source of funding.

g. The frequency of extreme events has increased in recent decades. Therefore, provision should be made for economic costs analysis of these events and for the management measures for chronically prone areas to flooding and drought. Several main actions may be concurred to achieving this goal. The creation of mechanisms of regional consultation, regional solidarity funds, drought and flood preparedness programs and early warning systems, mitigation plans at local and national levels, regional emergency funds and insurance programs for extreme events could be considered.

h. In a broader perspective, several priority activities should be financed including institutional and capacity building, integrated wastewater planning and management. Particularly, local support should be provided for sustainable solutions to communities, associations, local authorities and emerging local private sector.

i. Finally, financial resources can be best attracted to the sector when efforts are made to increase financial accountability and to reduce cost in particular. For this, specific actions could include restructuring of existing institutions, improving existing management through demand management/leak reduction, promoting competition in service provision, data collection and creating financial incentives, participation as well as the use of low cost technologies.

15.3.3 Priority Areas in Need of Financing

Areas in need of financing are grouped into the following divides:

- Institutional capacity building/support to policy and legislation
- Integrated wastewater Management
- Data collection, monitoring and integrated information management systems
- Local support for sustainable solutions to communities, associations, local authorities and emerging local private sector
- Investment to areas without access to basic needs

15.3.4 Strategies / Action for Cost Reduction

Several strategies and actions are recommended to address economic and financial issues related to wastewater Management. Such measures include:

- Restructuring of existing institutions to reduce cost
- Improving existing management such as demand management/leak reduction
- Promoting competition in service provision
- Improving existing data collection network
- Provision of financial incentives e.g. tax exemption for equipment and to private sector;
- Investing in under privileged areas
- Reliance on low cost systems and appropriate technologies including indigenous technologies
- Increasing accountability in system management

15.4 Risk Management Plan

An important component of the risk management will be the establishment of a set of systems for monitoring and recording relevant information.

General Risk Management Plan for Identified Environment and Social Risks are given in **Table 15.2** below

Table 15.2: Identified Environment and Social Risks and Mitigation Measures

ACTIVITY	PARAMETER	MITIGATION MEASURES CHECKLIST
0. General Conditions	Notification and Worker Safety	(a) The local construction and environment inspectorates and communities be notified of upcoming activities (b) The public be notified of the Works through appropriate notification in the media and/or at publicly accessible sites (including the site of the works) (c) All legally required permits obtained for construction and/or rehabilitation (d) Contractor formally agrees that all work be carried out in a safe and disciplined manner designed to minimize impacts on neighbouring residents and environment. (e) Workers' PPE comply with international good practice (always hardhats, as needed masks and safety glasses, harnesses and safety boots) (f) Appropriate signposting of the sites to inform workers of key rules and regulations to follow.
A. General Rehabilitation and /or Construction Activities	Air Quality	(a) Construction debris kept in controlled area and sprayed with water mist to reduce debris dust (b) During project construction, dust should be suppressed by ongoing water spraying and/or installing dust screen enclosures at site (c) The surrounding environment (sidewalks, roads) be kept free of debris to minimize dust (d) No open burning of construction / waste material at site (e) No excessive idling of construction vehicles at sites
	Noise	(a) Construction noise be limited to restricted times agreed to in the permit (b) During operations, the engine covers of generators, air compressors and other powered mechanical equipment be closed, and equipment placed as far away from residential areas as possible
	Water Quality	(a) The site establishes appropriate erosion and sediment control measures such as e.g. hay bales and / or silt fences to prevent sediment from moving off site and causing excessive turbidity in nearby streams and rivers.
	Waste management	(a) Waste collection and disposal pathways and sites be identified for all major waste types expected from demolition and construction activities. (b) Mineral construction and demolition wastes be separated from general refuse, organic, liquid and chemical wastes by on-site sorting and stored in appropriate containers. (c) Construction waste be collected and disposed properly by licensed collectors (d) Records of waste disposal be maintained as proof for proper management as designed. (e) Whenever feasible the contractor to reuse and recycle appropriate and viable materials (except asbestos)

ACTIVITY	PARAMETER	MITIGATION MEASURES CHECKLIST
B. Individual wastewater treatment system	Water Quality	(a) The approach to handling sanitary wastes and wastewater from building sites (installation or reconstruction) must be approved by the local authorities (b) Before being discharged into receiving waters, effluents from individual wastewater systems be treated to meet the minimal quality criteria set out by national guidelines on effluent quality and wastewater treatment (c) Monitoring of new wastewater systems (before/after) will be carried out (d) Construction vehicles and machinery will be washed only in designated areas where runoff will not pollute natural surface water bodies.
C. Physical cultural (s)	Cultural Heritage	(a) If the facility is to be constructed within a designated historic structure, very close to such a structure, or located in a designated historic district, notification shall be made and approvals/permits be obtained from local authorities and all construction activities planned and carried out in line with local and national legislation. (b) It shall be ensured that provisions are put in place so that artefacts or other possible “chance finds” encountered in excavation or construction are noted and registered.

In addition, there are a series of potential risks that are related to or linked with Climate Change. These are, for example, likely to alter or increase the water requirements of downstream communities, as well as the requirements for agriculture, and for other water related sectors of the economy. The relevant sectors are likely to include: Agriculture, Energy, Health, Biodiversity and Ecosystems, as indicated above under the section on Climate Change. Risk management related to Climate Change will need to be carried out in conjunction and collaboration with the new Climate Change Authority, established by Bill of Parliament and signed into law in May 2016.

