Chapter 8 Infrastructure Development Plan

8.1 Existing SEZ and Port Development Plan

8.1.1 National Development Plan (Kenya Vision 2030、Second Medium-Term Plan (MTP2) (2013-2017)

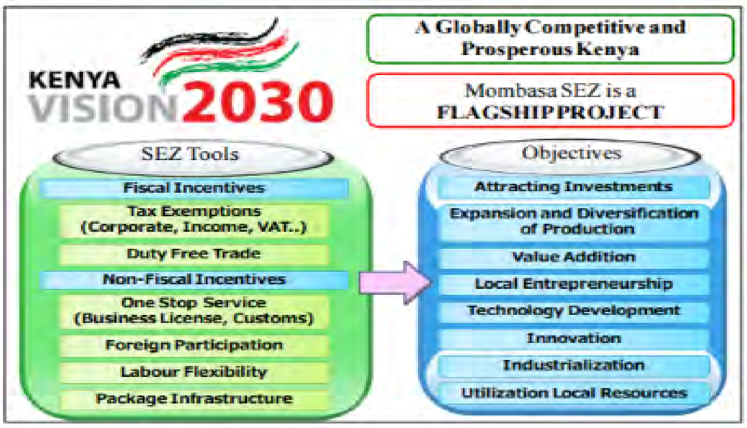
Vision 2030 is being implemented as part of the five-year medium-term plans, the first of which is covering the period of 2008–2012. The Ministry of Planning and National Development and Vision 2030 Delivery Secretariat have reviewed this First Medium-Term Plan, paying attention to the feedback of the stakeholders, as required by the 2010 Constitution, and this was used for the preparation of the 2013–2017 plan.

Establishment of the Special Economic Zone (SEZ) is a flagship project of Kenya Vision 2030. The specific objectives are as follows:

- Attraction of both local and foreign investments
- Expansion and diversification of the produced goods and services for domestic and export markets
- Promotion of value addition
- Promotion of local entrepreneurship through small and medium-sized enterprises (SMEs)
- Enhancement of technology development and innovation
- Promotion of rural and regional industrialization by exploiting comparative advantages of local resources.

On the Second Medium-Term Plan (MTP2) 2013-2017, there is a description stating that the SEZ will be established in Mombasa (including Dongo Kundu Free Port), Lamu, and Kisumu. The vision and contribution of the SEZ is shown in Source: JICA Design Team

.



Source: JICA Design Team

Figure 8.1.1 Needs of SEZ

8.1.2 Existing SEZ Development Plan

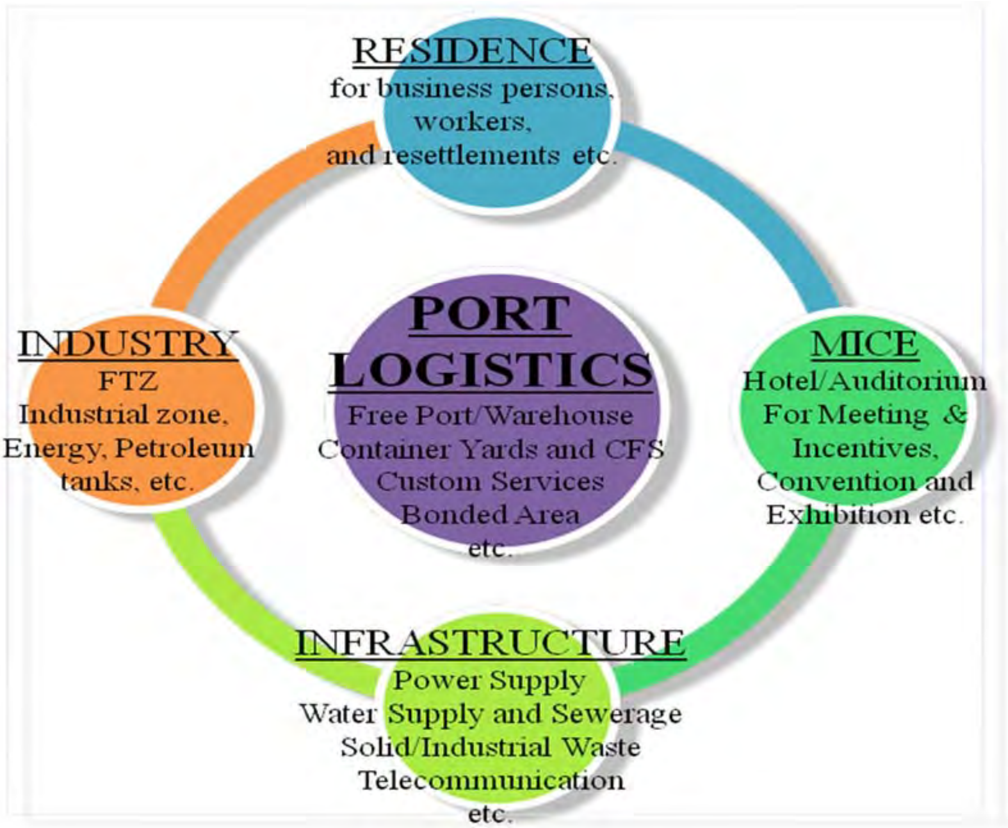
(1) Background

The previous master plan for the Mombasa SEZ was planned in the "Project on Master Plan for Development of Dongo Kundu, Mombasa Special Economic Zone (2014-2015)" (hereinafter referred to as the Mombasa SEZ M/P) funded by JICA. It was approved in February 2016 by the Cabinet of Kenyan government. In the Mombasa SEZ M/P, not only the land use plan but also the infrastructure development plan, and the environmental and social considerations were covered. Summary of the Mombasa SEZ M/P is shown below.

(2) Development Concept

To maximize the geographical advantages of the Mombasa SEZ in Dongo Kundu in consideration of the development goal, the development concept of the SEZ is determined as a "Multifunctional Port Logistics based SEZ", which consists of the following: (i) port, (ii) free port/free trade zone, (iii) industrial park, (iv) meeting-incentives-conference-exhibition, and (v) residential functions.

In addition, an integrated infrastructure, including the power supply, water supply, waste treatment and telecommunication, will be developed to attract domestic and foreign investors. Figure 3.2.1 illustrates the component ideas of the SEZ development.



Source: Project on Master Plan for Development of Mombasa Special Economic Zone / JICA, 2015

Figure 8.1.2 Component of the SEZ Development

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

8.1.3 Existing Port Development Plan

(1) Mombasa Port Master Plan (2015)

Due to the rapid economic development in the region and the increasing container handling volume at Mombasa Port, which is used not only for the trade of Kenya, but also for inland countries such as Uganda and Rwanda, the Japan International Cooperation Agency (JICA) supported the Kenya Ports Authority in expanding the container terminal on the northern side of the port under the "Mombasa Port Development Project" which a loan agreement was signed in November 2007 for the amount of 26.7 billion Japanese Yen. The cargo handling volume at Mombasa port has been increasing and taking the situations into consideration, it was required to formulate the master plan for the development of Mombasa Port, containing the vision and concept. The Mombasa Port master plan study (Port M/P) was completed in 2015 and summarized below.

i) Demand Forecast

The results of demand forecast for import, export and transit cargoes including container cargoes are shown below, comparing the demand forecast during SAPROF Review in 2013.

Table 8.1.1 Demand Forecast for Imported Cargos

(x1,000 tons)

	2014	SAPROF Review 2013				Updated Demand Forecast/Year 2014 Base				
		2015	2020	2025	2030	2015	2020	2025	2030	2035
Iron & Steel	1,367	1,259	1,935	2,684	3,461	1,357	2,067	2,853	3,668	4,397
Rice	651	326	313	210	141	331	316	262	145	0
Sugar	231	427	551	681	819	435	558	688	826	973
Chemicals & Insecticides	390	222	222	222	222	260	260	260	260	260
Plastic	662	330	330	330	330	399	399	399	399	399
M/Vehicle & Lorries	463	529	840	1,184	1,541	487	742	1,025	1,318	1,580
Paper & Paper Products	503	565	905	1,281	1,671	431	645	881	1,127	1,346
Cereal Flour	49	121	121	121	121	75	75	75	75	75
Fertilizer	102	73	73	73	73	81	81	81	81	81
Maize in Bags	37	31	31	31	31	31	31	31	31	31
Wheat in Bags	9	7	7	7	7	9	9	9	9	9
Others	4,649	6,624	10,339	14,454	18,721	6,075	9,152	12,560	16,095	19,256
Total General Cargo	**9,113**	**10,514**	**15,667**	**21,278**	**27,138**	**9,971**	**14,335**	**19,124**	**24,034**	**28,407**
Wheat in Bulk	1,908	2,336	3,380	4,537	5,737	1,981	3,088	4,497	6,203	8,063
Clinker	2,065	3,019	5,184	7,583	10,071	2,690	4,436	6,370	8,375	10,169
Fertilizer in Bulk	360	341	341	341	341	579	579	579	829	829
Coal	436	326	361	396	431	396	582	788	1,001	1,192
Other Cereals in Bulk	184	110	110	110	110	106	106	106	106	106
Maize in Bulk	0	414	414	414	414	485	492	471	466	564
Others	278	362	504	646	788	306	459	629	805	962
Total Dry Bulk	**5,231**	**6,908**	**10,294**	**14,027**	**17,892**	**6,543**	**9,742**	**13,440**	**17,785**	**21,885**
P.O.L.	6,286	7,425	10,048	12,953	15,966	6,757	8,654	10,755	12,933	14,882
Other Liquid Bulk	906	1,043	1,438	1,876	2,330	995	1,324	1,688	2,065	2,403
Total Liquid Bulk	**7,192**	**8,468**	**11,486**	**14,829**	**18,296**	**7,752**	**9,978**	**12,443**	**14,998**	**17,285**
Grand Total	**21,536**	**25,890**	**37,447**	**50,134**	**63,326**	**24,266**	**34,055**	**45,007**	**56,817**	**67,577**

Source: Mombasa Port M/P (2015)

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Table 8.1.2 Demand Forecast for Exported Cargos

(x1,000 tons)

	2014	SAPROF Review 2013				Updated Demand Forecast/Year 2014 Base				
		2015	2020	2025	2030	2015	2020	2025	2030	2035
Tea	554	469	513	558	603	522	605	698	811	912
Soda Ash	336	530	746	962	1,178	355	465	588	737	870
Coffee	256	260	293	326	359	265	313	368	434	493
Others	851	1,183	1,800	2,477	3,178	965	1,269	1,608	2,022	2,391
Total General Cargo	**1,997**	**2,442**	**3,352**	**4,323**	**5,318**	**2,107**	**2,652**	**3,262**	**4,004**	**4,666**
Titanium	363	0	0	0	0	450	450	450	450	450
Soda Ash in Bulk	0	29	29	29	29					
Cement in Bulk	0	2	2	2	2					
Flourspar	59	70	70	70	70					
Other Dry Bulk	0	11	11	11	11	84	84	84	84	84
Total Dry Bulk	**422**	**112**	**112**	**112**	**112**	**534**	**534**	**534**	**534**	**534**
Bulk Oil	19	92	92	92	92					
Bunkers	26	62	62	62	62					
Total Liquid Bulk	**45**	**154**	**154**	**154**	**154**	**112**	**112**	**112**	**112**	**112**
Grand Total	**2,464**	**2,708**	**3,618**	**4,589**	**5,584**	**2,753**	**3,298**	**3,908**	**4,650**	**5,312**

Source: Mombasa Port M/P (2015)

Table 8.1.3 Demand Forecast for Container Cargos

(x1,000 TEU)

	2014	SAPROF Review 2013				Updated Demand Forecast/Year 2014 Base				
		2015	2020	2025	2030	2015	2020	2025	2030	2035
Import										
Full	482	580	894	1,250	1,628	551	826	1,140	1,473	1,780
Empty	7	18	28	39	51	17	27	38	50	62
Subtotal	**489**	**598**	**921**	**1,289**	**1,678**	**568**	**853**	**1,178**	**1,523**	**1,842**
Export										
Full	131	160	222	290	362	145	183	226	279	326
Empty	332	438	700	998	1,317	424	670	952	1,244	1,517
Subtotal	**463**	**598**	**921**	**1,289**	**1,678**	**568**	**853**	**1,178**	**1,523**	**1,842**
Transshipment										
Full	53	11	22	36	54	11	22	36	54	66
Empty	8	7	13	21	31	7	13	21	31	38
Subtotal	**61**	**18**	**35**	**57**	**85**	**18**	**35**	**57**	**85**	**105**
Total	**1,012**	**1,214**	**1,878**	**2,634**	**3,442**	**1,154**	**1,741**	**2,412**	**3,131**	**3,789**

Source: Mombasa Port M/P (2015)

ii) Future Trend of Calling Ships

Ship sizes calling at Mombasa port in the future are forecasted by vessel types as shown in Table 8.1.4.

Table 8.1.4 Future Trend of Calling Ships

Vessel type	DWT (Max)	Load (TEU/ton)	LOA (m)	Beam (m)	Draft (m)
Container	60,000	4,300-5,400	275/285	37.2/40.0	12.7/13.8
General cargo	18,000	18,000	156	22.4	9.8
Car carrier	30,000	8,000 units	228	32.3	11.3
Bulk carrier	70,000	70,000	233	32.3	13.0
Tanker	100,000	100,000	250	42.7	14.8

Source: Mombasa Port M/P (2015)

Following points merit attention:

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

- Container ship: The size of container ships calling at Mombasa port is expected to increase in line with the world trend. Once the container terminal having a water depth of -15 m in the Mombasa Port Development Project Phase 1 is completed, 60,000 DWT container ships (post-Panamax type) will be able to call the port at full draft,
- Car carrier: If the Dongo Kundu Freeport Project is realized and the terminal has a sufficient water depth (more than -12.5 m) and berth length (at least 250 m), car carriers having a loading capacity of 8,000 units will be able to call the port at full draft,
- Bulk carrier: If the Dongo Kundu Freeport Project is realized and the terminal has a sufficient water depth (more than -15.0 m) and berth length (at least 250 m), 70,000 DWT bulk carriers (Panamax type) will be able to call the port at full draft,
- The sizes of general cargo vessels and tankers will remain unchanged because the volume of general cargo is expected to increase only marginally while tankers are already sufficiently large given the current volumes.

iii) Development Plans

Although the total volume of cargo handled at the port has duplicated over the past decade, various issues in cargo handling are witnessed in the port including absolute shortage of mooring facilities, inadequate staking area, extraordinarily high berth occupancy ratio and mismatch between the length of existing berths and LOA of calling vessels of which dimension has been enlarging. Cargo handling capacity of the port has been saturated with the cargo demand already. Consequently, long waiting time for berthing due to berth occupied by another ship and low productivity in cargo handling take place.

Mombasa Port has various advantages in maritime transport, namely long history as an international port, an international gateway function referred by Kenya and other landlocked countries and plenty of direct hinterland which could be developed as industrial area. Mombasa Port should be developed taking these advantages into consideration.

In Mombasa Port M/P, facility planning was conducted based on the following stances.

- To develop Mombasa Port in the most effective and efficient manner utilizing existing resources and potential of the port.
- To maximize cargo handling capacity of the port. Overflowing cargo will be handled in another international port including Lamu Port.
- To develop required mooring and other facilities in a timely manner. These required facilities include terminals for MPDP, Dongo Kundu SEZ Project and other necessary projects.
- To renew existing berths in Kilindini in series. Passenger facilities including a berth and terminal will be developed.
- To introduce more efficient cargo handling equipment to cope with the critical shortage of berths.

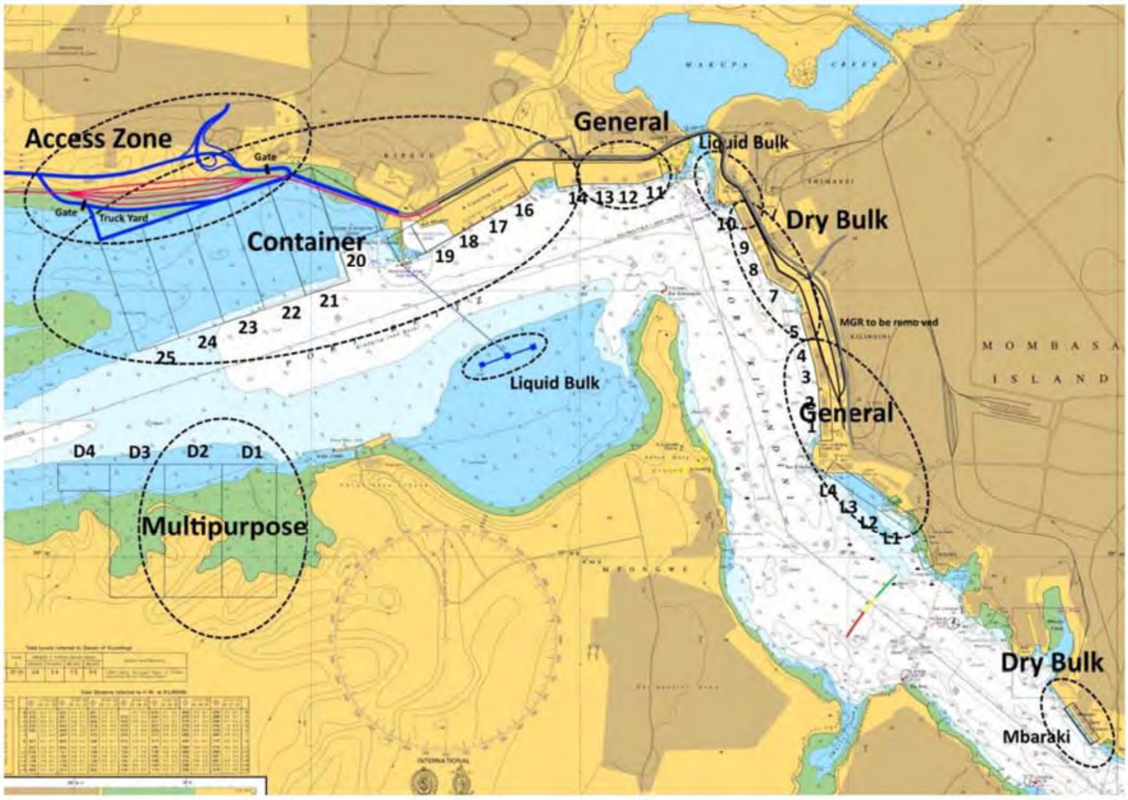
Two scenarios were presented in the Mombasa Port M/P and “Scenario 1” was considered recommended with the following characteristics.

- Amount of Investment is minimized.
- New berths at Dongo Kundu are deep-water multi-purpose terminals for rapidly increasing commodities including vehicle, wheat and container.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

- Other bulk cargo including clinker and coal are handled at existing berths.
- Cargo handling productivities are to increase. Since the productivities of vehicle and grain at deep-water terminal in Japan are three (3) to four (4) times of that in Mombasa Port, productivities at deep-water terminal in Dongo Kundu could be assumed to be three (3) to four (4) times of current productivities at existing terminals.
- Ship waiting time for berthing remains at current level.
- Cargo handling capacity may be saturated with cargo demand at a certain year

Two types of long-term spatial utilization plans were prepared. Figure 3.12 shows spatial utilization plan for "Scenario 1" that is in line with current spatial utilization.



Source: Mombasa Port M/P (2015)

Figure 8.1.3 Spatial Utilization Plan (Scenario 1)

(2) Mombasa Port Development Project (MPDP)

i) Construction of a New Container Terminal

This Project consists of the construction of a New Container Terminal on a total area of 100 hectares and capacity to handle over 1.45million TEUs per annum. Development for Phase I and Phase II has been financed by the Japan International Cooperation Agency (JICA).
The Project will be implemented in three phases.

Phase I

This involves construction of Berth No. 20 (210 meters) and 21 (350 meters) with a depth of 12 and 15 meters respectively. It provides additional capacity of about 470,000 TEUs for Berth No.21. It was completed in February 2016.

Phase II

Phase II consists of the construction of Berth No. 22 (250meters), 15 meters deep, and will give additional capacity of about 470,000 TEUs for Berth No.22. It was completed at the end of 2021.

Phase III

This comprises the development of Berth No. 23 which will be 300 meters in length, 15 meters deep, forming a total of continuous straight 900 meters for Phases I, II and III.
Phase III funding is yet to be identified.

ii) Construction of Berth No.19

In April 2013, KPA completed extension of the container terminal by 240 meters quay length, providing additional 5 acres of yard space and a dredged draft of 13.5 meters thereby creating another new Berth No. 19. This increased the terminal length to 840 meters, making it capable of berthing three vessels of 250 meters each. KPA can now handle larger vessels as evidenced by the recent call by Maersk owned Clemens Schulte with 255M LOA and 37M beam with an arrival draft of 13.9 meters even keel.

iii) KOT Relocation

The Kipevu Oil Terminal (KOT) was constructed in 1963 to handle crude oil ships. The facility is owned by KPA, as well as the concrete and jetty structure including the mooring dolphins.
The pipelines and their contents are owned by Kenya Petroleum Refineries Limited (KPRL) for receiving crude oil and Kenya Pipeline Company (KPC) for receiving and back-loading oil petroleum products being the principal jetty operators. The Kenya Ports Authority is responsible for maintenance of the jetty superstructure, safety, security, fire and oil pollution prevention and response in case of emergency.
Currently KOT handles white oil products only, the crude oil line is disused. Expansion of the current Container Terminal by constructing Berth 19 (completed in 2013) and the construction of a second Container Terminal, as well as the need for development of a. modern petroleum products handling facility necessitated relocation of the KOT.
The inception, concept and preliminary designs of the new KOT which will be an island offshore facility have been completed and the detailed designs are now in progress all under KPA internal funding with consultancy services from NIRAS Port Consults from Denmark. KPA will identify appropriate funding mechanisms to enable the project to be successfully undertaken during this Plan period.

iv) Fixed Berthing Window System

KPA introduced the Fixed Berthing Window System in the middle of 2016 at Berths No. 16 to 21. This system allocates berth slots to specific shipping lines and services so as to try to improve reliability of ship turn-around time. The system was introduced on trial basis but has picked very well and successfully resolved the challenges that KPA faced with delays in handling and clearing vessels.

(3) Standard Gauge Railway (SGR) Development

The standard gauge railway (SGR) project is a national flagship project under the Kenya Vision 2030 development agenda. Kenya Railways Corporation is developing the SGR project for passengers and cargo transportation between Mombasa and Nairobi. The SGR begins at Port Reitz of Mombasa Port and runs generally parallel to the old meter gauge railway. Passenger trains run between Mombasa Terminal in Miritini and Nairobi Terminal at Syokimau, near Jomo-Kenyatta International Airport. The new railway line constitutes the first phase of the SGR project that aims to connect Kenya, Uganda, Rwanda and South Sudan. It will also simplify transport operations across the borders and reduce travel costs, apart from benefiting the economies of Kenya and the neighboring countries. The construction began in October 2013 and was completed in May 2017. The single-track standard gauge railway between Mombasa and Nairobi has a total length of 609km. The construction for the Mombasa-Nairobi phase is estimated at KES327bn ($3.8bn). China Exim Bank provided 90% of the financing while the remaining 10% was contributed by the Kenyan Government.

The second phase of the SGR will extend the Mombasa–Nairobi line to Naivasha, and eventually to the Uganda border. A connecting standard gauge railway is expected to be built in Uganda, providing landlocked Uganda with high-capacity railway transport.

The railway line is designed to carry 22 million tons a year of cargo or a projected 40% of Mombasa Port throughput by 2035. The railway line will initially carry diesel cars while electrification is possible in the future. Freight trains have a capacity of 216 TEUs and travel at an average speed of 80km/h. A typical freight train on the line will consist of 54 double stack flat wagons and measure 880 m-long.

The SGR construction inside Mombasa Port reaches Berths No. 1. However, this narrows the backyard area of the existing Berths. KPA has a plan to rehabilitate Berths No. 11-14, deepening the berths and strengthening the quay-wall structure and as a result, aiming at increasing cargo handling productivity. The container loading/unloading platform area is designated behind the Second Container Terminal, enabling transporting containers from/to Mombasa Port to/from Nairobi and neighboring countries. The container marshalling yard, which is located behind the Second Container Terminal, is used to load/unload containers by use of rail-mounted gantry cranes. The Second Container Terminal is expected to expand westward in order to meet the increasing demand of containers.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Source: JICA Design Team

Figure 8.1.4 Second Container Terminal (Berths 20 and 21) and SGR (taken by JDT on 8th July 2017)

8.2 Land Use Plan

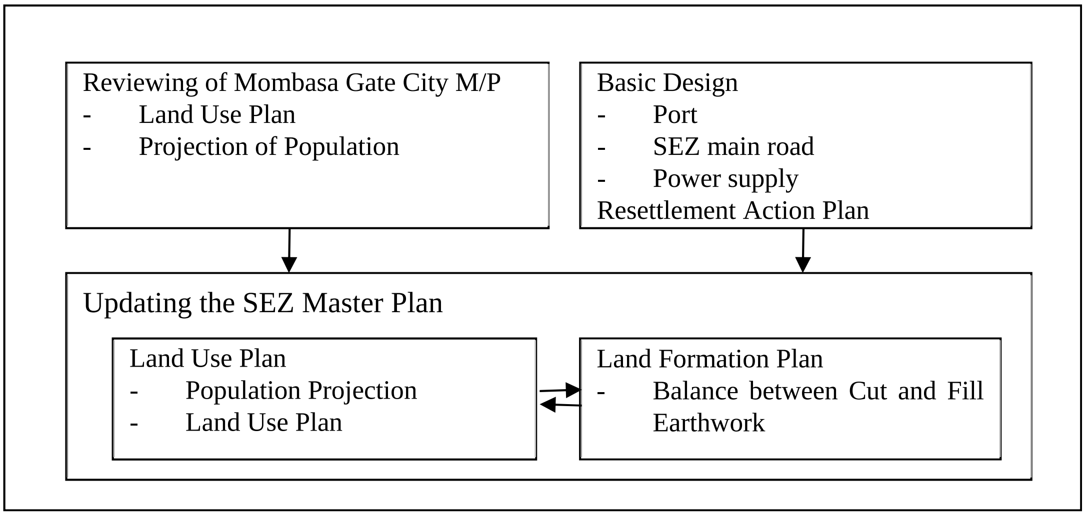
8.2.1 Overview

(1) Objective of the Survey

The objective of this study is to upgrade the land use and land formation plans of the Mombasa SEZ M/P in 2015 based on the basic design and the resettlement action plan (hereinafter referred to as w“RAP”) of SEZ for Phase 1. In this area, planning the land use based on a rational land formation plan is very important in a view of economic feasibility because of steep topography. Therefore, interactive study is essential between land use planning and land formation planning.

(2) Methodology of the Road Design

The flow chart of land use planning is shown in Figure 8.2.1



Source: JICA Design Team

Figure 8.2.1 Flow Chart of Land Use Planning

8.2.2 Land Use Plan

(1) Review of Mombasa Gate City M/P

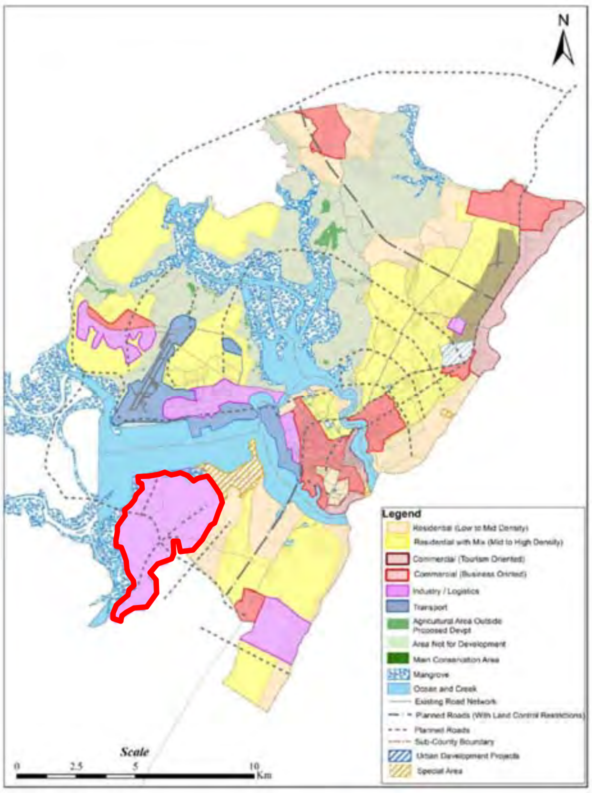
In the Mombasa SEZ M/P, future residential and labor population was projected based on the demand forecast of various facilities in the SEZ. After formulation of the Mombasa SEZ M/P, the study on the Mombasa Gate City Master Plan (hereafter referred to as "Gate City M/P") was commenced. Although the Gate City M/P is still in the process of finalization, the population projection which is updated in Gate City M/P and the consistency between this study and the Gate City M/P need to be ensured.

i) Land Use Plan

The land use of Dongo Kundu is proposed as industry and logistics uses in the Gate City M/P. On the other hand, mixed-use not only them, but also port, free trade zone (hereinafter referred to as "FTZ"), enterprise area, industrial park, residential area, and land for utilities are proposed in the Mombasa SEZ M/P. However, major land uses are industry and logistics excluding residential areas (the residential area is planned for resettlement for current residents), it can be judged that consistency between two plans are ensured.

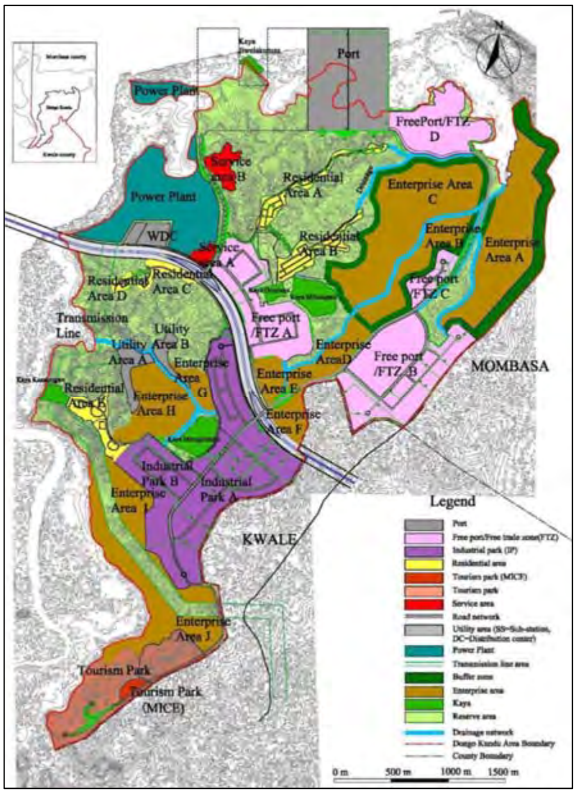
ii) Population Projection

The number of population projected in the existing Mombasa SEZ M/P is 4,300 for residents and 27,100 as total including labors. It should be reviewed after finalizing the Gate City M/P.



Source: Project for Formulation of Comprehensive Development Master Plan in the Mombasa Gate City in the Republic of Kenya, Draft Final Report, 2017, JICA

Figure 8.2.2 Proposed Land Use Plan of Mombasa Gate City Master Plan

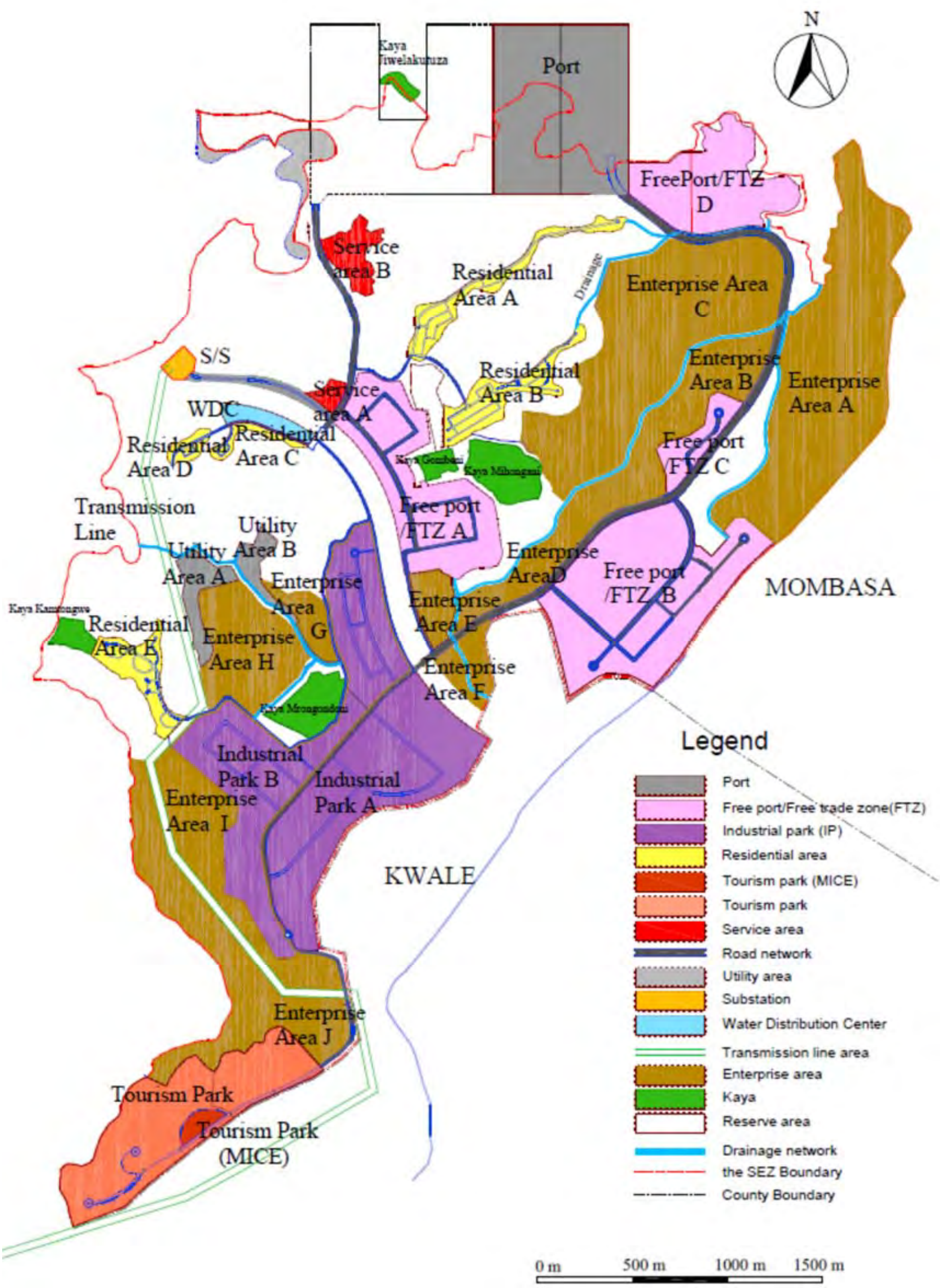


Source: Mombasa SEZ M/P

Figure 8.2.3 Land Use Plan of the SEZ

(2) Updating Land Use Plan

In Design Mission, basic designs for port and power supply system are covered. The land use plan was updated by the result of these basic designs. Figure 8.2.4 shows a draft land use plan as of July 2017. Major updating points of land use plan are listed below;

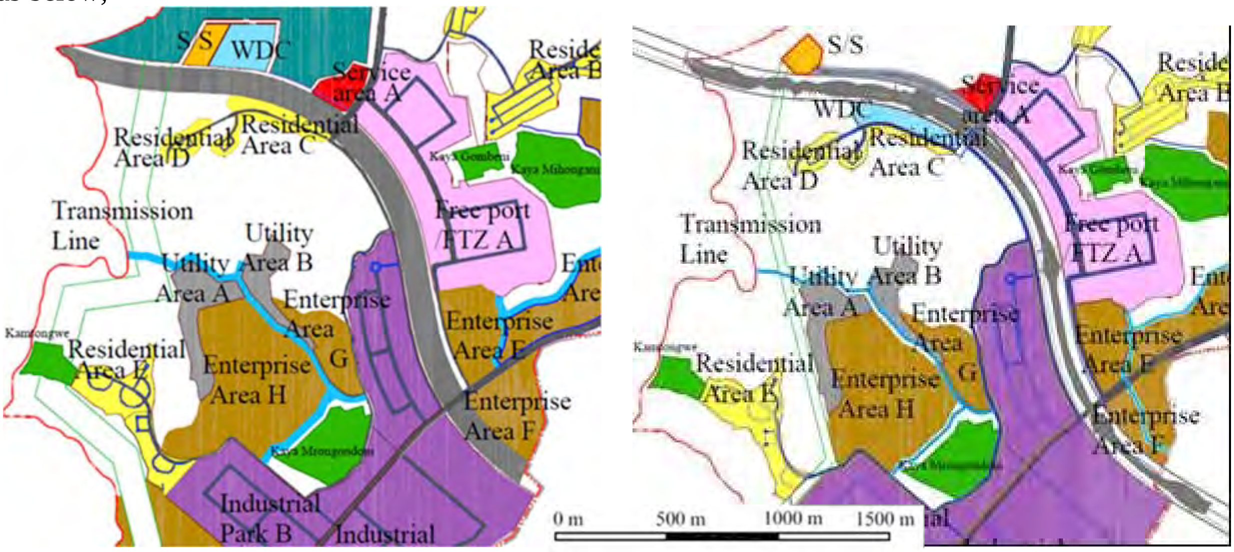


Source: JICA Design Team

Figure 8.2.4 Updated Land Use Plan (Draft)

i) Adjustment of the location of Mombasa Southern Bypass Road

The alignment of Mombasa Southern Bypass Road (hereafter referred to as "MSBR") is adjusted based on the detailed design of MSBR and topographic survey. Accordingly, land uses along the MSBR are updated as below;



[Updated Land Uses]

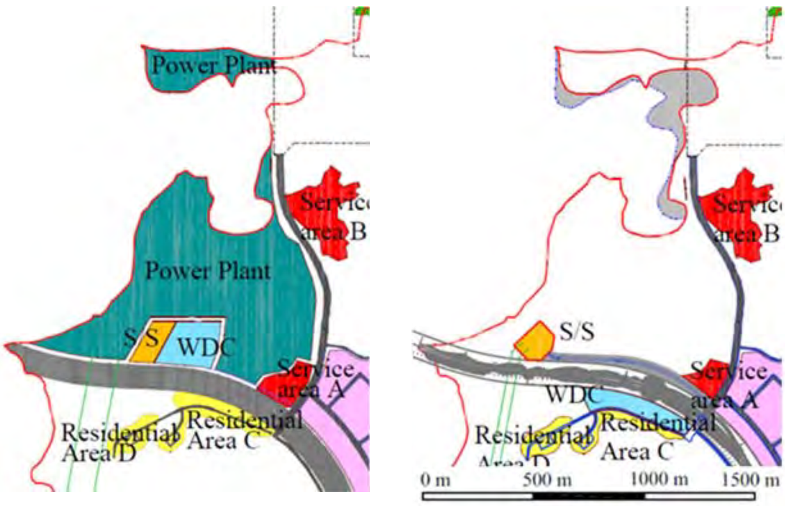
- FTZ A : Reshaped
- Enterprise E & F : Reshaped
- Industrial park A & B : Reshaped
- Service area A : Reshaped
- Substation : Updated
- Water distribution center : Sifted to highland
  …additional explanation is shown in v)
- Residential area C. : Reshaped

Source: JICA Design Team

Figure 8.2.5 Adjustment of MSBR Design (left : existing SEZ M/P, right : Updated plan)

ii) Cancelation of LNG power plant project

Due to increasing the cost of LNG, the power plant project within the SEZ which was proposed in the Mombasa SEZ M/P had been cancelled by the MoE. There is no development project is planned by the MoE, the area is kept as "Utilities and Others" for a seed site of the future power development project.

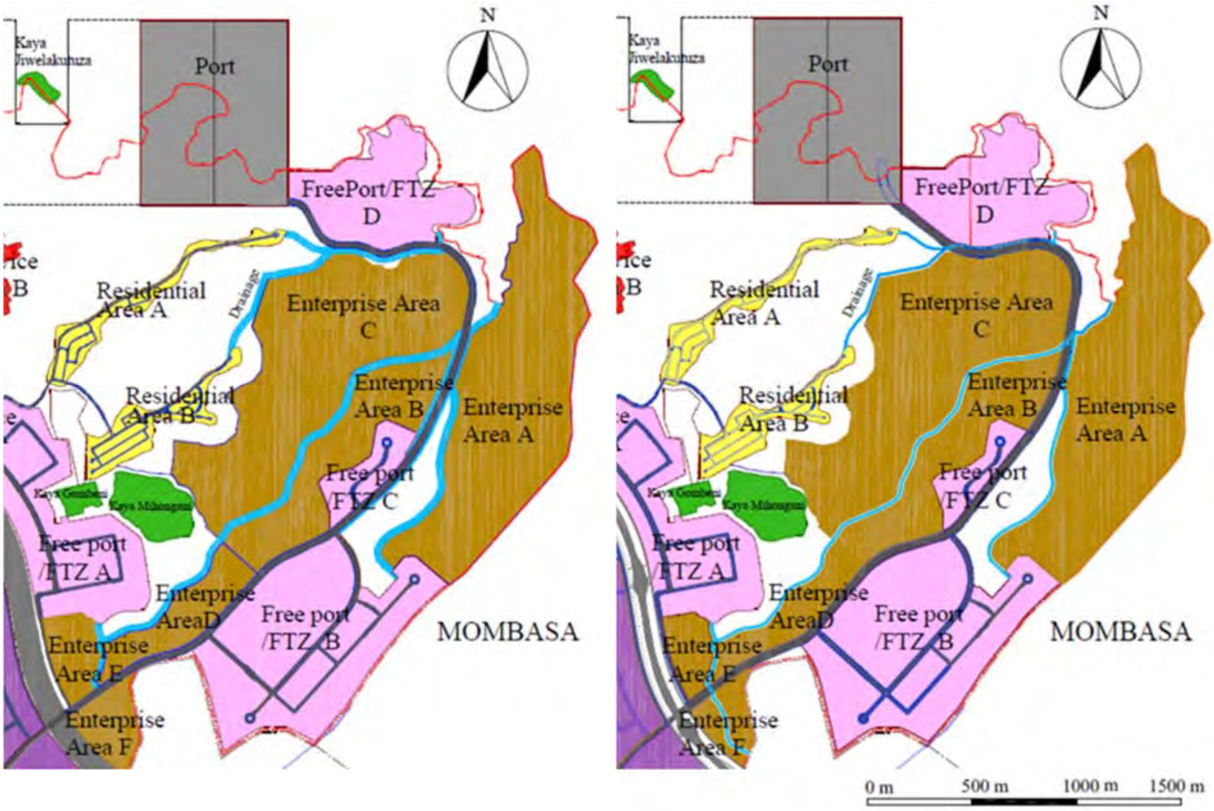


Source: JICA Design Team

Figure 8.2.6 Cancellation of LNG Power Plant (left : existing SEZ M/P, right : Updated plan)

iii) Basic design for port and SEZ main road

According to the progress of basic design for the port and the SEZ main road, a layout plan of the port and the alignment of SEZ main road are updated. The details are shown in Clause 8.3 and 8.4. The land use along SEZ main road was updated based on the basic design of port and SEZ main road.



[Updated Land Uses]

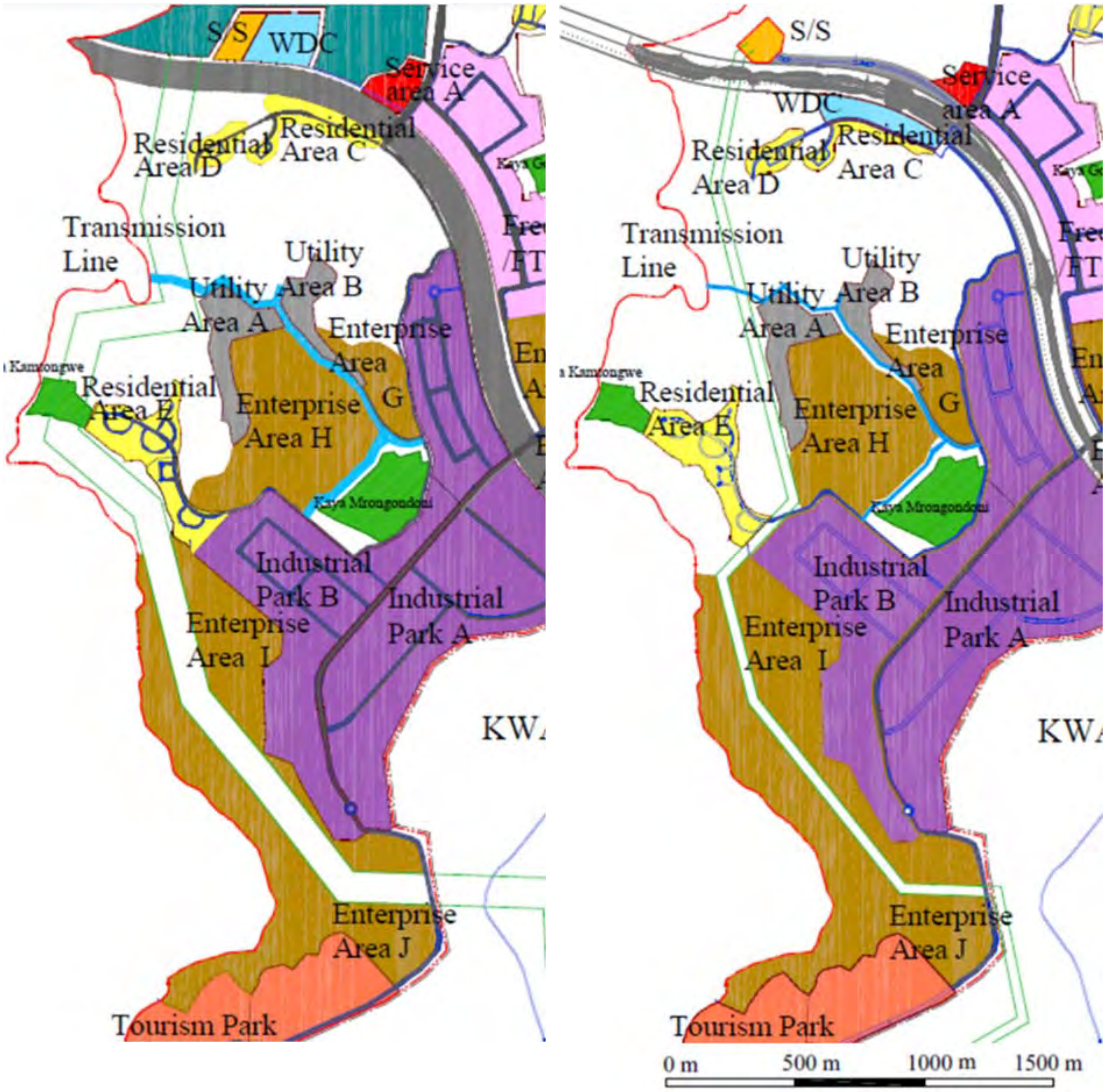
- Port : Updated
- SEZ main road: Updated
- FTZ B, C & D : Reshaped
- Enterprise area A, B, C, D, E & F : Reshaped
- Major open drainage crossing the SEZ main road : Updated

Source: JICA Design Team

Figure 8.2.7 Updating of Port and SEZ main road
(left : existing SEZ M/P, right : Updated plan)

iv) Basic design for transmission line

According to the progress of basic design for the transmission line from Mariakani substation to the substation inside SEZ, the alignment of transmission line is updated to avoid Kaya located south western part of the SEZ. The detail is shown in Clause 8.8. The land uses as followings are updated according to the basic design of transmission.



[Updated Land Uses]

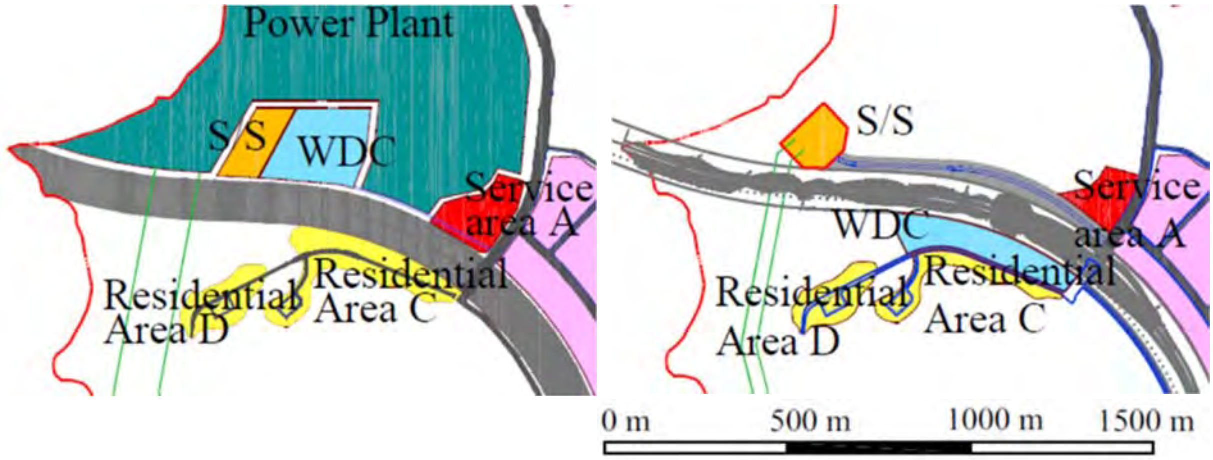
·	Transmission line	: Updated	·	Industrial park B	: Reshaped
·	Residential area E	: Reshaped	·	FTZ I & J	: Reshaped

Source: JICA Design Team

Figure 8.2.8 Updating of Transmission Line Route (left : existing SEZ M/P, right : Updated plan)

v) Basic design for substation and relocation of water distribution center

According to the progress of basic design for the substation, the layout of substation and location of water distribution center are updated. The detail of substation layout plan is shown in Clause 8.8. The location of water distribution center is sifted on higher elevated area than the proposal in the Mombasa SEZ M/P for efficient water distribution to the entire SEZ area. The land use as followings are updated according to the basic design of transmission.



[Updated Land Uses]

・	Substation	: Updated	・	Service area A	: Reshaped
・	Substation access road	: Newly planned	・	Water distribution center	: Sifted
・	Power distribution line	: Updated	・	Residential area C	: Reshaped
・	FTZ A	: Reshaped			

Source: JICA Design Team

Figure 8.2.9 Updating of Substation and Water Distribution Center Plans (left : existing SEZ M/P, right : Updated plan)

vi) Resettlement Action Plan

In the existing Mombasa SEZ M/P, residential areas inside the SEZ are proposed as relocation area for PAPs. However, the KPA proposes to relocate existing residents to the outside SEZ in their RAP study done in April 2016. According to the study, as total 1,522 households were surveyed in the entire SEZ. After forming the required RAP policy including compensation policy on them, the plan of residential area shall be updated.

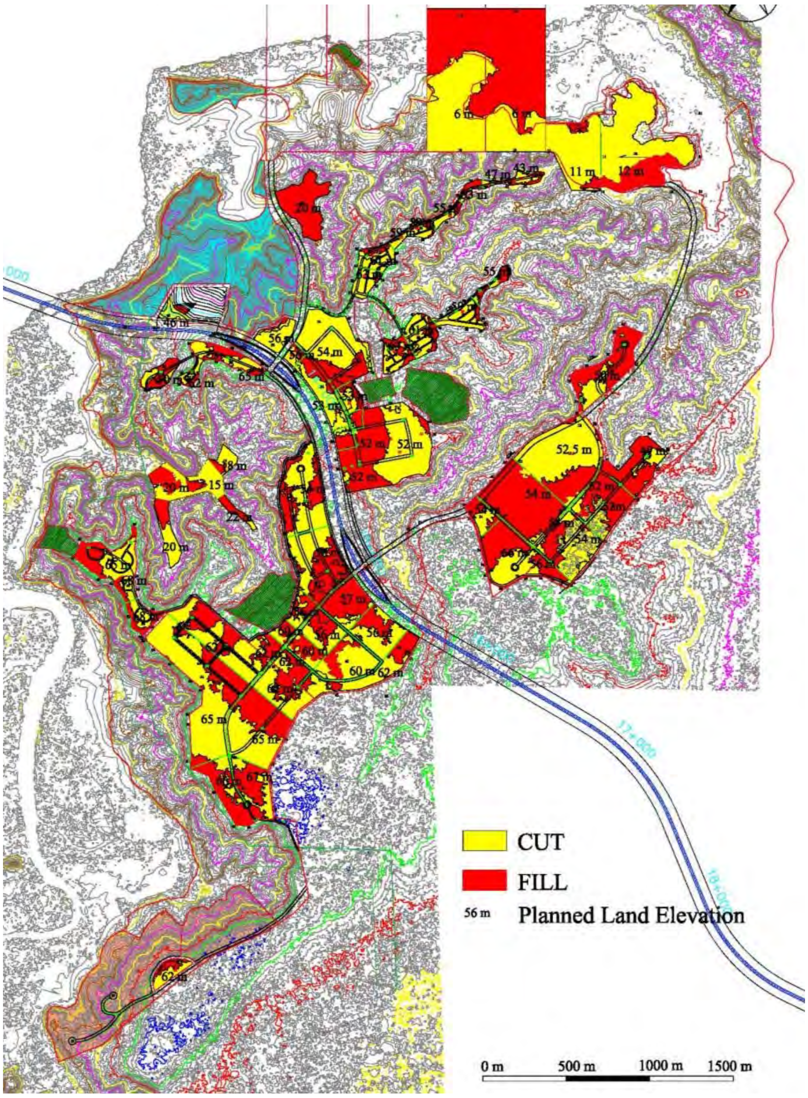
8.2.3 Land Formation Plan

Due to hilly topography, effective land formation plan to minimize earthwork is required for saving the construction cost. Proposed earthwork balance between cut and fill in the Mombasa SEZ M/P was almost equal shown in the figure below. However, land formation plan shall be updated after basic designs for the port, the SEZ main road and power supply facility are formed.

a) Cut-Fill Quantity Proposed in the Mombasa SEZ M/P

Item	Quantity (m^3)
Cut	8,302,000
Fill	5,545,000
Consideration settlement fill	1,535,000
Replacement sand	1,164,000
Balance	5,800
Waste soil	1,164000

Source: the Mombasa SEZ M/P



Source: the Mombasa SEZ M/P

Figure 8.2.10 Cut and Fill Plan in the Existing SEZ Master Plan

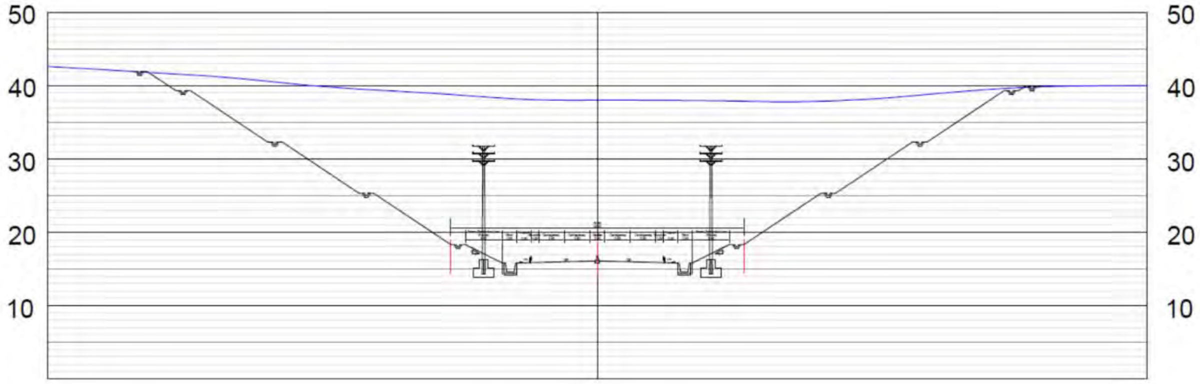
i) Updating points of land formation plan

a) Reflection of revised port layout plan

As the progress of the geotechnical investigation during the Design Mission, it was identified that some soils are too hard for cut work. However, in the Port Master Plan, cut soils were expected to be utilized for filling materials for the new port. For the reason, revision of the port layout plan is needed. According to this, cutting volume for the proposed port area will be reduced, and filling soil for the port will be transferred from outside of the SEZ.

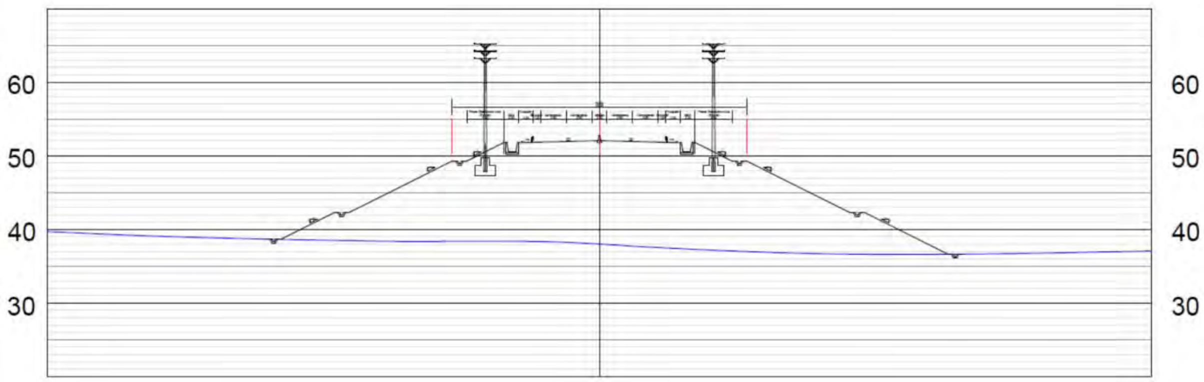
b) Updating SEZ main road design

Since container cargos and trucks pass SEZ main road, safety driving environment with gentle slope is required. However, targeted area is topographically steep, much earthwork is needed. Especially, the required height of cut and fill earthwork near intersection of the MSBR (shown in Figure 8.2.11) and connecting point to the port (shown in Figure 8.2.12) are almost 20m. In this case, width of slope is planned as more than 80m. Since basic design for SEZ main road shall be updated according to a result of topographic survey, the land formation plan also shall be updated by reflection the design.



Source: JICA Design Team

Figure 8.2.11 Cross Section at the Point with Maximum Cutting Work



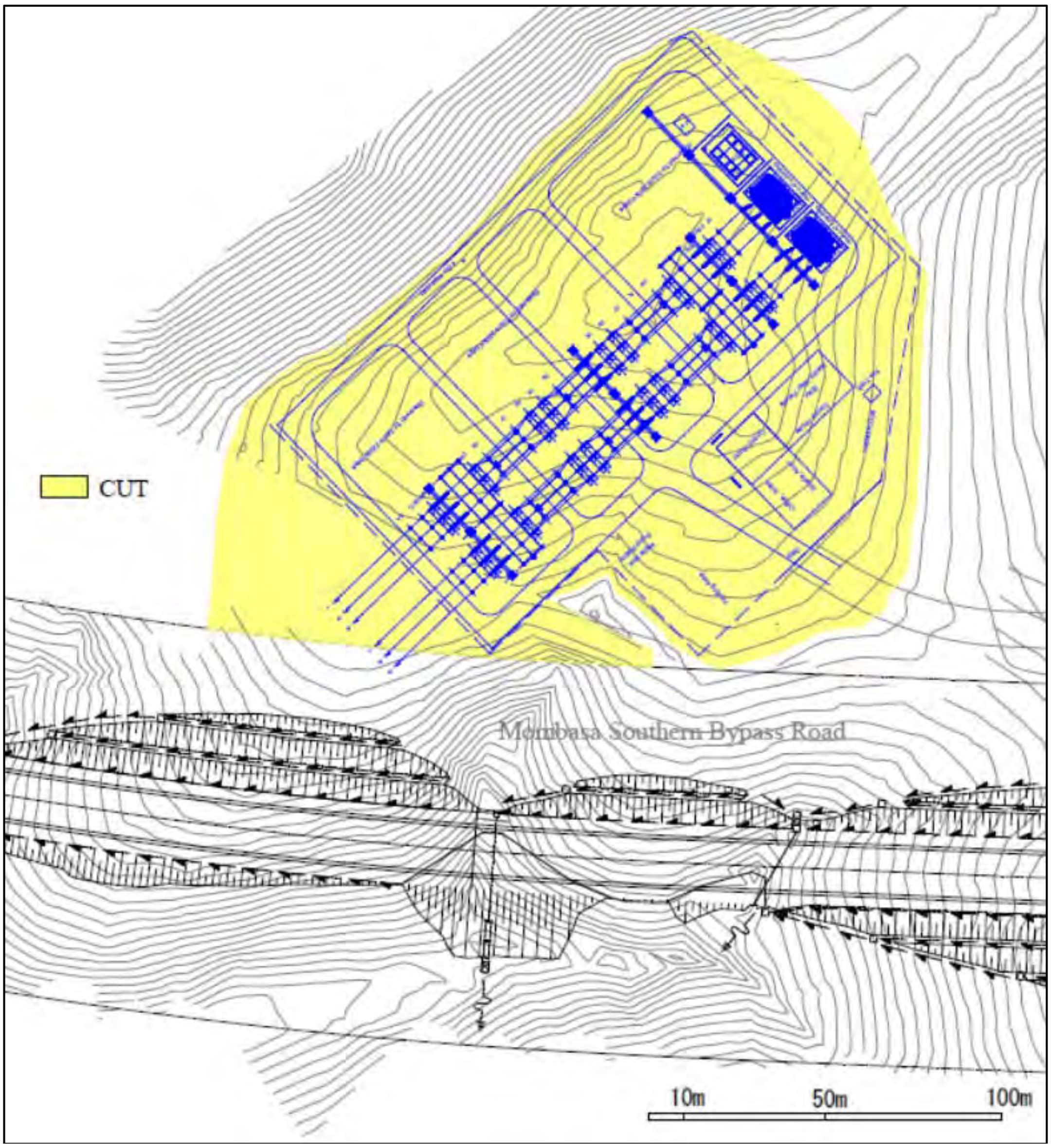
Source: JICA Design Team

Figure 8.2.12 Cross Section at the Point with Maximum Filling Work

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

c) Updating SEZ substation design

A draft land formation plan for the SEZ substation is shown in the Figure 8.2.13. The location of SEZ substation is sifted to west to minimize earthwork to save cost and environmental impact. As a result, it is proposed that cutting the hill top slightly and allocating the substation there. The plan will be finalized after receiving the topographic and RAP survey result.



Source: JICA Design Team

Figure 8.2.13 Land Formation Plan for the Substation (Draft)

Although a cost of construction work is a little expensive, since the construction period is short, the jacket type from which early opening of a port is attained, and a benefit is taken by early opening of a port is adopted.

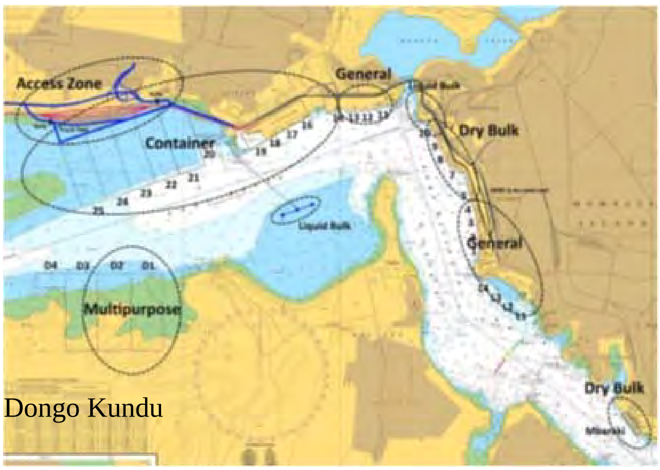
8.3 Port (Dongo Kundu)

8.3.1 Overview of the Port Development and Basic Design

Mombasa Port, located in Mombasa City, is the largest port in the East Africa Region and is used not only for the trade of Kenya but also for inland countries such as Uganda and Rwanda. In recent years, the cargo handling volume of Mombasa Port has been increasing and expansion of port facilities become one of the pressing issues. With the aforementioned situation, the Japan International Cooperation Agency (JICA) commenced the "Mombasa Port Master Plan including Dongo Kundu" (hereinafter referred as the Port M/P) in 2015 to revise the Mombasa Port Master Plan (in 2009 by KPA) and to prepare a comprehensive development plan of Mombasa Port including Dongo Kundu. Figure 8.3.1 shows a satellite image of Mombasa Port and Dongo Kundu, and Figure 8.3.2 shows the spatial utilization plan of Mombasa Port, which was presented in the Port M/P and berths of Dongo Kundu were allocated as multi-purpose berths. In this study, the basic design of port facilities will be conducted for berth No.1 of Dongo Kundu (hereinafter referred as DK1) based on the results of Port M/P and findings of this study.

Source: Google Earth modified by the JICA Design Team

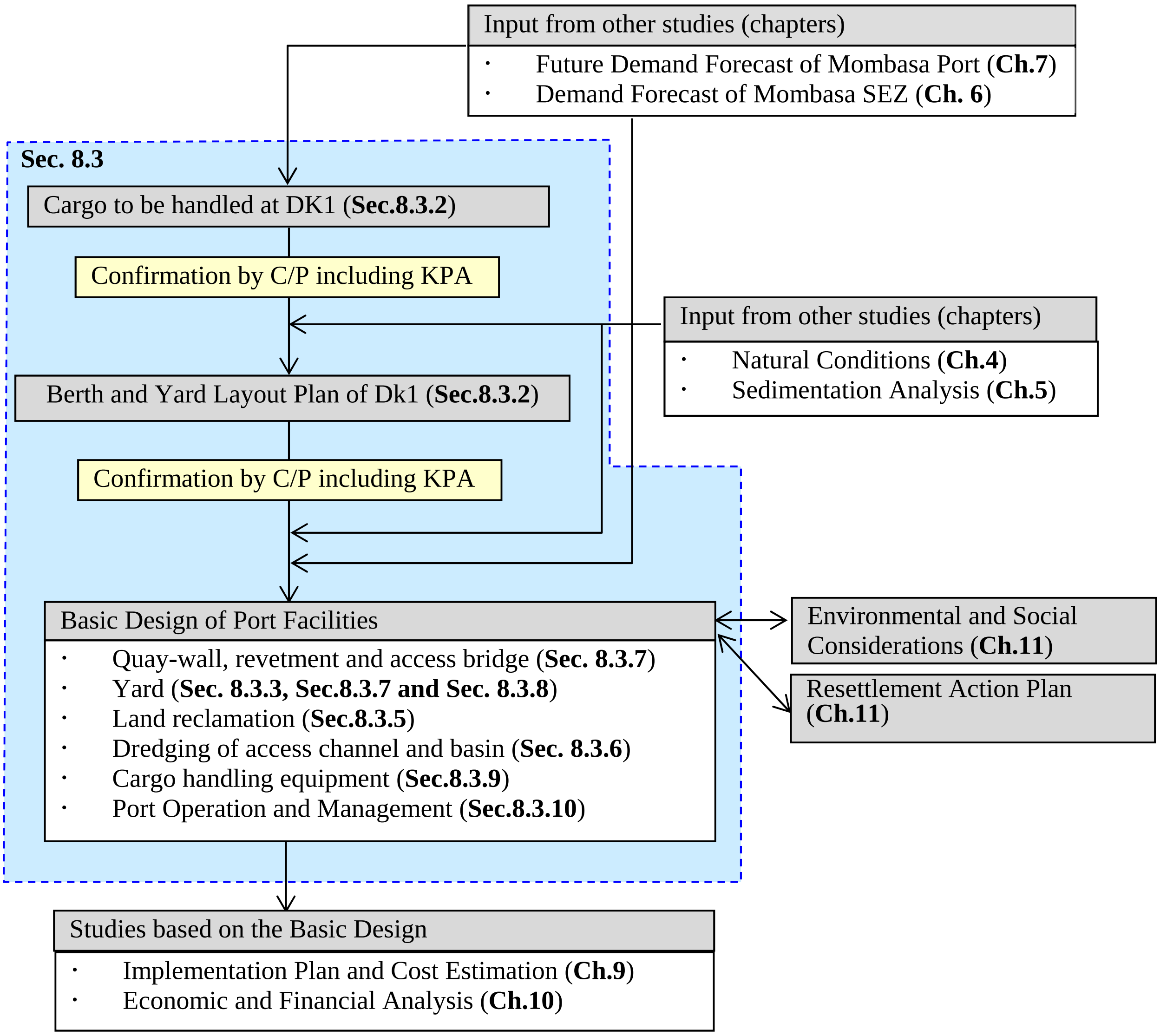
Figure 8.3.1 Satellite Image of Mombasa Port including Dongo Kundu



Source: Mombasa Port Master Plan including Dongo Kundu (JICA, 2015)

Figure 8.3.2 Spatial Utilization Plan of Mombasa Port

The study flow related to basic design of port facilities is presented in Figure 8.3.3 and relevant chapters in this final report are also shown in the figure as reference.



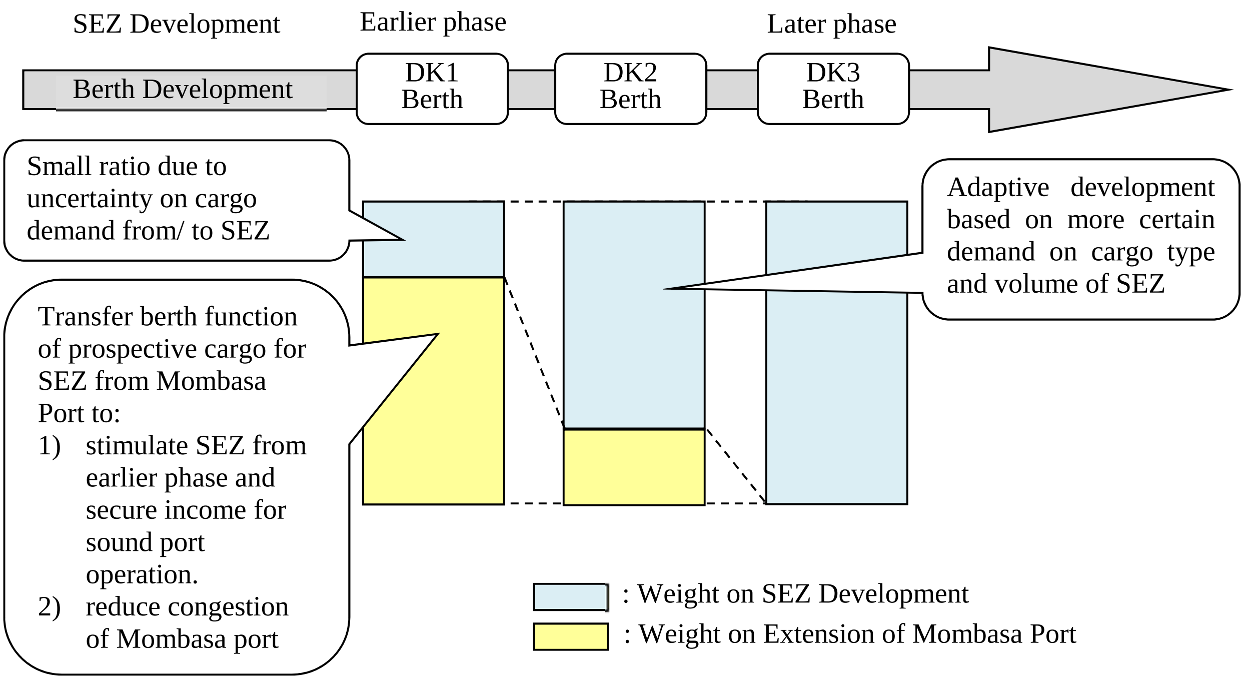
Source: JICA Design Team

Figure 8.3.3 Study Flow Related to Basic Design of Port Facilities

8.3.2 Development and Basic Design Policy

(1) Development Policy on Dongo Kundu Berths

Development of berths at Dongo Kundu basically aims to handle cargos mainly from/ to Mombasa SEZ located behind the berths. In this sense, these berths shall be designed based on the cargo demand in terms of cargo type and cargo volume forecasted by specific business enterprises that will move into the Mombasa SEZ in near future. However, it is very difficult to grasp reliable demand for SEZ at the planning phase in 2017. Also, since forecasting SEZ cargo demand at this initial phase is largely uncertain and deviation would likely occur at the actual implementation, setting the SEZ cargo demand at this moment is regarded as a risk for sound port operation. In this study, therefore, the development policy of Dongo Kundu berths is presented by conceptual diagram as shown in Figure 8.3.4. At the earlier phase of the SEZ development, when the uncertainty of SEZ cargo demand is large, DK1 will be developed mainly to handle the major cargo that will be transferred from Mombasa Port. This will reduce a risk on sound port operation in case actual cargo demand from/to SEZ is lower than expected and give an advantage in stimulating SEZ activities from earlier phase. This transfer also aims at reducing the congestion at Mombasa Port. At the middle and later phase of the SEZ development, more certain demand of the specific enterprise to move in and cargo type and volume will be grasped. After knowing these details, the berths (for example DK2 and DK3) shall be designed to fulfill the demand from/to SEZ by applying adaptive development.



Source: JICA Design Team

Figure 8.3.4 Concept of Adaptive Development of Dongo Kundu Berths (DK1-DK3)

(2) Cargo to be Transferred form Mombasa Port to DK1

i) Candidate Cargos based on Demand Forecast of Mombasa Port

In this section, the number of required berths by commodities at Mombasa Port was evaluated to select candidate cargo to be transferred from Mombasa Port to DK1, based on the demand forecast results in this study.

Firstly, the annual cargo volume of Mombasa Port expected in future which was examined in Chapter 7 was summarized in Table 8.3.1. Since there are so many commodities in the statistics and demand forecast, it was simplified by grouping using similar classifications as applied in the Port M/P and summarized in the Table.

Secondly, productivity by commodities in 1,000 tons/year per ordinary berth of Mombasa Port were summarized in Table. 8.3.2. These productivities were mostly quoted from the survey results of the Port M/P except for a few with some corrections to make them more realistic values. Also, improvement of handling capacity with 10% to 20% at maximum was included in the commodities, of which productivity by commodities were expected to be increased in future. On the other hand, some of them were set as same productivity as present if they were considered to have less room for improving congestion problem or to be regarded as maintaining sufficient productivity at this moment.

Finally, the number of required berths was obtained as shown in Table 8.3.3 by dividing the cargo volume (1,000 tons/ year/ berth, Table 8.3.1) by its productivity (1,000 tons/ year/ berth, Table 8.3.2). At present in 2016, required number of berths of Mombasa Port was calculated as 15.76 berths (also evaluated as 18 berths if summed as integer number by each commodity considering actual berth usage), which indicates that port capacity was almost saturated as the total number of berths was 18 in 2016 (note that berth 20 and 21 were excluded as it was in service from late 2016). Figure 8.3.5 shows comparison of the number of required berths and planned berths in 2035. It should be noted that the number of planned berths refers the Port M/P which is the latest and official report available to present future cargo allocation of Mombasa Port*. From the table in the Figure 8.3.5, there is a significant gap between the number of required berths and planned berths for general cargo except the containers; 9 for planned berths and 13.8 for required berths in 2035. For the other cargos, such as dry bulk, liquid bulk and containers, the gaps are not so significant between the number of planned berths in the Port M/P and that of required berths.

With a cargo allocation plan presented in the Port M/P, it can be concluded that the Mombasa Port will likely run short of berths in future for general cargo except for containers (i.e. motor vehicles, iron & steel, other general cargo). Therefore, these three types of cargoes are the candidates to be transferred toDK1.

* It should be noted that there was a facility improvement plan to convert Berths Nos. 11-14 (conventional cargos) to full container terminals and the project was under the fundraising process from EU, according to KPA officials. However, this future plan was not considered in this study because 1) the comprehensive cargo allocation plan of the Port, which was similar to that of the Port M/P, was not available and 2) it would not affect the conclusion aforementioned (i.e. shortage of berths mainly for general cargo except for containers).

Table 8.3.1 Annual Cargo Volume from the Demand Forecast Study (1,000 tons/ year)

Commodity		2016	2020	2025	2030	2035
General	Motor Vehicle	313	569	693	833	959
	Steel	1,594	2,404	3,618	4,928	6,238
	Other general	1,079	1,215	1,449	1,692	1,944
	Container	8,677	11,631	15,537	19,704	23,840
	Sub total(General)	11,663	15,819	21,298	27,157	32,981
Dry Bulk	Bulk Wheat	1,896	2,165	2,562	3,006	3,504
	Bulk Clinker	3,084	4,821	7,518	10,428	13,340
	Bulk Fertilizer	560	820	902	902	902
	Bulk Coal	455	669	985	1,327	1,669
	Other Bulk	452	442	442	442	442
	Sub total (Bulk)	6,447	8,916	12,409	16,105	19,857
Liquid Bulk	Other Liquid Bulk	41	831	831	831	831
	Sub Total (OLB)	41	831	831	831	831
Grand total		18,151	25,566	34,538	44,094	53,669

*Container volume(ton) was calculated based on general cargo volume(ton) and containerized ratio (see Ch. 7)
* Cargo volume related to the new oil terminal project of KPA were excluded in this evaluation (i.e. POL(import), Bulk oil(export), and Bunker Oil (export) were excluded)
Source: JICA Design Team

Table 8.3.2 Productivities in Future by Commodities per Berth (1,000 tons/ year/ berth)

Commodity		2016	2020	2025	2030	2035
General	Motor Vehicle	740	740	740	740	740
	Steel	1,100	1,210	1,210	1,320	1,320
	Other general	210	230	230	250	250
	Container 1	1,566	1,566	1,566	1,566	1,566
	Container 2	3,915	3,915	3,915	3,915	3,915
Dry Bulk	Bulk Wheat	2,070	2,280	2,280	2,480	2,480
	Bulk Clinker	2,620	2,880	2,880	3,140	3,140
	Bulk Fertilizer	690	760	760	830	830
	Bulk Coal	1,700	1,870	1,870	2,040	2,040
	Other Bulk	1,310	1,440	1,440	1,570	1,570
Liquid Bulk	Other Liquid Bulk	2,480	2,980	2,980	3,470	3,470

*Container 1 and 2 mean existing container berths and new container berths (i.e. Berth No.20 and 21), respectively.

Source: JICA Design Team and Mombasa Port M/P

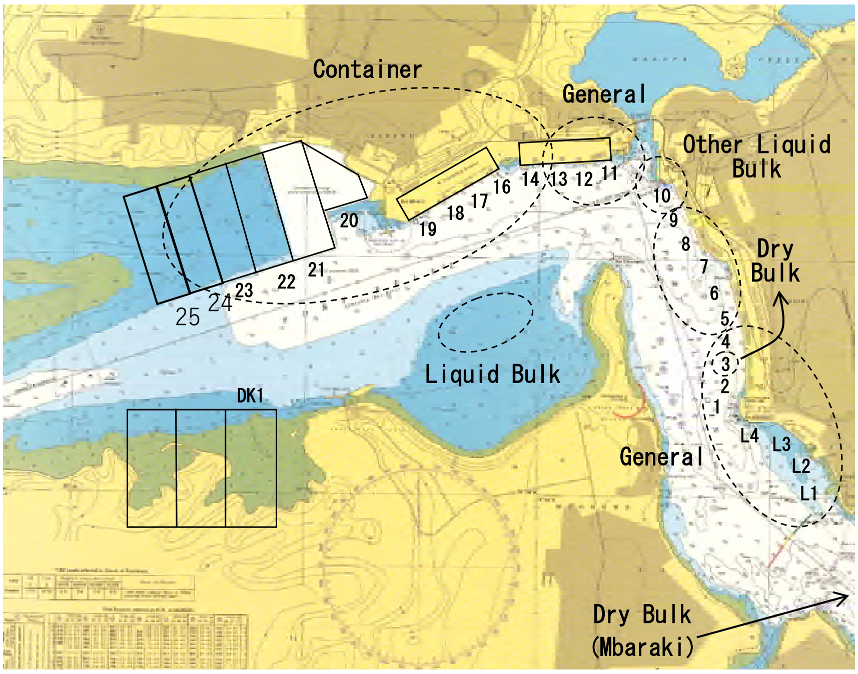
Table 8.3.3 Required Number of Mooring Facilities by Commodities

Commodity		2016	2020	2025	2030	2035
General	Motor Vehicle	0.42	0.77	0.94	1.13	1.30
	Steel	1.45	1.99	2.99	3.73	4.73
	Other general	5.14	5.28	6.30	6.77	7.78
	Sub total(General)	7.01	8.04	10.23	11.63	13.80
Container	Container 1	5.00	5.00	5.00	5.00	5.00
	Container 2	0.22	0.97	1.97	3.03	4.09
	Sub total(Container)	5.22	5.97	6.97	8.03	9.09
Dry Bulk	Bulk Wheat	0.92	0.95	1.12	1.21	1.41
	Bulk Clinker	1.18	1.67	2.61	3.32	4.25
	Bulk Fertilizer	0.81	1.08	1.19	1.09	1.09
	Bulk Coal	0.27	0.36	0.53	0.65	0.82
	Other Bulk	0.35	0.31	0.31	0.28	0.28
	Sub total (Bulk)	3.52	4.37	5.75	6.55	7.85
Liquid Bulk	Other Liquid Bulk	0.02	0.28	0.28	0.24	0.24
	Sub Total (OLB)	0.02	0.28	0.28	0.24	0.24
Grand total		**15.76**	**18.65**	**23.23**	**26.45**	**30.97**

*Number of berths are presented in ordinary (averaged) scale of berth in Mombasa Port, thus it does not necessary match with specific/exact demand of berth.

Source: JICA Design Team

Berth No.	General	Dry Bulk	OLB	Container
Mbaraki		✔		
1,2	✔			
3		✔		
4	✔			
5		✔		
7		✔		
8		✔		
9		✔		
10			✔	
11	✔			
12	✔			
13	✔			
14				✔
16				✔
17				✔
18				✔
19				✔
20,21				✔
22				✔
23				✔
24				✔
25				✔
Lighter area 1	✔			
Lighter area 2	✔			
Lighter area 3	✔			
Lighter area 4	✔			
Planned No. of Berths	9	6	1	10
Required No. of Berths	13.80	7.85	0.24	9.09



*Berth 1 & 2 and 20 & 21 are counted as one berth, respectively, considering actual usage.

*Lighter areas that are currently not in use are considered to be developed for general cargo handling in future (the Port M/P)

Source: JICA Design Team

Figure 8.3.5 Cargo Allocations in 2035 and Required No. of Berth

ii) Selection of Cargo to be transferred from Mombasa Port to DK1

The candidate cargoes are evaluated by using three criteria to select a cargo that is most suitable for DK1 and the result is shown in Table 8.3.4. Evaluation details for each criterion are shown in the following part.

Table 8.3.4 Comparisons of Cargos to be Transferred toDK1

Criteria for selection	General Cargo (except for containers)		
	Motor Vehicles	Iron & Steel	Other general
Possibility to improve productivity at Mombasa Port	Low	Fair	High
Causes of congestion at Mombasa Port	High	Fair	Fair
Cargo Demand for SEZ	High	High	High
Evaluation results	Recommended	Fair	Fair

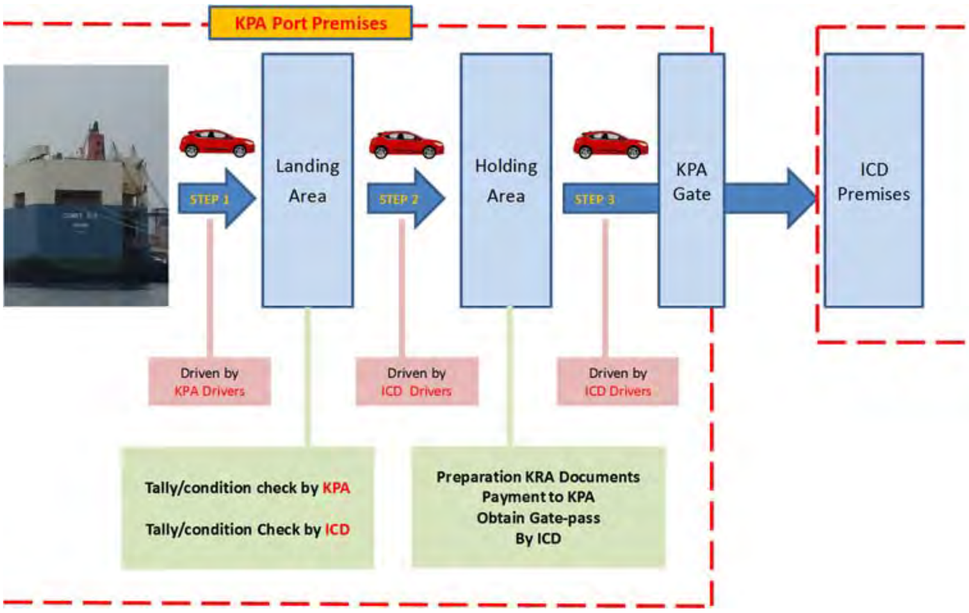
Source: JICA Design Team

a) Possibility to improve productivity at Mombasa Port

If this criterion was evaluated as high, then it means necessity of transfer to DK1 is relatively low because the present productivity can be improved at existing Mombasa port without transfer. “Other general cargo” is the un-containerized cargo. Containerized ratio in Mombasa Port in 2016 is about 70% from KPA figures for imports, which is not so high comparing with other international ports with full-equipped container terminals. If these other general cargos can be containerized as demand increases, the productivity will be much improved as these will be handled at container terminals and it requires less berths even if the volume would be the same (if other general cargo can be handled as containerized ones, then the productivity will increase at least three or four times, see the productivities of general cargo and container in Table 8.3.2 for example).

On the other hand, the productivity of the motor vehicles will not be improved as long as they are handled at the existing berths inside of Mombasa Port. Figure 8.3.6 shows motor vehicle landing procedures in Mombasa Port. At first, motor vehicles were driven by KPA drivers from vessel and parked at landing area which is a space just behind the berth No.1 and 2. After checking the conditions at landing area, vehicles were driven to holding area to prepare KRA documents and payments to KPA because there is not enough space to conduct this procedure at landing area. This is one of the causes of serious congestion at Mombasa Port. In addition, almost 100% motor vehicles landed at Mombasa Port were handled by ICDs (Inland Container/Cargo Depo) to take them out from the Port area within 18 hours after landing and store them at ICD premises to avoid further congestion inside of the Port. Therefore, it is difficult to improve productivity for motor vehicles due to limited space for vehicle yard in Mombasa Port.

For iron & steel, the possibility to improve productivity at Mombasa Port is considered as fair because neither major problem in present productivities nor significant improvement in future productivity can be observed or expected comparing with those of motor vehicles and other general cargo.



Source: JICA Design Team

Figure 8.3.6 Motor Vehicle Landing Procedure in Mombasa Port

b) Causes of Congestion at Mombasa Port

The number of discharging motor vehicles sometimes reached to 1,000 – 2000 units/vessel while average was about 300- 400 units/vessel. As described above, a transfer of vehicles from landing space to holding space is one of the main causes for congestion of Mombasa Port. On the other hand, iron & steel and other general cargo are evaluated as fair as a cause of Mombasa Port because they can be generally discharged and handled at designated berths.

c) Cargo Demand for SEZ

As described in Chapter 6 for the demand forecast of the Mombasa SEZ, steel (& iron) and tea (which included in other general cargo) sectors are listed as key potential anchor tenants. In addition, SEZ will have high potential as an auto-industry hub, especially for the second-hand car market and some existing ICD in Mombasa show their interest to move into SEZ in future to expand their business. Therefore, cargo demand of these three sectors are considered to be equivalently high for the SEZ.

With considerations in terms of these three criteria aforementioned, motor vehicle is evaluated as the most recommended cargo to be transferred from Mombasa Port to DK1.

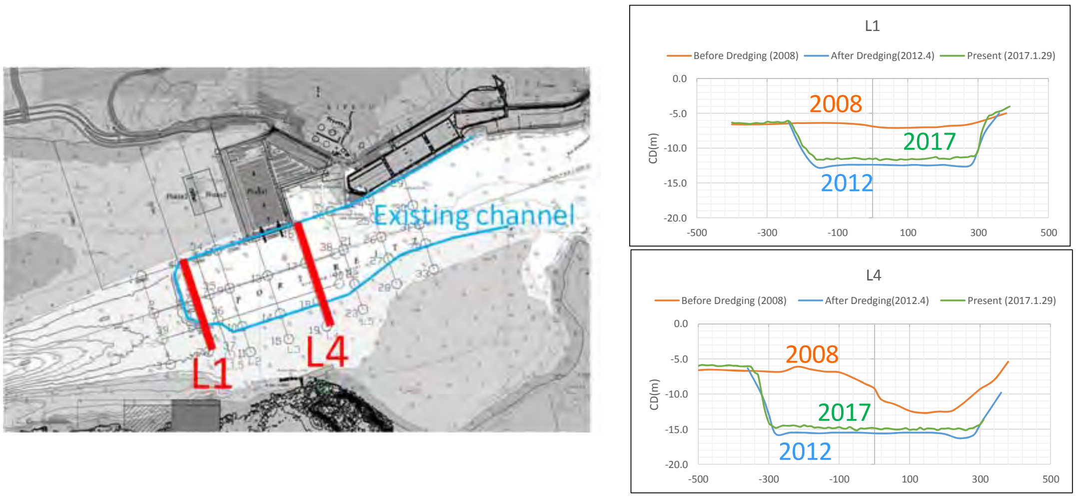
(3) Berth and Yard Layout Plan of DK1

Basic design policy for the berth and yard layout of DK1 are considered as following sequence. Those design policies were developed based on the basic layout presented in the Port M/P in 2015.

i) Considerations on Survey Results of Natural Condition

a) Bathymetric Survey

A bathymetric survey was conducted at the existing channel to confirm whether sedimentation has occurred around this area or not and its amount in case it has (see Chapter 4 for details). Figure 8.3.7 shows the sample of the bathymetric survey results and comparisons in cross sections. The results showed that sedimentation had occurred about 1 m for the last five years, which was from 2012 to 2017, but its annual rate, calculated at 0.2 m/year, is not so significant at the existing channel. But it is also noted that this result was obtained at the existing channel where its dredged depth was only less than 10 m.



Source: JICA Design Team

Figure 8.3.7 Sample of Bathymetric Survey Results

b) Geotechnical Investigations

Geotechnical investigations were conducted to confirm whether cut earth from the SEZ area could be used for reclamation materials for port yard or not (see Chapter 4 for details). Figure 8.3.8 shows the locations of the boreholes and four of six locations were located inside of the SEZ area.

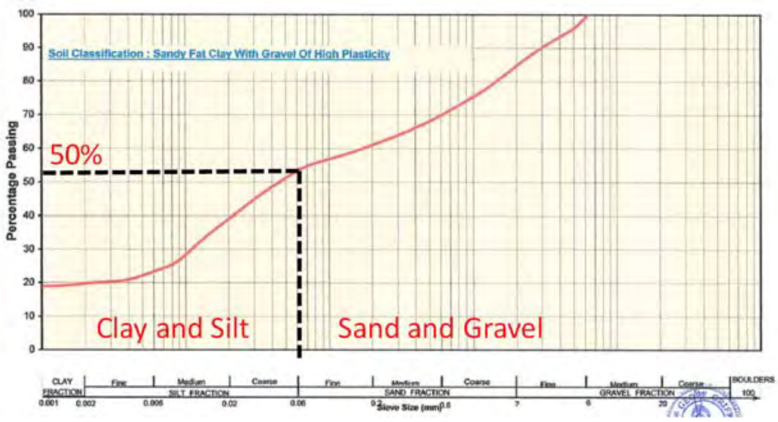
(Red circles show boreholes inside of SEZ)

(Photo during survey)

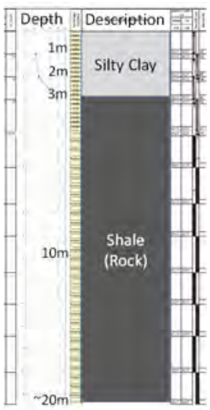
Source: JICA Design Team

Figure 8.3.8 Borehole Locations for Geotechnical Investigations

Figure 8.3.9 shows the results of sieve analysis and borehole log at Location No. 1 that is located nearest to the DK1. The result of sieve analysis shows that the soil contained silt and clay with high ratio at about 50%, which are generally not suitable for reclamation materials. The result of borehole log shows that soil layer is so thin with about 3 m and the rest deeper layer consists of shale rock, which is also generally difficult to apply as reclamation materials without any improvements. Other geotechnical investigation that are presented in Chapter 4 showed similar tendency of this sample. Therefore, it can be concluded from geotechnical investigations in this study that the applicability of cut earth from SEZ as reclamation materials is not so high in terms of quality and quantity.



(Sieve Analysis)



(Borehole Log)

Source: JICA Design Team

Figure 8.3.9 Sample Result of Geotechnical Investigations

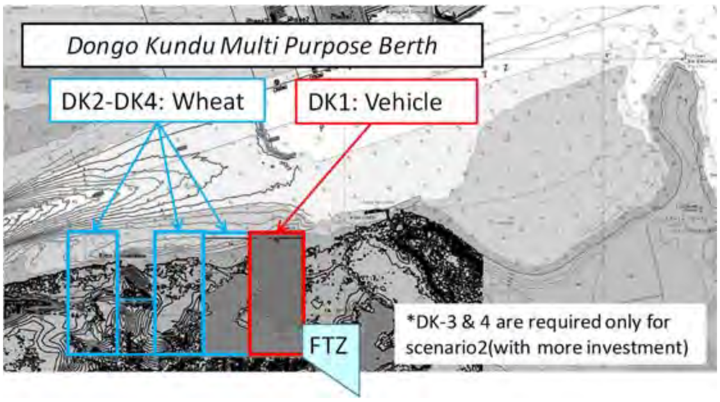
ii) Cargo to be Handled at DK1

a) Review on the Port M/P

Based on the demand forecast results and cargo allocation plan of Port M/P, berths at Dongo Kundu were planned as multi-purpose berths and priority cargos to be handled were motor vehicles and dry bulk, which was mainly wheat. There are two types of scenarios for cargo allocation, Scenario-1 with less investment and Scenario-2 with more investment; and the former was recommended as realistic development scenario in the Port M/P. Cargo allocation presented in the Port M/P is listed as follows and shown in Figure 8.3.10. Motor vehicle is set as priority cargo to be handled at DK1 for both scenarios.

<Scenarios and cargo to be handled in the Port M/P >

- Scenario-1 (less investment, recommended): Motor vehicles at DK1 and dry bulk (wheat) at DK2
- Scenario-2 (more investment): Motor vehicles at DK1 and dry bulk (wheat and others) at DK2 – DK4



Source: JICA Design Team

Figure 8.3.10 Cargo Allocation at Dongo Kundu Based on the Port M/P

b) Re-examination in this Study

As already discussed in this chapter for the cargo to be transferred from Mombasa Port, motor vehicle is the main cargo to be handled at DK1. Though DK1 will handle motor vehicles as its main cargo but it also needs a function to handle some containers that will be required from SEZ industries even at an earlier phase. Thus, DK1 will be designed as a multi-purpose berth that can handle motor vehicles and containers. It is noted that a fixed cargo handling machine such as gantry crane which is generally equipped at full container terminal would not be appropriate for DK1 as this berth will mainly handle motor vehicles and such fixed machines on berth can be obstacles for discharging the motor vehicles. Thus, containers on this berth will be handled with mobile harbor crane or cranes equipped in vessels.

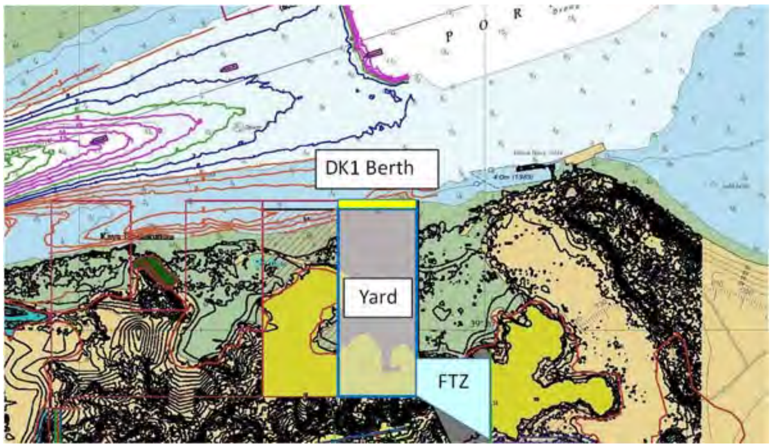
c) Cargo to be handled at DK1

- 1st Priority : Motor vehicles
- 2nd Priority: Containers (using cranes equipped in vessels or mobile harbor cranes)

iii) Basic Layout of DK1 Berth and Yard

Figure 8.3.11 shows the layout plan of DK1 berth in the Port M/P and this layout plan was put on review of this study as following procedures considering aforementioned conditions; natural conditions survey results and cargo to be handled at DK1 berth.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: JICA Design Team

Figure 8.3.11 Layout Plan of DK1 Presented in the Port M/P

a) Design Policy on Berth Face Line

According to the Port M/P, berth face line of DK1 was set at a shallow area at around C.D.L. +0 m. However, setting the berth face line at a shallower area is not necessarily cost effective as it requires a considerable amount of dredging for access channel instead. In addition, dredging at a shallower area for access channel will increase the risk of sedimentation after dredging and its maintenance cost. Although the bathymetric survey results in this study showed that no significant sedimentation had occurred at the existing channel, it was only the case with dredged depth less than 10 m. On the other hand, the dredging depth of DK1 will be deeper than that of the existing channel and this will increase a risk of sedimentation in the future as well. With these considerations, therefore, design policy on berth face line is presented as follows:

<Design Policy on Berth Face Line >

- Set berth face line not shallower than that of the Port M/P (i.e., C.D.L. +0 m) considering a risk for sedimentation.
- Set it at a bit deeper location as long as it is cost effective and it does not interfere the way of main channel.

b) Design Policy on Yard Area

Figure 8.3.12(a) shows the berth and yard layout presented in the Port M/P and the berth was 300 m in length and yard depth was approximately 800 m. This layout was proposed referring to the dimension of Berth No. 21 in Mombasa Port as shown in the same figure, which is a full container terminal that can handle more than 400,000 TEU/ year.