Similarly, there are long-term risks associated with the onset of Peak Oil, and predicted increases in crude oil prices, resulting in increased costs and changes to sectors of the economy. Current trends in the international crude oil prices, based on daily price data from the year 2000 to the present, indicate a trend towards a doubling of current crude oil prices by the year 2018. Such cost increases may result in changes in the tendency for population increase in the major urban. Such changes would modify the demands for wastewater services. Risk management therefore needs to be aware of this potential situation and the possible requirements for changes in the wastewater management schemes.

16.0 CONCLUSION OF THE MASTER PLAN

The current waterborne system in Mombasa Island requires extensive rehabilitation and expansion to sever the needs of the growing urban center. In areas of Mombasa Island and North Mainland where residents use on-plot sanitation means such as septic tanks and pit latrines and lacking a proper sludge management and disposal facility is a health hazard to the residents and an environmental risk.

As an immediate intervention, rehabilitation works on existing sewerage system, construction of Ablution Blocks at designated Public Places and a centralized Sludge Handling Facility is necessary. It is equally important to ensure procurement of Exhaust Vehicles to provide desluging and transport services. A summary of the Immediate Sanitation Measures and their costs estimates are given **Tables 16.1, 16.2** and **16.3** below.

Table 16.1: Details of the Ablution Blocks – Immediate Sanitation Measures

Number Proposed	Details of each Ablution Block			Total Capital Cost	
	No. of Toilets	No. of Shower Rooms	Max. Daily capacity	Ksh.	USD
6	6	2	720	93,000,000	902,913

Table 16.2: Details of the Sludge Handling Facility – Immediate Sanitation Measures

S/No.	Component	Details	Total Capital Cost	
			Ksh.	USD
1	Tanker Discharge Bay	• Bar Screens, Collection Chamber, Hard-stand Washing Bay & Parking Space	58,299,957	566,019
2	Sludge Drying Beds	• 8 Beds; each 13 x 10m		
3	Twin-Septic Tanks	• 2 Tanks; each 98 m³ capacity		
4	Land Requirement	• 0.7 Ha		
5	Exhaust Discharge Tanker	• Minimum 1 Nr (Either owned by MOWASSCO or Private Providers)	-	-

Table 16.3:: Details of Rehabilitation Works – Immediate Sanitation Measures

Rehabilitation Works on Mombasa Island sewers	Total Capital Cost	
	Ksh.	USD
• Replacement of missing / vandalised manhole covers, • Repair of broken manholes, • unblocking of partially / fully blocked sections of the sewer line and flushing, • Identify, expose and raise above ground levels buried manholes, • Replacement of collapsed sections of the sewer line, • Supply of Aluminium Telescopic Ladders • Ancillary works on Pumping Stations.	24,781,000	2,147,694

To provide a sustainable sanitation system, a de-centralized wastewater management system comprising of a gravity sewage conveyance system with limited pumping (29 Nr Pumping Station) and a Waste Stabilization Ponds system based Wastewater Treatment Plant - ultimate capacities – 77,300 m³/d at Nguu Tatu and 9,900 m³/d at Shimo la Tewa and has been selected from the developed alternative schemes. The implementation of this strategy is to be carried out in 2 phases i.e. Medium Term Plan (2021 -2025) and Long Term Plan (2026 – 2040).

The implementation details of the selected Wastewater Management Scheme in the 2 Phases are given in **Tables 16.4 and 16.5** below.

Table 16.4: Summary of Implementation Cost: Medium-Term Plan Plan (2021 -2025)

S/No.	Component	Details	Cost (Kshs)	Cost (USD)
1	Land Acquisition	• 185 Ha	10,804,077,515	104,893,956
2	Sewers	• 225 – 1,200 mm Dia; Total length 340 km		
3	Pumping Stations	• 28 Nr		
4	Waste Water Treatment Plant	Waste Stabilization Ponds; • Capacity 38,650 m³/d at Nguu Tatu • Capacity 4,950 m³/d at Shimo la Tewa		

Table 16.5: Summary of Implementation Cost: Long-Term Plan Plan (2026 -2040)

S/No.	Component	Details	Cost (Kshs)	Cost (USD)
1	Sewers	• 100 – 225 mm Dia; Total length 31 km	4,927,778,000	47,842,505
2	Pumping Stations	• 1 Nr		
3	Waste Water Treatment Plant	Waste Stabilization Ponds; • Capacity 38,650 m³/d at Nguu Tatu • Capacity 4,950 m³/d at Shimo la Tewa		

Financial analysis of the selected Wastewater Management Scheme presented the following Financial Ratios / Performance Indicators;

- **Benefit – Cost (BC) Ratio;** 1.14 - 1.47
- **Net Present Values (NPV);** Ksh. 7,611,825,333 @ 5% cost of capital
  Ksh. 1,758,548,750 @ 8% cost of capital
- **Financial Internal Rate of Return (FIRR);** 9.70%

On the other hand, economic analysis presented the following Performance Indicators;

- **Net Present Values (NPV);** Ksh. 3,061,239,678 @ 10% cost of capital
  Ksh. 1,188,043,219 @ 8% cost of capital
- **Economic Internal Rate of Return (EIRR);** 14%

Sensitivity analyses also indicate that the project viability is susceptible to shocks of 10% and 20% increase in O&M and project costs and reduction in net income.

Thus, it can be concluded that the selected scheme is both financially and economically viable.