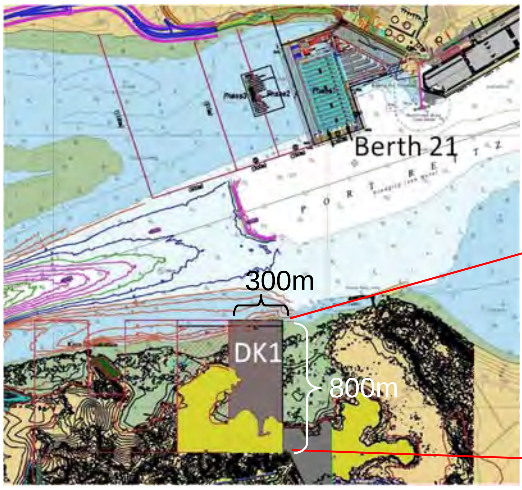
However, considering that DK1 would mainly handle vehicles, it would require much less yard compared with that of a full container terminal.

In addition, geotechnical investigations in this study showed that cut earth from SEZ area is not suitable as reclamation material. Other candidates for sand borrow can be either quarry site on land or sea bottom at offshore of Mombasa, however, it is obvious that procurement cost is higher than that of cut earth from SEZ due to material and transportation cost.

In the environmental and social points of view, there are a wide mangrove forest at the Dongo Kundu area and Kaya (sacred forest) that would be affected by reclamation as shown in Figure 8.3.12(b). With these considerations, the design policy on yard is presented as follows:

<Design Policy on Yard Area>

- Minimize yard area as long as it can fulfill its cargo handling function, to reduce the Project cost and to reduce reclamation materials and minimize environmental impact by reclamation.



(a) Berth Layout in the Port M/P

(b)Mangorve Forest Spread at Dongo Kundu

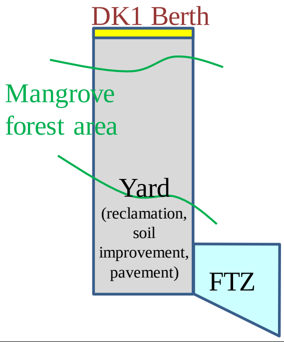
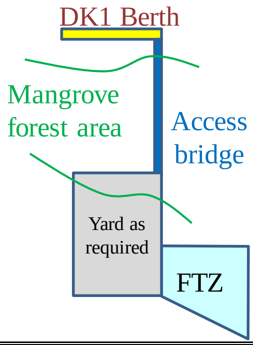
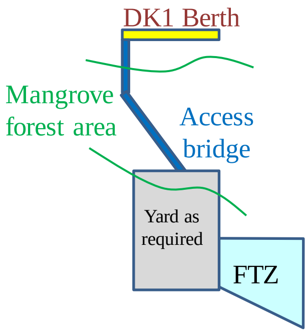
Source: JICA Design Team

Figure 8.3.12 Berth Layout in the Port M/P and Mangrove Forest Spread at Dongo Kundu

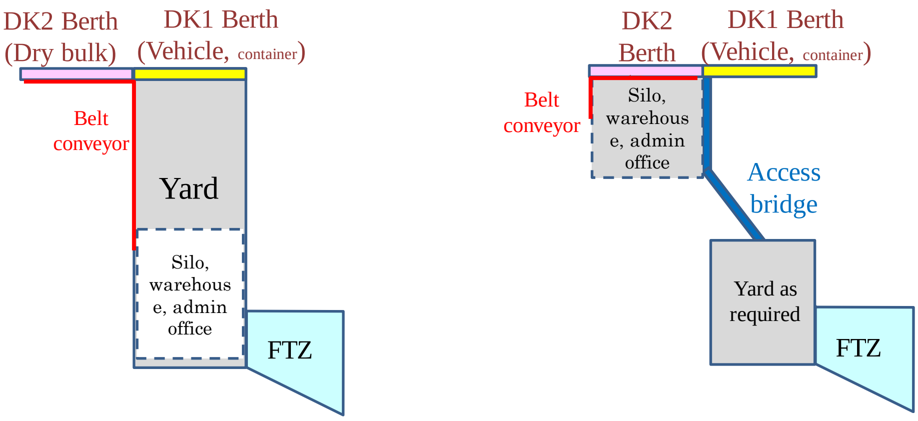
iv) Basic Layout Comparison for Berth and Yard

With design policies for berth face line and yard area, comparisons of the basic layout for both of the berth and yard are conducted as shown in Table 8.3.5. It should be noted that each figure is schematic to show its design concept and does not show any exact dimension for facilities. For example, the yard area in the table is an image and requires further study to determine the exact dimensions.

Table 8.3.5 Comparison of the Basic Layout for Berth and Yard

Comparison Items	Original (the Port M/P)	Alternative-1	Alternative-2
Schematic Layout			
Cost	More (large reclamation volume with necessary soil improvement and pavement)	Less (less reclamation due to minimized yard area and access bridge)	Less (same as Alternative-1)
Environmental Impact	More (reclamation make an impact on existing mangrove forest)	Less (access bridge and minimized yard area make less impact on mangrove forest)	Less (same as Alternative-1)
Expandability to DK2 and its Example	High (enough yard space, see Figure 8.3.13 for example)	Less (less accessible)	High (accessible by using the access bridge of DK1, see Figure 8.3.13 for example)
Concern	Most yard area might be left unused	Difficult to set minimal yard area considering uncertainty of SEZ industry	(Same as Alternative-1)
Evaluation	Not recommended	Fair	Recommended

Source: JICA Design Team



(Original)* (Alternative-2)*

*These figures are just examples under conditions that DK2 will handle dry bulk and silos will be needed inside of the port area

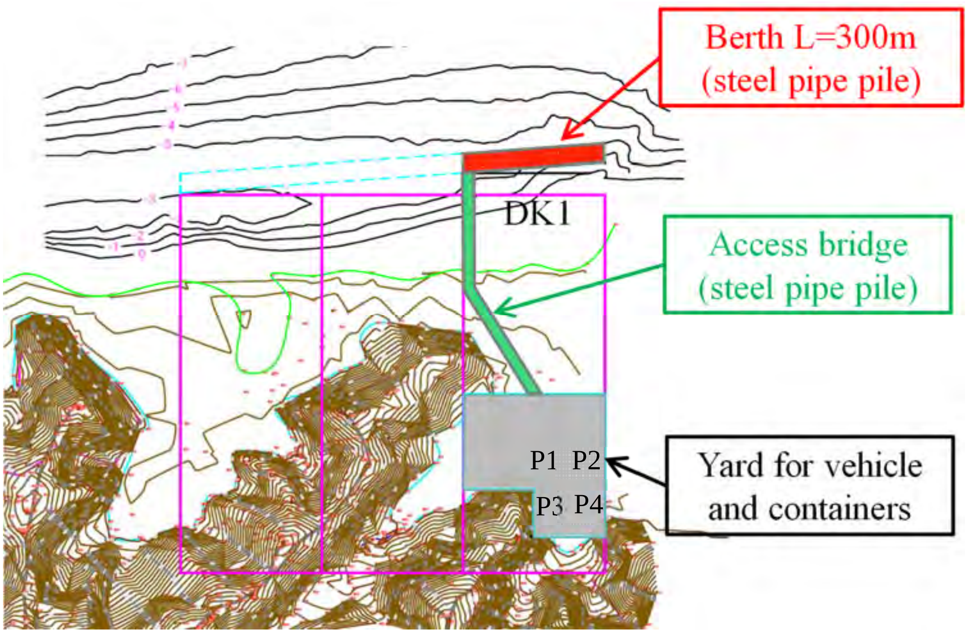
Source: JICA Design Team

Figure 8.3.13 Examples of Expandability to DK2

v) Recommended Port Layout

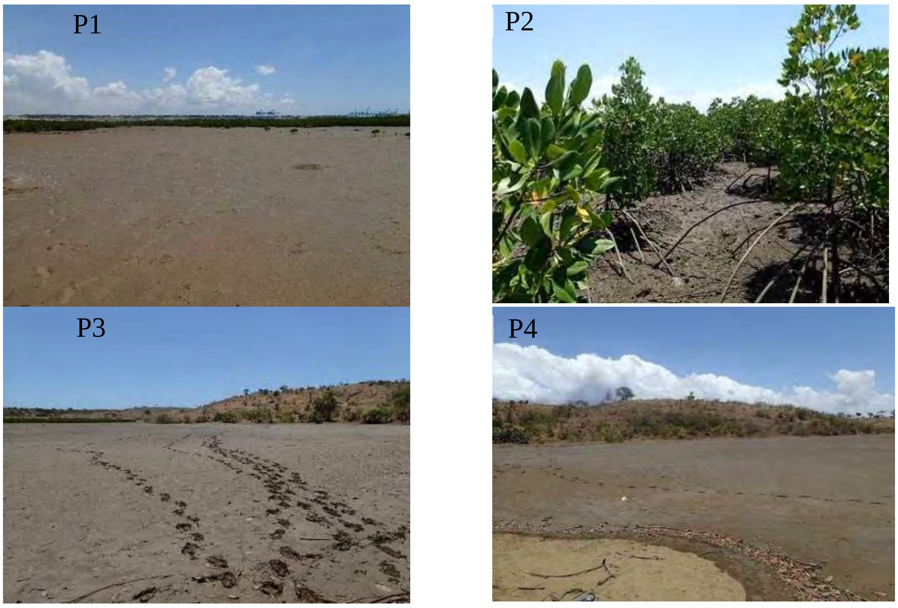
Figure 8.3.14 shows a recommended port layout based on the concept of "Alternative-2" in the previous Table 8.3.5. Figure 8.3.15 also shows site photographs taken from the yard area in Figure 8.3.14. For reference, Figure.8.3.16 shows the offshore container terminal of Tanjung Perak Port in Surabaya, Indonesia as an example of port layout similar to that of Figure 8.3.14. In the case of Tanjung Perak Port, the access bridge was applied to reduce maintenance cost for dredging.

As already presented in Figure 8.3.4, the following berths, DK2 and DK3 are to be developed based on more certain cargo demand and volume from SEZ, which is expected to be identified at later phases. One candidate cargo, for example, can be dry bulk for DK2 and full container terminal for DK3. A dry bulk (grain bulk) could be one of the main cargos in SEZ if the area was specified as a grain hub in the development plan prepared by the Kenyan Government. A full container terminal will be needed at later phase if the demand increased as similar manner as that of the SEZ M/P (i.e. 400,000TEU/year at Phase 3). DK3 is suitable for development of container terminal as it has wider flat land area. Containers handled at DK1 can be transferred to DK3 after the completion and the left space of DK1 can be used for supplemental yard for vehicles or other general cargos.



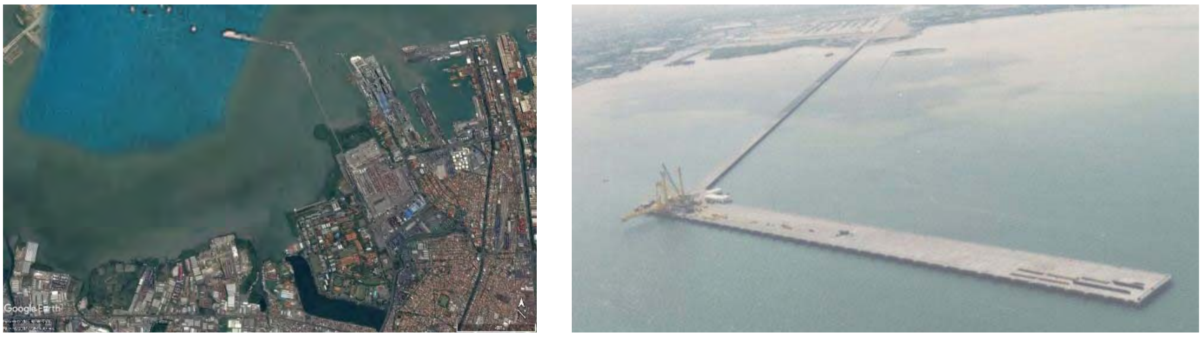
Source: JICA Design Team

Figure 8.3.14 Port Layout based on the Concept of Alternative-2 (Tentative)



Source: JICA Design Team

Figure 8.3.15 Site Photographs taken from Yard Area in Figure 8.3.14



Source: JICA Design Team

Figure 8.3.16 Offshore Container Terminal with Access Bridge of Tanjung Perak Port

8.3.3 Cargo Volume for Design Yard Area of DK1

Cargo volume for design yard area of DK1 were evaluated for both motor vehicles and containers in this section and section 8.3.7 shows yard layout based on this cargo volume. Design vessel sizes were set referring to the largest vessel size and future vessel size of the Port M/P as shown in Section 8.3.4.

i) Motor Vehicles

Design cargo volume for motor vehicles was set as same as that of demand forecast in this study as summarized at item (b) in the Table 8.3.6. Productivity of handling motor vehicles at Mombasa Port by ICDs is currently about 40 units/hour, which is equivalent to 1,000 units/day. According to interview survey to ICD, however, their target productivity in future is about twice of that of the present, which is about 80-90 units/hour, 1,920-2160 units/day though they realized difficulty to accomplish this target value under the current congested condition at Mombasa Port. It was assumed that motor vehicles at DK1 will be mainly handled by ICDs that will transfer to SEZ and/or business firms for reselling vehicles. In that case, a vehicle yard of DK1 can be used as temporally yard after landing as landed vehicles can be transported and stored

at ICD's yard in SEZ or FTZ (Free Trade Zone) to be developed at nearby DK1 in Phase 1. Therefore, a storage period of motor vehicles in the vehicle yard of DK1 was assumed to be one day (24 hours) referring to actual condition at Mombasa Port (i.e. 18 hours) and the dimension of yard area is determined so that it can allocate maximum number of vehicles discharged in a day (i.e. equivalent to maximum productivity in a day). The unit area required per vehicle was about 25m^2/vehicle including access road according to the hearings from business firms and about 20m^2/vehicle from actual condition of vehicle yard at the Bremerhaven Port, which is famous as one of the largest import/export ports in Europe. The unit area of 25m^2/vehicle was used in this study in order to secure higher work efficiency inside of the yard.
Considering as above, the required yard area for motor vehicles can be calculated as;

- Required yard area for motor vehicles = a) x b) x c) = 2,000 units/day x 25m^2 x 1 day=50,000m^2 (5 ha)

where
a) is the productivity of 2,000 units/day,
b) is the required area per vehicle which is 25m^2/unit including access space and road,
c) is the storage period inside of the yard which was set almost same as present condition at Mombasa Port as 1 day (24 hours).

ii) Containers

Since DK1 is a multi-purpose berth and motor vehicle is the main cargo, the handling capacity of containers will be affected by that of motor vehicles. Therefore, volume of containers that can be handled at DK1 was calculated as shown in Table 8.3.6. Firstly, number of work days required for handling the demanded number of motor vehicle units at DK1 was calculated as shown in item (e) in the Table. Work days for containers was then calculated by subtracting item (e) from total work days in a year (363 days). The productivity of the containers (TEU/day) as shown in item (g) was obtained survey results from the Port M/P. It is noted that this productivity was obtained from the berths with no fixed container handling machines such as gantry cranes as DK1 will not be equipped with the fixed ones. Finally, the productivity of containers (TEU/year) was calculated as shown in item (h). Annual productivity of containers will decrease in time series as demand for motor vehicles increases and it is estimated to handle about 60,000TEU/year at earlier phase in 2025. According to the SEZ M/P in 2015, the cargo demand in 2030 was roughly estimated as 400,000 TEU/year from/ to SEZ which is much bigger than the capacity of DK1. This value is almost equivalent to the productivity of the full container terminal with several gantry cranes such as berth No.21. As already described in previous Section 8.3.2, if demand of cargo will be likely to develop in such a scale, adaptive development of DK2 or DK3 will be required as a full container terminal to cover the demand.
Details of productivity of containers and required yard area are calculated in Section 8.3.8 (Cargo handling equipment) as they are mainly determined by capacity of the handling equipment such as mobile harbor cranes, reach stackers and trailers.

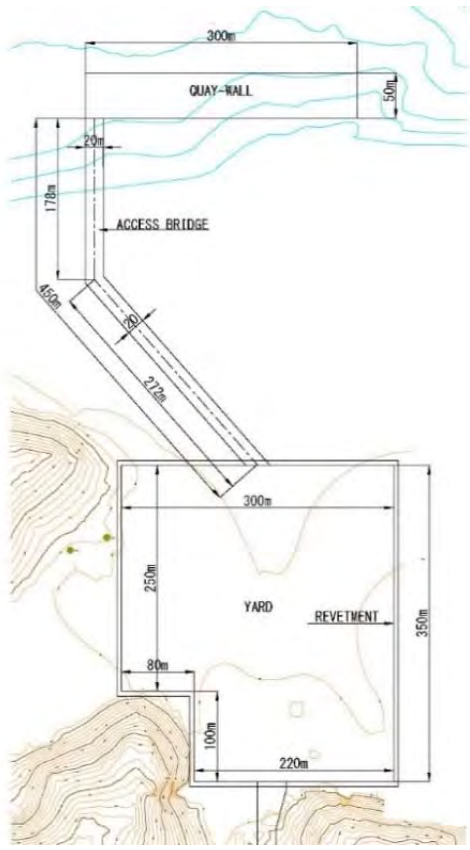
Table 8.3.6 Productivity and Approx. Work Days for Cargos at DK1

Year		2020 (Reference	2025	2030	2035	Description
Motor Vehicles	(a) Daily Productivity (units/day)	1,500	1,500	1,500	1,500	Average of low and high (1,000 - 2,000 units/day)
	(b) Target Annual Porductivity (units/year)	177,877	216,995	260,904	299,812	Value from the demand forecast result
	(c) Berth Occupancy Ratio(B.O.R)	80%	80%	80%	80%	Survey from the Port M/P
	(d) Work ratio	0.85	0.85	0.85	0.85	Survey from the Port M/P
	(e) Work days (day) [(b)/(a)/(c)/(d)]	174	213	256	294	
Containers	(f) Work days left for containers [363 days-(e)]	189	150	107	69	
	(g) Productivity (TEU/day)	400	400	400	400	Survey from the Port M/P; berths with no fixed container handling machine
	(h) Productivity (TEU/year) [(f)x(g)]	75,444	60,104	42,885	27,627	

Source: JICA Design Team

8.3.4 Design Condition

The port facilities, which are going to be designed are quay wall, access bridge, revetment and yard.
In this section, the common design conditions of port facility are indicated and the details will be presented in the design section of each facility.
The port facilities plan is shown in Figure 8.3.17.



Source: JICA Design Team

Figure 8.3.17 Plan of Port Facilities

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

(1) Natural Conditions

i) Tide Level

The HHWL, MWL, LLWL and CDL are quoted from tidal tables of KPA. The LWL and HWL are calculated from the tidal data kilindini (2002, 2003, 2004 and 2009).
The tide level conditions are shown in Table 8.3.7.

Table 8.3.7 Tide Condition

Highest Water Level	H.H.W.L	CDL＋4.10 m
Mean Springs High Water Level	H.W.L	CDL＋3.80 m
Mean Water Level	M.W.L	CDL＋1.88 m
Mean Springs Low Water Level	L.W.L	CDL +0.10 m
Lowest Low Water Level	L.L.W.L	CDL -0.10 m
Datum Level	CDL	CDL±0.00 m

Source: Mombasa Port M/P

ii) Wind Velocity

The wind velocity was decided as shown below from Mombasa Port M/P. It is quoted from the tide tables of KPA

- V=22.5 m/s

iii) Tidal current

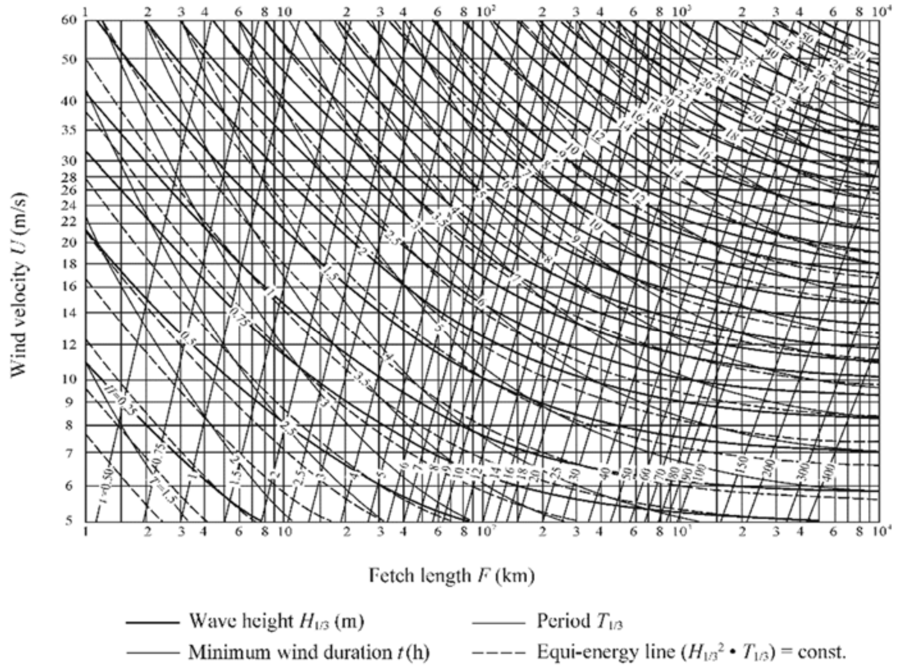
The tidal current was decided as shown below from Mombasa Port M/P.

- V=0.8 m/s

iv) Wave

Since the berth is located in the inner part of a bay, where waves do not enter directly from an open-sea, a wind wave was used as design wave.
The wind wave was calculated by the SMB method. The conditions are the followings;

- Wind velocity V=22.5 m/s : Fetch F=1 km
- The result of a wave forecasting
- Wave height H=0.5 m : Period T=2.0 sec



Source: Technical Standard and Commentaries for Port and Harbor Facilities in JAPAN, 2009

Figure 8.3.18 Wind Hindcasting Diagram by the S-M-B Method

v) Seismic Coefficient

According to Kenyan seismic code (1973), Mombasa is located in Zone-Ⅵ. The seismic acceleration of Zone-Ⅵ is 0.0125g.

- Design horizontal-seismic-coefficient: kh=0.0125.

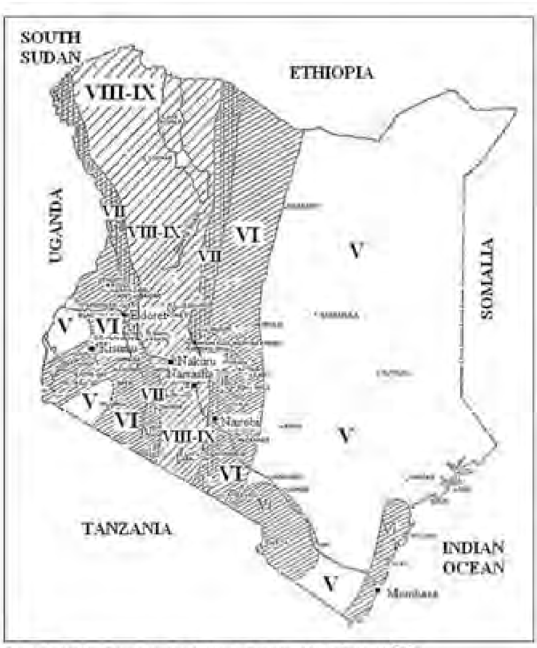


Figure 1 The seismic zoning map of Kenya in terms of MMI scale (MWK 1973)

Source: Kenyan Ministry of Works

Figure 8.3.19 The Seismic Zoning Map of Kenya

vi) Soil Condition

The soil conditions were set up from the soil investigation report done by the Port M/P and soil investigation in this study.

vii) Design Vessels

Design vessels were determined as followings and shown in the Table 8.3.8.

- Container ship: Based on the Port M/P, the largest vessel of Mombasa port except those at full container terminal equipped with quay gantry crane (i.e. largest vessel at berth No.11-14)
- Pure car carrier ship: Based on the Port M/P, the largest vessel of Mombasa Port was selected, resulted from a comparison made with the future forecast of vessel size.

Table 8.3.8 Design Vessels

	Container Ship	Pure Car Carrier Ship (PCC)
Gross Tonnage (GT)	35,878 GT	72,408 GT
Length overall (Loa)	212 m	232 m
Molded breadth (B)	32 m	32 m
Full load draft (d)	11.6 m	11.7 m
Berthing Velocity	0.10 m/s	0.10 m/s

Source: JICA Design Team

viii) Loading Conditions

a) Surcharge

The surcharge condition is set as below considering the weight of vehicles and cargos.
The surcharge at unusual condition is 0.5 time of the surcharge at usual condition.

- Usual q=20 kN/m^2
- Unusual q'=10kN/m^2

b) Surcharge

The unit weight of each material is shown in Table 8.3.9.

Table 8.3.9 Unit Weights of Materials

Materials	Unit Weight (kN/m^3)
Steel	77.0
Reinforced concrete	24.0
Plain concrete	22.6
Timber	7.8
Asphalt concrete	22.6
Stone(Granite)	26.0
Stone（Sandstone）	25.0
Sand, Gravel, Rubble (Dry condition)	16.0
Sand, Gravel, Rubble (Wet condition)	18.0
Sand, Gravel, Rubble (Saturated condition)	20.0

Source: Technical Standard and Commentaries for Port and Harbour Facilities in JAPAN, 2009

c) Other Materials Surcharge

Other materials are based on Japanese Industrial Standards (JIS).

ix) Design Standard

- Technical Standard and Commentaries for Port and Harbor Facilities in JAPAN, 2009
- Also BS, PIANC, and EURO -CORD are referred.

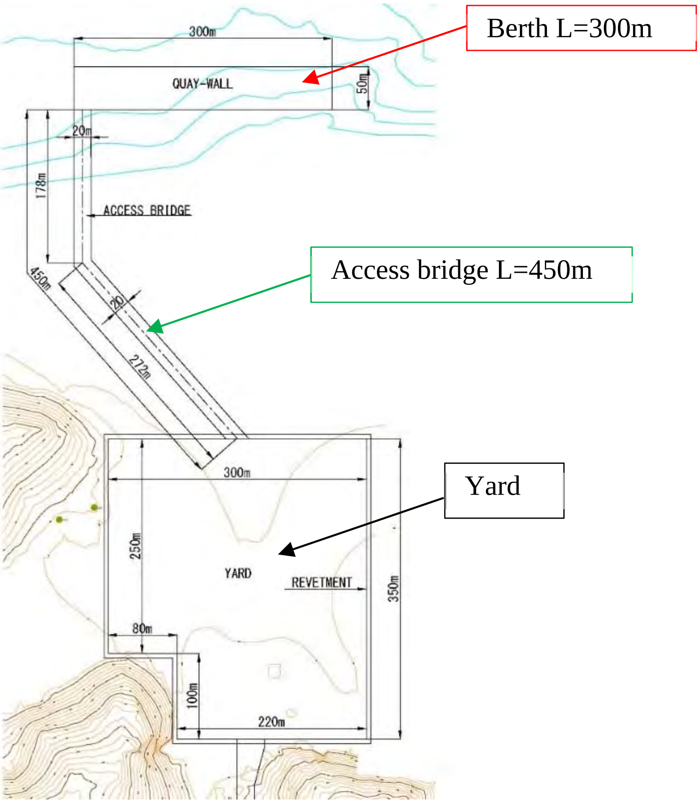
8.3.5 Land Reclamation

(1) Field Conditions Related to Reclamation

i) Layout of face line of DK1 Wharf and the Yard

The face line of DK1 Wharf and layout plan of DK1 yard shown in Figure 8.3.20 has been proposed in consideration of the following conditions.

- DK1 Berth is mainly used as a car terminal and it may also receive containers up to a volume that can be handled without quay gantry cranes.
- The face line of DK1 Berth is set at the location where the water depth is larger than that at the location of the face line proposed in the Port M/P.
- The layout plan of the yard should be elaborated to minimize the volume of landfill and the adverse effects on the environment to the extent possible. Also, the access from the yard to DK1 Berth should be planned as a bridge type structure.



Source JICA Design Team

Figure 8.3.20 Layout Plan of DK1 Berth

ii) Borrow Pit for the Landfill Material for Reclamation

The Mombasa SEZ M/P recommended to use the dredged earth and sand and the soils cut from the hilly area during grading of the SEZ site as the landfill materials for reclamation if they are suitable for landfill. However, the results of the geotechnical investigations at the SEZ site showed the soil itself is judged not suitable for landfill, because of the large quantity of clay constituent and the existence of bedrock at relatively shallow depths. Thus, the materials for landfill of the yard should be brought from the other borrow pit(s).

As for a candidate source of the land sand, the borrow pit at Kilifi located 80 km to the north of Mombasa Port (see Figure 8.3.21) was expected as a potential source. Through the investigation by a field reconnaissance, it was confirmed that the land sand there is suitable as the filling material for the yard area of this project.

As for the candidate source of sea sand, while the Mombasa Port container terminal construction project Phase 1, funded by Yen Loan, took the sea sand from the several locations near the entrance of Mombasa Port and used them for the landfill of Berth 20 and 21, sea sand mining has become an issue for fishing rights and the compensation has yet to be settled.

Note) Prior to the construction of Berth 21 and 22 of Mombasa Port, a survey was carried out within the area indicated in the Figure 8.3.22 to find suitable landfill materials, and the several locations about five (5) km away from the entrance of Mombasa Port (at a depth of approximately-30 m) was chosen to take sea sand. The Phase 2 of the project is about to start, and the same area is expected to be the souse of sea sand for the landfill of Berth 22.

Considering the situation stated above, prior to the implementation of this project, it is necessary to carry out a survey for the borrow sites to ensure the sites are able to provide enough volume of landfill materials. It is also necessary to obtain the approval of KMA (the Kenya Maritime Authority) for the borrow sites as well as for the dumping sites of dredged materials.

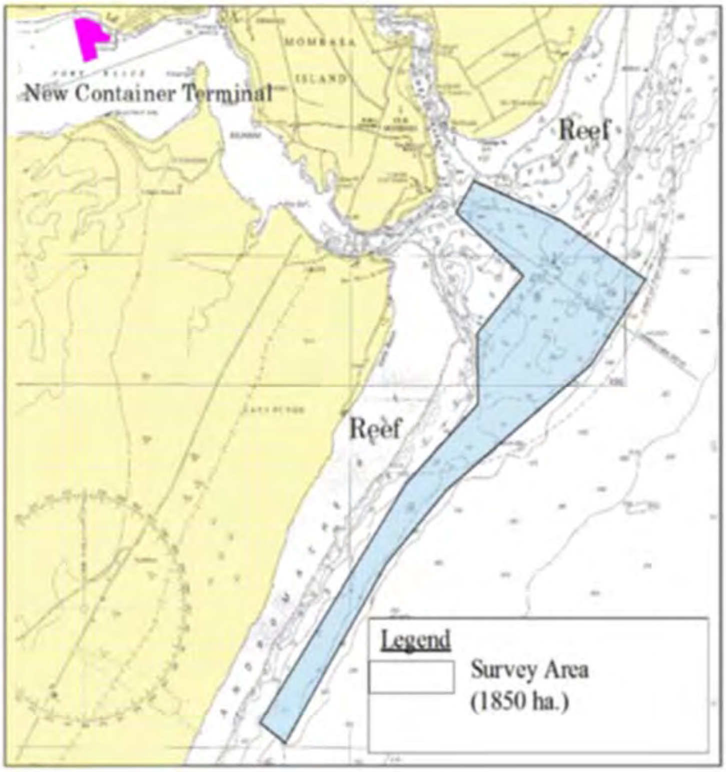
Another possible option is to use the materials generated from the project site by grading of the SEZ site after mechanical stabilization of chips and mucks generated from cutting the bedrock in the subsoil (Sh layer), because the silty surface layer of the material contains clay which is by itself judged as unsuitable for landfill.

Source Google, JICA Design Team

Figure 8.3.21 Location of Land Borrow Pit (1)

Source Google, JICA Design Team

Figure 8.3.22 Location of Land Borrow Pit (2)



Source: Consultancy Team of Container Terminal Phase 1

Figure 8.3.23 Location of Offshore Sand Survey Area

(2) Selection of Reclamation Method

As described in (1) Field conditions related to reclamation, the soil obtained by grading the SEZ area has been judged unsuitable for landfill due to the high content of clay. Therefore, the landfill materials should be brought from other sources. Methods to be employed for the three different landfill materials are discussed hereunder.

- Case-1: Reclamation method for sea sand (Offshore borrow pit)
- Case-2: Reclamation method for land sand (On-land borrow pit)
- Case-3: Reclamation method for chips and mucks generated from cutting the bedrock in the subsoil (Sh-layer)

The following are brief explanations of each method:

i) Case-1: Reclamation Method for Sea Sand (Offshore borrow pit)

A dredger (it is assumed that a self-propelling drag suction dredger is employed) pumps up sea sand from an off-shore borrow pit and stocks the sand in a hopper in its hull. After filling up the hopper, the dredger moves to the reclamation site and discharges through a discharge pipe or the sand directly from its hopper: this method is called “the Rainbow Method”. The expected offshore borrow pit is located within 10 km from the entrance of Mombasa Port. The total travel distance between the borrow pit and the reclamation site is calculated as follows in consideration of the 18 km long navigation channel between the reclamation site and the entrance of the port.

- L＝18.0 km ＋ 10.0 km = 28.0 km ≒ 30 km
- The maximum water depth of borrow pit is set to be about -30 m.

ii) Case-2: Reclamation Method for Land Sand (On-land Borrow Pit)

Pit sands should be brought from an on-land borrow pit 80 km away from Dongo Kundu reclamation area. A jetty for loading stones, which was constructed by a Chinese company, exists in Kilifi Creek about 24 km away from Kilifi Quarry, and the jetty is used for unloading stones for Lamu Port Project. (see Figure 8.3.21 Location of Land Borrow Pit). The jetty will be transferred to the local county government after the project completes, and it is possible that the jetty is utilized for the loading of the filling material for the yard reclamation work of Dongo Kundu DK1Berth. Thus, the filling materials for this project shall be firstly transported from Kilifi Quarry to the jetty by dump trucks, then loaded on hopper barges and shipped to Mombasa Port area, and finally unloaded at a temporary wharf, which is to be constructed near the reclamation area of DK1 Yard, and dumped at the reclamation site.

iii) Case-3: Reclamation Method for Chips and Mucks generated by Grading of SEZ from cutting the Bedrock in the Subsoil (Sh layer)

The chips and mucks generated by grading of SEZ, which is located 3 to 5 km away from the reclamation site, are mechanically stabilized there and transported by trucks to a temporary pier constructed near the reclamation site, and then transported by hopper barges to the reclamation site since there is no access road.

iv) Comparison among the Three Methods mentioned above

The approximate costs calculated for the three methods mentioned above are compared in Table 8.3.10.

- Approximate filling volume V= 638,400 m^3 (including sand mat and preloading embankment)

Table 8.3.10 Costs of the Reclamation of the Abovementioned Three Methods

Cost per reclamation volume 1.0 m^3

Case	Reclamation Method	Approximate Cost
Case-1	Reclamation by the offshore sand	3,000KES
Case-2	Reclamation by the on-land sand	3,500KES
Case-3	Reclamation by the site generated rock material	700KES

Source: JICA Design Team

Additional boring tests have been carried out at two locations within the area where the construction of DK1 yard is planned. The field boring test showed that, a soft clay sub-layer having N=0 with a thickness of about 6.0 m exists at the location Bor. SBH-1 on land side. It was judged that the soil improvement (Vertical Drain : PVD Method) is necessary, because the magnitude of the consolidation settlement is estimated to be about 110cm as described in the result of the analysis in the following chapter. Since the average ground elevation of the yard site is assumed to be about + 2.5 m, an embankment of 3.0 m to 3.5 m thickness is required to make the elevation of the reclamation land as high as + 5.5 m to + 6.0 m in accordance with the plan. It is, therefore, judged that a half of the landfill material should be sand mats. Also, since the placement of PVD drain may be difficult in case a sublayer made of site-crushed rocks and the like is filled beneath the sand mat, it is judged that site-crushed rock or blasted rock material (used in Case-3) is not suitable as sand mat or sublayer.

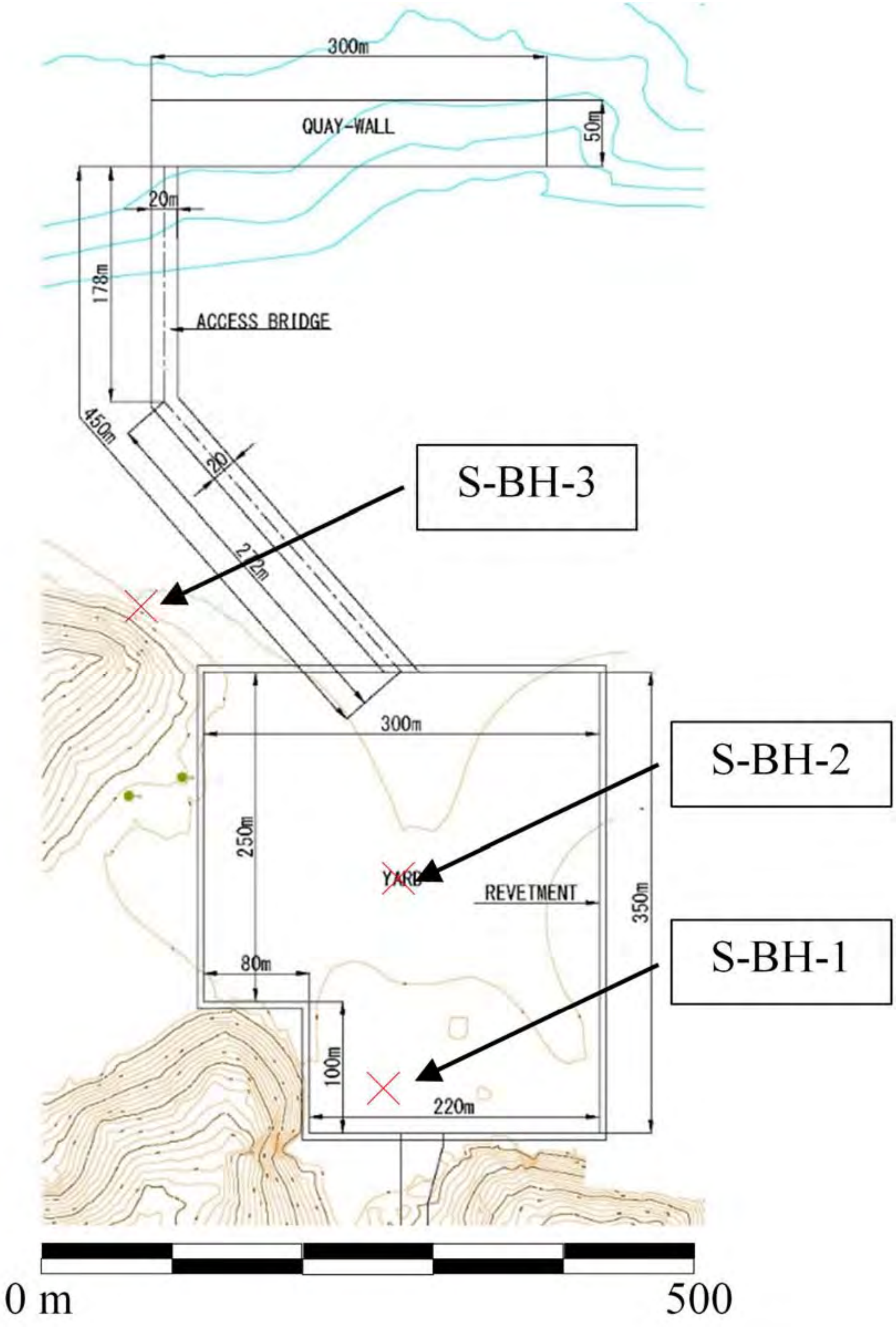
The use of sea sand (Case-1) is the most economical method, but the offshore borrowing requires compensation for fishing right as explained above and the amount has not yet fixed. In addition, there are many uncertain issues including environmental problems. Therefore, it is judged at this stage that land sand (Case -2) is the most suitable method for the reclamation.

(3) Examination of the Soil Improvement of the Reclamation Site

Additional boring test has been carried out at two locations within the planned site of the yard of DK1 berth (S-BH-1 and S-BH-2, see Figure 8.3.24. The consolidation of the yard site without soil improvement was examined by a consolidation test at SBH-1 where a soft subsoil layer with N=0 was found.

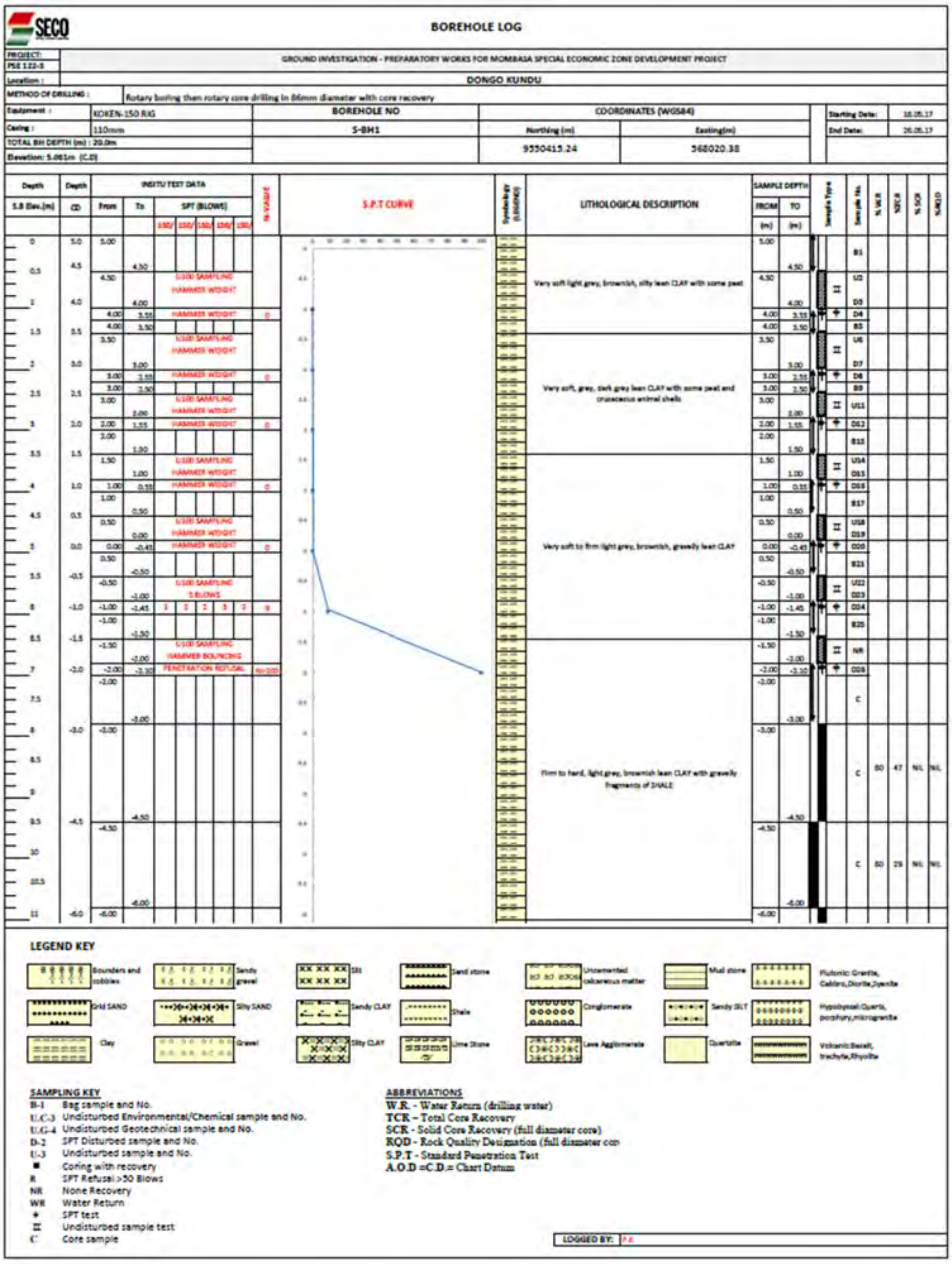
The results of the two boring tests (S-BH-1 and S-BH-2) showed different characteristics (such as N-value) to each other, and it is envisaged that the stratum structure of the yard is quite complicated. In addition, the Cv-value obtained by the consolidation test is extremely low. The relation between the consolidation yield stress and the overburden load shows that even the surface layer of soft clayey soil exhibits some characteristics of over-consolidated clay and the N-value at S-BH-1 remained zero (0) with no improvement in strength. The consolidation characteristics of the soil will give a large impact on the designing of soil improvement discussed hereunder and result in differences in the characteristics of the improved soil.

Thus, further examination will be required during the detail design stage for verification of the consolidation characteristics including additional boring tests within the yard.



Source: JICA Design Team

Figure 8.3.24 Location of Additional Boring Sites of Yard



Source: JICA Design Team

Figure 8.3.25 Borehole Log of S-BH1

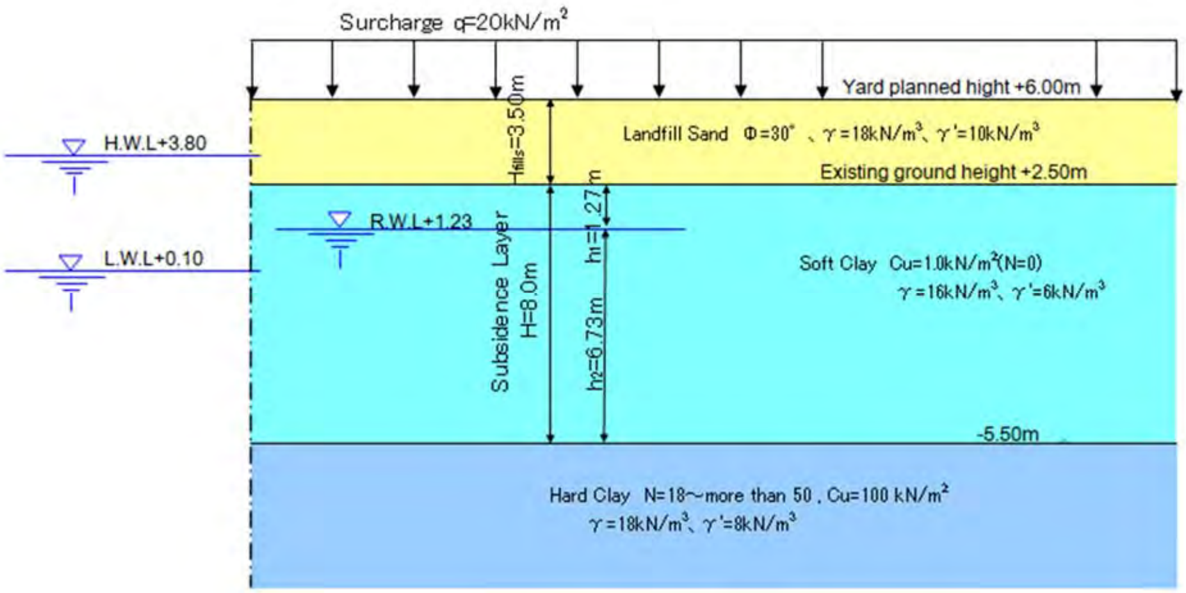
i) Calculation of Consolidation Settlement for the Case without Soil Improvement

As mentioned above, the stratum structure of yard reclamation area is found to be quite complicated. For investigation purpose, a ground model having an 8m-thick soft subsoil layer was formulated as a typical ground structure for the consolidation calculation. The model stratum of consolidation settlement in the yard reclamation area was made, based on the results of the additional boring tests (Bor. S-BH-1 and S-BH-2) that was carried out at the planned reclamation site. And consolidation of the model stratum was calculated as the one without improvement.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

The model stratum is schematically shown in Figure 8.3.26. As seen in the Figure, the soft layer beneath the 3.5 m thick landfill is assumed to have a thickness of 8 m and N-value of zero.
The results of the additional boring tests are as follows:

- The consolidation characteristics obtained at Bor. S-BH-1 are shown in Figures 8.3.26, 8.3.27, 8.3.28 and Table 8.3.11.
- At Bor. S-BH-1, soft soil having N=0 was detected at the 6.0m-thick surface layer only, while a shale layer having N>50 exists underneath.
- At B-BH-2, the surface layer up to the depth of 10 m is a clay having N-value of 4 to 9, the layer beneath the surface layer up to the depth of 20 m is a hard clay having N= 18 to 50, and a Shale layer having N>50 is detected underneath.



Source: JICA Design Team

Figure 8.3.26 The Model for the Consolidation Calculation

The consolidation calculation has been done for the three different methods under the conditions described above: Mv Method, e-log Method, and Cc Method. The results are shown in Table. 8.3.11.

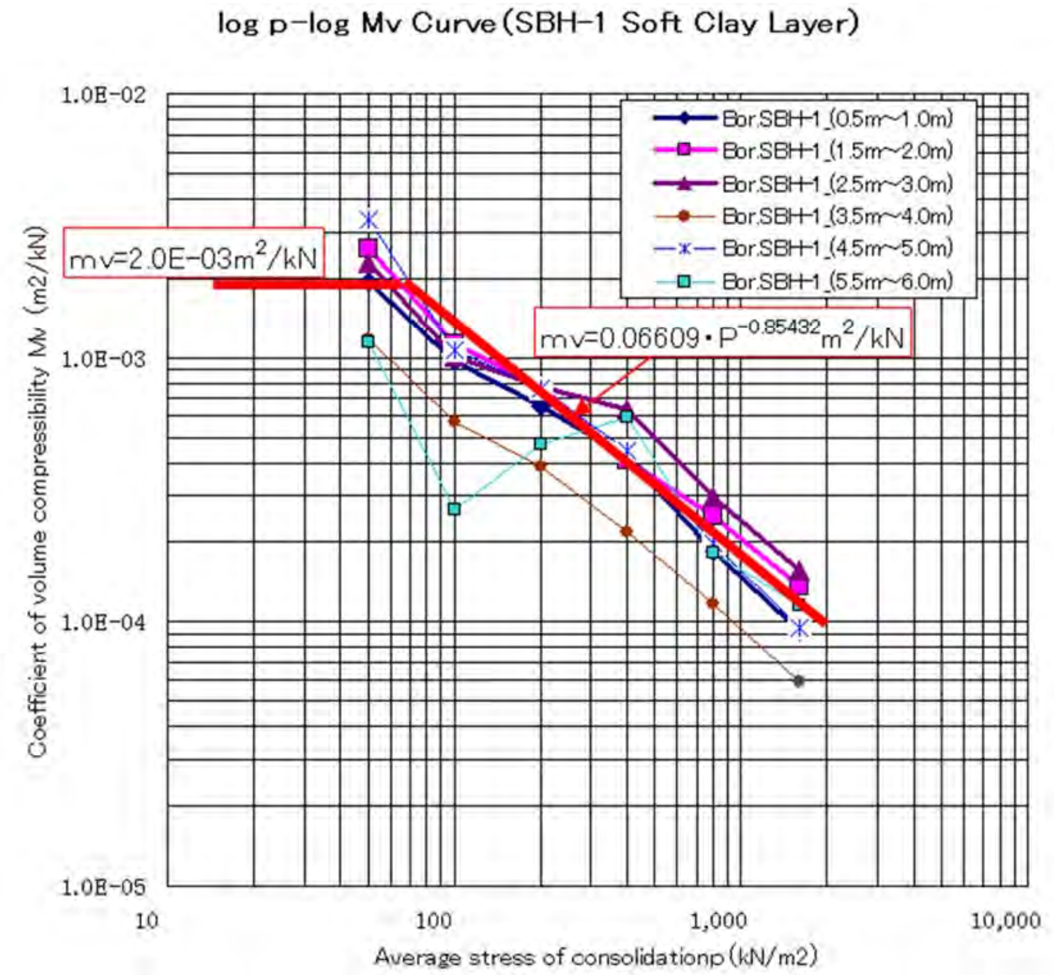
Table 8.3.11 The Result of Consolidation Calculation

Method	Final Settlement(cm)	Consolidation Time U=90% (Year)
Mv	110.6	27,136day (74.3 Year)
e-logP	78.0	
Cc	107.9	

Source: JICA Design Team

In the "Technical Standards and Commentaries for Port and Harbor Facilities in Japan", Mv Method is mainly adopted, and thus, the result by Mv Method shall be employed for the soil improvement. Though the measured value of consolidation coefficient Cv, which has an impact on the consolidation time, varies over a wide range, Cv=20 cm^2 /day was chosen with consideration of the value (Cv=30 cm^2/day) that was employed for the Phase 1 container terminal design at the opposite shore. Since the data of the consolidation tests is lacking, additional tests are required during the detail design stage.

The consolidation time continues long and required time for the consolidation settlement of 90% is estimated as 74.3 years. It is judged that soil improvement is required to reduce consolidation settlement, because consolidation will last long until it reaches to 1.1 m, and in the case of without soil improvement, adverse effects of unequal consolidation to the pavement of the yard, drainage facilities and structures may occur after the completion of construction.



Source: JICA Design Team

Figure 8.3.27 Log p-log Mv Curve

Consolidation Characteristic Value (Bor.SBH-1 Soft Clay Layer)

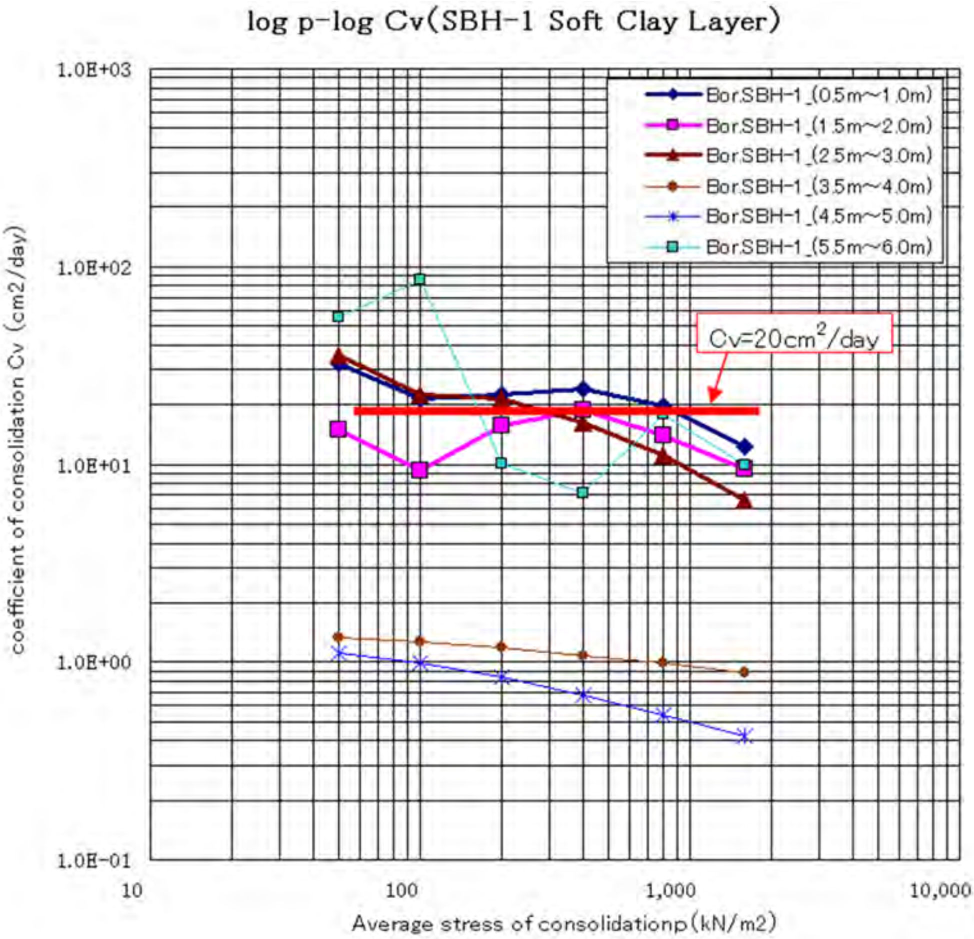
Source: JICA Design Team

Figure 8.3.28 e-logP Curve

Table 8.3.12 Consolidation Index (Cc)

Bor.No SBH-1 Depth	Consolidation Yield Stress		Consolidation Index Cc
	Pc(Kpa)	Pc(kN/m2)	
0.5m ~1.0m	90	90	0.532
1.5m ~2.0m	80	80	0.259
2.5m ~3.0m	150	150	0.864
3.5m ~4.0m	70	70	0.316
4.5m ~5.0m	80	80	0.545
5.5m ~6.0m	160	160	0.681
Consolidation Index Average			**0.533**

Source: JICA Team



Source: JICA Design Team

Figure 8.3.29 Log p-log Cv Curve

ii) Selection of Soil Improvement Method

The results of the settlement examination of unimproved ground, which was based on the results of the consolidation settlement of Bor.S-BH-1 in the yard reclamation area, showed that the settlement S=110.6 cm. 90% settlement time t=74.3 year.

The soil improvement measures generally applied for reducing the settlement are Vertical Drain (PVD) Method, Sand Compaction (SCP) Method and Deep Mixing Stabilization (CDM) Method. As a countermeasure against settlement suitable for large area such as yard, PVD Method is recommended from the viewpoint of economic standpoint (generally, the cost of SCP is twice and CDM is three times higher than that of PVD) and because of the plenty experiences it has. The PVD Method was also employed as a countermeasure to the settlement in the Phase 1 project (Barth 20 and 21) of the Mombasa Container Terminal. Therefore, the same method will be employed in this project for the soil improvement with the main purpose of anti-settlement.

The procedures of PVD soil improvement work and the designing work are as follows:

① High quality sand (having high permeability coefficient) shall be used as the sand mat material for reclamation from existing ground elevation up to +5.5 m, ② Construction of PVD (appropriate distance of PVD construction is determined so that the consolidation settlement completes 80% within eight (8) months,

③ Preloading by embankment (the elevation of the embankment should be higher than 1.5 m plus design reclamation elevation after 80% of the total settlement),

④ Leave the preload for eight (8) months (the period is to ensure 80% completion of the settlement),

⑤ Removing the minimum 1.5 m thick of upper layer of the preloading embankment to adjust the ground elevation of the yard to +5.5 m

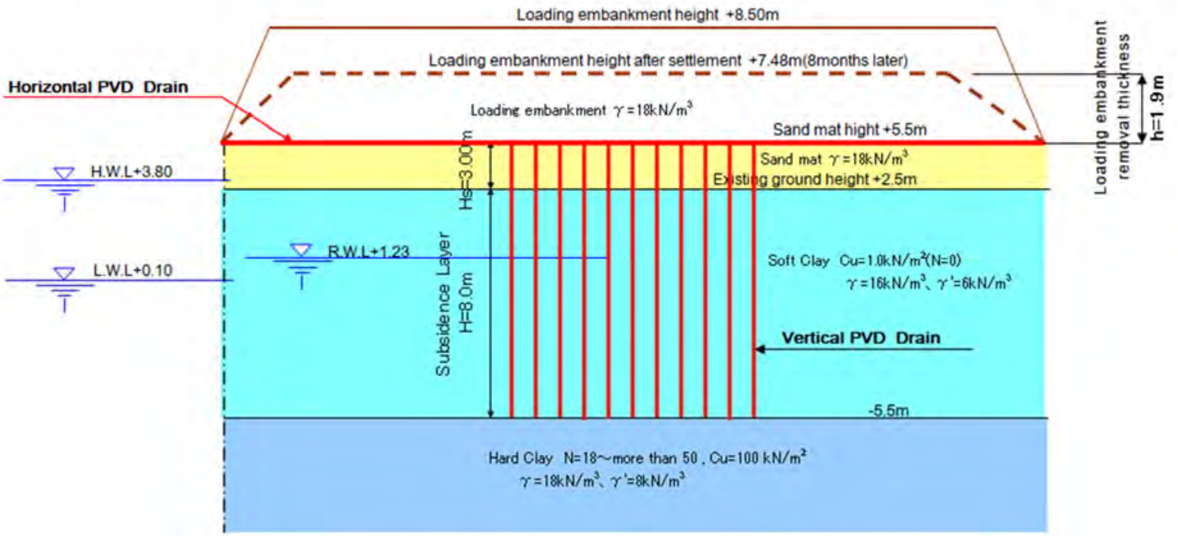
⑥ (the yard ground should be over-consolidated in order to avoid settlement occurs when the upper load ($q=20\ kN/m^2$) is placed on the yard area after completion of the project),

⑦ Over consolidation load = 1.5m x 18.0 kN/m^3 x 80% (degree of consolidation) = 21.6 kN/m^2

⑧ Final elevation of reclamation ground; +5.50 m (considering thickness of pavement at 0.50m)

⑨ Pavement work (planned yard elevation: + 6.0m, crown elevation of yard perimeter revetment: +5.5m, drainage gradient is taken into consideration)

⑩ Completion of the yard.



Source: JICA Design Team

Figure 8.3.30 Model for PVD ground improvement method

iii) PVD Soil Improvement

① Design condition of PVD soil improvement

- Ground elevation of the construction of PVD drain: +5.5 m
- Positioning of drain: Square formation
- Spacing of drain: 0.80 m (assumed)
- Thickness of soil layer to be improved: h = 8.0 m
- Horizontal coefficient of consolidation of cohesive soil: Ch = 20 cm^2/day (assumed Ch= Cv)
- Coefficient of permeability of cohesive soil ground: Kc = 1.00 E-7 cm/sec
- Coefficient of permeability of drain material: Kw = 1.00 E-2 cm/sec
- Effect of well-resistance: taken into consideration
- Preloading period: Eight (8) months (Degree of Consolidation U=80 % or over)

- Design upper load of the yard: $q= 20kN/m^2$
- Consolidation by preloading: After 80% completion of consolidation settlement by preloading embankment,at least 1.5 m thick of its upper layer shall be removed, so that no further settlement occurs when upper loads are placed.
- Preloading for over–consolidation $\alpha = 1.50\ m \times 18\ kN/m^3 \times 80\% = 21.6\ kN/m^2$
- Allowable residual settlement: $\delta_a = 10$ cm.

② Examination result of PVD soil improvement

- Diameter of PVD drain: $d_w= 0.05$ m
- Positioning of drain: Square formation
- Spacing of drain: d = 0.80 m
- Diameter of Equivalent Effective Circle: $d_e=1.13\times d=0.90m$
- Thickness of soil layer to be improved: h = 8.0 m
- Elevation of sand mat: +5.50m (Thickness of sand mat h=1.0m - 2.0m)
- Crest elevation of preloading embankment: +8.5m
- Thickness of preloading embankment: h=3.00m
- Settlement of unimproved ground by preloading embankment: $\delta c=125.4cm$
- Degree of consolidation and settlement after 8 months preloading: U=81.4%, $\delta =102.1cm$
- Crest elevation of preloading embankment after 8 months preloading: +8.5m → +7.48m
- Thickness of the removed layer of preloading embankment : h=1.9m (7.48-5.50 ≒1.9 m)
- Over-consolidation load after removal of preloading embankment: $\alpha =1.9m\times 18kN/m^3\times 81.4\%$ $= 27.8N/m^2$
- Crest elevation of the yard after removal of embankment: +5.50m
- Residual settlement after completion of the yard: $\delta =8.0cm < \delta a=10cm$

As observed in the above listed results of the examination, all the design conditions are fulfilled as follows:

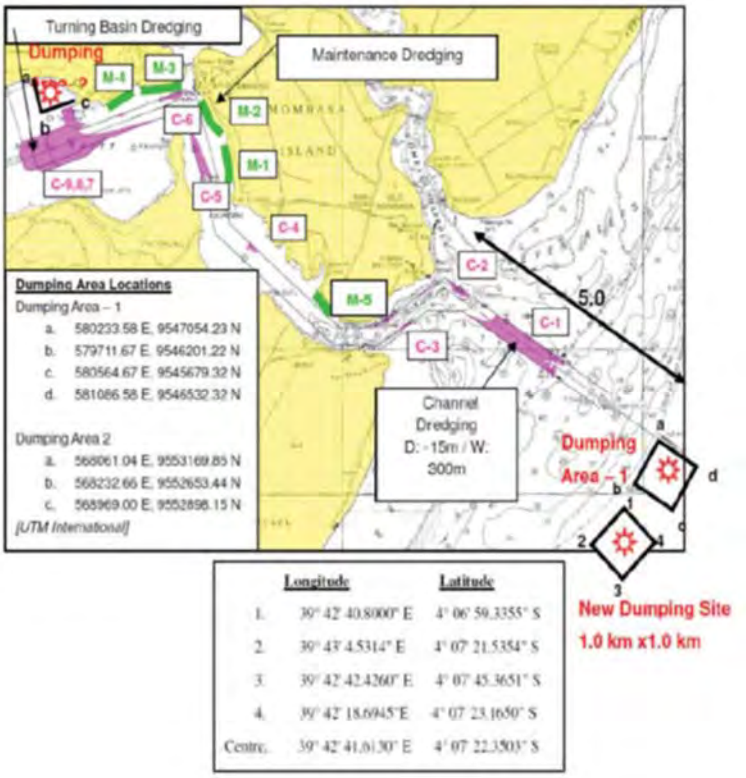
- Spacing of drain placing; d=0.80m (Square formation),
- Elevation of sand mat; +5.50m,
- Crest elevation of preloading embankment; +8.50m,
- Crest elevation of preloading embankment after 8 months preloading (degree of consolidation U=81.4%); +7.48m,
- Thickness of the removed layer of preloading embankment; h=1.9m,
- Crest elevation of the yard after removal of embankment; +5.50m,
- Over-consolidation load after removal of preloading embankment; $\alpha =27.8kN/m^2$, and
- Residual settlement after completion of the yard; $\delta =8.0m$

Thus, these quantities listed above are accepted as the characteristic quantities of PVD soil improvement. In order to accelerate the drainage of the water from the vertical drains through the sand mat, horizontal drains shall be placed on the sand mat. The horizontal drains shall be interconnected to the heads of the vertical drains to make the function of the horizontal drain more effective.

8.3.6 Dredging of Navigation Channel and Basin

(1) Field Conditions related to Dredging

In the Mombasa SEZ M/P, it was proposed to utilize dredged materials as the filling of DK1 berth, provided that dredged material is suitable. However, the seabed sampling at 21 locations over the existing navigation channel and proposed dredging area showed that the seabed material is not suitable for landfill because cotton soil, which has high swelling and high shrinking natures and contains a lot of clay, was found. Therefore, dredged material should be disposed. Since Mombasa Port has no authorized dumping area, it is anticipated that an offshore dumping area located 5 km away from the entrance of Mombasa Port (see Figure 8.3.31) to be used as an authorized dumping area, which was used to be the disposal site for the dredged material from navigation channel maintenance (2011-2012), and the container terminal construction Phase 1 (Berth 20 and 21). It should be noted that environmental problems have to be settled and the approval by Kenya Maritime Authority (KMA) be obtained.



Source: Completion Report of Dredging and Hydrographic Works at the Port of Mombasa, May 2012

Figure 8.3.31 Dumping Area Location

Considering the stretch of navigation channel between the dredging site and the entrance of Mombasa Port is 18 km, the travelling distance to the anticipated offshore dumping site is calculated as follows:

- L = 18.0km ＋ 5.0km = 23 km ≒ 25 km

(2) Determination of the Dimensions of Navigation Channel and Basin

i) Design ship

Based on the port design conditions, design ship dimensions are chosen as follows. However, it should be noted that there is a possibility that larger size of ship would utilize DK1 if the berth is operated together with container terminal on Mombasa Port side.

Table 8.3.13 Design Ship Dimensions

Design Vessels	Gross Tonnage (GT)	Length Overall (Loa)	Molded Breadth (E,	Full Load Draft (d)
Pure Car Carrier	72,408 GT	232 m	32 m	11.7 m
Container	35,878 GT	212 m	32 m	11.6 m

Source: JICA Design Team

ii) Determination of Dimensions of Navigation Channel and Basin

Dimensions of navigation channel and basin are determined in accordance with Chapter 3 Waterways and Basins under Vol. 4 of "Technical Standards and Commentaries for Port and Harbor Facilities in Japan, 2007". Pure car carrier (PCC) is chosen as the design ship because it requires the largest size of navigation channel and basins. The following are the results of the calculations of the dimensions:
Calculation conditions: For the cases where a design ship and navigation environment are not designated

Table 8.3.14 Calculation Results of the Dimensions of Navigation Channel and Basin

Channel depth (D=1.1・d)	13.0 m	Waterway in a port where waves/swells do not affect ship motion >D=1.1・d=1.1×11.7= 12.87 m
Channel width (W=1.5・Loa)	350 m	>W=1.5・Loa=1.5×232.0= 348.0 m
Channel curve (4・Loa)	950 m	>4・Loa=4×232.0 =928 m
Turning basin diameter (2・Loa)	500 m	> 2・Loa=2×232.0= 464.0 m

Source: JICA Design Team

iii) Gradient of Slope of Navigation Channel

The turning basin in front of the container terminal is constructed by dredging up to -13.0 m from the existing sea bed level of - 3.0 m, therefore, the possibility of siltation of the navigation channel may become higher. One of the efficient countermeasures is to reduce the gradient of the side slope of the channel. Thus, the slope gradient of 1:6 is adopted against the currently adopted data (Table.8.3.15).

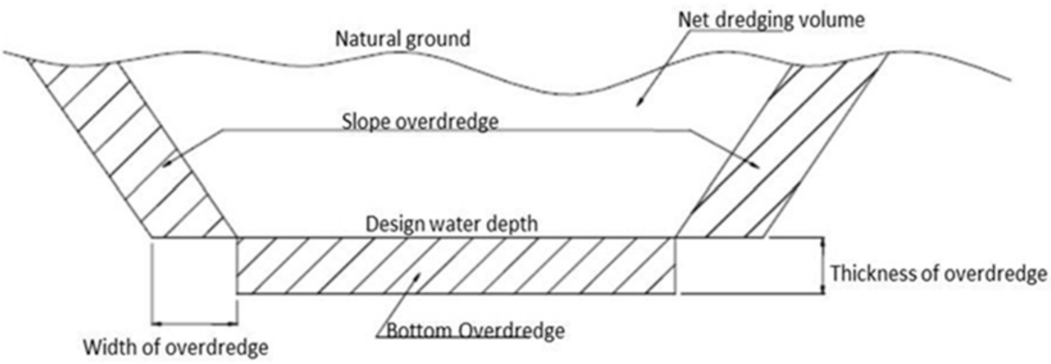
Table 8.3.15 Guidelines for the Safe Design of Commercial Shipping Channels (Canada)

Table 12: Recommended Side Slopes	
SOIL MATERIAL	SIDE SLOPE Horizontal:Vertical
All Materials, minimum required side slopes	1:1
Preferred side slopes	
• Firm Rock	1:1
• Fissured rock, more or less disintegrated rock, tough hardpan	1:1
• Cemented gravel, stiff clay soils, ordinary hardpan	1:1
• Firm, gravely, clay soil	1:1
• Average loam, gravely loam	3:2
• Firm clay	3:2
• Loose sandy loam	2:1
• Very sandy soil	3:1
• Sand and gravel, without or with little fines	3:1 - 4:1
• Sand and gravel with fines	4:1 - 5:1
• Muck and peat soil	4:1
• Mud and soft silt	6:1 - 8:1

Source: "Guidelines for the Safe Design of Commercial Shipping Channels" (Canada)

iv) Over-dredge of Navigation Channel

The thickness of the over-dredge of bed and slope of navigation channel should follow the following guidelines:



Source: "Standards of Estimation of Civil Works", Ministry of Land, Infrastructure and Transport

Figure 8.3.32 Bottom Over-dredge and Slope Over-dredge

Table 8.3.16 Depth of Bottom Over-dredge

Soil Material	Type of Dredger	Dredging Water Depth		
		Less than -5.5m	Over -5.5 m and less than -9.0 m	Over -9.0 m
Ordinary soil	Pump dredger	0.6m	0.7 m	1.0 m
	Grab dredger	0.5 m		0.6 m
	Backhoe dredger	0.5 m		
Rock	Grab dredger	0.5 m		
	Backhoe dredger			

Source: "Standards of Estimation of Civil Works", Ministry of Land, Infrastructure and Transport

Table 8.3.17 Width of Slope Over-dredge

Soil Material	Type of Dredger	Width of Slope Over Dredge	Note
Ordinary soil	Pump dredger	6.5 m	
	Grab dredger	4.0 m	
	Backhoe dredger	2.0 m	
Rock	Grab dredger	2.0 m	
	Backhoe dredger	1.0 m	

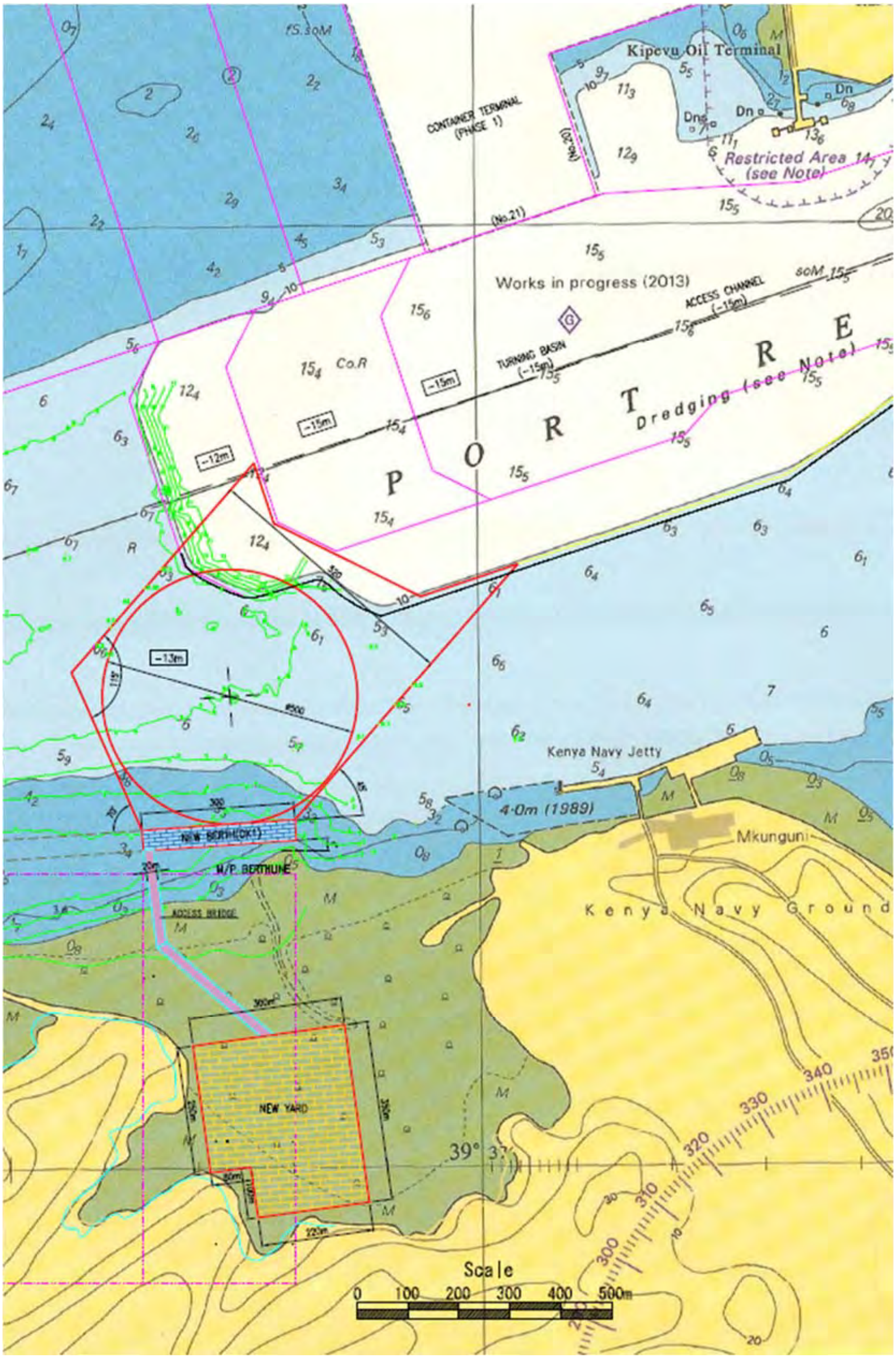
Source: "Standards of Estimation of Civil Works", Ministry of Land, Infrastructure and Transport

The figure 8.3.33 shows the plan view of the navigation channel and basin.
The approximate dredging volumes of the navigation channel and the basin are shown in the table below and selection of the dredging methods can be referred to the following section.

Table 8.3.18 Dredging Volumes of the Navigation Channel and the Basin (including the overdredge)

Dredging by Grub Dredger	700,000 m^3
Dredging by TSHD	2,050,000 m^3
Dredging Total Volume	2,750,000 m^3

Reference; Dredging area of the Navigation Channel and the Basin A=314,000 m^2
Source: JICA Design Team



Source: JICA Design Team

Figure 8.3.33 Plan View of Navigation Channel and Basin

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

(3) Selection of Dredging Method

Under the environmental conditions at the dredging site, it is recommended that the type of work vessel to be employed for dredging is selected in consideration of the following conditions:

- One-way travel distance to the dumping area L = 25 km
- Approximate dredging volume V= 2,750,000 m^3

Followings are the types of dredgers commonly used for dredging and reclamation work:

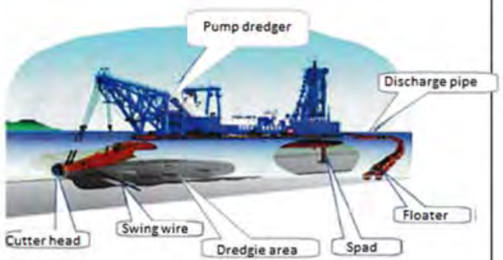
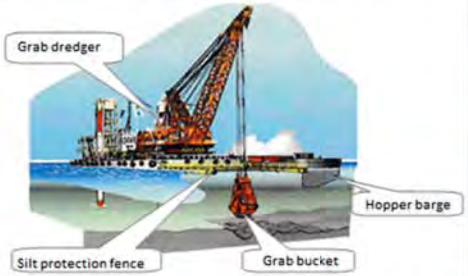
① Pump dredger (Non-self-propelling type, Self-propelling type)
② Grab dredger (Non-self-propelling type, Self-propelling type)
③ Trailing suction dredger (Self-propelling type)
④ Bucket-ladder dredger (Non-self-propelling type)
⑤ Backhoe dredger (Non-self-propelling type)

The dredging work of this project requires to use the navigation channel for dredging and dumping, thus, employment of a self-propelling type dredger is recommended for efficient performance of the dredging work.

A table of dredging methods is shown in Figure 8.3.34. Based on the comparison shown in Figure 8.3.34, a drag suction (trailing suction) dredger is chosen as the best dredging method for this project, considering the distance of 5 km between the dumping area and the entrance of Mombasa Port, the frequency of a dredger (or a hopper barge) pass along the existing navigation channel for transporting the dredged materials, and the experiences of being employed for a large-scale dredging work in the port.

However, the required draft for a drag suction dredger of 5,000 to 8,000 cubic meters class is assumed to be -8.0 m or less. For dredged areas shallower than this depth shall be dredged by Grab dredger (Self-propelling type) used for excavation of foundation at quay walls and access road (bridge type).

Comparison of dredging methods

Type	Pump dredger (Self-propelling type)	Grab dredger (Self-propelling type)	Drag suction dredger (Self-propelling type)
Image of work			
Characteris-tics of the method	· This type is suitable for large scale dredging and reclamation · A ladder equiped with a cutter head at the tip is lowered onto a sea bed. Bed materials cut by rotating cutter head are pumped up together with sea water through a drainage pipe and are transported to a hopper barge or directly to a dumping site through discharge pipe. · Most of the self-propelling dredgers of this type have a engine capacity larger than 8,000 HP. · Only few large sized self-propelling dredgers of this type are available.	· Clatching bed material by a grab bucket and placing the dredged material into the built-in hopper or a slongside hopper barge, the dredger or the hopper barge movies to a dumping site for discherge the dredged material. · For ancholing, dredgers are equiped with either anchor system or spad. · This type of dredgers are suitable for small to midium scale dredgeing. · Practically there are no restriction of water depths or soil. · This type of dredger are able to operate within narrow water areas, and, thus, are widely employed. · The dredged surface done by grab dredgers are flatter than that done by pump dredgers.	· This type of dredgers have a hopper within thier hull and are self-propelling. They are often employed for large scale dredging and borrowing soil. They are so-called all round dredgers. In the case of sandy sea bed, dredging at a slow speed of two (2) to four (4) knots with the tip of their drag arms on the sea bed and emiting a water jet from drag head at the the tip of the drag arm, pumping up soil and sea water and storing them in the own hopper, they travel to the dumping area for discherge. · Travel speed is over 10 knots with full load. · Economically advantageous when the dumping area is far apart from the dredging site. Suitable for large scale dreging work. · Hopper capacities are 10,000 m3 or larger. · Full load draft is 10 m, and, for dredging shallow water area, pre-dredging is required.
Supporting fleet	Hopper barge and others	Hopper barge and others	None
Transfer of fleet	Easy	slightly difficult	Very easy
Volume to dredge	Large volume	Small volume	Large volume
Speed of dredge/dump	Speedy	Slow	Speedy
Experience in Mombasa Port	Small scale dredging only	Small scale dredging only	Large volume of dredging during the construction of of the navigation channel and Phase 1 (B20 & B21) of the container berth project (funded by Yen Loan)
Overall evaluation	○	△	◎

Source: JICA Design Team

Figure 8.3.34 Comparison of Dredging Methods

8.3.7 Quay wall, Revetment, Access Bridge and Yard

The basic cross-section of quay wall, access bridge and revetment are designed. A basic review of the yard about position and scale is carried out.

(1) Quay wall

i) Dimensions

a) Crown Height

The crown height of quay wall is calculated with the following Table 8.3.19.

Table 8.3.19 Crown Height

	Tidal range 3.0m or more	Tidal range less than 3.0m
Wharf for large vessels (water depth of 4.5m or more)	+0.5 - 1.5m	+1.0 - 2.0m
Wharf for small vessels (water depth of less than 4.5m)	+0.5 - 1.5m	+0.5 - 1.5m

Source: Technical Standard and Commentaries for Port and Harbour Facilities in JAPAN, 2009

Tidal range : (H.W.L+3.80m)-(L.W.L+0.10m)=3.70m > 3.0m
Water depth : 4.5m or more
Crown Height of Wharf : (H.W.L+3.80m)+(0.5m～1.5m)=+4.30m - +5.30m
The crown height of quay wall is set to +5.50m.

b) Berth Water Depth

The berth water depth is calculated by the following formula.
Berth water depth = Maximum draft + Under Keel Clearance
The under keel clearance is 10% of the maximum draft.

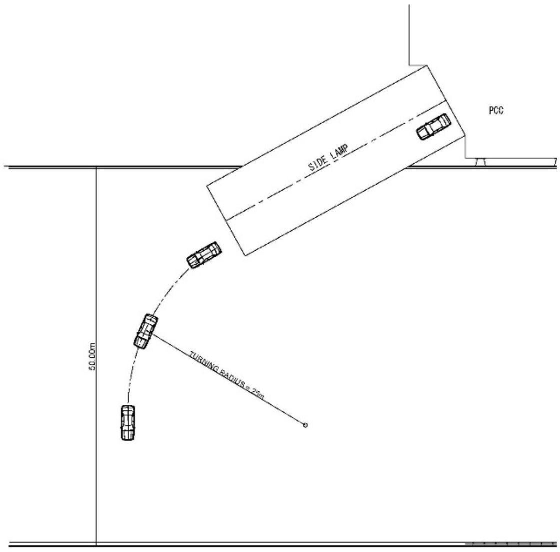
- Container Ship D=d+0.1d=11.6+0.1x11.6=12.76 m≒13.0 m
- Pure Car Carrier Ship D=d+0.1d=11.7+0.1x11.7=12.87 m≒13.0 m

c) Berth Length

Berth length was designed as L=300 m with consideration of the length of the design vessel (a pure carrier ship with 232 m LOA) and mooring lines for bow and stern with 30 degrees against the berth.

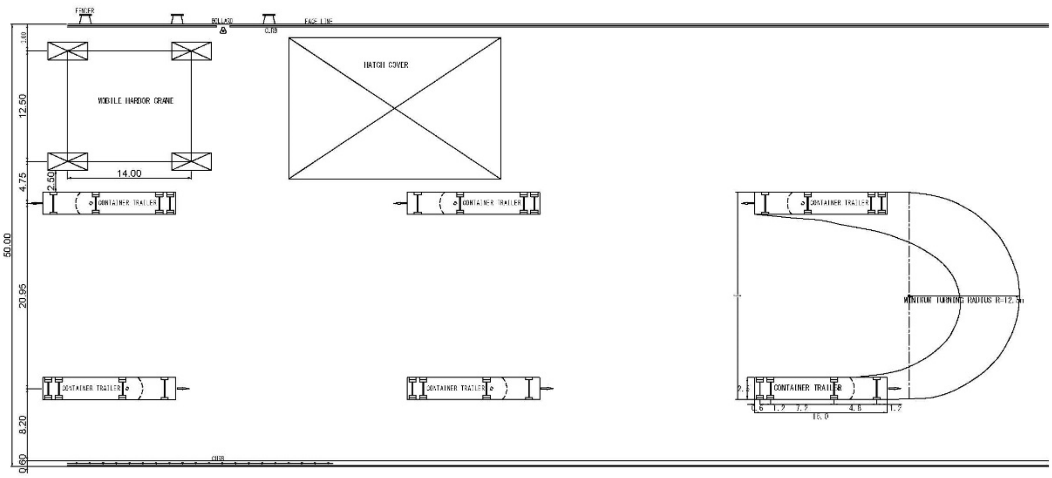
d) Width

Width is decided from the locus of a quay wall using vehicle.
The locus chart of a vehicle is shown in Figure 8.3.35, and the locus chart of a container trailer is shown in Figure 8.3.36. With considerations of these, the width is decided to be 50m and details can be referred in sec. 8.3.8.



Source: JICA Design Team

Figure 8.3.35 Locus Chart of a Vehicle



Source: JICA Design Team

Figure 8.3.36 Locus Chart (the minimum turning radius) of a Container Trailer

ii) Design Conditions

a) Soil Condition

The soil conditions are set up from the soil investigation results reported in the Mombasa Port M/P.

Table 8.3.20 Soil Character Constant

Elevation (m)	Soil	Ground Symbol	Mean N-value	U nit Weight γt (kN/m^3)	Cohesion c (kN/m^2)
-1.38 -11.9	sandy silty CLAY	CH-1	1	17.9	6.3
-11.9 -26.9	sandy silty CLAY	CH-2	8	17.9	50
-26.9 -35.9	sandy silty CLAY	CH-3	50	17.9	375
-35.9 -41.6	SANDST-ONE	Ss	50	20	1,538
-41.6	SHALE	Sh	50	20	1,538

Source: JICA Design Team

b) Loading Conditions

Tractive Force

The tractive force is decided from Table 8.3.21.

Table 8.3.21 Values of Tractive Forces by Ships

Gross tonnage of ship(t)	Tractive force acting on mooring post(kN)	Tractive force acting on bollard(kN)
Over 200 and not more than 500	150	150
Over 500 and not more than 1,000	250	250
Over 1,000 and not more than 2,000	350	250
Over 2,000 and not more than 3,000	350	350
Over 3,000 and not more than 5,000	500	350
Over 5,000 and not more than 10,000	700	500
Over 10,000 and not more than 20,000	1,000	700
Over 20,000 and not more than 50,000	1,500	1,000
Over 50,000 and not more than 100,000	2,000	1,000

Source: Technical Standard and Commentaries for Port and Harbour Facilities in JAPAN, 2009

- Container Ship: 35,878 GT, Tractive force action on bollard is 1,000 kN
- Pure Car Carrier Ship: 72,408 GT, Tractive force action on bollard is 1,000 kN

Berthing Force (Fender Reaction)

The calculation of berthing force is carried out by a pure car carrier ship which is larger.

- Rubber fender ; Circle Type (with fender board) 1150H
- Absorption energy by fender ; E=361.6 kNm
- Fender reaction ; R=927.78 kN

c) Materials

Steel

- Steel Pipe Pile

  Characteristic values of Yield Strength

  SKK400: $f_y=235$ N/mm^2

  SKK490: $f_y=315$ N/mm^2

  where

  fy: Axial tensile stress (per net cross-sectional area)

- Structural Steel

  SS400: $f_a=245$ N/mm^2 $\leq$ t=16 mm

fa=235 N/mm^2 t=16 to t=40mm
SM490: fa=325 N/mm^2 ≤ t=16 mm
fa=315 N/mm^2 t=16 to t=40mm

where
fa : tensile yield strength
t : Thickness

Other Materials

The other materials are based on Japan Industrial Standards (JIS).

d) Corrosion Rate of Steel

The corrosion rate of steel materials is shown in Table 8.3.22.

Table 8.3.22 Corrosion Rates for Steel

Corrosive environment		Corrosion rate (mm/year)
Seaside	HWL or higher	0.3
	HWL – LWL-1m	0.2
	LWL-1m - seabed	0.15
	Under seabed	0.03
Landside	Above ground and exposed to air	0.1
	Underground (residual water level and above)	0.03
	Underground (residual water level and below)	0.02

Source: Technical Standard and Commentaries for Port and Harbour Facilities in JAPAN, 2009

Corrosion method

The Corrosion protection method is carried out as follows.

- Above LWL-1.0m: Covering/Coating
- Below LWL-1.0m: Cathodic Protection

Condition of cathodic protection is shown as follows.

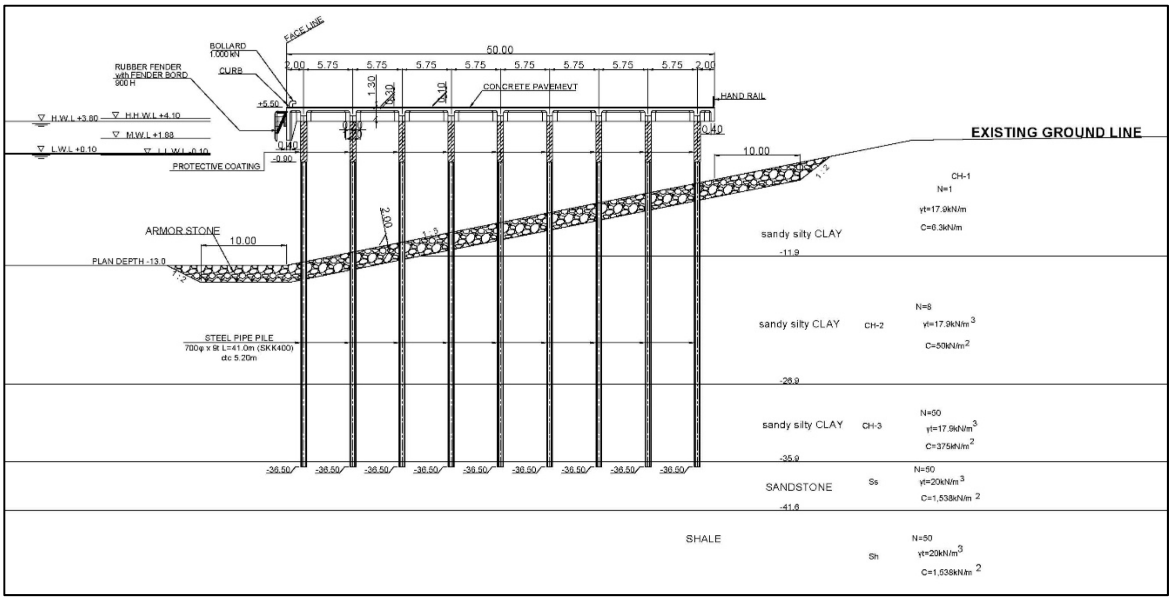
- The corrosion efficiency rate of cathodic protection is 90%.
- Service period: 50 years

iii) Comparison Design

Comparison design of the quay wall is carried out for the 4 types structures.
The structure of quay wall is decided by comparing the construction cost and constructability.

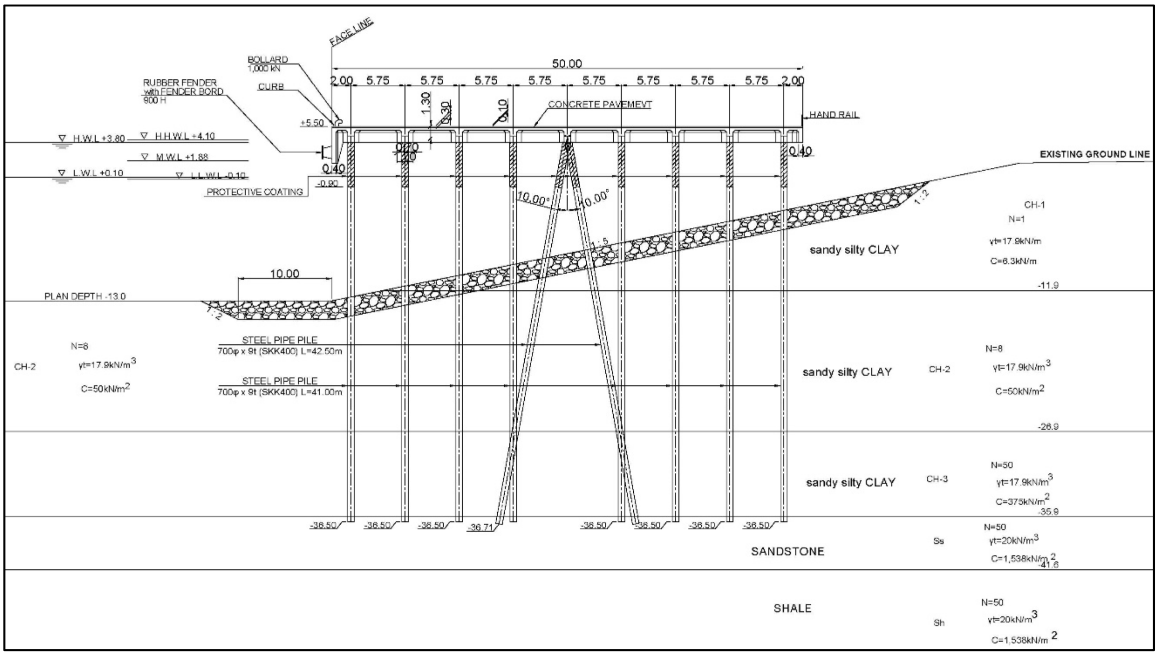
- Vertical pile type
- Batter pile type
- Jacket type
- Strut type

The cross section diagram of each structure is shown in the following figures.



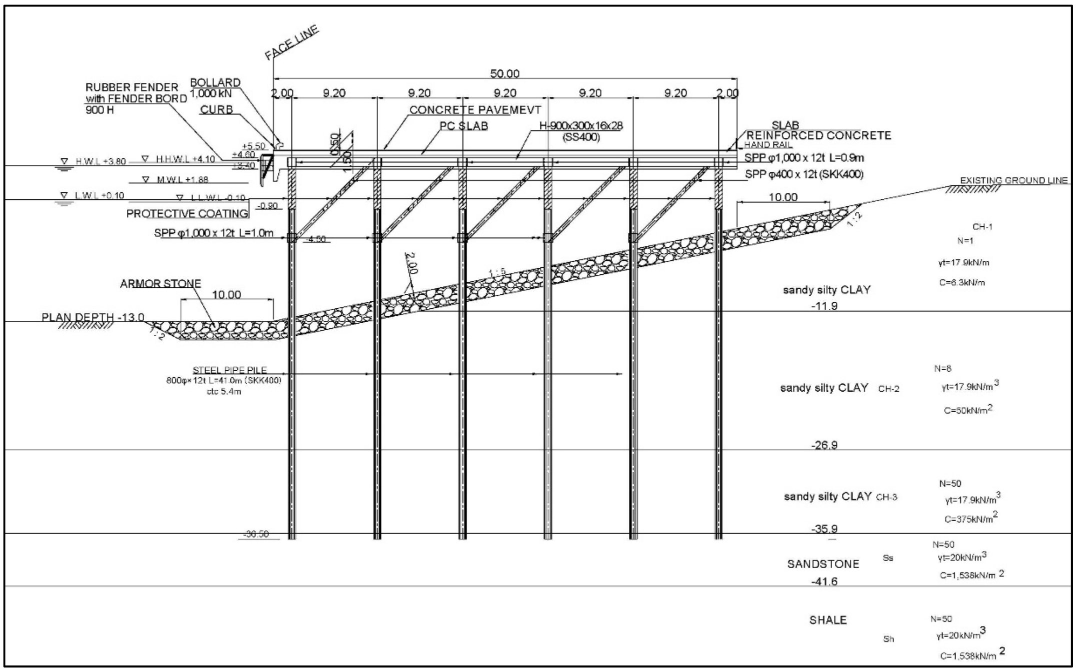
Source: JICA Design Team

Figure 8.3.37 Cross Section of Vertical Pile Type



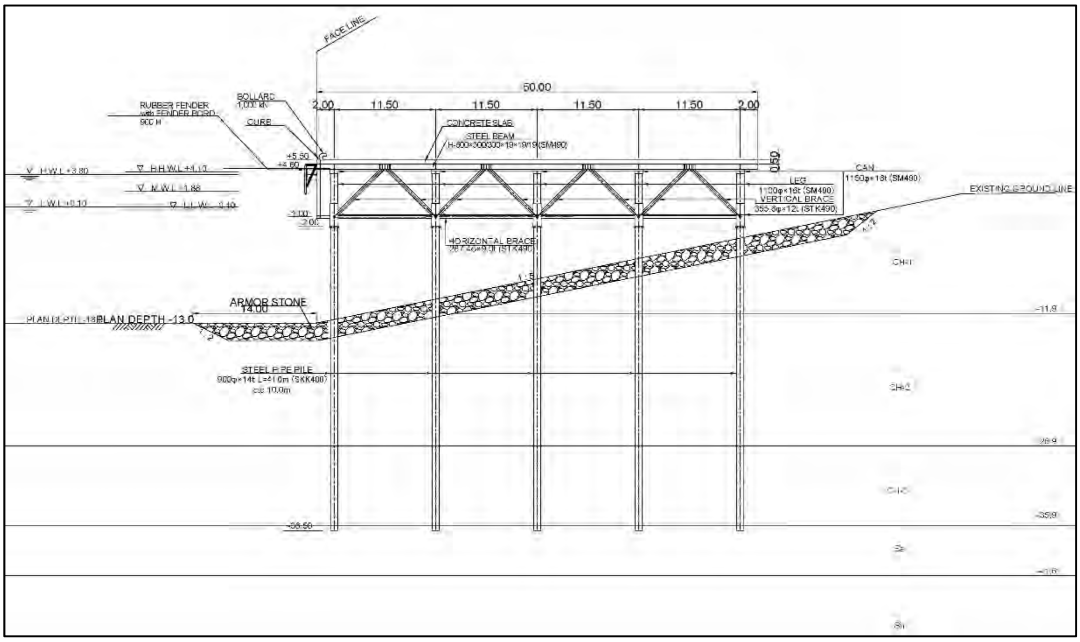
Source: JICA Design Team

Figure 8.3.38 Cross Section of Batter Pile Type



Source: JICA Design Team

Figure 8.3.39 Cross Section of Strut Type



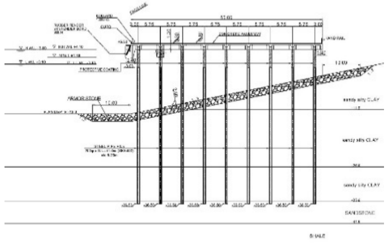
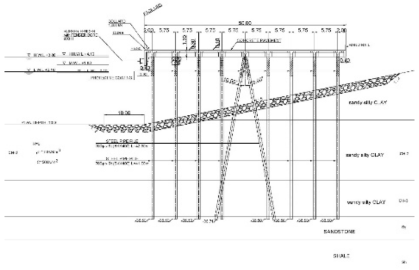
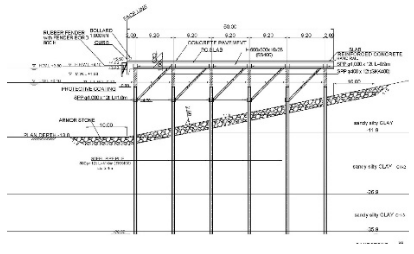
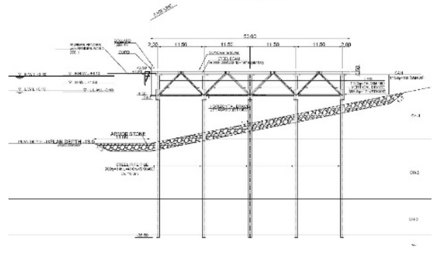
Source: JICA Design Team

Figure 8.3.40 Cross Section of Jacket Type

iv) Selection of the Structure of a Quay wall.

The structure types were compared and evaluated, and the Jacket type was recommended as shown in Table 8.3.23 in terms of construction period and benefit due to earlier operation.

Table 8.3.23 Quay Wall Structure Comparison Table

	Vertical Pile Type	Batter Pile Type	Strut Type	Jacket Type
Cross section/ structural characteristic				
	・No. of piles: 540 piles/300m ・An general and simple structure ・The corrosion protection required	・No. of piles: 500 piles/ 300m ・Batter piles applied to increase resistance to horizontal force ・The corrosion protection required	・No. of piles: 360 piles/ 300m ・Strut members applied to increase resistance to horizontal force ・The corrosion protection required	・No. of piles: 150 piles/ 300m ・Jacket, a truss frame, covered on piles to increase resistance to horizontal force ・The corrosion protection required
Technical aspect ・Difficulty in construction ・Technology transfer	・Not technically difficult in construction though largest No. of piles required ・Technology transfer level is fair as applies common technology	・Bit high difficulty in construction due to piling of batter piles ・Technology transfer level is fair as it applies common technology	・Very high difficulty in construction as it requires 1) underwater work for welding of strut member to piles and 2) double high accuracy(± 5cm) for piling works ・Technology transfer level is high as it involves advanced technology for piling and welding	・Bit high difficulty in construction as it requires double high accuracy(± 5cm) for piling works ・Technology transfer level is high as it involves advanced technology for piling and welding
Economic aspect				
1. Construction cost	・2nd lowest cost (Ratio: 1.04)	・Lowest cost (Ratio: 1.00)	・3rd lowest cost (Ratio: 1.11)	・4th lowest cost (Ratio: 1.13)
	1.04 (+ approx.. 2.2 mil USD)	1.00	1.11 (+ approx.. 6 mil USD)	1.15 (+ approx.. 7 mil USD)
2. Benefit due to early operation	N/A (Longest construction period, construction period: 27 months/300m)	N/A (Base, construction period: 26 months)	Approx.. 1.9 mil USD* (1 month earlier, construction period: 25 months)	Approx.. 13.5 mil USD* (7 months earlier, construction period: 19 months)
Environmental impact	Relatively larger disturbance of water flow and impact on topographic change created due to large No. of piles Evaluation: Middle	Relatively larger disturbance of water flow and impact on topographic change created due to large No. of piles Evaluation: Middle	Relatively less disturbance of water flow and impact on topographic change created due to small No. of piles Evaluation: Small	Least disturbance of water flow and impact on topographic change created due to smallest No. of piles Evaluation: Minimal
Overall evaluation	・Technical aspect is evaluated as fair ・2nd lowest cost but longest construction period ・Environmental impact evaluated as middle	・Technical aspect is evaluated as fair ・Lowest cost but longer construction period ・Environmental impact evaluated as middle	・Technical aspect is evaluated as fair ・3rd lowest cost and longer construction period required compared to Jacket type. ・Environmental impact evaluated as small	・Technical aspect is evaluated as superior to others ・4th lowest cost, however largest benefit expected due to early operation. ・Environmental impact evaluated as minimal
	Not recommended	**Not recommended (secondary recommended)**	**Not recommended**	**Recommended**

* Calculated based on the annual financial benefit evaluated in Chapter 10
Source: JICA Design Team

(2) Access Bridge

i) Design Depth

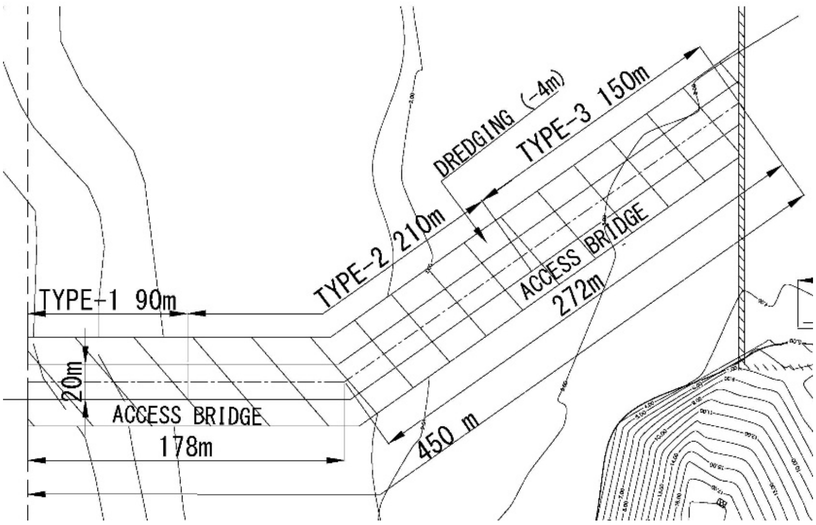
The level of the current ground is about +3.5 meters. Considering the operation efficiency of pile driving barge, the ground is dredged to -4.0 meters. The designed water depth is set to -4.0 meter.

ii) Design Conditions

a) Soil Condition

The design soil conditions of the access bridge divides the design soil layer into three types in consideration of the vertical section of soil layer alteration.

The design division plan is shown in Figure 8.3.41.



Source：JICA Design Team

Figure 8.3.41 Plan of Design Division

The design soil conditions of each type are shown in Table 8.3.24-26.

Table 8.3.24 Design Soil Condition (Type-1)

Elevation (m)	Soil	Ground Symbol	Mean N-value	Unit Weight γ t (kN/m^3)	Cohesion c (kN/m^2)
-1.38 -11.9	sandy silty CLAY	CH-1	1	17.9	6.3
-11.9 -26.9	sandy silty CLAY	CH-2	8	17.9	50
-26.9 -35.9	sandy silty CLAY	CH-3	50	17.9	375
-35.9 -41.6	SANDST-ONE	Ss	50	20	1,538
-41.6	SHALE	Sh	50	20	1,538

Source: JICA Design Team

Table 8.3.25 Design Soil Condition (Type-2)

Elevation (m)	Soil	Ground Symbol	Mean N-value	Unit Weight γ t (kN/m^3)	Cohesion c (kN/m^2)
+4.3 +0.3	Silty CLAY	M-CH	4	16.0	23
+0.3 -4.7	CLAY	CH	7	16.0	46
-4.7 -8.7	Silty CLAY	M-CH	23	16.0	143
-8.7 -18.7	CLAY	CH	50	20	353
-18.7	CLAY	CH	23	20	143

Source: JICA Design Team

Table 8.3.26 Design Soil Condition (Type-3)

Elevation (m)	Soil	Ground Symbol	Mean N-value	Unit Weight γ t (kN/m^3)	Cohesion c (kN/m^2)
+4.7 -4.2	Silty CLAY	M-CH	5	16	32
-4.2 -13.2	Silty Clay	M-CH	27	16	172
-13.2	CLAY	CH	50	20	625

Source: JICA Design Team

b) Loading Condition

It is the same as that of the conditions of the quay wall design.

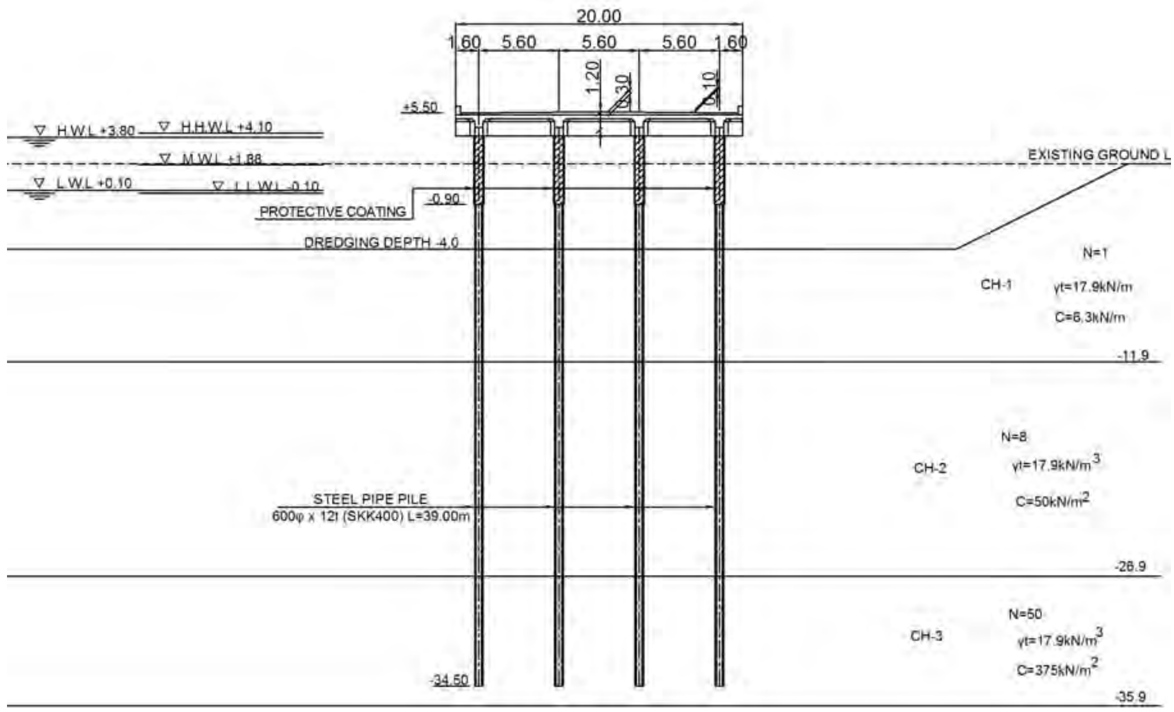
c) Material Conditions and Steel-material Corrosion

It is the same as that of the conditions of the quay wall design.

iii) Structure of Access Bridge

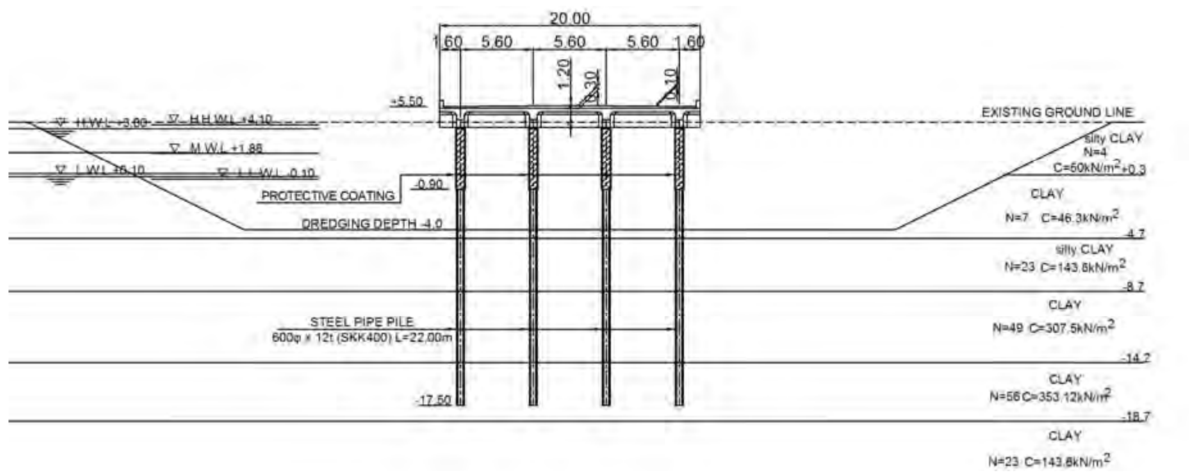
The soil layer is composed of accumulation of loose cohesive soil for 10 meters to 20 meters and has a bearing stratum (N> 50) at the bottom. If cohesive soil is not replaced, the gravity structure cannot secure a bearing capacity. Therefore, the open type structure which does not need an excavation is considered.

The cross section of each type of a connecting bridge is shown in Figure 8.3.42-44.



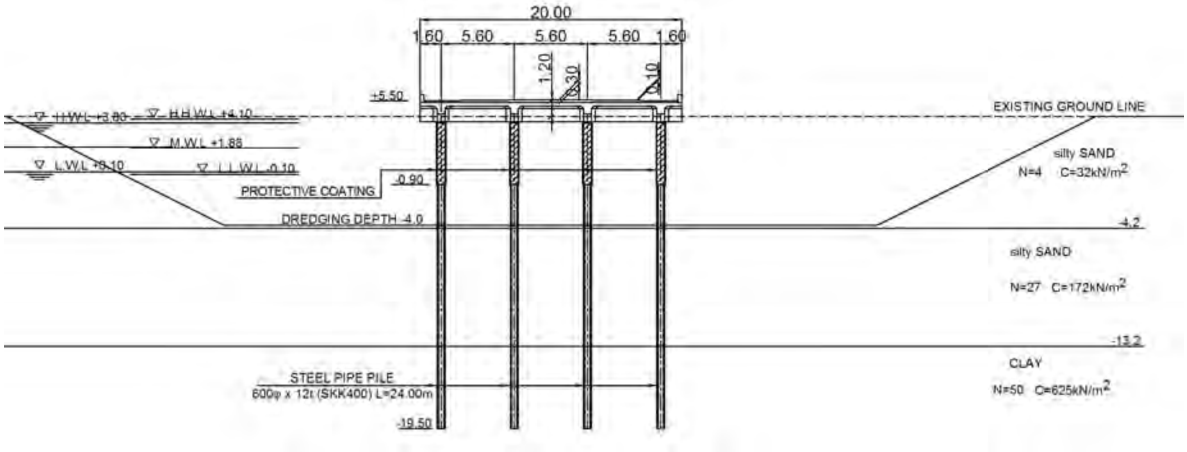
Source: JICA Design Team

Figure 8.3.42 Cross Section of Access Bridge (TYPE-1)



Source: JICA Design Team

Figure 8.3.43 Cross Section of Access Bridge (TYPE-2)



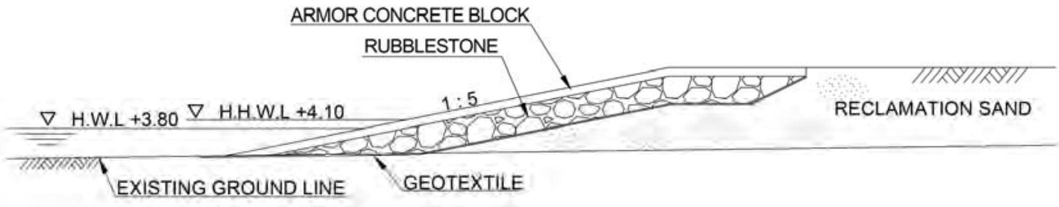
Source: JICA Design Team

Figure 8.3.44 Cross Section of Access Bridge (TYPE-3)

(3) Revetment

It is constructed after removing the surcharge filling of the soil stabilization of reclaimed land. The current ground level does not have an influence of waves at +3.0 meters to +4.5 meters. The structure of revetment sets the armor stone in front of the reclamation earth and sand.

The cross section of revetment is shown in Figure 8.3.45.



Source: JICA Design Team

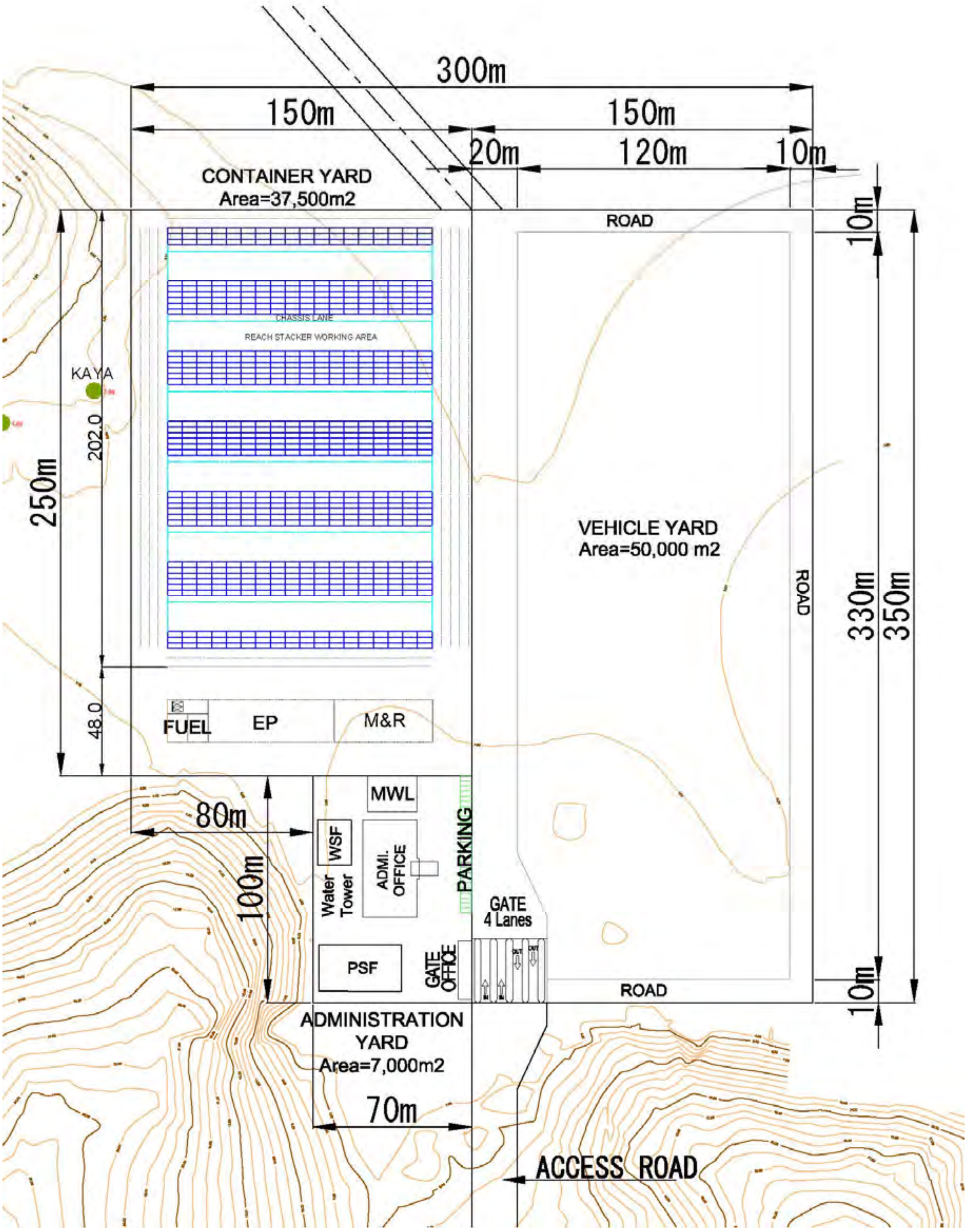
Figure 8.3.45 Cross Section of Revetment

(4) Yard

Refer to the item 8.3.2, 8.3.3, and 8.3.8 for a setting of yard dimensions.

The layout of yard is shown in Figure 8.3.46.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Note : Arrangement and scale of facilities are reference.
Source: JICA Design Team

Figure 8.3.46 Layout of Yard

8.3.8 Security System

In addition to the 2nd container terminal (Berth 20 and 21) which is already constructed at the opposite shore of Dongo Kundu, security system is planned to be introduced to the Berth 22 and the container yard behind which is currently under construction. Introduction of security system will also be planned for the new multi-purpose terminal at Dongo Kundu side, for which the following equipment and systems will be included.

- Access Control (including metal detector and x-ray inspection device)
- Intercom System
- Intrusion Detection System (shore and offshore side)
- Video Management System
- Number Plate Sensing System
- Face Recognition System
- CCTV System

8.3.9 Cargo Handling Equipment

(1) Conditions for Cargo Handling Equipment Planning

i) Cargoes to be handled at DK1 Terminal

Cargoes to be handled at DK1 terminal and cargo volumes were determined during the port planning process in the study, namely, imported automobiles and container cargoes related to the SEZ which will be developed behind the Dongo Kundu District of Mombasa Port. The majority of imported automobiles at Mombasa Port is expected to be handled at DK1. Accordingly, working days for automobile unloading operations will be gradually increased from 175 days (in 2020) to 294 days (in 2035) per year. The remaining available working days for DK1 terminal of one year (363 days) is planned to be divided out for the SEZ related container cargoes mentioned above. Thus, working days for container will be gradually decreased from 188 days (2020) to 69 days (2035). Cargo volume and available working days for the planning of cargo handling equipment (container cargo) are summarized in Table 8.3.27.

Table 8.3.27 Container Handling Work days of DK1 Terminal

Year		2020	2025	2030	2035	Description
Motor Vehicles	(a) Daily Productivity (units/day)	1,500	1,500	1,500	1,500	Average of low and high (1,000-2,000 units/day)
	(b) Target Annual Productivity (units/year)	177,877	216,995	260,904	299,812	Value from the demand forecast result
	(c) Berth Occupancy Ratio (B.O.R.)	80%	80%	80%	80%	Survey from the Port M/P
	(d) Work ratio	0.85	0.85	0.85	0.85	Survey from the Port M/P
	(e) Work Days (day) [(b)/(a)/(c)/(d)]	175	213	256	294	
Containers	(f) Work days left for containers [363days-(e)]	188	150	107	69	
	(g) Productivity (TEU/day)	400	400	400	400	
	(g) Productivity (TEU/year) [(f) x (g)]	75,200	60,000	42,800	27,600	

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

ii) Calling Vessels

Main characteristics of calling vessels on DK1, i.e. GT, LOA, capacity, breadth and draft are listed in Table 8.3.28. As shown in the table, the maximum size calling vessel is Panamax type.
Thus, the assumed size of vessels for cargo handling equipment planning is Panamax type vessel (on deck containers in13 rows).

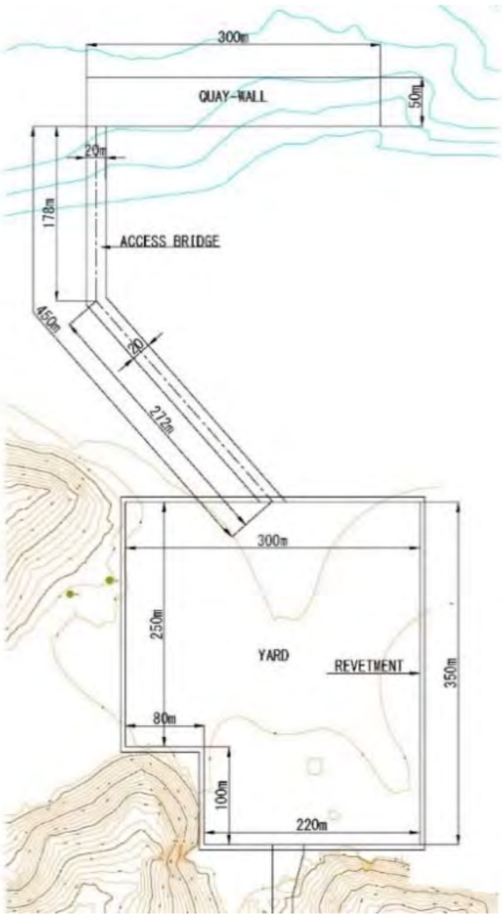
Table 8.3.28 Largest Vessel Particulars for Cargo Handling Equipment Planning

	Container Ship	Remarks
Gross tonnage (GT)	35,878 GT	
Capacity (TEU)	3,500~4,200 TEU	Panamax-type Vessel
Length overall (LOA)	212 m	
Molded breadth (B)	32 m	
Full load draft (d)	11.6 m	

Source: JICA Design Team

iii) Basic Layout of the Terminal

The basic layout of DK1 is designed in the port facility plan; 1) incorporating the Jetty with a quay wall length of 300 m and 2) connecting bridge between the Jetty and yard area of about 450 m in length. The cargo handling equipment plan is based on this layout (see Figure 8.3.47).



Source: JICA Design Team

Figure 8.3.47 Basic Layout of DK1 Terminal

(2) Basic Policy for DK1 Terminal Operation

The DK1 terminal is primarily operated as a Ro/Ro terminal for automobile imports while the remaining capacity is used for SEZ container cargo.
If the handling volume of automobiles increases in the future, DK1 will be operated as a dedicated car terminal. In case the container handling volume increases rapidly or container cargo exceeds the container handling capacity of DK1 due to an increase in automobile handling volume in the future, a new container terminal (DK2/DK3) will be developed.
Thus, container handling in DK1 is considered to be temporary, and full-scale container handling equipment (QGC and RTG) will not be introduced in this terminal so as to realize economically efficient investment and to avoid interference with Ro/Ro operations.

(3) Basic Policy for Cargo Handling Equipment Planning

i) Quayside Operation;

Cargo handling equipment to be installed needs to cover both full container vessels (non-geared) and geared vessels which will account for around 50% of total cargoes.
MHC (Mobile Harbor Crane) system will be selected as ship to shore cranes for full container vessels. Considering the required capacity of DK1, single lift system will be sufficient.
In loading and unloading operations of ship geared vessels (especially for unloading operations), unloaded container is often required to be placed temporarily on the quay (not directly on the trailer chassis) for reasons of safety and efficiency. Thus, loading and unloading operations of the ship geared vessels, yard operation as well as container transportation between yard and quay-side is often disconnected. To perform this type of operation, reach stackers or top lifters will be introduced for loading containers (placed on the ground) to the tractor chassis.

ii) Yard Operation

Reach Stacker system will be adopted in the yard for container handling as it allows effective and flexible use of the land area.

iii) Container Transportation between Quayside and Yard

Horizontal movement between the quayside jetty and the yard is done by tractor / chassis.
In consideration of the long distance between the quayside jetty and the yard, sufficient quantity of tractors and chassis will be introduced for ensuring efficient operation.

(4) Required Cargo Handling Equipment and Quantity

Required equipment for DK1 terminal is listed in the Table 8.3.29.

Table 8.3.29 Required Equipment and Quantity

Equipment item	Role	Type of equipment/main specifications	Quantity
1 MHC	Ship to shore container handling (loading and discharging)	1-1 To enable to accommodate Panamax size vessel (13 rows on deck) 1-2 Rated load : 40.5 ton at 13th row under single lift spreader 1-3 To have an equivalent capability to Gottwald HMK 6507model or IHI JWC 2100 model	2
2 Reach Stacker	Container handling in the yard (stacking)	2-1 Maximum stacking height: 5 tiers at the 1st row (the nearest position) and 4 tiers at the 3rd row 2-2 Rated load : 16/31/45Ton 1st/2nd/3rr row from the nearest position from machine)	4
3 Reach Stacker /Top Lifter	Container handling at the quayside (back-up for ship gear operation)	3-1 Maximum stacking height: 3 tiers at the 1st row (the nearest position from machine) 3-2 To have an equivalent capability to Kalmar TFC－45 model (reach stacker) or TCM FD-430 model (top lifter)	2
4 Tractor & Chassis	Container transportation between quayside and yard	4-1 To have a capability to carry 20/40 feet containers	12

Source: JICA Design Team

i) Quantity and Basic Specification of MHC

As the interruption of loading and unloading work due to a crane malfunction has a great influence on the quayside operation, the quay crane is usually operated by a two-unit system. Thus, MHC for DK1 adopts 2 units in this plan.

The capacity of MHC shall be sufficient to handle 13 rows of containers on deck (Panamax-type vessel) assuming the maximum weight of a container is in accordance to IMO's standard (refer to Figure8.3.48 and Table8.3.30). MHC should have a standard container cargo handling efficiency: maximum 25 Box / hour (average cargo handling efficiency 20 Box / hour considering variability of ships).

ii) Quantity and Basic Specification of Reach Stacker

Four units of reach stackers are introduced for yard stacking operation, two for the quayside operation and two for the landside operation. Two reach stackers will be introduced at the quayside jetty so that two gangs can be independently allocated for ship gear loading and unloading work.

Reach stackers for yard operation requires a rated load of 45/31/16 tons (for the 1st/2nd/3rd rows from the nearest position of machine) and maximum stacking height of 5 tiers at the 1st row and 4 tiers at the 3rd row.

iii) Quantity of Tractor & Chassis

The tractor / chassis cycle time is assumed to be in the range of 13.2 to 15.2 minutes (refer to Table 8.3.30), considering the travel distance between the quay wall and the yard.

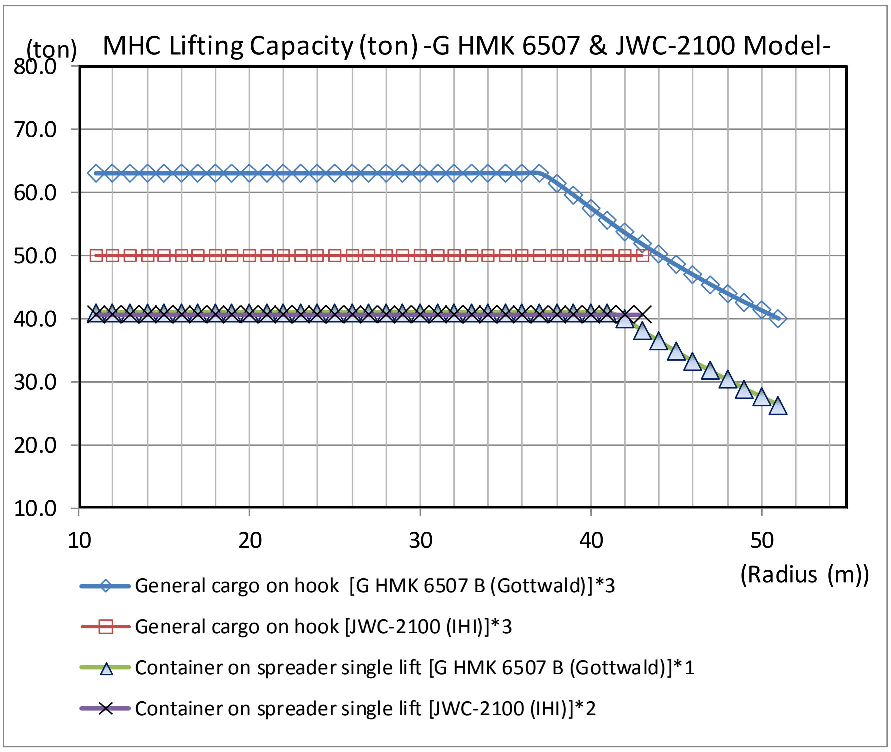
The required number of tractor / chassis is 11.0 ~ 12.7 sets in order to cope with MHC's maximum cargo handling productivity of 25 Boxes/hour with 2 cranes, and 8.8 ~ 10.1 units to cope with the average productivity of 20 Boxes/ hour with 2 cranes in which ship-to-ship variations are taken into account.

In this project, the number of units to be introduced is 12 units so that it can accommodate a maximum of 25 Boxes/ hour - crane (refer to Table 8.3.30).

Table 8.3.30 Required Quantity of Trucks

Facility				Jetty	Connection bridge	Yard	Total
Truck travelling time	Travel distance	(m)	(a)	150	500	200	850
	Round trip [(a)x2]	(m)	(b)	300	1000	400	1700
	Travel speed	(km/h)	(c)	10	20	10	
	[(c)x 1000/3600]	(m/sec)	(d)	2.78	5.56	2.78	
	Traveling time [(b)/(d)]	(sec/cycle)	(e)	108	180	144	432
Truck handling time		(sec/cycle)	(f)	180 ～ 240		180 ～ 240	360 ～ 480
Truck cycle time [(e)+(f)]		(sec/cycle)	(g)				792 ～ 912
	[(g)/60]	(min/cycle)	(h)				**13.2 ～ 15.2**
MHC handling productivity (for 2 MHC)		(box/hour)	(i)	40	～	50	40 ～ 50
Required quantity of trucks [(i)x(h)/60]		(sets)	(j)	8.8 ～ 10.1		11.0 ～ 12.7	**8.8 ～ 12.7**

Source: JICA Design Team



Source: JICA Design Team

Figure 8.3.48 Example of Load Curve of Standard MHC (1)

Table 8.3.31 Example of Load Curve of Standard MHC (2)

	General cargo on hook		Container on spreader single lift	
Radius (m)	General cargo on hook [G HMK 6507 B (Gottwald)]*3 (Ton)	General cargo on hook [JWC-2100 (IHI)]*3 (Ton)	Container on spreader single lift [G HMK 6507 B (Gottwald)]*1 (Ton)	Container on spreader single lift [JWC-2100 (IHI)]*2 (Ton)
	(75%)		(75%)	
11	63.0	50.0	41.0	40.6
12	63.0	50.0	41.0	40.6
13	63.0	50.0	41.0	40.6
14	63.0	50.0	41.0	40.6
15	63.0	50.0	41.0	40.6
16	63.0	50.0	41.0	40.6
17	63.0	50.0	41.0	40.6
18	63.0	50.0	41.0	40.6
19	63.0	50.0	41.0	40.6
20	63.0	50.0	41.0	40.6
21	63.0	50.0	41.0	40.6
22	63.0	50.0	41.0	40.6
23	63.0	50.0	41.0	40.6
24	63.0	50.0	41.0	40.6
25	63.0	50.0	41.0	40.6
26	63.0	50.0	41.0	40.6
27	63.0	50.0	41.0	40.6
28	63.0	50.0	41.0	40.6
29	63.0	50.0	41.0	40.6
30	63.0	50.0	41.0	40.6
31	63.0	50.0	41.0	40.6
32	63.0	50.0	41.0	40.6
33	63.0	50.0	41.0	40.6
34	63.0	50.0	41.0	40.6
35	63.0	50.0	41.0	40.6
36	63.0	50.0	41.0	40.6
37	63.0	50.0	41.0	40.6
38	61.5	50.0	41.0	40.6
39	59.5	50.0	41.0	40.6
40	57.5	50.0	41.0	40.6
41	55.5	50.0	41.0	40.6
42	53.6	50.0	39.9	40.6
43	51.8	50.0	38.1	40.6
44	50.1		36.4	
45	48.5		34.8	
46	46.9		33.2	
47	45.4		31.7	
48	44.0		30.3	
49	42.6		28.9	
50	41.3		27.6	
51	40.0		26.3	

Note: *1 Deadweight of spreader: VATCII-ETW for 20'-40' = 13.7 ton
*2 Deadweight of spreader: BROMMA EH5U = 9.0 ton
*3 Deadweight of hook swivel gear SMAG SW125 = 3.2 ton

Source: JICA Design Team

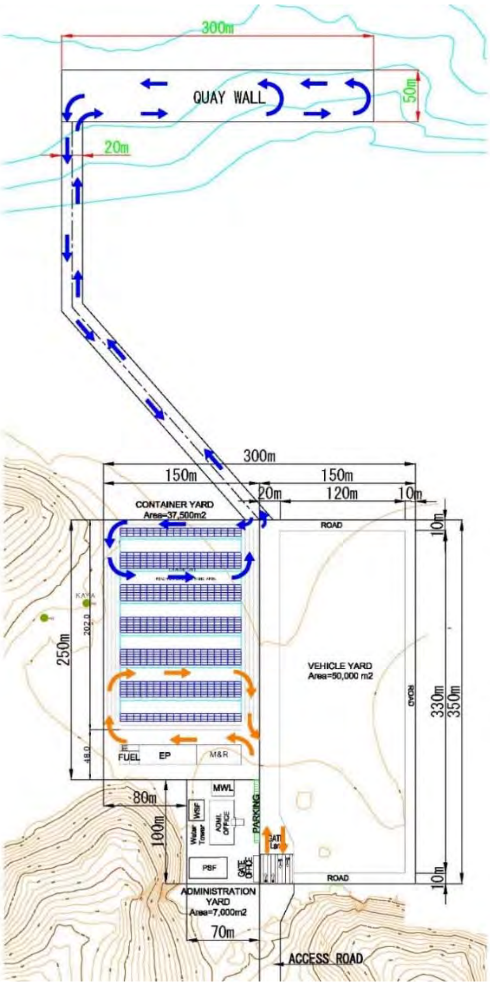
(5) Container Handling Operation Model assumed at DK1

Container handling operation model which is necessary for cargo handling equipment planning is described below.

i) Truck flow line

Based on the basic layout of DK1 container, the flow lines of internal tractor –chassis (trucks) are shown in Figure 8.3.49.

(a) Since the berthing position of the vessel is at the northern side (outer side) of the Jetty, it is considered appropriate that the container vessels come alongside the pier on portside and the internal truck flow line in the terminal is planned to be counterclockwise.
(b) In the reach stacker system which is applied for yard stacking, the internal truck usually enters into the working area between stacking blocks, where containers are loaded or unloaded by reach stacker. Therefore, the same counterclockwise truck flow line is adopted in this project as it enables effective yard management (see Figure 8.3.49).
(c) As the direction of flow line of external trucks is required to be same as internal trucks in the working area for safety reasons, external truck flow line in the terminal is planned to be clockwise (see Figure 8.3.49).



Source: JICA Design Team

Figure 8.3.49 Track Flow Line in DK1

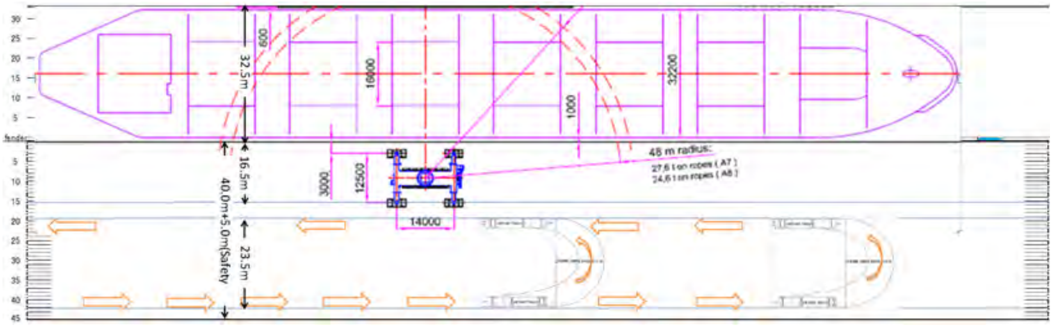
Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

ii) Quayside Operation by MHC

Figure 8.3.50-51 shows the arrangement of MHC during container handling operation at the DK1 jetty and the truck flow line. As a reference, photos of the quayside operation with MHC at jetty are shown in Figure 8.3.52 to 54.

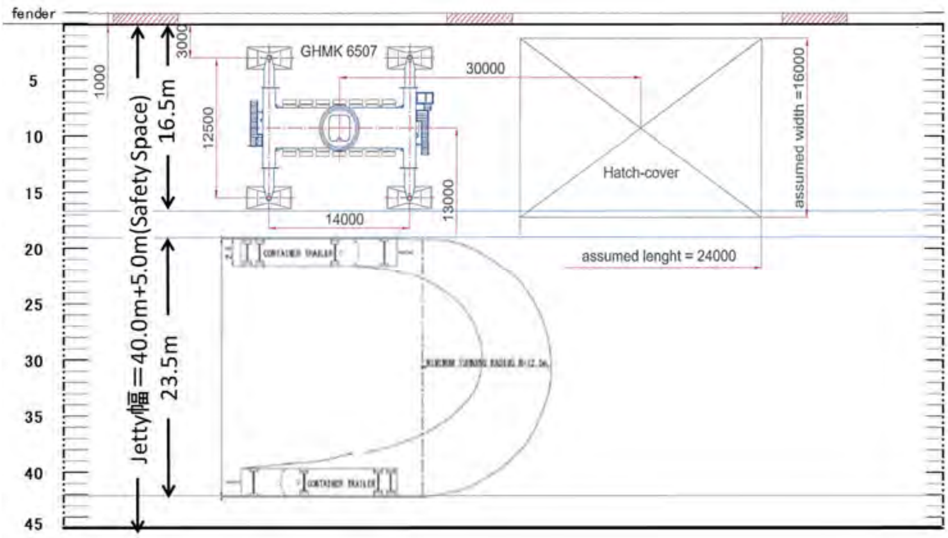
(a) In the case of standard MHC (compatible with Panamax type vessel), it is necessary to secure an exclusive space of about 16.5 m from the quay wall line to the landside edge of the MHC main body (refer to Figure 8.3.50-51). As two MHC will usually be dedicated per ship in this plan, the empty space between MHC is used as a temporary place for hatch covers or for temporary container stacking place.

(b) Since the turning diameter of the internal truck is required to be about 23.5 meters, it is necessary to secure a jetty width of <u>at least 40 m (preferably 45 to 50 m)</u>.



Source: JICA Design Team

Figure 8.3.50 Truck Flow Line and MHC Position at DK1 Jetty (1)



Source: JICA Design Team

Figure 8.3.51 Truck flow Line and MHC Position at DK1 Jetty (2)

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Source: JICA Design Team

Figure 8.3.52 Quayside MHC Operation with Sufficient Working Space on the Jetty (Jetty width: about 50m)

Source: JICA Design Team

Figure 8.3.53 Tractor-chassis Turning on the Jetty（Jetty width: about 50m）

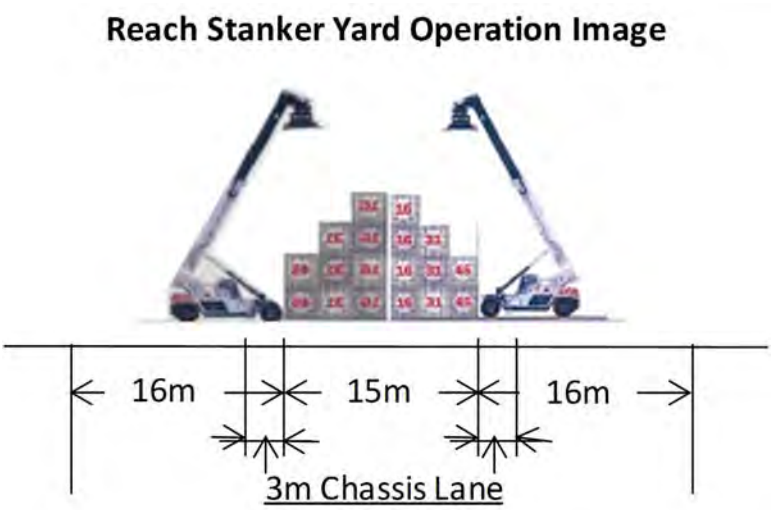
Source: JICA Design Team

Figure 8.3.54 Quayside MHC Operation in Narrow Working Space on the Jetty（Berth width: about 35m）

iii) Yard Operation with Reach Stackers and Stacking Block Size

The reach stacker used for container yard stacking operation is generally a model which is capable of stacking three (3) rows on one side (1st/2nd/3rd rows from the front) and lifting the IMO container (maximum load of 30.5 tons) in the second row. Although it is depending on the model, this plan assumes the rated load capacity of 45/31/16 tons from the front (see Figure 8.3.54). From the viewpoint of effective utilization of the yard area, the stacking block is planned to constitute as one block with 6 rows (width 15 m = container width 2.5 m × 6 rows) so that loading and unloading operations are usually possible from both sides. The working space for the reach stackers between stacking blocks requires at least 16 m because 1) length of a reach stacker is 12 m, 2) width of chassis lane is 3 m, and 3) the required safety margin is 1 m.

Thus, the yard stacking module is formed with stacking block (width 15 m) and reach stacker working space (width 16 m), totaling 31 m as one pitch (see Figure. 8.3.55).

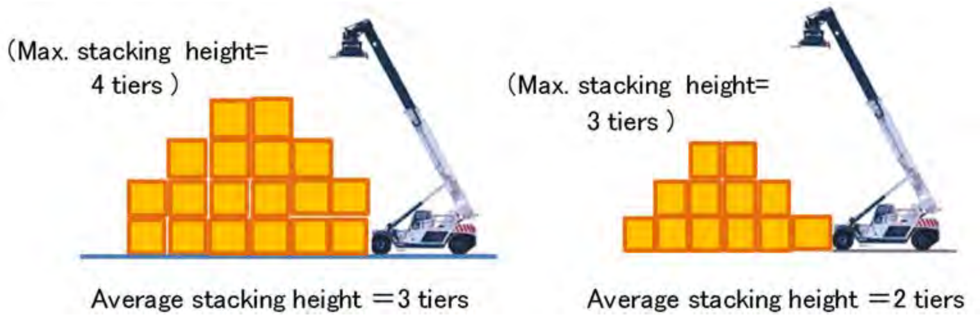


Source: JICA Design Team

Figure 8.3.55 Block Size and Working Area of Reach Stacker Yard

The height of the stacking block is determined by the capacity of the reach stacker and the stability of the piled containers, which is usually set at 4 tier (the third row from the front), 3 tier (the 2nd row) and 2 tier (the 1st row) stacking is possible. In this case (case-A), the average stacking height of the block is 3 tiers. In actual operation, considering the efficiency of handling work (to minimize shuffling work), most terminals operate one tier lower than case-A’s height in each row (maximum 3 rows (3rd row)). In this case (case-B), the average stacking height is two tiers (see Figure 8.3.56).

In this DK1 yard plan, we will consider the average stacking height as 2.0 to 2.5 tiers (mean height of case-A and case-B) as a basic plan, then we will finally select the optimum option by considering the required whole yard capacity including Ro/Ro yard.



Source: JICA Design Team

Figure 8.3.56 Stacking Height of Yard Block

(6) Remarks for Civil Engineering Facility Designing

The items to be considered in designing civil engineering facilities of DK1 based on the results of the cargo handling equipment plan are addressed below. The first item is the width and the ground tolerance of the jetty, the second is the required area of the container stacking yard, and the third is the ground tolerance of the connecting bridge between the jetty and the yard.

i) Required Jetty Width and Load Condition

The quay wall width requires at least 40 m (preferably 45m～50m) as described in the previous section ((5).ii) Quayside operation by MHC) (see Figure 8.3.50-51).

The loading conditions of the jetty to be taken into account from the viewpoint of cargo handling equipment planning are a) the load on the outrigger during cargo handling operation, b) the wheel load during the reach stacker traveling, c) the load caused by the temporary placing of the container.

a) Load on outrigger during cargo handling operation by MHC

General specifications (crane specifications, axial weight during crane travelling, load conditions at loading/ unloading operation) of the standard MHC corresponding to the Panamax vessels are described in Table 8.3.32. Depending on the model of the crane, the total crane weight is about 420 tons to 535 tons, and the maximum stabilizer pad loading during operation ranges from 240 tons to 250 tons. In the case of introducing this type of crane, the quay wall ground resistance against the corner load of at least 250 tons is necessary for the entire loading area on the quay.

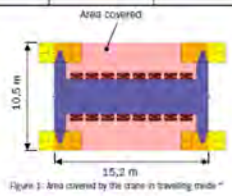
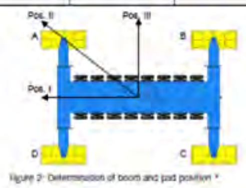
b) Reach stacker axle load during operation

Overall specifications of the reach stacker of the rated load of 45 ton classes are described in Table 8.3.33. Total weight of the machine is about 72 tons, and in lifting maximum 45 tons cargoes, the axle weight applied to the front wheels is about 87 to 102 tons. This figure is less than half as compared with MHC, thus the influence on the whole jetty structure is smaller than MHC.

c) Load at temporary placement of container

In ship gear operation at a jetty with a long distance away from the stacking yard, the jetty is frequently required to have a buffer function and containers are temporarily placed on the quay for safety reasons and for adjusting cycle time difference between quayside operation and yard stacking operation. Assuming that the maximum temporary placement level (stacking height) of the containers is three (3) tiers, the maximum load at the jetty is 91.5 tons and the maximum load pressure is about 6.1 tons / m^2 (30.5 tons × 3 tiers ÷ 20 'container projected area 15.0 square meter).

Table 8.3.32 Lifting Capacities and Crane Propping Forces of MHC (for panama size vessel)

		Panamax Vessel Model			Panamax Vessel Model		
Vessel Beam Size		32.5 m			32.5 m		
Number of rows for on-deck container		13 Row			13 Row		
Example of MHC Model (Gottwald)		G HMK 6507 B (Gottwald)			JWC-2100 (IHI)		
Main Crane Data							
1	Total crane weight	420 Ton			535		
2	Maximum load	65Ton			50 Ton		
3	Maximum load on operation	485Ton			585 Ton		
4	Number of axles	7			8		
5	Length of chassis without stabilizer pads	18.5 m			n.a.		
6	Width of chassis without stabilizer pads	9.0 m			n.a.		
7	Propping base (length, width)	14.0 m x 12.5 m			n.a.		
8	Stabilizer pad size (standard)	2.0 m x 4.5 m =9.0 ㎡			2.8 m x 2.8 m =7.8 ㎡		
9	Stabilizer pads per corner	1			2		
Crane in Travelling Mode							
1	Uniformly distributed load during travelling						
	(1) Area covered	(15.2m x 10.5m) =160.4㎡*1			n.a.		
	(2) Uniformly distributed load	420Ton/160.4㎡ =2.62Ton/㎡			n.a.		
2	Pressure under wheel						
	(1) Axle load	420Ton/7axles =60 Ton			n.a.		
	(2) Wheels per axle	4			4		
	(3) Load per wheel	15.0 Ton			18.5		
	(4) Supporting Area per wheel	1,690 c㎡			2,140 c㎡		
	(5) Pressure under wheel	8.88 kg/c㎡			8.64 kg/c㎡		
Crane in Operation							
1	**Maximum Propping Forces [at Heavy Load - 75%]**						
	Boom Position (See Fig 9.2.7-1)	I	II	III	I	II	III
	(1) Load (Ton)	64.3	64.3	64.3	n.a.	50	n.a.
	(2) Radius (m)	30	30	30	n.a.	42.5	n.a.
	(3) Stabilizer pad loading (Ton)	202.4	239.1	211.2	n.a.	250	n.a.
	(4) Pad(s) on which load is exerted	A,D*2	A*2	A,B*2	n.a.	A*2	n.a.
	(5) Stabilizer pad area (㎡)	9.00	9.00	9.00	n.a.	15.60	n.a.
	(6) Ground Pressure (kg/c㎡)	2.25	2.66	2.35	n.a.	1.60	n.a.
Note		*1 			*2 		

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Table 8.3.33 Main Dimensions and Axle Load of 45 Ton Reach Stackers

Model			TFC 45 Rh*	SMV 45-31 TC5*	
Max Stacking Height	8'6"	Tier	5/5/4	5/5/4	1st /2nd/3rd row
	9'6"	Tier	5/4/3	5/4/3	
Maximum Lifting Capacity		Ton	45/ 31/ 16	45/ 31/ 16	1st /2nd/3rd row
Total Weight (with Spreader)		Ton	72	71.8	
Axle Road	Unladen	Ton	36/ 36	37.5/ 34.3	front/ rear
	Laden 45 ton	Ton	87/ 30	102.2/14.6	
	Laden 30 ton	Ton	69/ 33	95.5/ 7.3	
Wheel and Tires	Number of wheels		4/ 2	4/ 2	front/ rear
	Tire size		18.00-25"	18.00-25"	
	Rim size		13.00-25"	13.00-25"	
Main Dimensions	Overall length	mm	11,950	11,500	with spreader
	Wheel base	mm	6,000	6,400	
	Rear overhang	mm	1,300		
	Width	mm	4,190/ 3,350		front/ rear
Distance front tire to load center of;	1st row	mm	2,500	2,800	
	2nd row	mm	3,860	4,650	
	3rd row	mm	6,400	7,150	
Note: *1: Konecranes					

Source: JICA Design Team

ii) Yard Layout and required Yard Area

Based on the bay profile including number of rows, stacking height of the stacking block described in the previous section ((5) iii) "Yard operation with reach stackers and stacking block size"), a yard layout plan is described as follows:

a) Yard stacking blocks

The stacking capacity of the block is indicated in Table 8.3.34 assuming that the block length is within 150m in the east-west direction, which is planned in the basic layout plan. This stacking capacity is calculated corresponding to two cases with the average stacking height of 2.0 tiers and of 2.5 tiers.
As is indicated in this table, the number of bays of one block can be secured to 18 TEUs, and the block capacity varies from 216 TEUs /block when the average stacking height is 2.0 tiers to 270 TEUs/ block at 2.5 tiers.

Table 8.3.34 Container Yard Block Size and Yard Capacity of DK1 Terminal

Block size					Number of blocks to be introduced	Average dwelling days			
Maximum staking height	Average staking height	Number of rows	Number of bays	Stacking capacity		7 days	6 days	5 days	4 days
						Turn over rate per year			
(Tier)	(Tier)	(Rows/ block)	(TEU/ block)	(TEU/ block)		52.1	60.8	73.0	91.2
						Yard capacity (TEU/year)			
4	2.5	6	18	270	**5**	**70,000**	**82,000**	**99,000**	**123,000**
					6	84,000	98,000	118,000	148,000
3	2.0	6	18	216	**5**	56,000	**66,000**	**79,000**	98,000
					6	**68,000**	**79,000**	95,000	118,000

Source: JICA Design Team

b) Yard capacity

Required number of stacking blocks and yard capacity (yard handling capacity) calculated based on the unit block capacity are listed in Table 8.3.34.

(a) The yard capacity should be consistent with the quayside ship handling capacity, thus yard capacity is targeted at about 70,000 TEU (refer to (7) i) "Evaluation of ship handling capacity ").
(b) Dwelling time of the container in the yard is the most critical factor affecting the yard capacity. In developing countries, it can take up to two weeks at some terminals, but we estimate the dwelling time of DK1 to be 6 to 7 days on the assumption that this port will be improved by technical assistance from Japan.
(c) In order to realize yard capacity of 70,000 TEU per year, assuming an operation with an average stacking height of 2.5 tiers, DK1 terminal is required to introduce five (5) blocks and maintain an average of 7 dwelling days. In the case of an average stacking height of 2.0 tiers, average dwelling days at DK1 terminal should be 5.5 days when introducing five (5) blocks, and 6.5 days when introducing six (6) blocks.
(d) Since it is considered difficult to consistently achieve an average stacking height of 2.5 tiers, it is strongly recommended to construct of six (6) stacking blocks for DK1 yard.

c) Yard layout of reach stacker system and required area dimension

The layout model and dimensions of reach stacker yard in DK1 terminal based on the above study result (truck flow line, yard block dimensions, and yard capacity) is shown in Figure 8.3.57 and Table 8.3.35. As shown in Figure 8.3.57, this layout plan requires expansion of one module (31 m) in the north-south direction.

The layout plan should be elaborated at the detail design stage considering the following aspects; sufficient truck turning radius when entering and exiting from the yard blocks, appropriate location of the gate in the yard, connecting position and angle of the bridge, and location of terminal facility such as maintenance shop, office, etc.

Table 8.3.35 Dimension of Container Stacking Area

Number of blocks	Dimension of stacking area		Dimension in basic plan		Modification of basic plan	
	North-south direction	East-west direction	North-south direction	East-west direction	North-south direction	East-west direction
	(m)	(m)	(m)	(m)	(m)	(m)
5	171	148.5	172	150	-1	-1.5
6	202				30	

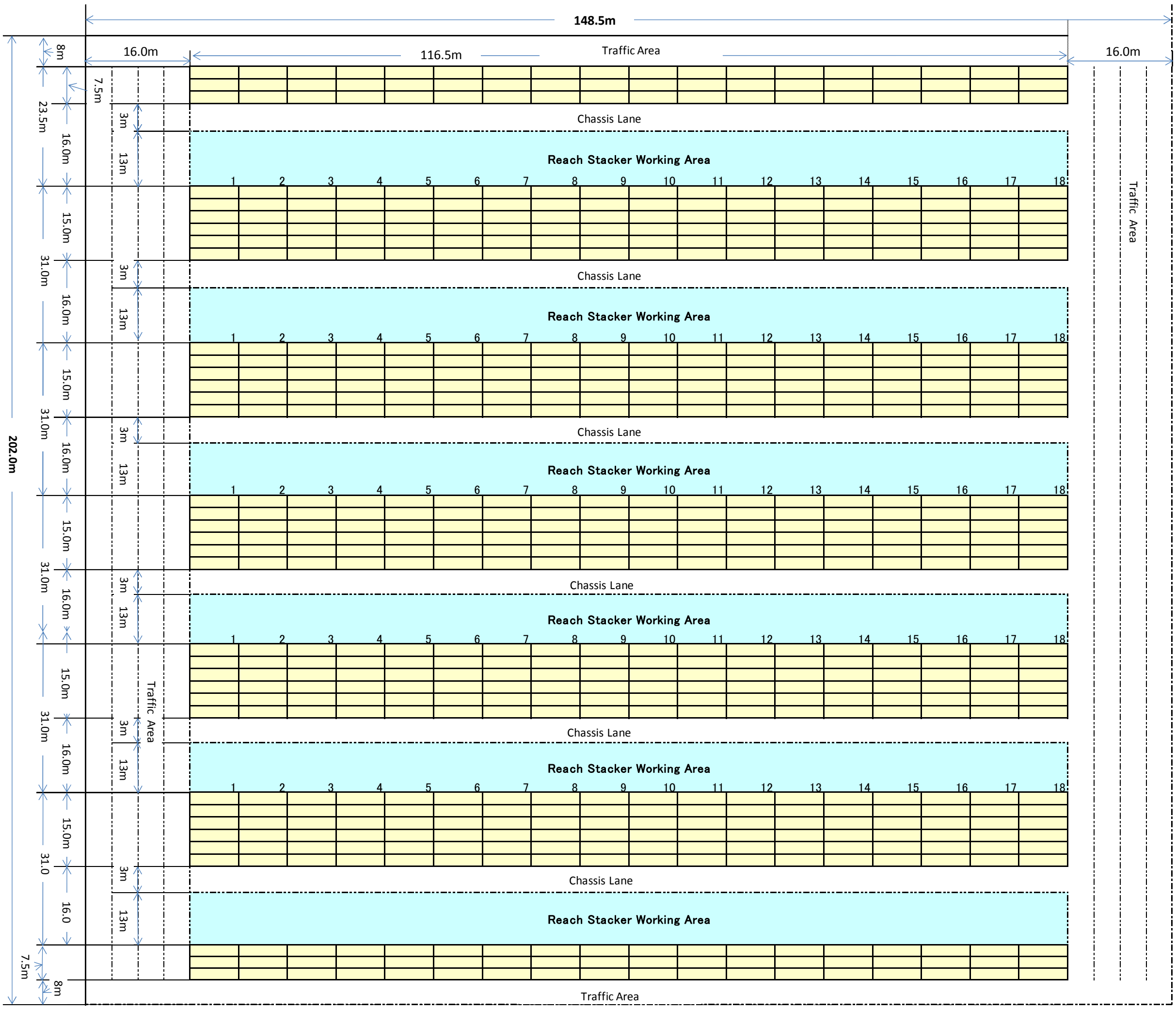
Source: JICA Design Team

iii) Width and Withstanding Load of Connecting Bridge

Considering the future fluctuation of the container cargo volume at DK1 (basically, the downward trend), the MHC introduced in this Jetty is likely to be diverted to other uses. In this case, it will pass through the bridge and be transferred to other places. Therefore, it is necessary to design the width of the connecting bridge and the load bearing strength in consideration of the load condition during MHC travelling.

(a) Machine width during MHC travelling
MHC standard model compatible with Panamax ship has a machine width of 10.5 m to 11.1 m when travelling. Therefore, the width of the bridge (20 m) in the basic layout plan is sufficient (see Table 8.3.32).

(b) Load condition during travelling
The total weight of the same model is 420 tons (with 7 axles / 4 tires) to 535 tons (8 axels /4 tire), and this weight is dispersed to each axle and tire when travelling. Detailed load distribution is listed in Table 8.3.32. Therefore, the connecting bridge should be able to withstand these load conditions.



Source: JICA Design Team

Figure 8.3.57 DK1 Container Yard Layout Model

(7) Evaluation of Container Handling Capacity

i) Evaluation of Ship Loading and Unloading Capacity

The DK1 terminal is used as a terminal for imported automobiles, and it is planned to be used as a container terminal by using the remaining capacity. Based on this policy, the number of available days for container handling in DK1 is studied by the port planning and is identified as 189 days (52% of the total annual capacity) to 69 days (19%) from 2020 to 2035. Consequently, container handling capacity in DK1 is presumed on the basis of this number of working days available for container handling (see Table 8.3.27).

a) Estimation of Container Handling Productivity

Estimation of the container handling productivity at the DK1 is based on Net Productivity (the crane productivity during net working hours). Due to various kinds of interruptions (equipment breakdown, bad weather, document deficiency, cargo disarrangement, shift change, etc.), actual productivity during operation decreases to 80% of Net Productivity (Operational efficiency: 80%= (Net operation hours)/ (Gross operation hours)). Usually gross operation hours, which is the duration from the commencement to the completion of handling operation, are about 90% of the time of the vessel at berth (Work hour ratio: 89% (quoted from the M / P survey result)). Hence, it is estimated that vessel productivity per time vessel at berth (Berth time) will be about 70% of Net Productivity (see Table 8.3.36).

The Net Productivity of MHC is typically 20 Boxes/hour (maximum 25 Boxes/ hour) per crane on average, and Net Productivity of ship gear is about 10 Boxes/ hour per gang on average. This level of productivity can be performed sufficiently at DK1.

From the above results, it is estimated that Vessel Productivity of MHC (at 2 cranes) is 28.5 Boxes/berth-hour and Vessel Productivity of Ship Gear (at 2 gangs) is about 14.2 Boxes/ berth-hour (refer to Table 8.3.36). Therefore, the productivity per day is estimated to be 957 TEUs/berth-day (7,368 tons/ berth-day) using two MHCs, and the productivity of two Ship Gear's operation is 478 TEUs/berth-day (3,684 tons/berth-day). The TEU conversion factor (1.4) and the average cargo quantity per TEU (7.7 Ton / TEU) used in this estimation are quoted from actual cargo handling results at Mombasa port and the survey results in the M / P study.

Assuming that the ratio of the container volume handled by MHC (Full Container Vessel) to that handled by ship gear (Geared Vessel) is 50% / 50%, the average cargo handling productivity of both is 638 TEUs/berth- day (4,912 tons/ berth-day) (see Table 8.3.36).

Table 8.3.36 Container Handling Productivity at DK1

Crane	Item	Data	Description
Mobile Harbor Cranes (MHC)	(a1) Net Productivity (Units /Net operation hour)	40.0	2 mobile harbor cranes
	(b1) Operational efficiency [(Net operation hour) /(Gross work hour)]	80%	
	(c1) Work hour ratio [(Gross work hour) / (Berth hour)]	89%	Survey from the Port M/P(*)
	(d1) Working ratio [(b1)*(c1)]	71%	Survey from the Port M/P(**)
	(e1) Vessel Productivity (units/ berth hour) [(a1)*(d1)]	28.5	
	(f1) TEU coefficient [1+40' container ratio(%)]	1.40	Survey from the Port M/P(***)
	(g1) Daily Productivity (TEU/Berth day) [(a1)*(d1)*(f1)*24]	957	
	(h1) Daily Productivity (Ton/day) [(g1)*(Unit weight)]	7,368	Unit weight=7.7 Ton/TEU(****); Survey from the Port M/P
Ship Gears (SG)	(a2) Net Productivity (Units /Net operation hour)	20.0	2 mobile harbor cranes
	(b2) Operational efficiency [(Net operation hour) /(Gross work hour)]	80%	
	(c2) Work hour ratio [(Gross work hour) / (Berth hour)]	89%	Survey from the Port M/P(*)
	(d2) Working ratio [(b2)*(c2)]	71%	Survey from the Port M/P(**)
	(e2) Vessel Productivity (units/ berth hour) [(a2)*(d2)]	14.2	
	(f2) TEU coefficient [1+40' container ratio(%)]	1.40	Survey from the Port M/P(***)
	(g2) Daily Productivity (TEU/ berth day) [(a2)*(d2)*(f2)*24]	478	
	(h1) Daily Productivity (Ton/ berth day) [(g1)*(Unit weight)]	3,684	Unit weight=7.7 Ton/TEU(****); Survey from the Port M/P
Average	(i) Average Daily Productivity (TEU/ berth day)	638	1/(i) = {1/(g1)+1/(g2)}/2
	(j) Average Daily Productivity (Ton/ berth day)	4,912	1/(j) = {1/(h1)+1/(h2)}/2

Source: JICA Design Team

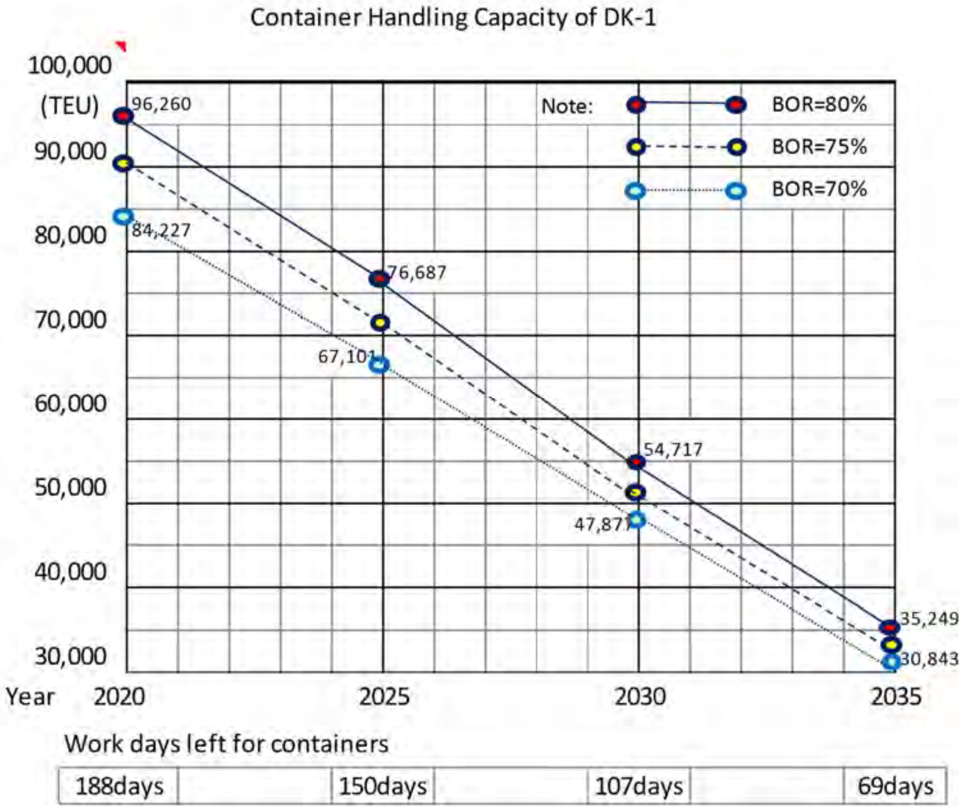
b) Evaluation of Quayside Container Handling Capacity

Quayside container handling capacity of the DK1 terminal from 2020 to 2035, which is estimated based on the productivity above, is indicated in Table 8.3.37 and Figure 8.3.58. As the quayside capacity depends on the berth occupancy rate (BOR), this plan estimates it by changing the BOR from 70% to 80%. Generally, the standard BOR is about 70% to 75%. The BOR is assumed to be slightly higher than normal because quayside container handling capacity is estimated to be about 67,000 TEU to 72,000 TEU in 2025 (the time when the maximum available days for container can be expected after DK1 operation starts).

Table 8.3.37 Quayside Container Handling Capacity of DK1

Year			2020	2025	2030	2035
Motor Vehicles	(a) Daily Productivity (units/day)*1		1,500	1,500	1,500	1,500
	(b) Target Annual Productivity (units/year)*2		177,877	216,995	260,904	299,812
	(c) Berth Occupancy Ratio (B.O.R.)*3		80%	80%	80%	80%
	(d) Work ratio*3		0.85	0.85	0.85	0.85
	(e) Work Days (day) [(b)/(a)/(c)/(d)]		175	213	256	294
Containers	(f) Work days left for containers [363days-(e)]		188	150	107	69
	[(f)/ 363]		52%	41%	30%	19%
	Case 1	(g1) Berth Occupancy ratio (B.O.R.)	**70%**	**70%**	**70%**	**70%**
		(h1) Available berth days for container [(f)*(g1)]	132	105	75	48
		(i1) Average Daily Productivity (TEU/berth day)	638	638	638	638
		(j1) Container Handling Capacity (TEU/ year)	**83,954**	**67,101**	**47,877**	**30,843**
	Case 2	(g1) Berth Occupancy ratio (B.O.R.)	**75%**	**75%**	**75%**	**75%**
		(h1) Available berth days for container [(f)*(g1)]	141	113	80	52
		(i1) Average Daily Productivity (TEU/berth day)	638	638	638	638
		(j1) Container Handling Capacity (TEU/ year)	**89,951**	**71,894**	**51,297**	**33,046**
	Case 3	(g1) Berth Occupancy ratio (B.O.R.)	**80%**	**80%**	**80%**	**80%**
		(h1) Available berth days for container [(f)*(g1)]	150	120	86	55
		(i1) Average Daily Productivity (TEU/berth day)	638	638	638	638
		(j1) Container Handling Capacity (TEU/ year)	**95,948**	**76,687**	**54,717**	**35,249**
Note:	*1:	Average of low and high (1,000-2,000 units/day)				
	*2:	Value from the demand forecast result				
	*3:	Survey from the Port M/P				

Source: JICA Design Team



Source: JICA Design Team

Figure 8.3.58 Quayside Container Handling Capacity of DK1

ii) Evaluation of Container Yard Capacity

Container yard capacity at DK1 terminal is described in detail in the previous section (6) ii)(b) "Yard capacity "(Refer to Table 8.3.34).

In conclusion, in order to be consistent with the quayside capacity of 70,000 TEUs/year (the median of 67,000 TEU to 72,000 TEU) in 2025, six (6) yard blocks are necessary with average stacking height of two (2) tiers. In addition, average Dwelling Time must be within six (6) or seven (7) days.

(8) Cost of Cargo Handling Equipment

Estimated cost of container handling equipment for DK1 terminal are listed in Table 8.3.38. Estimates of European machine manufacturers that have been delivered to Mombasa port together with the estimates of Japanese machine manufacturers are examined.

The total amount is 1.83 billion yen (Case A: cost estimate of the European maker) and 2.56 billion yen (Case B: combination of cost estimate of MHCs and quayside top lifter by Japanese maker and that of other equipment by European maker). At the current exchange rate there is a considerable difference between the two cases (100 (Case A): 150 (Case B)).

As MHC and Reach Stacker are already mass-produced commodity-type machines and European manufacturers are specialized in these types of products, and have successfully expanded their sales channel all over the world. Furthermore, because of the delivery area of this Project, shipping costs of the European manufacturers would be less than that of Japanese manufacturers. Due to these reasons, Japanese manufacturers tend to offer higher prices.

Table 8.3.38 Approximate Cost of Container Handling Equipment in DK1Terminal

Exchange rate (130JPY/€)

Equipment item	Role	Type of equipment/main specifications	Quantity	Unit price (JPY Million/unit)		Total price (JPY Million/unit)	
				Estimate of European manufacturer	Estimate of Japanese & European manufacturer	Estimate of European manufacturer	Estimate of Japanese & European manufacturer
1 MHC	Ship to shore container handling (loading and discharging)	1-1 To enable to accommodate Panamax size vessel (13 rows on deck) 1-2 Rated load: 40.5 ton at 13th row under single lift spreader 1-3 To have an equivalent capability to Gottwald HMK 6507model or HIJWC 2100 model	2	656.50	1,000.00	1,313.00	2,000.00
2 Reach Stacker	Container handling in the yard (stacking)	2-1 Maximum stacking height: 5 tiers at the 1st row (the nearest position) and 4 tiers at the 3rd row 2-2 Rated load: 16/31/45Ton 1st/2nd/3rr row from the nearest position from machine)	4	55.40	-	221.60	221.60
3 Reach Stacker /Top Lifter	Container handling at the quayside (back-up for ship gear operation)	3-1 Maximum stacking height: 3 tiers at the 1st row (the nearest position from machine) 3-2 To have an equivalent capability to Kalmar TFC-45 model (reach stacker) or TCM FD-430 model (top lifter)	2	54.60	78.00	109.20	156.00
4 Tractor & Chassis	Container transportation between quayside and yard	4-1 To have a capability to carry 20/40 feet containers	12	15.60	-	187.20	187.20
	Total					1,831.00	2,564.80

Source: JICA Design Team

8.3.10 Port Operation and Management

Current port administration model of Mombasa Port is Public Service Port. This is the most traditional method of administer the ports in which public authority takes almost all the responsibilities of port activities. Infrastructures and superstructures are provided by public authority. Port labor is hired directly by public authority. Other ancillary functions of the port, such as pilot, tug, line handling and so on is also provided by public authority.
Strength and weakness of Public Service Port is summarized as follows:

Table 8.3.39 Strength and Weakness of Public Service Port

Strength	Weakness
・One single organization (government) is responsible for infrastructure development and port operation.	・Limited area for private sector ・Lack of internal competition ・Less user-oriented/market-oriented ・Lack of innovation

Source: JICA Design Team

As an advanced model of Public Service Port, there is a model called Tool Port. In this model, infrastructures and superstructures are provided and managed by public authority. But port labor is arranged through private sector. Since private sector tends to function merely as labor pool, effect of efficiency improvement in port management and operation is minimal.
Strength and weakness of Tool Port is summarized as follows:

Table 8.3.40 Strength and Weakness of Tool Port

Strength	Weakness
・Efficient infrastructure development is achieved by single organization.	・Private sector tend to function as labor pool ・Risk of under-investment ・Lack of Innovation

Source: JICA Design Team

In the current port operation in the world, the most popular model is Landlord Port.
In the Landlord port model, the public authority owns and provides infrastructure of a port but port operation is carried out by private sector. Superstructure including cargo handling equipment is provided by private sector. Other ancillary port services are provided by public authority and private sector depending on the nature of the services.
Strength and weakness of Landlord Port is summarized as follows:

Table 8.3.41 Strength and Weakness of Landlord Port

Strength	Weakness
・Single entity (private sector) executes cargo handling operation ・Terminal operators are loyal to the port ・High motivation is maintained for long-term contract ・Expected better performance	・Risk of misjudging the proper timing of capacity addition/investment

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Benefit of the introduction of terminal operation by private sector is summarized as follows:

- Efficiency and productivity of port operation is improved
- Service level to the customers is improved
- Productivity is improved by being motivated by profit

Following is the comparison of current KPA model as Public Service Port and typical method of private sector participation in the Landlord Port Model (Management Contract and Concession Contract):

Table 8.3.42 The Comparison of KPA Model as Public Service Port and Private Sector Participation

Item	Case I	Case II	Case III
	Public Service Port Model (KPA's own Operation)	Private Participation (Management Contract)	Private Participation (Concession Contract)
Owner of facility	KPA	KPA	KPA
Operator	KPA	Private Operator	Private Operator
Operation Control	KPA	KPA	Operator
Operation Revenue	KPA	KPA/Operator	Operator
Freedom of operator	N/A	Operator's commercial freedom is limited	Operator has freedom in managing the terminal operation
Advantage	Flexible cargo handling management in the port	Utilize specialized skill of private operator	Maximize the value of the asset (DK1)
Disadvantage	Low productivity	1) Possibility of conflict of interest in operation policy between landlord and operator 2) Lack of motivation of operator	Risk of misjudging the timing of future investment

Source: JICA Design Team

Further explanations of each case for DK1 management and operation are as follows:

i) Case I (KPA Operation)

- KPA itself is responsible for all the operation of DK1.
- This is the extension of the same system currently applied to all the cargo operation at Mombasa Port (except Bulk Grain) to DK1.

ii) Case II (Private Participation: Management Contract)

- KPA entrust the operation of DK1 to a private operator.
- The Operator works on behalf of KPA.
- Infrastructure and cargo handling equipment are all provided by KPA.
- Investment by private operator is minimal.

Revenue flow under the management contract is as follows:

1. Revenue from operation is collected by KPA as KPA revenue.
2. KPA pays management fee to the Operator or KPA and the operator agree on revenue sharing scheme where the total revenue from the operation is shared between KPA and the operator with fixed share of percentage.

Management contract generate relatively small returns to operator against considerable amount of inputs of time for management. There is also a history of failure caused by conflicts over strategy, usually arising when private operators are not given the freedom they need to satisfy public sector objectives of the contract.

iii) Case III (Private Participation: Concession Contract)

- KPA gives the sole operation right at DK1 to a private operator (concessionaire).
- KPA provides basic infrastructure and operator provides necessary equipment for cargo operation.
- Operator manages and operates the berth with its own business plan and efforts for cargo inducement.

Revenue Flow under the concession contract is as follows:

1. Revenue from operation is collected by the Operator.
2. KPA receives Concession Fee from the Operator (Fixed fee).
3. KPA further receives additional revenue from the Operator depending on the outturn of operation at DK1 (Variable fee).

Performance standard is set as a benchmark of operation at DK1. Performance target is set to assure the minimum level of operation performance by operator. If operator failed to keep minimum level, penalty is imposed to the Operator. Concession is intended to encourage efficiency of specialized operator and to maximize the value that can be created from the facility.

iv) Recommendation

At the start-up of DK1 operation, it is expected that SEZ industries will not generate sufficient cargo to fully utilize DK1. Therefore, it is recommended to start the operation of DK1 with KPA's own operation so that the facility is used as one additional berth for entire operation of conventional cargo of KPA. Maximum utilization of the DK1 berth would be possible in this way through the arrangement of flexible cargo assignment among the various conventional berths of Mombasa Port under the control of KPA.

KPA primarily has a power to control the entire port area as a port management body of Mombasa Port including DK1 berth. At the same time, because of the special location of the port facility in the midst of SEZ area, DK1 berth has close and inseparable relationship with the SEZ industries.

Due to the particular characteristic of the DK1 berth as direct outlet of Mombasa SEZ industrial zone, the cargo to/from SEZ area will have significant weight in cargo flow of DK berths in future.

Therefore, it is also recommended to establish a joint organization by KPA and SEZ operator to facilitate effective utilization of DK berths. It is recommendable to set up such organization and mechanism at early stage of port facility development so that requirement of each party is clearly identified and reflected in actual implementation of the port operation of DK berths.

8.4 Roads

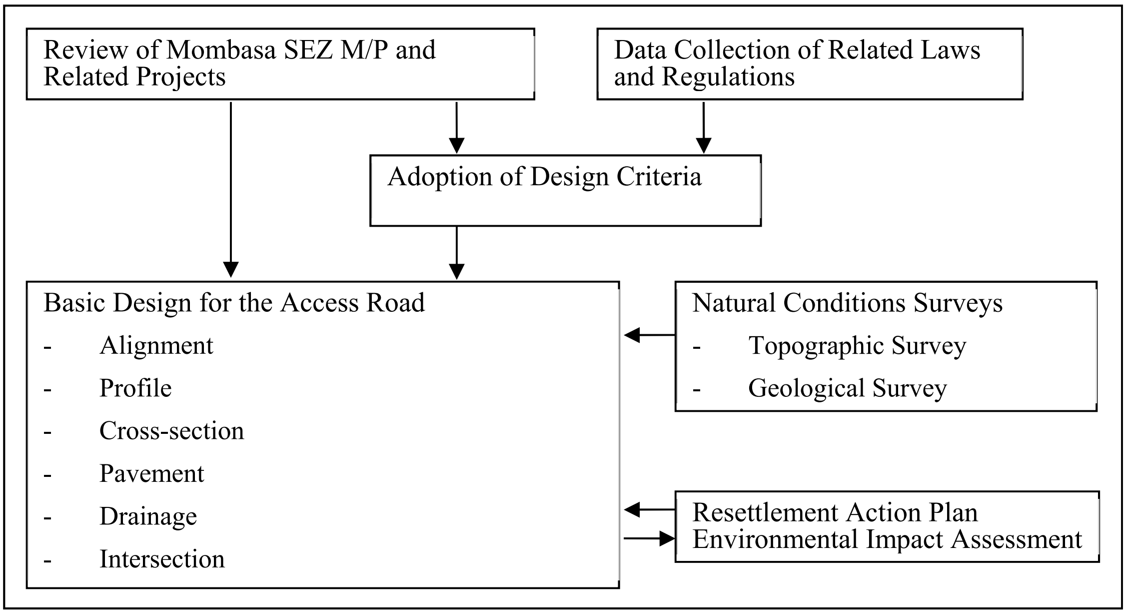
8.4.1 Overview

(1) Objective of the Survey

The objective of this study is to provide economically and technically effective basic infrastructure design and cost estimation. These are in line with the idea of cost saving for the port and substation access road construction, which will be implemented under the Japanese Official Development Assistance (ODA) scheme. The SEZ main road is the only road that connects from the Mombasa Southern Bypass Road (MSBR) to the Dongo Kundu Port. It is also the main road where electricity and water supply will be installed. The substation access road is needed in order to operate the substation within the SEZ. The two roads are essential facilities for the utilization of the SEZ for Phase 1.

(2) Methodology of the Road Design

The flow chart of road design is shown in Figure 8.4.1



Source: JICA Design Team

Figure 8.4.1 Flow Chart of Road Design

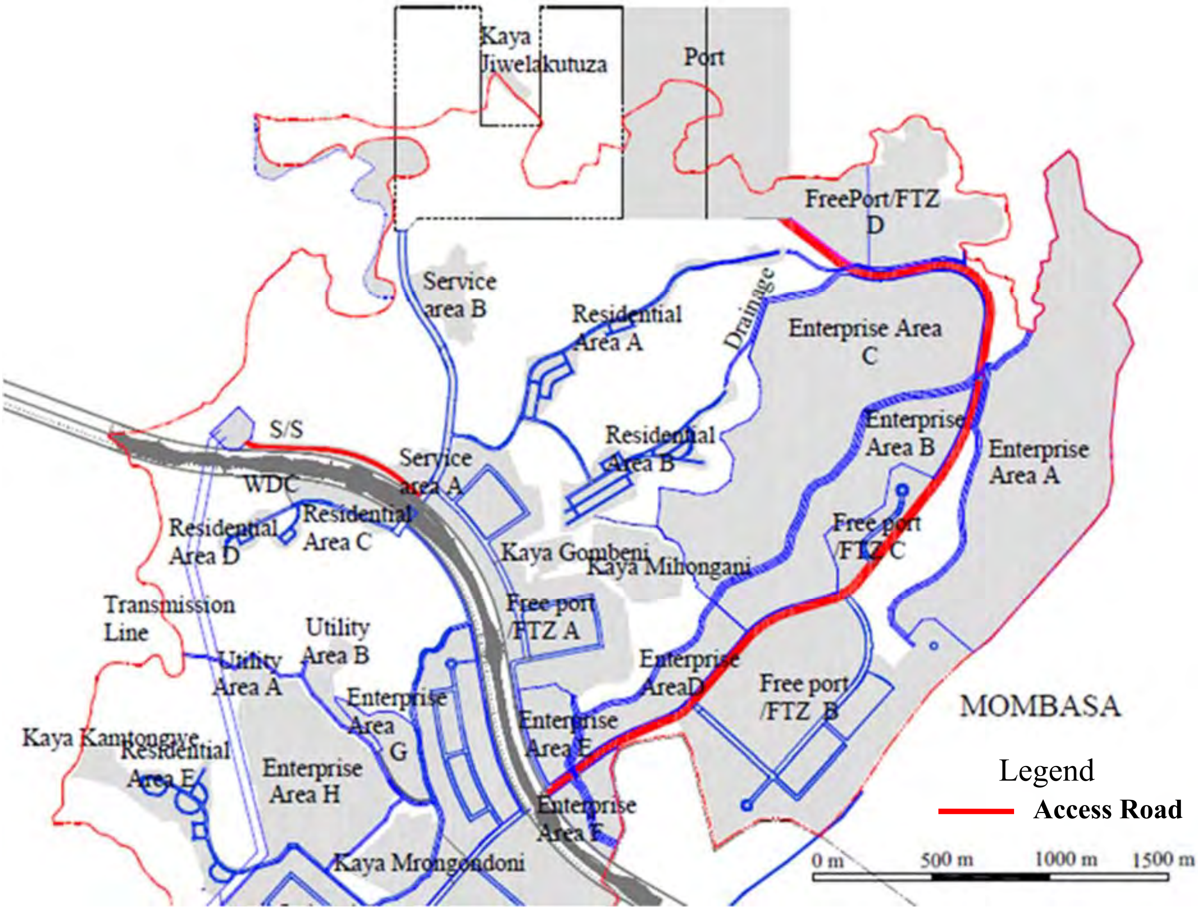
8.4.2 Current Conditions and Related Projects

(1) Current Conditions

The SEZ main road is engineered to connect the northeast side of the SEZ and the MSBR (highlighted in pink in Figure 8.4.2). The length of the currently proposed alignment is about 4,300 m. In Mombasa SEZ M/P, land use along the SEZ main road was designated as port, FTZ, and enterprise area.

The substation access road is planned as a part of the substation. The only passengers passing through the substation access road will be authorized personnel concerned with substation operations since there will be no specific land use along the 800-m substation access road.

Due to steep topography, the construction cost of both roads is estimated to be expensive. Therefore, the major design issue is to balance economic feasibility with road safety and driving comfort and to consider the current topographic and geological conditions of the area.



Source: JICA Design Team

Figure 8.4.2 Location of Two Roads

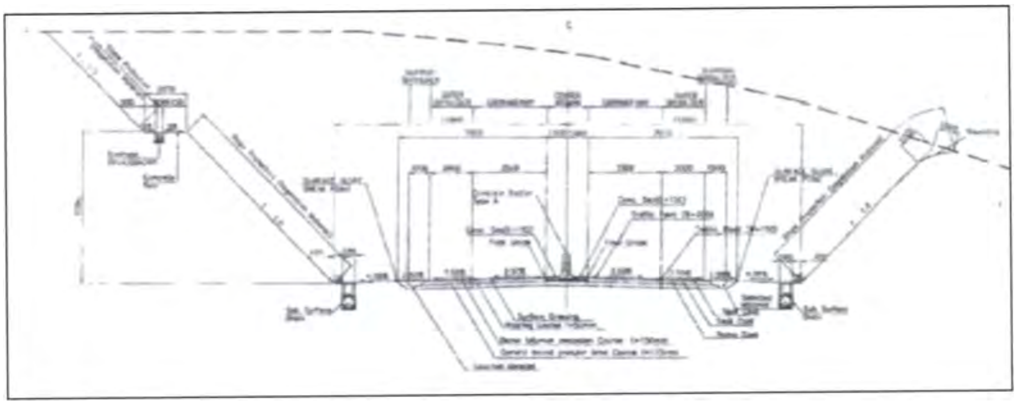
Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

(2) Mombasa Southern Bypass Road Project

The MSBR will be the sole access arterial road from the Mombasa City Center to the SEZ. This is managed by the Kenya National Highway Authority (KeNHA).

Source: Mombasa Port Area Road Development Project, JICA Loan No. KE-P29, Engineering Report Final, 2014, JICA, KeNHA and Japan ODA

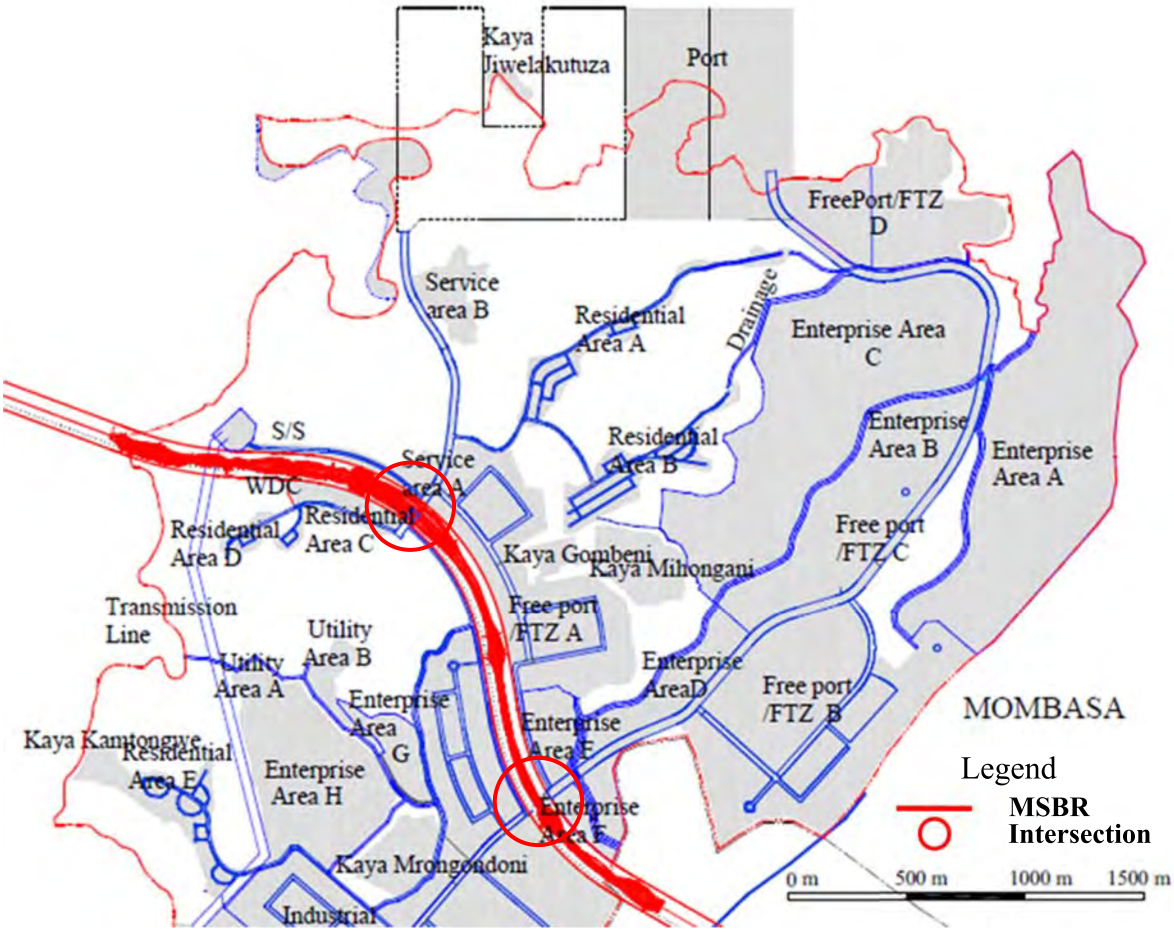
Figure 8.4.3 Alignment of the MSBR



Source: Mombasa Port Area Development Project, JICA Loan No. KE-P29, Engineering Report Final, 2014, JICA, KeNHA and Japan ODA

Figure 8.4.4 Typical Cross-section of Mombasa Southern Bypass Road

In the SEZ area, a four-lane road with a median is planned together with two intersections as shown in Figure 8.4.5. The detailed design of the MSBR is finished, and the construction for Package-3 has already commenced last 2018.
The design of the two roads should be based on detailed design parameters such as datum, elevation level, and other factors in the design criteria. However, there are some gaps between the detailed design of the MSBR project and the proposal of the Mombasa SEZ M/P.



Source: JICA Design Team

Figure 8.4.5 Location of Mombasa Southern Bypass Road and Two Intersections within the SEZ

Table 8.4.1 Construction Schedule of the MSBR as of March 2017

Package	Construction Area	Status
1	North part of the MSBR (Kipevu Terminal – Miritini Junction – Mwache Junction)	Under Construction
2	Bridge to connect the north part and southern part of Mombasa (Mwache Junction – Dongo Kundu)	Construction from January 2018
3	South part of the MSBR (Dongo Kundu – Kibundani Interchange)	Construction from March 2018

Source: JICA Design Team

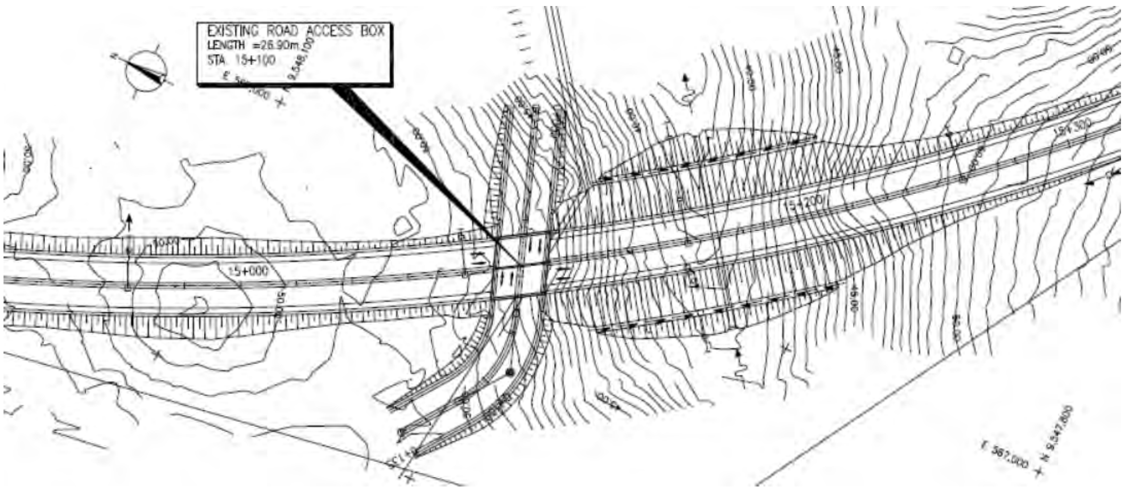
Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

i) Gap of Design Condition of an Overpass at Station (STA.) 13+700

In the Mombasa SEZ M/P, an intersection at STA. 13+700 of the MSBR was proposed as four lanes crossing over the MSBR. Although the overpass was designed with two lanes in the detailed design of the MSBR, it has been revised to accommodate four lanes. However, contents of the design criteria, such as the gradient and cross-section, have not been updated with requirements of the future development of the Mombasa SEZ. In case it is impossible to revise the design for the MSBR construction, an improvement project for this intersection will be required to connect berth 3, which will be developed in the final phase of the SEZ development.

ii) Gap of Intersection type of an Underpass at Station (STA.) 15+100

In the Mombasa SEZ M/P, an intersection at STA. 15+100 of the MSBR was proposed as four lanes crossing over the MSBR with ramps in a diamond interchange. However, it is designed as a two lanes underpass without ramps as shown in Figure 8.4.6. Widening of the underpass and construction of ramps is required.

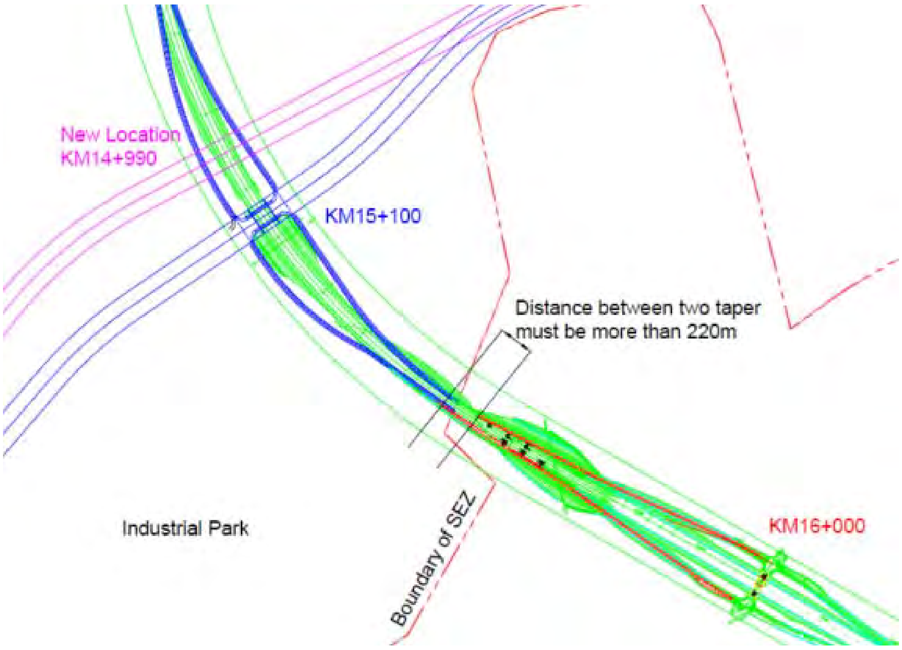


Source: Mombasa Port Area Road Development Project, JICA Loan No. KE-P29, Engineering Report Final, 2014, JICA, KeNHA and Japan ODA

Figure 8.4.6 Original Design of Underpass at STA.15+100 of the MSBR Detailed Design

iii) Allocation of an Intersection around STA.15+100 of the MSBR

Distance between the southern intersection which was proposed at STA. 15+100 of the MSBR and intersection at STA. 16+000 of the MSBR is too short (as shown in Figure 8.4.7). According to the Kenyan Standard, at least 220 m is desirably required between ramps of two intersections.



Source: JICA Design Team

Figure 8.4.7 Problem of Distance between two Intersections

8.4.3 Road Network and Transportation Planning

(1) Traffic Demand Forecast

Future traffic is categorized as cargo and commuter in the Mombasa SEZ M/P. Traffic demand is projected based on the Mombasa SEZ M/P and the land use plan as shown in Clause 8.2.

a) Cargo Traffic

Cargo traffic in 2040 is projected by referring to the demand forecast of export and import for Dongo Kundu Port as shown in Table 8.4.2 and by going through the generation and attraction of traffic by trucks in the SEZ as shown in Table 8.4.3.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Table 8.4.2 Demand Forecast of Export/Import cargo for Dongo Kundu

Berth	Item	2025	2030	2035	2040
DK1 *1	Motor Vehicle [vehicles/year]	216,688	260,448	299,605	299,605
	Container [TEUs/year]	60,104	42,885	27,627	0
DK2 *2	Container [TEUs/year]	0	277,115	372,373	400,000
DK3 *3	Dry Bulk [ton/year]	0	0	1,750,000	3,500,000

DK1 *4 *5 *6	Import [PCU/day]	964	978	991	821
	Export [PCU/day]	333	238	153	0
DK2 *6	Import [PCU/day]	0	1,708	2,295	2,466
	Export [PCU/day]	0	1,537	2,066	2,219
DK3 *7	Import [PCU/day]	0	0	1,438	2,877
	Export [PCU/day]	0	0	0	0

Source: JICA Design Team

*1 DK1 will be utilized for motor vehicle from 2024

*2 The total demand of the container in Dongo Kundu is projected as 400,000 TEUs/year in 2035 in the Mombasa Port M/P. All containers in Dongo Kundu will be handled at DK2 by 2040.

*3 The total demand of dry bulks in Mombasa is projected as 3,500,000 tons/year. DK3 will be utilized for dry bulks from 2035, and all dry bulks in Mombasa will be handled at DK3 by 2040.

*4 The ratio of import/export of motor vehicles and container are 100%/0% and 50%/50%

*5 The PCU per day of motor vehicles is calculated as follows: X vehicles / assumed number of loaded vehicles on car carrier (3.0 vehicles) * PCU conversion ratio of car carrier (3.0) / 365 days

*6 The PCU per day of container is calculated as follows: X TEUs of import * assumed weight per TEU (15 ton/TEU) / assumed loaded weight on heavy goods (10 ton/vehicle) * PCU conversion ratio of heavy goods (3.0) / 365 days, X TEUs of export * assumed weight per TEU (13.5 ton/TEU) / assumed loaded weight on heavy goods (10 ton/vehicle) * PCU conversion ratio of heavy goods (3.0) / 365 days

*7 PCU per day of dry bulk is calculated as follows: X ton / assumed loaded weight on heavy goods (10 ton/vehicle) * PCU conversion ratio of heavy goods (3.0) / 365 days

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Table 8.4.3 Projection of Generation/Attraction Number of Cargo Traffic to/from the SEZ

Land Use	Area [ha]	Trip Rate (Generation & Attraction) [vehicles/day/ha]	Traffic Volume [vehicles/day]	PCU Conversion Ratio	Traffic Volume [PCU/day]
Port1	-	- *1	547	3.0 *3	1,642
Port2	-		3,123		9,370
Port3	-		1,918		5,753
FTZ	146.7	25 *2	3,668		11,003
Enterprise area	175.7	8 *2	1,406		4,217
Industrial Park	112.5		900		2,700
Residential area	39.0	0	0		0
Tourism Park	49.0	0	0		0
MICE	2.2	0	0		0
Service area	8.8	0	0		0
WDC	2.0	0	0		0
S/S	2.0	0	0		0
Utility Area	11.5	0	0		0

Source: JICA Design Team
*1 referring to Table 8.4.2
*2 referring to the Preparatory Survey on Mombasa City Road Development Project in The Republic of Kenya, Final Report, Nov. 2011, JICA/KATAHIRA & ENGINEERS INTERNATIONAL
*3 referring to the Kenyan Standard, "Design Manual for Roads and Bridges -2nd Draft- (2009), Ministry of Roads"

b) Commuter Traffic

Commuter traffic in 2040 is projected as shown in Table 8.4.4 based on the Mombasa SEZ M/P.

Table 8.4.4 Projection of Generation/Attraction Number of Commuter Traffic to/from the SEZ

Land Use	Area [ha]	Unit Number of Workers *1 [persons/ha]	Number of Workers [persons]	Modal split, Number of passengers, PCU conversion ratio *1	Traffic volume [PCU/day]
Port1	-	-	500	Light Van: 80%, 15, 2.0 Passenger Car: 20%, 1.5, 1.0	240
Port2	-		500		240
Port3	-		500		240
FTZ	146.7	50	5,810		2,780
Enterprise area	175.7		8,786		4,220
Industrial Park	112.5	100	11,250		5,410
Residential area	39.0	120	4,680		2,250
Tourism Park	49.0	20	980		470
MICE	2.2	300	660		320
Service area	8.8	100	880		420
WDC	2.0	10	20		10
S/S	2.0	20	40		20
Utility Area	11.5	20	230		110

Source: JICA Design Team
*1 referring to the Mombasa SEZ M/P

c) Total Traffic Volume

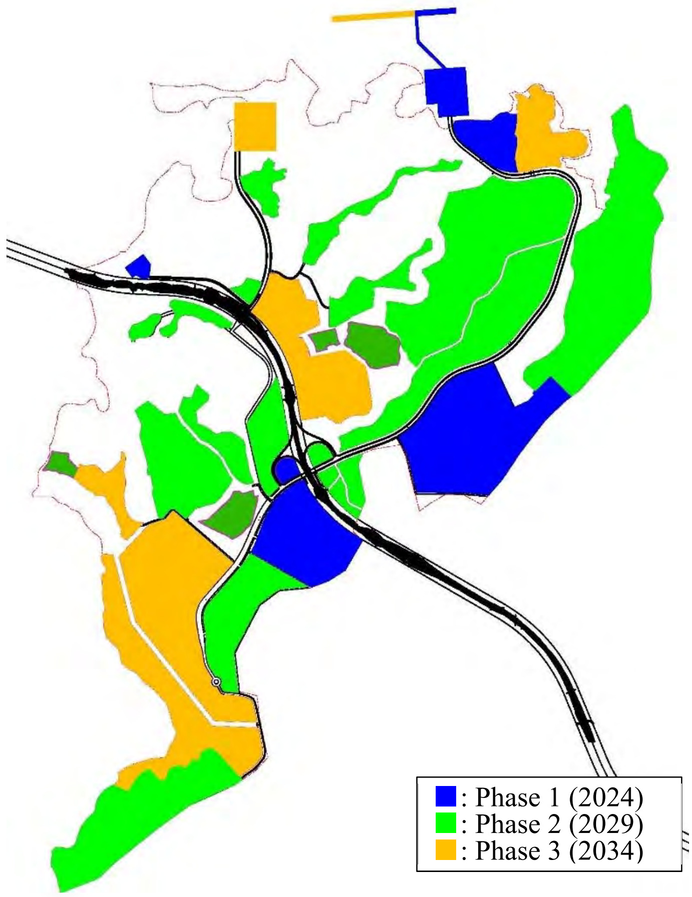
A traffic volume projection of each year shown in Table 8.4.5 is estimated according to the development phase planning as shown in Figure 8.4.8. The total cargo and commuter traffic of the SEZ in 2040 will be at 51,414 PCU/day.

Table 8.4.5 Projection of Total Traffic Volume of the SEZ [PCU/day]

Land Use	Construction Year	2025	2030	2035	2040
Port1	2024	2,835	2,672	2,529	1,882
Port2	2030	0	6,731	8,963	9,610
Port3	2035	0	0	3,117	5,993
FTZ A	2034	0	0	1,565	3,913
FTZ B	2024	2,653	6,643	6,643	6,643
FTZ C	2029	0	298	750	750
FTZ D1	2024	409	1,018	1,018	1,018
FTZ D2	2034	0	0	586	1,460
Enterprise Area A	2029	0	1,357	3,383	3,383
Enterprise Area B	2029	0	376	935	935
Enterprise Area C	2029	0	735	1,823	1,823
Enterprise Area D	2029	0	136	336	336
Enterprise Area G	2029	0	76	181	181
Enterprise Area H	2029	0	256	636	636
Enterprise Area I	2034	0	0	104	265
Enterprise Area J	2034	0	0	355	878
Industrial Park A1	2024	1,018	2,535	2,535	2,535
Industrial Park A2	2029	0	793	1,978	1,978
Industrial Park B1	2029	0	1,036	2,594	2,594
Industrial Park B2	2034	0	0	403	1,004
Residential A	2024	240	600	600	600
Residential B	2024	260	660	660	660
Residential C	2029	0	110	280	280
Residential D	2029	0	60	140	140
Residential E	2034	0	0	230	570
Tourism Park	2029	0	190	470	470
MICE	2029	0	130	320	320
Service Area A	2029	0	40	90	90
Service Area B	2029	0	130	330	330
WDC 1	2024	5	5	5	5
WDC 2	2029	0	5	5	5
S/S	2024	20	20	20	20
Utility Area A	2029	0	30	70	70
Utility Area B	2029	0	20	40	40
Total		7,440	26,662	43,692	51,414

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



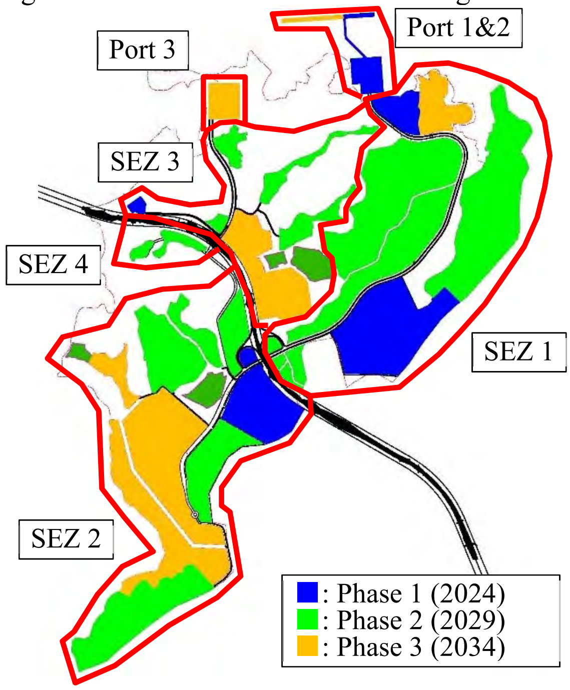
Source: JICA Design Team

Figure 8.4.8 Phasing Plan of the Mombasa SEZ Development

(2) Projection of Traffic Volume of Internal Arterial Road of the SEZ

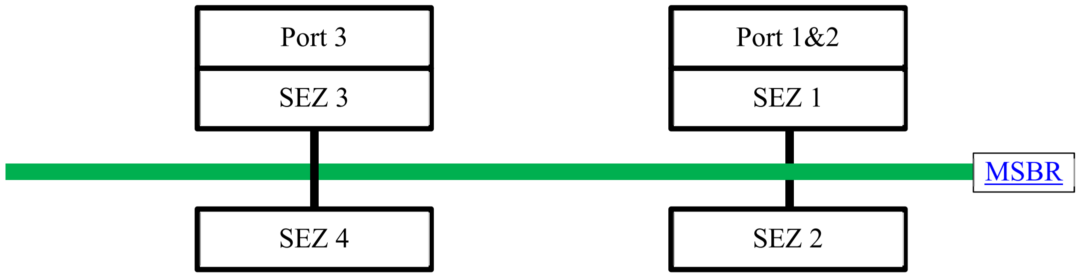
a) Transportation Zone and Phasing

Transportation in the SEZ is categorized into six zones as shown in Figure 8.4.10 and Table 8.4.6.



Source: JICA Design Team

Figure 8.4.9 Traffic Zones of the SEZ



Source: JICA Design Team

Figure 8.4.10 Diagram of Traffic Zones of the SEZ

Table 8.4.6 Traffic Zones of the SEZ

Zone	Land Use
Port 1 & 2	Port1, Port 2
Port 3	Port3
SEZ 1	FTZ B to D2, Enterprise A to F
SEZ 2	Enterprise area G to J, Industrial Park A1 to B2, Residential E, Tourism Park, MICE, WDC, Utility Area
SEZ 3	Residential A & B, Service area, S/S
SEZ 4	Residential C & D

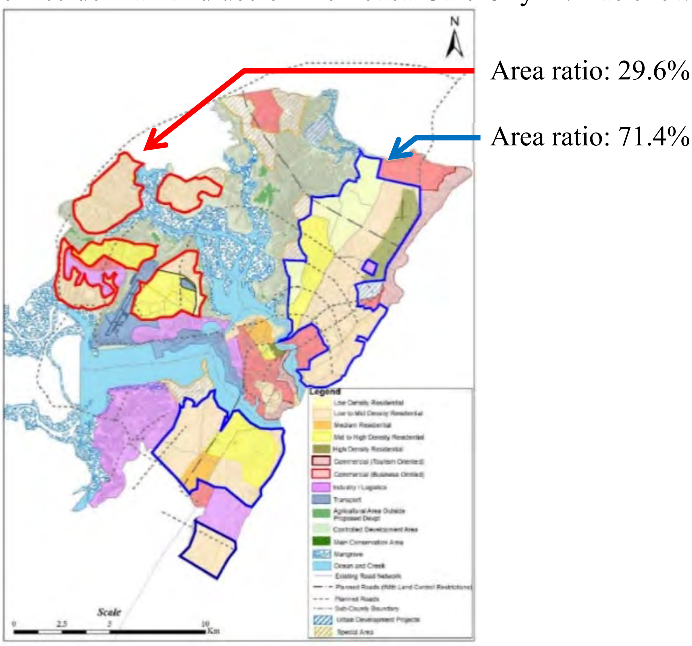
Source: JICA Design Team

b) Traffic Ratio for Outbound/Inbound Direction

All kinds of transportation to and from the outside areas together with all cars heading to the north or south are passing through two prescribed intersections within the SEZ. The traffic ratio of the northern and southern areas is determined by characteristics of traffic.

Cargo traffic to and from the north and south are assumed as 76% and 24%, respectively, of the total traffic volume to and from the SEZ. This is according to the destination/origin of the exported and imported cargo (Chapter 10).

All workers who live in the residential area within the SEZ (4,680 people) will work for the SEZ. The rest of the workers (30,710 people) will be coming from the outside. Commuter traffic to and from the north and south are respectively assumed as 30% and 70% of the total traffic volume to and from the SEZ. This is according to the area of residential land use of Mombasa Gate City M/P as shown in Figure 8.4.11.



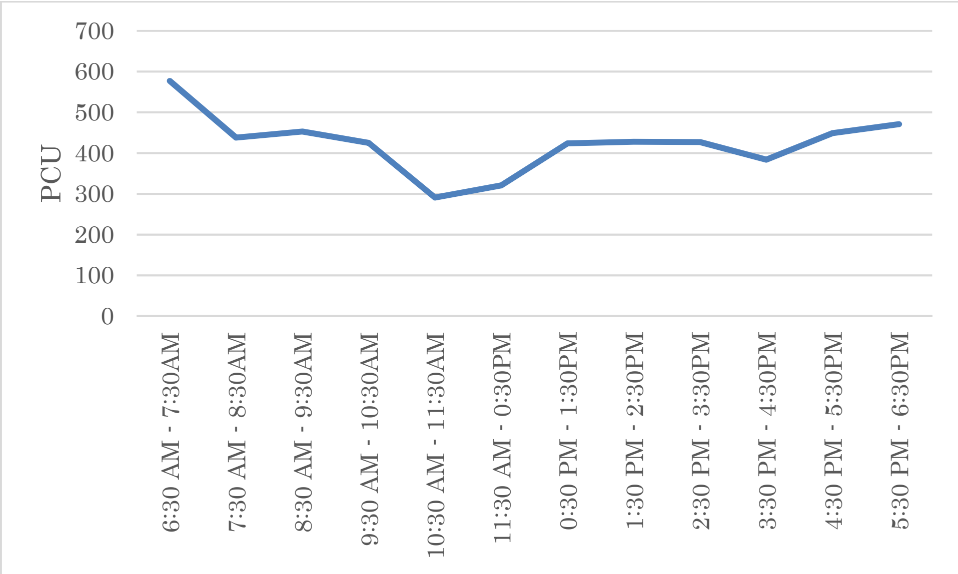
Source: Edited on Land Use Plan of Mombasa Gate City M/P

Figure 8.4.11 Area of Residential Zone in the MGC M/P

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

c) Peak Hour Ratio

Peak hour ratio is assumed as 10% of the daily traffic volume based on the traffic survey near the gate of an existing port.



Source: Summarized of Traffic Survey of Mombasa Gate City M/P

Figure 8.4.12 Freight Interview at Port Gate No.18

Table 8.4.7 Traffic Volume at Port Gate No.18

Duration	PCU/hour	Peak Ratio against 24 hr
6:30 AM - 7:30AM	577	9.5%
7:30 AM - 8:30AM	438	
8:30 AM - 9:30AM	453	
9:30 AM - 10:30AM	425	
10:30 AM - 11:30AM	291	
11:30 AM - 0:30PM	321	
0:30 PM - 1:30PM	424	
1:30 PM - 2:30PM	428	
2:30 PM - 3:30PM	427	
3:30 PM - 4:30PM	384	
4:30 PM - 5:30PM	449	
5:30 PM - 6:30PM	471	
12 hr.	5,088	
24 hr. (12 hour*1.2)	6,106	

Source: Summarized of Traffic Survey of Mombasa Gate City M/P

d) Origin-Destination Matrix

The Origin-Destination Matrix is shown in Table 8.4.8 to Table 8.4.11.

Table 8.4.8 Origin-Destination Matrix in 2025 [PCU/day]

From/To	North	South	Port1&2	Port3	SEZ1	SEZ2	SEZ3	SEZ4
North	0	0	757	0	311	138	3	0
South	0	0	289	0	234	184	7	0
Port1&2	278	137	0	0	884	80	38	0
Port3	0	0	0	0	0	0	0	0
SEZ1	785	382	261	0	0	0	104	0
SEZ2	143	187	72	0	0	0	108	0
SEZ3	3	7	38	0	104	108	0	0
SEZ4	0	0	0	0	0	0	0	0

Source: JICA Design Team

Table 8.4.9 Origin-Destination Matrix in 2030 [PCU/day]

From/To	North	South	Port1&2	Port3	SEZ1	SEZ2	SEZ3	SEZ4
North	0	0	2,098	0	1,495	720	29	0
South	0	0	776	0	1,188	1,068	67	0
Port1&2	1,406	558	0	0	2,274	412	46	6
Port3	0	0	0	0	0	0	0	0
SEZ1	2,157	1,393	1,405	0	0	0	289	39
SEZ2	749	1,081	371	0	0	0	295	40
SEZ3	29	67	46	0	289	295	0	0
SEZ4	0	0	6	0	39	40	0	0

Source: JICA Design Team

Table 8.4.10 Origin-Destination Matrix in 2035 [PCU/day]

from/to	North	South	Port1&2	Port3	SEZ1	SEZ2	SEZ3	SEZ4
North	0	0	2,558	1,123	2,017	1,328	260	0
South	0	0	930	416	1,924	2,125	312	0
Port1&2	1,747	673	0	0	2,400	595	321	9
Port3	30	70	0	0	989	347	117	4
SEZ1	3,435	2,368	1,526	0	0	49	270	90
SEZ2	1,633	2,225	536	2	49	110	305	100
SEZ3	441	369	187	13	270	305	41	7
SEZ4	0	0	9	4	90	100	7	0

Source: JICA Design Team

Table 8.4.11 Origin-Destination Matrix in 2040 [PCU/day]

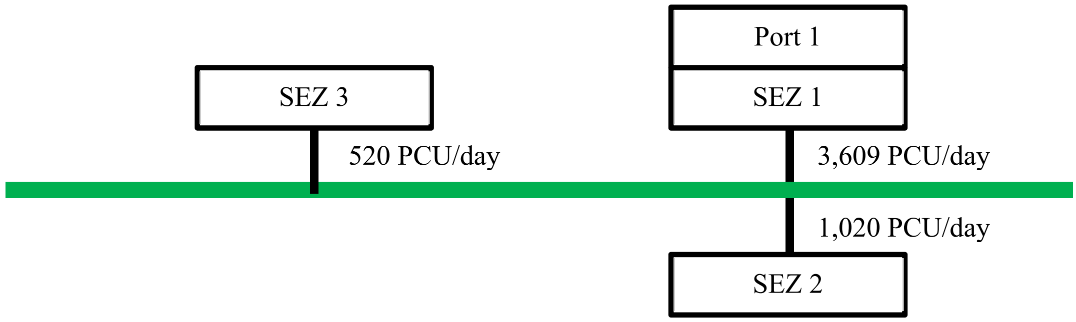
From/To	North	South	Port1&2	Port3	SEZ1	SEZ2	SEZ3	SEZ4
North	0	0	2,557	2,216	1,946	1,411	513	0
South	0	0	928	760	1,889	2,320	533	0
Port1&2	1,746	672	0	0	2,126	568	626	8
Port3	30	70	0	0	1,781	655	457	4
SEZ1	3,873	2,494	1,374	0	0	110	243	81
SEZ2	1,946	2,493	512	5	110	277	327	102
SEZ3	1,049	703	367	12	243	327	91	15
SEZ4	0	0	8	4	81	102	15	0

Source: JICA Design Team

e) Projection of Internal Arterial Roads of the SEZ

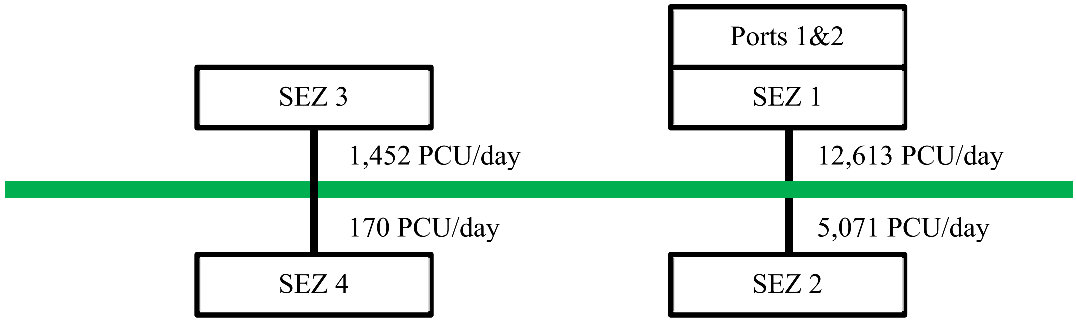
According to the prescribed Origin-Destination Matrix, the traffic volumes of internal arterial roads of the SEZ are shown in Figure 8.4.13 to Figure 8.4.16.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



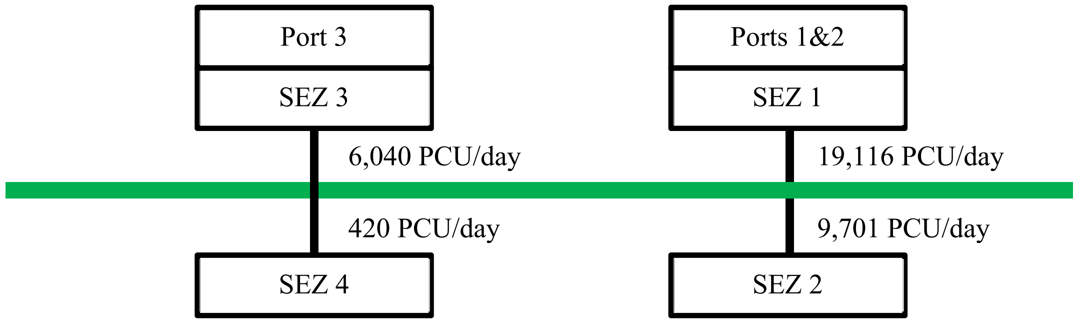
Source: JICA Design Team

Figure 8.4.13 Traffic Volume of Internal Arterial Roads of the SEZ in 2025



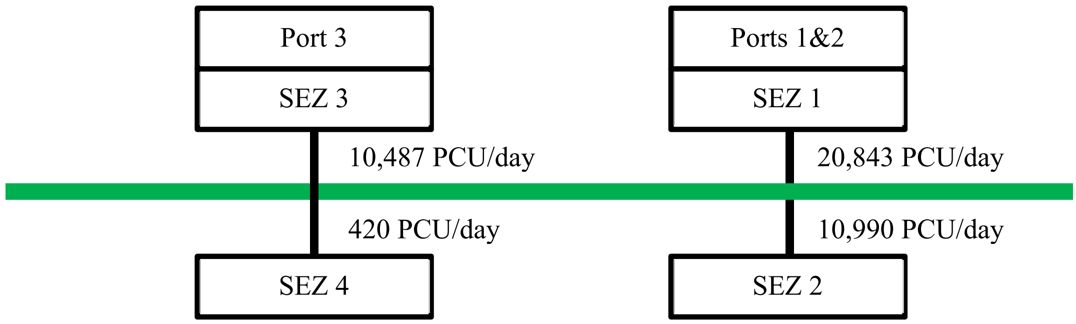
Source: JICA Design Team

Figure 8.4.14 Traffic Volume of Internal Arterial Roads of the SEZ in 2030



Source: JICA Design Team

Figure 8.4.15 Traffic Volume of Internal Arterial Roads of the SEZ in 2035



Source: JICA Design Team

Figure 8.4.16 Traffic Volume of Internal Arterial Roads of the SEZ in 2040

Number of lanes

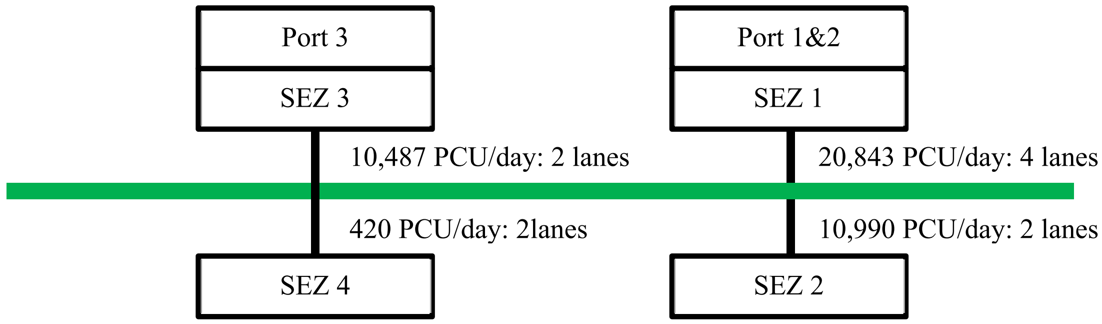
The number of lanes is determined based on the balance between design capacity and projected traffic volume. Table 8.4.12 shows the design capacity.

Table 8.4.12 Cross-section and Capacity

Number of Lane	Carriageway	Road Capacity (PCU/day/both way)	Free Flow Speed (km/h)
6	With median	105,000	40
4	With median	70,000	40
2	With median	15,000	30
	Without median	13,000	30

Source: Mombasa SEZ M/P

According to Figure 8.4.16 and Table 8.4.12, the number of lanes of the internal arterial roads of the SEZ are as shown in Figure 8.4.17.



Source: JICA Design Team

Figure 8.4.17 Traffic Volume of Internal Arterial Roads of the SEZ in 2040

After calculations, there are two lanes of internal arterial roads of the SEZ, except for the SEZ main road. However, it is required to study the necessity of adding climbing lanes to consider cargo traffic or an extra lane for roadside access for the development of roads during the design stage.

8.4.4 Basic Design Policy

The scope of this project includes the basic design of the SEZ main road, with a half clover leaf interchange, and the substation access road.

(1) Alignment and Profile

The biggest problem in the design of a horizontal and vertical alignment is the steep topography. A design for slope protection needs to be developed in order to provide a smooth and safe driving environment. This is necessary, not only to achieve a safe and comfortable driving experience, but also to save construction costs and to secure more area for roadside land use. From this, it is recommended that the two roads be designed considering natural conditions, identified through topographic and geotechnical surveys.

The alignment of the roads affects the RAP and EIA studies. The right-of-way is determined by the design of the alignment and the profile. It is also important to consider the impact of these to the current residents and to the environment for a sustainable and serviceable design.

(2) Cross-section

The cross-section is determined according to the road design manual. Considerations such as the projected traffic volume, opinions from future management body (KeNHA), and required utilities along the roads, such as water and electricity, are some of the main items addressed in the design.

(3) Pavement

Parameters of each paving component are determined by the road design manual. Here, the design load of car traffic that includes trucks and commuter buses are taken into account.

(4) Drainage

The drainage system is designed as a gravity flow method. Its principal feature is an open channel based on the road guidelines in Kenya. The construction of the two roads will not change the existing catchment area. To reduce the construction cost for the drainage facility along the road, the design will allow rainwater discharge to flow into the main drainage route that already exists in the valley.

(5) Intersection

Intersection at STA.14+990 of the MSBR is designed to satisfy traffic demand.

(6) Other Facilities

Traffic control devices, road marking, and median are also designed.

8.4.5 Design Conditions

(1) Introduction

The adoption of proper design standards is required to ensure road safety and driving comfort. To adopt the road criteria based on the Road Design Manuals in Kenya, references are listed as follows:

Design Manual for Roads and Bridges -2nd Draft- (2009), Ministry of Roads:

1) Part I Geometric Design
2) Part II Drainage Design
3) Part III Pavement Design Manual

(2) Road Classification

It is suitable that two roads be defined as rural type. This is because the density of the SEZ area, mainly developed for logistics and industry, is low. Also, traffic passing through the two roads is only for cargo and commuter vehicles and the MSBR is adopted as rural type.

The "Design Manual for Roads and Bridges -2nd Draft-(2009) Part I Geometric Design" defines the seven major classes for rural roads in Kenya. The classifications and characteristics are summarized in Table 8.4.13.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

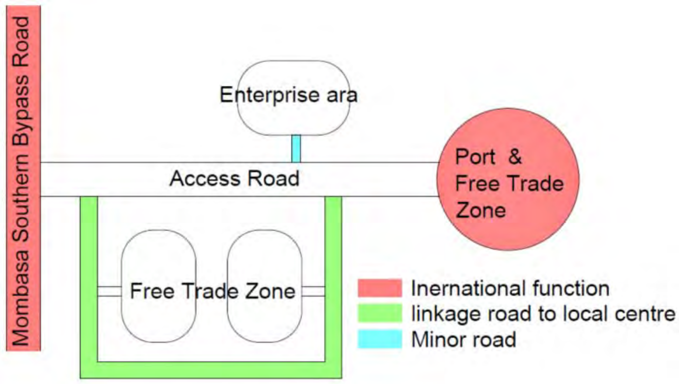
Table 8.4.13 Road Classes in Kenya

Class	Name	Road Characteristic
Class A	Major Arterial or International Roads	Roads forming strategic routes and corridors, connecting international boundaries and international terminals such as international ports.
Class B	Minor Arterial or National Trunk Roads	Roads forming important national routes, linking province headquarters or other important centres to the capital, to each other or to Class A roads.
Class C	Major Collectors or Inter-District Roads	Roads linking district headquarters and other major designated towns to the higher-level network or to each other.
Class D	Minor Collectors or Divisional Roads	Roads forming routes of moderate length, linking divisional headquarters and other minor towns to the District towns or higher-level network.
Class E	Major Local or Minor Feeder Roads	Roads linking one or more markets, location centres or sub-location centres to divisional centres or the higher-level network.
Class F	Minor Local or Minor Feeder Roads	Roads will usually provide a connection to a sub-location centre, a more important market or the higher-level network.
Class G	Local Access or Farm to Market Roads	Roads providing direct access between farming areas and the nearest market or the higher-level road network.

Source: Design Manual for Roads and Bridges -2nd Draft-(2009) Part I Geometric Design

a) SEZ main road

The class of the SEZ main road is identified through its function. The purpose of the SEZ main road is to link the Dongo Kundu Port, Berth 1 and Berth 2, and the MSBR through FTZs and enterprise areas as shown in Figure 8.4.18. The SEZ main road connects Dongo Kundu Port, which is an international port, and MSBR, which is designed as Class B. The road also connects local roads to roadside land such as FTZs and enterprise areas. Thus, the function of the SEZ main road can be considered that Class B or C of rural road is suitable.



Source: JICA Design Team

Figure 8.4.18 Diagram of SEZ main road and Linking Facilities

Through discussion with KeNHA based on the function of the road and surrounding land use in the future, Town of DR3 categorized as Class B is adopted.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Table 8.4.14 Rural Road Design Classes in Kenya

<table>
<tr><th rowspan="2">Design Class</th><th rowspan="2">Capacity [ADT x 1,000/day]</th><th colspan="4">Maximum Design speed (Km/h)</th><th colspan="6" rowspan="2">Functional Classification</th></tr>
<tr><th>Flat</th><th>Rolling</th><th>Mountainous</th><th>Town</th></tr>
<tr><td>DR1</td><td>> 2.5</td><td>110</td><td>90</td><td>70</td><td>50</td><td rowspan="3">Major Arterial 'A'</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>DR2</td><td>1.5 to 2.5</td><td>110</td><td>90</td><td>70</td><td>50</td><td rowspan="3">Minor Arterial 'B'</td><td></td><td></td><td></td><td></td></tr>
<tr><td>DR3</td><td>0.5 to 1.5</td><td>110</td><td>85</td><td>60</td><td>50</td><td rowspan="3">Major Collector 'C'</td><td></td><td></td><td></td></tr>
<tr><td>DR4</td><td>0.15 to 0.5</td><td>80</td><td>65</td><td>50</td><td>40</td><td></td><td rowspan="3">Minor Collector 'D'</td><td></td><td></td></tr>
<tr><td>DR5</td><td>0.05 to 0.15</td><td>80</td><td>65</td><td>50</td><td>40</td><td></td><td></td><td rowspan="2">Major Local 'E'</td><td></td></tr>
<tr><td>DR6</td><td><0.05</td><td>50</td><td>40</td><td>30</td><td>30</td><td></td><td></td><td></td><td>Minor Local 'F'</td></tr>
</table>

Source: Ministry of Road, Kenya

b) Substation access road

The substation access road is constructed for a limited use. Therefore, this is classified as Class G.

(3) Access Control

a) SEZ main road

The SEZ main road is classified under Class C. By definition, the SEZ main road is determined to have "full access control". This means that traffic is limited and only selected public roads have access to this. A direct private access connection is also prohibited. All traffic to FTZs and enterprise areas through the SEZ main road is permitted from inner arterial roads where intersections are required to be regulated.

b) Substation access road

The substation access road is classified under Class G. Under this definition, the substation access road is determined to have "unrestricted access". This means that the manual does not limit any traffic in accessing the substation access road. However, access to the roadside is recommended to be limited only to people involved in the maintenance of the substation.

(4) Terrain

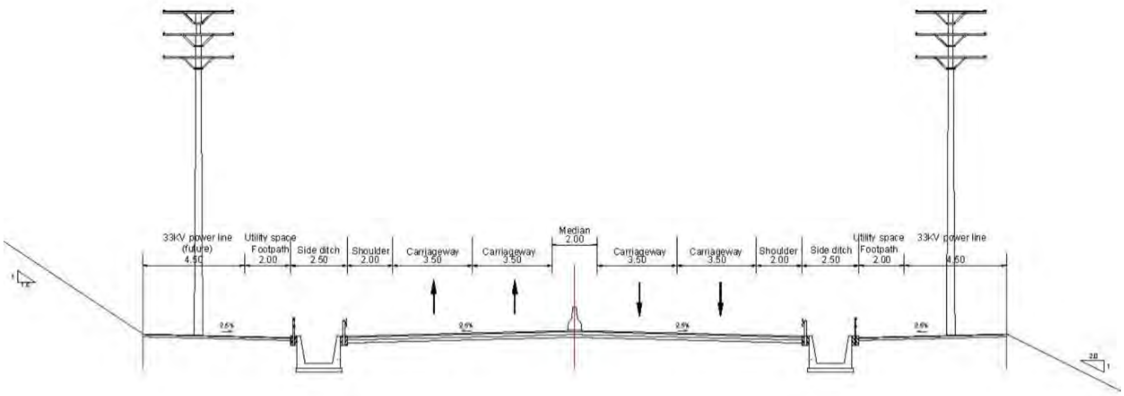
The terrain is suitable to be defined as mountainous because the designed roads within the SEZ are greatly restricted by the steep topography. Even if the maximum parameters described in Kenyan standards were adopted, wide slope protection methods or retaining walls are needed to construct roads within the SEZ.

(5) Cross-section

The cross-section is determined according to the SEZ development plan based on the general plan according to the Kenyan Standard.

i) General plan

A general cross-section according to the Kenyan Standard is shown in Figure 8.4.19.



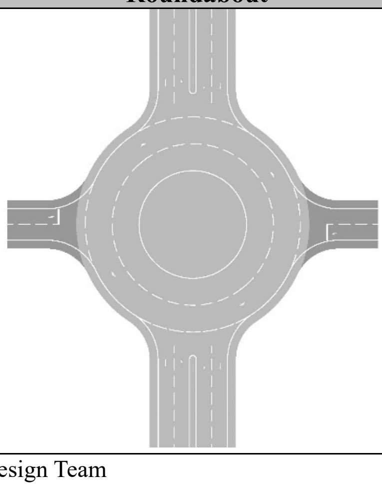
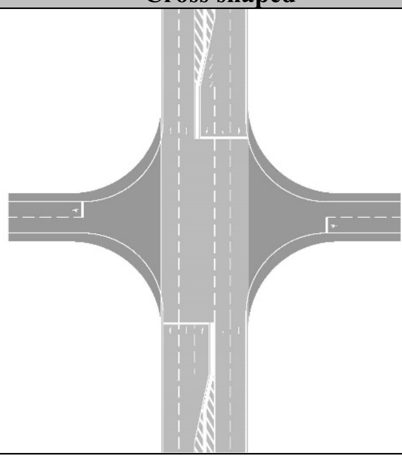
Source: JICA Design Team

Figure 8.4.19 General Typical Cross-section

ii) Type of At-Grade Intersections

It is estimated to install almost ten intersections on the SEZ main road in order to access to the planned FTZ and enterprise areas. There shall be intersections to access inner collector roads within each zone because the access control of the SEZ main road is full access control. If the typical intersection type is adopted as roundabout which is the most common type in Kenya but required area is larger, the locations of roundabout should be decided because reconstruction cost is quite high after construction of the SEZ main road without intersections (as shown in Table 8.4.15). But the location of intersections cannot be finalized because the developers of zones roadside are not decided. According to it, type of at-graded intersections shall be adopted as cross shaped intersections.

Table 8.4.15 Comparison of Intersection Type

	Roundabout	Cross shaped
Drawing ■: area to be constructed by this project ■: area to be constructed after this project		

Source: JICA Design Team

iii) Consideration of Widening

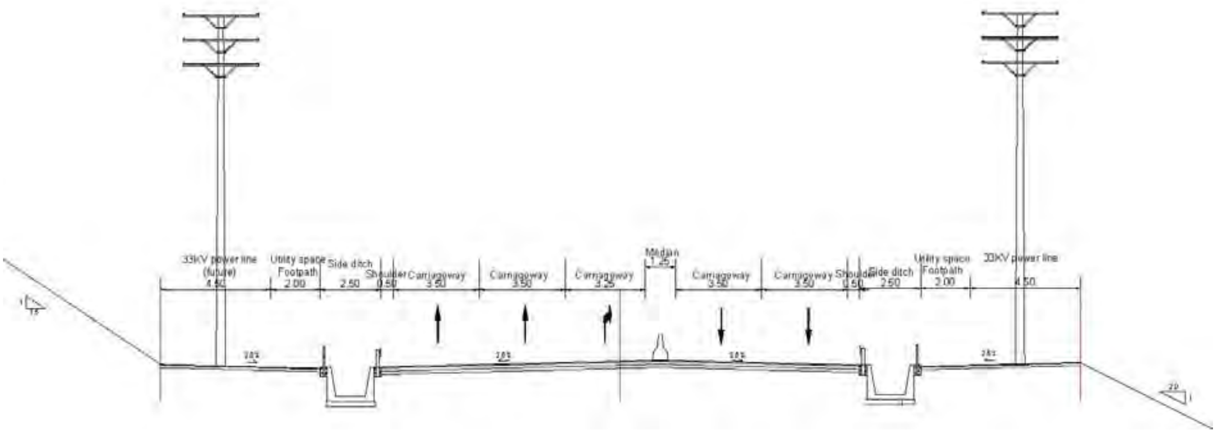
In order to install right-turn lane in the intersection, road widening is required. For widening, there are two options; 1) to widen when the exact locations of intersections are decided after the loan project, and 2) to secure enough width in the loan project to avoid economic burden in the future (shown in Table 8.4.16).

Table 8.4.16 Comparison of Widening Policy

	Option 1	Option 2
Description	to widen when the exact locations of intersections are decided after completion of the SEZ main road	to secure enough width in the SEZ main road construction to avoid economic burden in the future
Advantage	Amount of yen loan for the SEZ main road project shall be minimized.	Feasibility of the SEZ development is secured because no large reconstruction cost shall not be required.
Disadvantage	It may be ineffective because structures which will be constructed by Japanese loan project should be removed and reconstructed to widen later. And budget of Kenyan government or investment by developer is required for the reconstruction. It can affect feasibility and planned schedule of the SEZ development.	It may be ineffective because enough width shall be secured in all alignment where intersections can be installed.

Source: JICA Design Team

With considering to whole of the SEZ project, option 1 may not be appropriate from the view of the SEZ development feasibility. In the case of selecting option 2, it is required to be as effective as possible for the initial construction of the Japanese loan project. In this context, summarized width of median and shoulders are proposed as 5.5m which is the minimum width at the intersections to install right-turn lane as shown in Figure 8.4.20.



Source: JICA Design Team

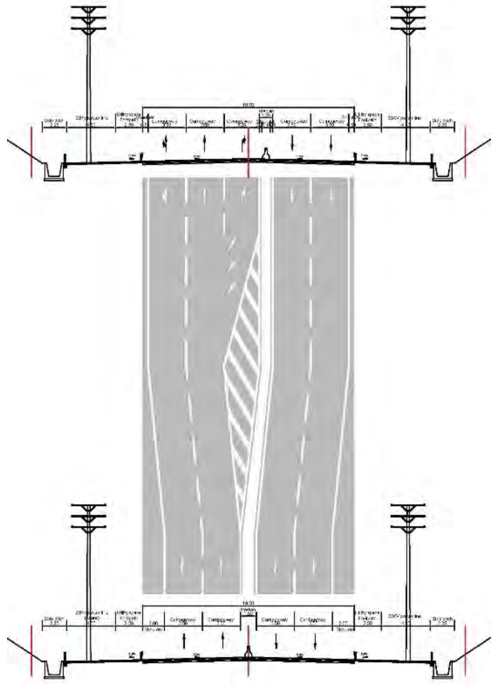
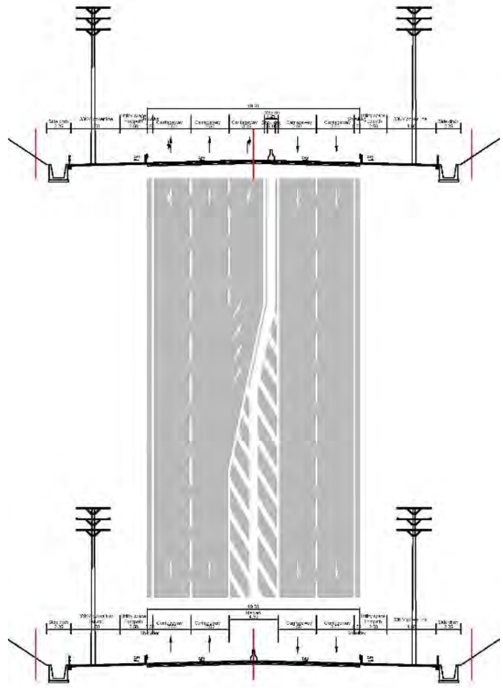
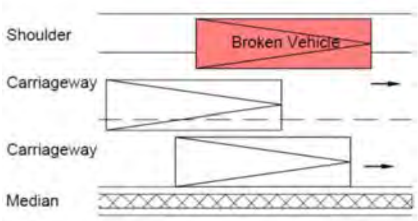
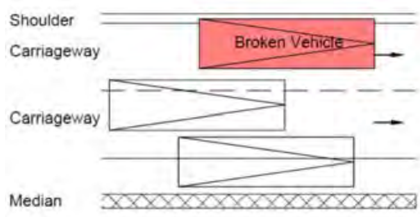
Figure 8.4.20 Cross-section at Intersection with Consideration of Widening

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

iv) Median and Shoulder

There will be almost ten intersections as described. Driving shift and addition of right-turn lane with tapers are required near intersections. In order to reduce accident risks and cost for additional work, combination of narrow shoulders and wide median is proposed as shown in Table 8.4.17.

Table 8.4.17 Comparison of Combination of Median and Shoulders

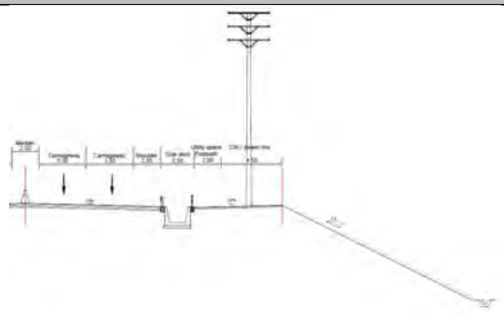
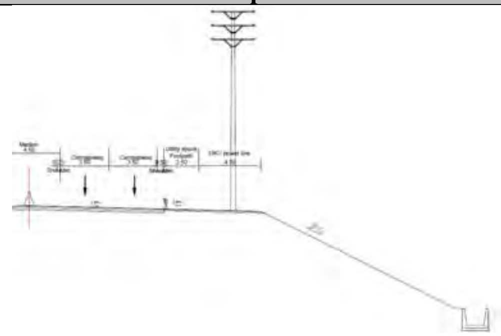
	General	Proposal
Description	At general section median: 1.5m, shoulder (one side): 2.0m, total 5.5m At intersection median: 1.25m, shoulder (one side): 0.5m total 2.25m	At general section median: 4.5m, shoulder (one side): 0.5m, total 5.5m At intersection median: 1.25m, shoulder (one side): 0.5m total 2.25m
Drawing		
Accident risks	It is inferior because all vehicles must be sifted near intersections.	It is superior because only right-turn vehicles must be sifted near intersections.
Additional work	Median and marking relocation must be required. Total length of median and marking is longer because the ghost island taper for sift is longer than the taper for installation of right-turn lane	Median and marking relocation must be required. Total length of median and marking is shorter.
Passing for emergency vehicle or aside broken vehicle	It is easier and safer to pass because the sift width is smaller 	It may cause congestion because it is difficult to pass safely at high speed. 

Source: JICA Design Team

v) Side Ditches

Side ditches are commonly installed between carriageway and non-motorized lane or outside of typical cross-section. In order to reduce construction cost, side ditches at filling slope side are proposed to allocate at the bottom of filling slopes as shown in Table 8.4.18.

Table 8.4.18 Comparison of Side Ditches Location

	General	Proposal
Drawing		
Cost	More cost due to more filling earthwork	Less cost because of less filling earthwork
Drainage	Better because rainfall is directly flown from carriageways and footpaths to ditches.	Worse because all rainfall at filling section are flown on footpaths and slopes. However, stability of filling slope is not affected because slope will be covered by shotcrete due to geological conditions of filling materials.

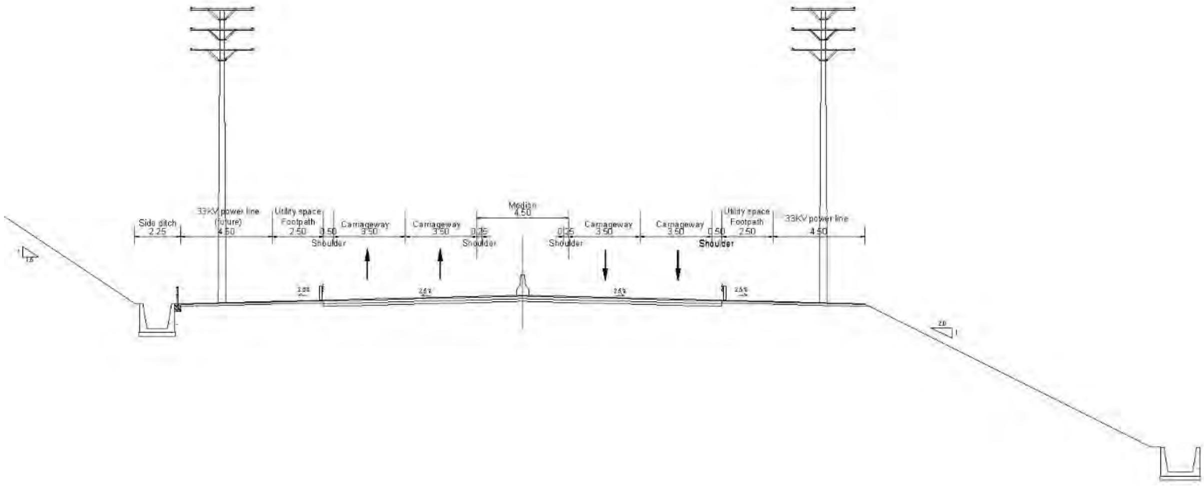
Source: JICA Design Team

vi) Right of Way

Width of ROW is defined as from 40 to 60m for Class B. Wider ROW is commonly required to secure lands for future widening and utilities installation. However, lane number of the SEZ main road is determined based on the projection of traffic demand after completion of the SEZ development, and the demand shall not be exceeded because land use along the SEZ main road are restricted to special purposes according to the SEZ operation. And also, utility spaces for the SEZ development are prepared in the SEZ main road. On the other hand, wider ROW affects financial feasibility of roadside development because it reduces sellable lands. According to these conditions, proper width of ROW for the SEZ main road shall be 40m.

vii) Adopted Cross-section

According to study from view of traffic and the SEZ development, cross-section is proposed as shown in Figure 8.4.21.



Source: JICA Design Team

Figure 8.4.21 Proposed Cross-section

(6) Adopted Design Parameters

i) SEZ main road

Main alignment

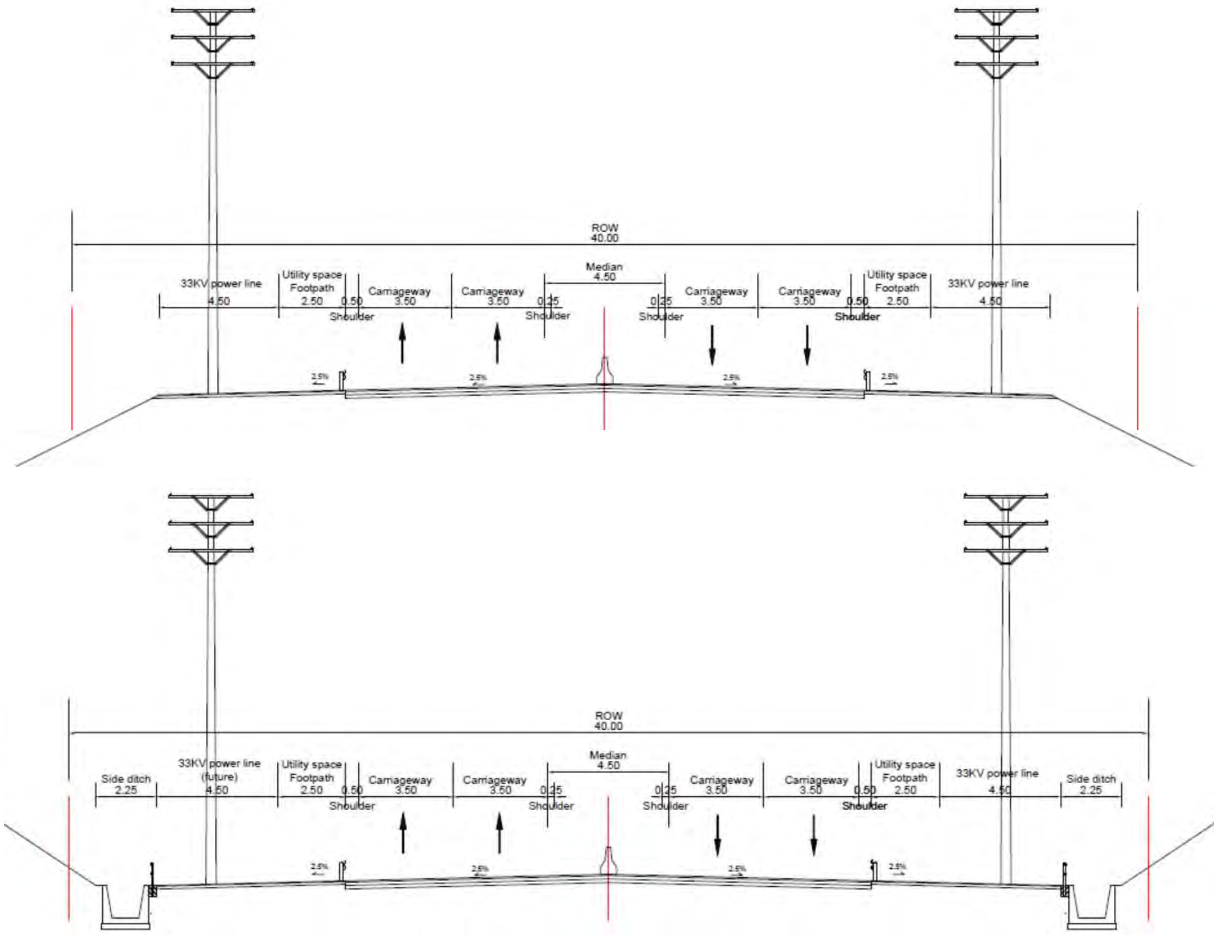
Adopted design parameters for the SEZ main road are summarized in Table 8.4.19. Median and footpath are not required for rural roads, but it is still suitable to construct them for safety. The footpath will be separated physically by installing a guardrail between the path and carriageway.

Table 8.4.19 Summaries of Adopted Design Parameters for SEZ main road

Design Element		Standard (above: Kenyan below: Japanese)	Adopted Parameter	Remarks
Road classification		- -	Town of DR3 Class III-2	
Design speed		60-110km/h 40-60km/h	60km/h	According to Kenyan and Japanese standard
Access Control		Full or Partial -	Full	No driveway facing to the SEZ main road to access roadside directly should be allowed. All traffic to roadside should be from inner collector road within each zone and the number of intersections on the SEZ main road should be minimized.
Cross-section				
Lane	Number of lanes	- -	4 lanes	According to traffic demand forecast
	Width	3.4m 3.5m	3.5m	According to Japanese standard (3.25m + required widening on curve: 0.25m)
	Cross slope	2.5-4.0% 1.5-2.0%	2.5%	According to Kenyan standard
Median	Width	1.5m≦ 1.0m≦	4.5m	For right lanes, shoulder and median at intersections

Design Element		Standard (above: Kenyan below: Japanese)	Adopted Parameter	Remarks
Shoulder	Width for left side	2.0m 0.5m≦	0.5m	According to Japanese standard (2.0m is not required because of the four (4) lanes and no parking are allowed due to full access control)
	Width for median side	- 0.25m≦	0.25m	
	Cross slope	2.5-4.0% 1.5-2.0%	2.5%	According to Kenyan standard
Combined gradient (Cross slope and vertical gradient)		- ≦10.5%	≦10.5%	According to Japanese standard to be on the safe side
Superelevation rate		≦6% ≦10%	≦6.0%	According to calculation of combined gradient
Rate of change of superelevation		≦1/167 ≦1/125	≦1/167	According to Kenyan standard
Non-motorized lane	Width	2.0m≦ 2.0m≦	2.5m	Grade separated from carriageway. Effective width: 2.0m+ guardrail:0.5m
	Cross slope	2.5%≦ 1.5-2.5%	2.5%	According to Kenyan and Japanese standard
Drainage	Width	- -	2.25m	According to drainage design
Utility space	Width	- -	(2.5+4.5m)[*2]	2.5m: for water and communication line under footpath, 4.5m: for 33kV distribution line
Side slope	Fill	- -	V:H=1:2	According to geological survey
	Cut	- -	V:H=1:1.5	
Vertical clearance		5.5m 4.5m	5.5m	According to Kenyan standard
Road reserve		40-60m -	40m	According to Kenyan standard
Horizontal Alignment				
Curve radius		135m≦ 150m≦	150m≦	According to Japanese standard
Curve length		- 100m≦	100m≦	According to Japanese standard
Clothoid parameter		R/2≦A≦R 50m≦L	50m≦L	According to Japanese standard
Stopping site distance		85m≦ 75m≦	85m≦	According to Japanese standard
Vertical Alignment				
Gradient		0.5-8.0% 0.3-7.0%	0.5-4.0%	Minimum: according to Kenyan standard. Maximum: according to criteria shown in 0
Vertical curve	Crest radius	- 1400m≦	1400m≦	According to Japanese standard
	Sag radius	570m≦ 1000m≦	1000m≦	According to Japanese standard
	Curve length	- 50m≦	50m≦	According to Japanese standard

Source: JICA Design Team



Source: JICA Design Team

Figure 8.4.22 Typical Cross-section of the SEZ main road
(above: filling section, below: cut section)

Steep Section

To avoid adverse effect of traffic safety and capacity by causing significant increases in speed difference between cars and heavy vehicles in steep gradients, length of steep section should be limited. According to the Kenyan standard, corresponding fall in the design speed applicable to C Class roads shall be less than 20 km/h. The criteria are shown in Table 8.4.20.

Table 8.4.20 Maximum Length of Steep Gradients Section

Section	Approaching Speed	Applicable Speed	Gradient	Maximum length
Main alignment	60km/h	40km/h	4%	670m

Source: Effect of length and steepness of grade speed on the speed of typical heavy vehicles in Kenya of Road Design Manual Part 1

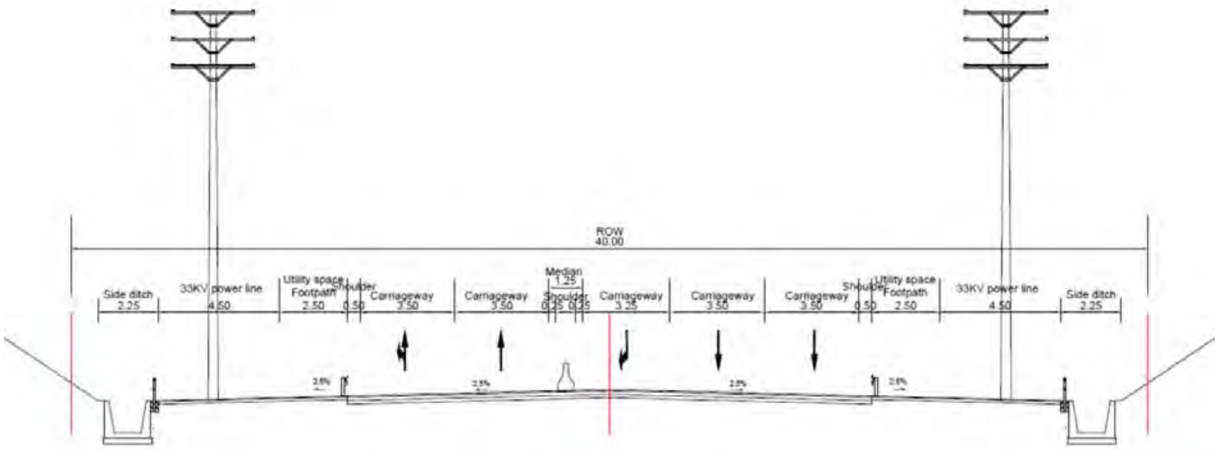
At Intersections

Adopted design parameters for the SEZ main road at intersections are summarized in Table 8.4.21. At the intersections, the median is narrowed and an additional lane for turning right is developed.

Table 8.4.21 Summaries of Adopted Design Parameters for SEZ main road at Intersections

Design Element		Above: Parameter at non-intersection Below: Japanese	Adopted Parameter	Remarks
Cross-section				
Lane	Number of Lanes	4 lanes	5 lanes	To add a lane for turning right
	Width for Right-out	-	3.25m	According to Japanese standard (no widening required around intersection because the curve radius is more than 600m as described below)
Median	Width	4.5m	1.25m	As minimum width to provide additional lane for turning right
Horizontal Alignment				
Curve Radius	For Intersection	150m≦	600m≦	According to Kenyan standard
Stopping site distance		85m≦	105m≦	According to Japanese standard
Vertical Alignment				
Gradient		0.5-3.0% 0.3-2.5%	0.5-2.5%	Minimum: according to Kenyan standard. Maximum: according to Japanese standard

Source: JICA Design Team



Source: JICA Design Team

Figure 8.4.23 Typical Cross-section of the SEZ main road at Intersections

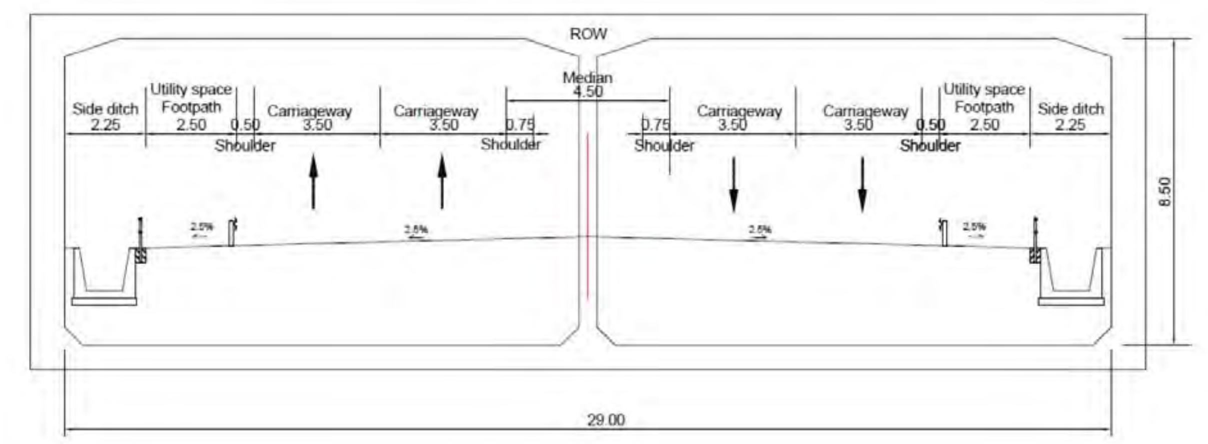
Box culvert under the MSBR

SEZ main road connects to the MSBR as half clover leaf interchange. The structure of the underpass is box culvert under the MSBR as shown in Table 8.4.22 and Figure 8.4.24. The internal size of the box culvert is as follows: height is 8.5m, and width is 29.0m. Necessity of lighting shall be considered in detailed design.

Table 8.4.22 Summaries of Adopted Design Parameters for Box Culvert under the MSBR at STA.14+990

Design Element		Standard (above: Kenyan below: Japanese)	Adopted Parameter	Remarks
Road classification		- -	Town of DR3 Class III-2	
Design speed		60-110km/h 40-60km/h	60km/h	According to Kenyan and Japanese standard
Cross-section				
Lane	Number of Lanes	- -	4 lanes	According to traffic demand forecast
	Width	3.4m 3.5m	3.5m	According to Japanese standard (3.25m + required widening on curve: 0.25m)
	Cross slope	2.5-4.0% 1.5-2.0%	2.5%	According to Kenyan standard
Median	Width	1.5m≦ 1.0m≦	4.5m	For right lanes, shoulder and median at intersections. It can be inclusive width for structure of box culvert.
Shoulder	Width for left side	2.0m 0.5m≦	0.5m	According to Japanese standard (2.0m is not required because 4 lanes and no parking are allowed due to full access control)
	Width for median side	- 0.75m≦	0.75m	According to Japanese standard
	Cross slope	2.5-4.0% 1.5-2.0%	2.5%	According to Kenyan standard
Non-motorized lane	Width	2.0m≦ 2.0m≦	2.5m	Grade separated from carriageway. Effective width: 2.0m+ guardrail:0.5m
	Cross slope	2.5%≦ 1.5-2.5%	2.5%	According to Kenyan and Japanese standard
Drainage	Width	- -	2.25m	According to drainage design
Utility space	Width	- -	(2.5m)	2.5m: for water and communication line under footpath.
Vertical clearance		5.5m 4.5m	5.5m	According to Kenyan standard
Length		- -	45m	According to plan
Vertical Alignment				
Gradient		0.5-8.0% 0.3-7.0%	1.5%	

Source: JICA Design Team



Source: JICA Design Team

Figure 8.4.24 Typical Cross-section of the Box Culvert under the MSBR at STA.14+990

Ramps

The design parameters of ramps are basically based on the MSBR detailed design and the Japanese standard because the Kenyan standard only has a few parameters specialized for ramps. Table 8.4.23 and Table 8.4.24 show adopted parameters for ramps.

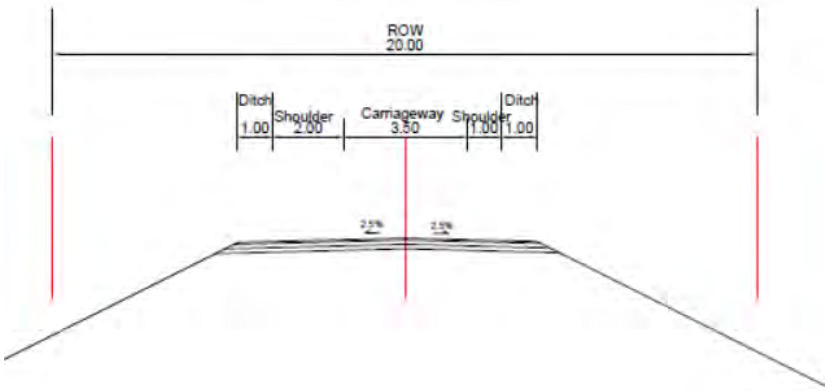
Table 8.4.23 Summaries of Adopted Design Parameters for Ramps

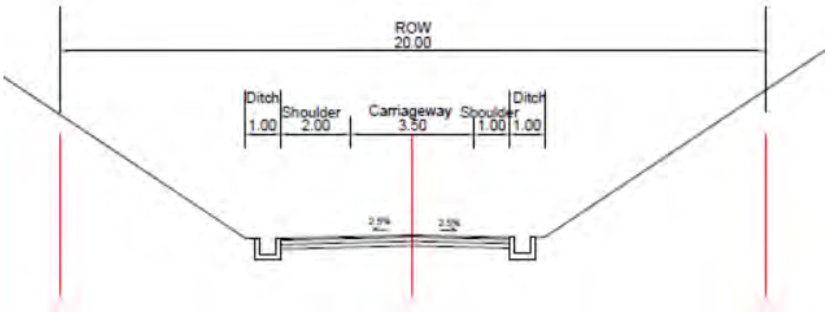
Design Element		Standard (above: MSBR below: standard)	Adopted Parameter	Remarks
Road classification		- -	Town of DR3	
Design speed		50km 35 - 50km/h	50km/h	According to the MSBR detailed design
Cross-section				
Lane	Number of Lanes	1 lane (oneway) -	1 lane (oneway)	According to the MSBR detailed design and traffic demand forecast
	Width	3.5m 3.5m	3.5m	According to the MSBR detailed design (including required widening on curve)
	Cross slope	2.5% 1.5-2.0%,2.5-4.0%	2.5%	According to the MSBR detailed design
Shoulder	Width for left side	2.0m 1.5m≦	2.0m	According to the MSBR detailed design
	Width for right side	1.0m 0.75m≦	1.0m	According to the MSBR detailed design
	Cross slope	2.5% 1.5-2.0%,2.5-4.0%	2.5%	According to the MSBR detailed design
Combined gradient (Cross slope and vertical gradient)		- ≦11.5%	≦11.5%	According to Japanese standard
Superelevation rate		≦6.0% ≦10.0%	≦10.0%	According to Japanese standard
Rate of change of superelevation		≦1/150 ≦1/115	≦1/150	According to Kenyan standard

Design Element		Standard (above: MSBR below: standard)	Adopted Parameter	Remarks
Drainage	Width	1.0m -	1.0m	According to the MSBR detailed design and drainage design
Side slope	Fill	V:H=1:2 -	V:H=1:2	According to the MSBR detailed design and geological survey
	Cut	V:H=1:1.5 -	V:H=1:1.5	
Road Reserve		- -	20m	To secure sight distance of Kenyan standard
Horizontal Alignment				
Curve radius	Alignment	90m≦ 100m≦	100m≦	According to Japanese standard
	Around nose	90m≦ 170m≦	170m≦	According to Japanese standard
Curve length		- 80m≦	80m≦	According to Japanese standard
Clothoid parameter		R/2≦A≦R 40m≦L	40m≦L	According to Japanese standard
Stopping site distance		60m≦ 55m≦	60m≦	According to Japanese standard
Acceleration lane	Type	Parallel type Parallel or taper type	Parallel	According to the MSBR detailed design
	Taper	55m 50m	60m	According to the MSBR detailed design
	Acceleration lane	160m 160m	160m	According to the MSBR detailed design
Deceleration lane	Type	Taper type Taper type	Taper	According to the MSBR detailed design
	Taper	1:15-1:20 1:15-1:20	1:15-1:20	According to the MSBR detailed design
	Deceleration lane	80m 80m	80m	According to the MSBR detailed design
Vertical Alignment				
Gradient		0.5-9.0% 0.3-8.0%	0.5-4.0%	Minimum: according to Kenyan standard. Maximum: according to criteria shown in Table 8.4.20
Vertical curve	Crest radius	900m≦ 800m≦	900m≦	According to the MSBR detailed design
	Sag radius	1100m≦ 700m≦	1100m≦	According to the MSBR detailed design
	Curve length	60m 40m≦	60m≦	According to the MSBR detailed design

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc





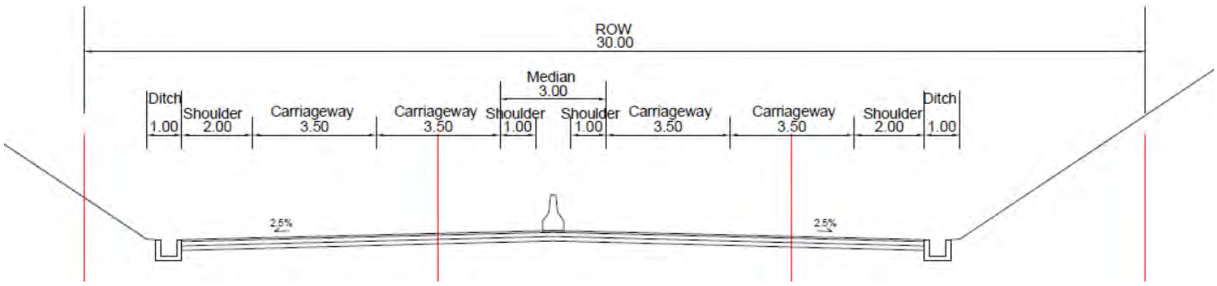
Source: JICA Design Team

Figure 8.4.25 Typical Cross-section of the Ramps (above: filling section, below: cut section)

Table 8.4.24 Summaries of Adopted Design Parameters for Ramps at Intersections

Design Element	Above: Parameter at non-intersection Below: Japanese	Adopted Parameter	Remarks
Cross-section			
Number of lanes	1 lane (oneway)	2 lanes (oneway)	For an additional lane for turning right or acceleration lane
Horizontal Alignment			
Curve radius	100m≦	500m≦	According to Japanese standard
Stopping site distance	60m≦	80m≦	According to Japanese standard
Vertical Alignment			
Gradient	0.5-3.0% 0.3-2.5%	0.5-2.5%	Minimum: according to Kenyan standard. Maximum: according to Japanese standard

Source: JICA Design Team



Source: JICA Design Team

Figure 8.4.26 Typical Cross-section of the Ramps at Intersections

ii) Substation access road

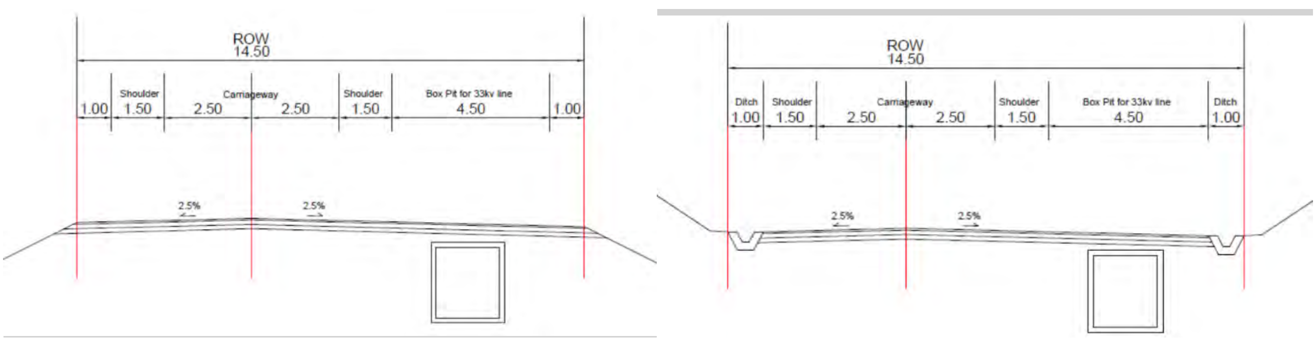
Adopted design parameter for elements for the substation access road is summarized in Table 8.4.25.

Table 8.4.25 Summaries of Adopted Design Parameters for Substation Access Road

Design Element		Standard (above: Kenyan below: Japanese)	Adopted Parameter	Remarks
Road classification		- -	Class F Class III-5	
Design speed		30-50km/h 20-40km/h	40km/h	According to Kenyan and Japanese standard
Cross-section				
Lane	Width	5.0m 4.0m	5.0m (bothway)	According to Kenyan standard
	Cross slope	2.5-4.0% 1.5-2.0%	2.5%	According to Kenyan standard
Shoulder	Width for left side	1.5m 0.5m≦	1.5m	According to Kenyan standard
	Cross slope	2.5-4.0% 1.5-2.0%	2.5%	According to Kenyan standard
Combined gradient (Cross slope and vertical gradient)		- ≦11.5%	≦11.5%	According to Japanese standard
Superelevation rate		≦6% ≦10%	≦6.0%	According to Kenyan standard
Rate of change of superelevation		≦1/143 ≦1/100	≦1/143	According to Kenyan standard
Drainage	Width	- -	1.0m	According to drainage design
Utility space	Width	- -	8.5m*2	For duct of 33kV distribution line
Side slope	Fill	- -	V:H=1:2	According to geological survey
	Cut	- -	V:H=1:1.5	
Road Reserve		20m -	30m	According to total width of the substation access road

Design Element		Standard (above: Kenyan below: Japanese)	Adopted Parameter	Remarks
Horizontal Alignment				
Curve radius		55m≦ 60m≦	60m≦	According to Japanese standard
Curve length		- 70m≦	70m≦	According to Japanese standard
Stopping site distance		50m≦ 55m≦	55m≦	According to Japanese standard
Vertical Alignment				
Gradient		0.5-10.0% 0.3-10.0%	0.5-10.0%	According to Kenyan standard
Vertical curve	Crest radius	- 450m≦	450m≦	According to Japanese standard
	Sag radius	390m≦ 450m≦	450m≦	According to Japanese standard
	Curve length	- 35m≦	35m≦	According to Japanese standard

Source: JICA Design Team



Source: JICA Design Team

Figure 8.4.27 Typical Cross-section of the Substation Access Road (left: filling section, right: cut section)

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

8.4.6 Basic Design

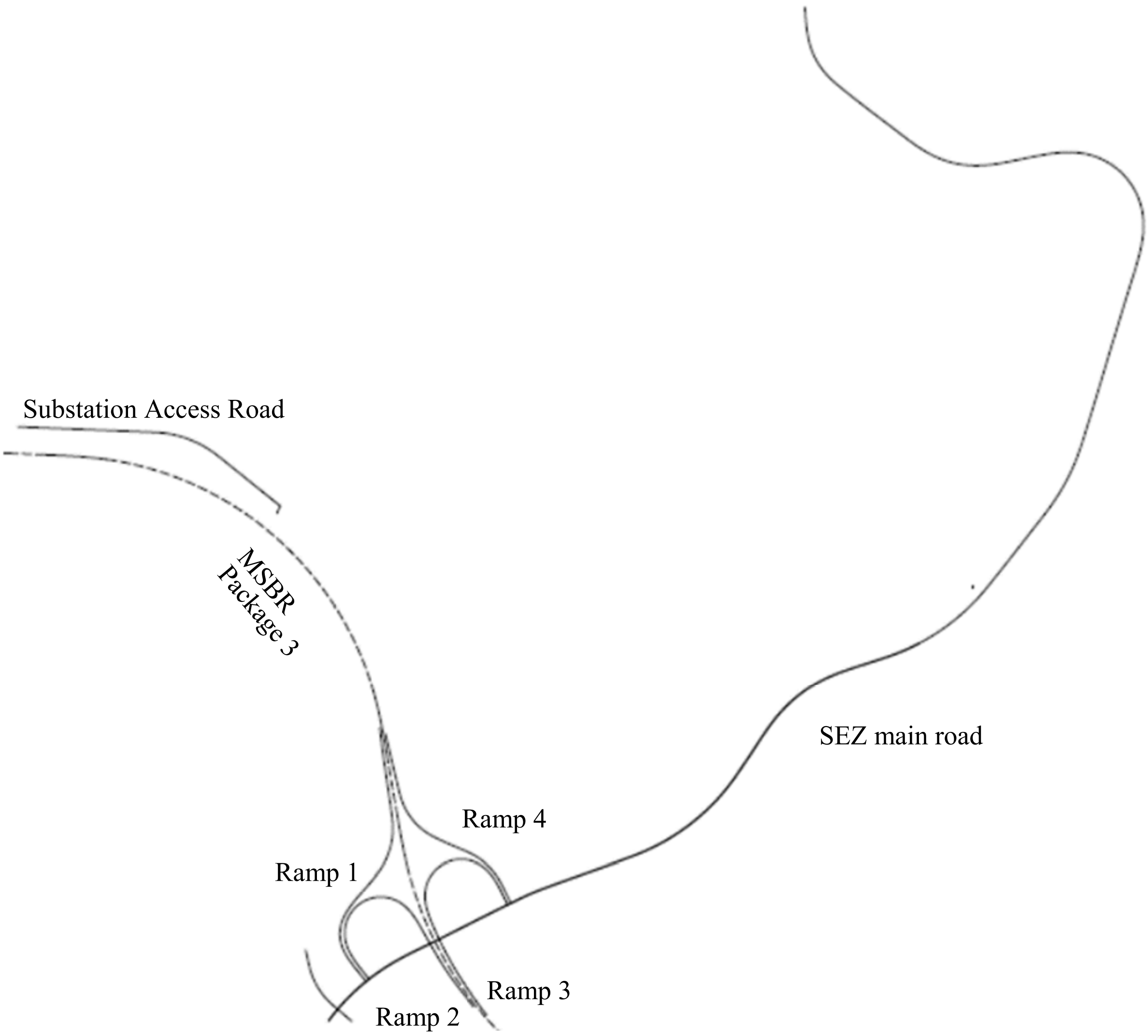
(1) Geometric Design

Table 8.4.26 and Figure 8.4.28 show geometric design elements.

Table 8.4.26 Summaries of Geometric Design

Road	STA.		Remark
	Beginning	End	
SEZ main road	0+000.000	4+616.795	4 lanes, bothway
Ramp 1	0+000.000	0+767.359	1 lane, oneway
Ramp 2	0+000.000	0+714.568	1 lane, oneway
Ramp 3	0+000.000	0+722.862	1 lane, oneway
Ramp 4	0+000.000	0+618.351	1 lane, oneway
Substation Access Road	0+000.000	0+789.450	2 lanes, bothway

Source: JICA Design Team



Source: JICA Design Team

Figure 8.4.28 Key plan

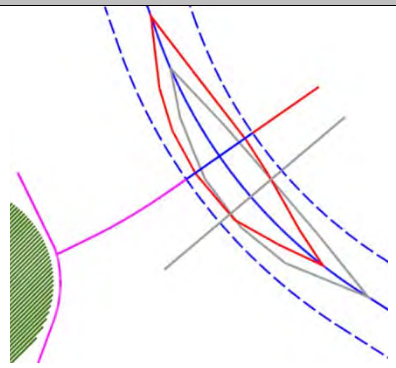
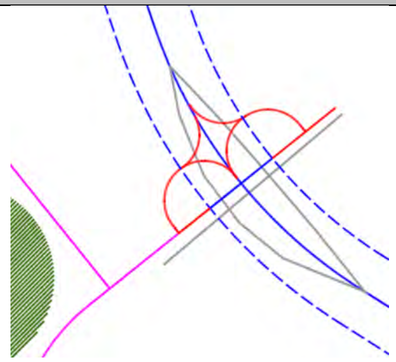
(2) SEZ main road and Ramps

i) Interchange

a) Location and Interchange Type of Southern Intersection

As described in Clause 8.4.2, distance between southern intersection and diamond interchange at STA.16+000 of the MSBR should be more than 220m according to the Kenyan standard. It is required 1) to move the location from STA. 15+100 to north as possible, and 2) to reconsider a interchange type of southern intersection. In addition, it is also important to minimize influences on the MSBR project because the construction of the MSBR will be started soon. As comparison of two alternatives shown in Table 8.4.27, a half clover leaf interchange at STA. 14+990 is adopted.

Table 8.4.27 Comparison of Location and Interchange Type of Southern Intersection

		Alternative1	Alternative 2
Diagram --Row of MSBR —proposal of SEZ M/P [Constructed by MSBR] —MSBR and Box culvert for underpass [Constructed by SEZ] —new interchange —internal road ● Kaya			
Description		Diamond interchange as proposal of the Mombasa SEZ M/P at STA.14+880	Half clover leaf interchange at STA. 14+990
Road	Capacity	Insufficient	Enough
	Comfortability	Worse	Better
Land use	Area of IP	More	Less
Cost	MSBR project	Higher	Lower
	SEZ project	Lower	Higher
Evaluation		Fair	Recommended

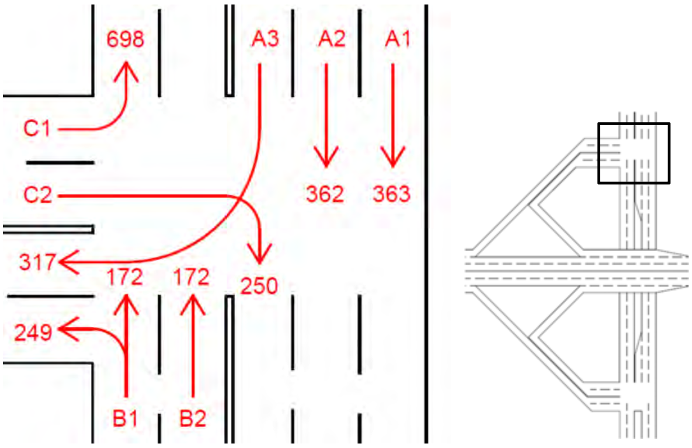
Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

b) Analysis of Traffic Flow of At-grade Intersections of Ramps

A half clover leaf interchange has two at-grade intersections between the ramps and the sub-road (SEZ main road). Traffic flow at these intersections is analyzed to identify countermeasures against congestions.

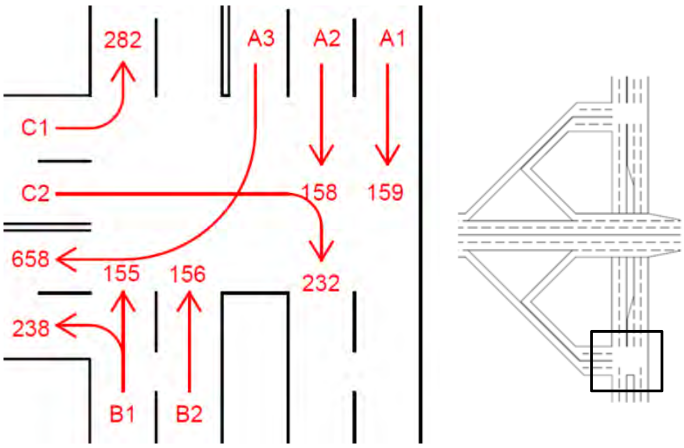
Figure 8.4.29 and Figure 8.4.30 show the peak time traffic volume [PCU/h] of two at-grade intersections along the SEZ main road in 2040 in the form of a OD matrix.



[PCU/h]

Source: JICA Design Team

Figure 8.4.29 Projected Traffic Volume at Northern T-shape Intersection of Ramps in 2040



[PCU/h]

Source: JICA Design Team

Figure 8.4.30 Projected Traffic Volume at Southern T-shape Intersection of Ramps in 2040

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Intersection capacity is calculated as shown in Table 8.4.28 and Table 8.4.29 according to the capacity calculation for non-signalized intersections of the Japanese guideline "Planning and Design of At-graded Intersection, 2007".

Table 8.4.28 Capacity Calculation for Northern Non-Signalized T-shape Intersection

	A1&A2	A3	B1	B2	C1	C2
Description	Straight	Right-out	Straight & Left out	Straight	Left-in	Right-in
Critical gap [second]	-	5.5	-	3.0	6.0	8.0
2025	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	128	52	48	30	121	25
Cross traffic volume [vehicle/h]	-	30	-	-	22	51
Lane capacity [PCU/h]	4,000	1,104	2,000	2,000	1,034	692
Reserve Capacity [PCU/h]	3,872	1,052	1,952	1,970	913	667
Delay	None	None	None	None	None	None
Queueing length [m]	-	7	-	-	-	4
2030	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	435	195	224	117	397	105
Cross traffic volume [vehicle/h]	-	120	-	-	100	239
Lane capacity [PCU/h]	4,000	989	2,000	2,000	930	447
Reserve Capacity [PCU/h]	3,565	794	1,776	1,883	533	342
Delay	None	None	None	None	Very little	Very little
Queueing length [m]	-	27	-	-	-	17
2035	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	652	304	395	172	612	208
Cross traffic volume [vehicle/h]	-	190	-	-	176	433
Lane capacity [PCU/h]	4,000	907	2,000	2,000	838	275
Reserve Capacity [PCU/h]	3,348	603	1,605	1,828	226	67
Delay	None	Very little	None	None	Little	Much
Queueing length [m]	-	47	-	-	-	33
2040	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	725	317	421	172	698	250
Cross traffic volume [vehicle/h]	-	192	-	-	186	461
Lane capacity [PCU/h]	4,000	905	2,000	2,000	828	258
Reserve Capacity [PCU/h]	3,275	588	1,579	1,828	130	8
Delay	None	Very little	None	None	Delayed	Very much
Queueing length [m]	-	50	-	-	-	39

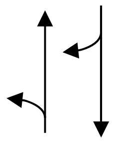
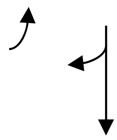
Delay: None, Very little, Little, Delayed, Much, Very much in good evaluation order
Source: JICA Design Team

Table 8.4.29 Capacity Calculation for Southern Non-Signalized T-shape Intersection

	A1&A2	A3	B1	B2	C1	C2
Description	Straight	Right-out	Straight & Left out	Straight	Left-in	Right-in
Critical gap [second]	-	5.5	-	3.0	-	8.0
2025	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	33	121	38	13	52	18
Cross traffic volume [vehicle/h]	-	16	-	-	16	75
Lane capacity [PCU/h]	4,000	1,123	2,000	2,000	1,042	683
Reserve Capacity [PCU/h]	3,967	1,002	1,962	1,987	990	620
Delay	None	None	None	None	None	None
Queueing length [m]	-	24	-	5	-	4
2030	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	147	394	181	73	196	107
Cross traffic volume [vehicle/h]	-	91	-	-	80	293
Lane capacity [PCU/h]	4,000	1,025	2,000	2,000	956	473
Reserve Capacity [PCU/h]	3,853	631	1,819	1,927	760	221
Delay	None	None	None	None	None	Little
Queueing length [m]	-	79	-	22	-	21
2035	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	272	587	344	141	285	213
Cross traffic volume [vehicle/h]	-	183	-	-	153	490
Lane capacity [PCU/h]	4,000	915	2,000	2,000	865	339
Reserve Capacity [PCU/h]	3,728	328	1,656	1,859	580	-67
Delay	None	Very little	None	None	Very little	Jammed
Queueing length [m]	-	117	-	41	-	43
2040	**A1&A2**	**A3**	**B1**	**B2**	**C1**	**C2**
Traffic volume [PCU/h]	317	658	393	156	282	232
Cross traffic volume [vehicle/h]	-	205	-	-	172	541
Lane capacity [PCU/h]	4,000	891	2,000	2,000	843	311
Reserve Capacity [PCU/h]	3,683	233	1,607	1,844	561	-133
Delay	None	Little	None	None	Very little	Jammed
Queueing length [m]	-	132	-	48	-	46

Delay: None, Very little, Little, Delayed, Much, Very much in good evaluation order
Source: JICA Design Team

As per Table 8.4.28, the northern T-shape intersection will not require a traffic signal in 2040. However, the reserve capacity on C2 (right-in from ramps to the SEZ main road) will not be sufficient after 2035. According to the situational development of Phase 3 of the SEZ, installation of traffic signal may be considered. A pattern of signal control and capacity calculation for signalized intersections in 2040, according to the Japanese guideline, is shown in Figure 8.4.31 and Table 8.4.30.

	ϕ 1	ϕ 2	ϕ 3
Diagram			

Source: JICA Design Team

Figure 8.4.31 Signal Control Pattern for Northern Intersection After Phase 3 Development

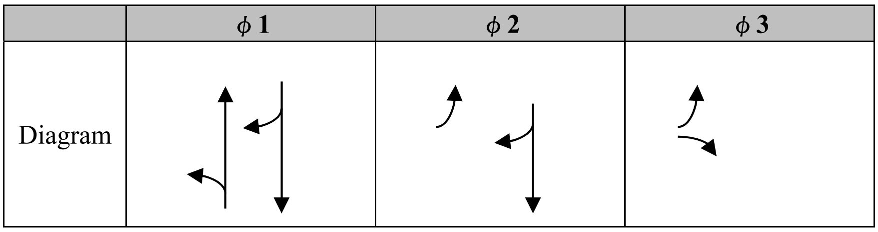
Table 8.4.30 Capacity Calculation for Signalized Intersection of Northern Intersection in 2040

		A1&A2	A3	B1	B2	C1	C2
Description		Straight	Right-out	Straight & Left out	Straight	Left-in	Right-in
Traffic Volume [PCU/h]		272	587	344	141	285	213
Large size vehicle ratio [%]		41.3	69.8	30.0	26.6	34.8	17.4
Basic saturation flow rate [PCU/h]		4000	1800	2000	2000	1800	1800
Correction	Width	1.00	1.00	1.00	1.00	1.00	1.00
	Gradient	0.95	0.95	0.99	0.99	1.00	1.00
	Large size vehicle	0.77	0.66	0.85	0.80	0.80	0.89
Corrected saturation flow rate [PCU/h]		1,463	1,253	1,677	1,431	1,446	1,787
Saturation of intersection	ϕ 1	0.092		0.223	0.084		
	ϕ 2		0.511			0.197	
	ϕ 3						0.133
	Total	0.866					
Signal cycle length [second]		130					
Clearance length [second]		5					
Effective green time	ϕ 1 [second]	30	30	30	30		
	ϕ 2 [second]	67	67			67	
	ϕ 3 [second]					18	18
Lane capacity [PCU/h]		2,200	592	356	385	946	222
Evaluation		OK	OK	OK	OK	OK	OK
Queueing length		-	86	-	-	-	41

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

As per Table 8.4.29, the traffic demand of the southern intersection will exceed its capacity after 2035. During Phase 3 of the SEZ from 2034, installation of traffic signal should be considered. A Pattern of signal control and capacity calculation for signalized intersection in 2040, according to the Japanese guideline, is shown in Figure 8.4.32 and Table 8.4.31.



Source: JICA Design Team

Figure 8.4.32 Signal Control Pattern for Southern Intersection After Phase 3 Development

Table 8.4.31 Capacity Calculation for Signalized Intersection of Southern Intersection in 2040

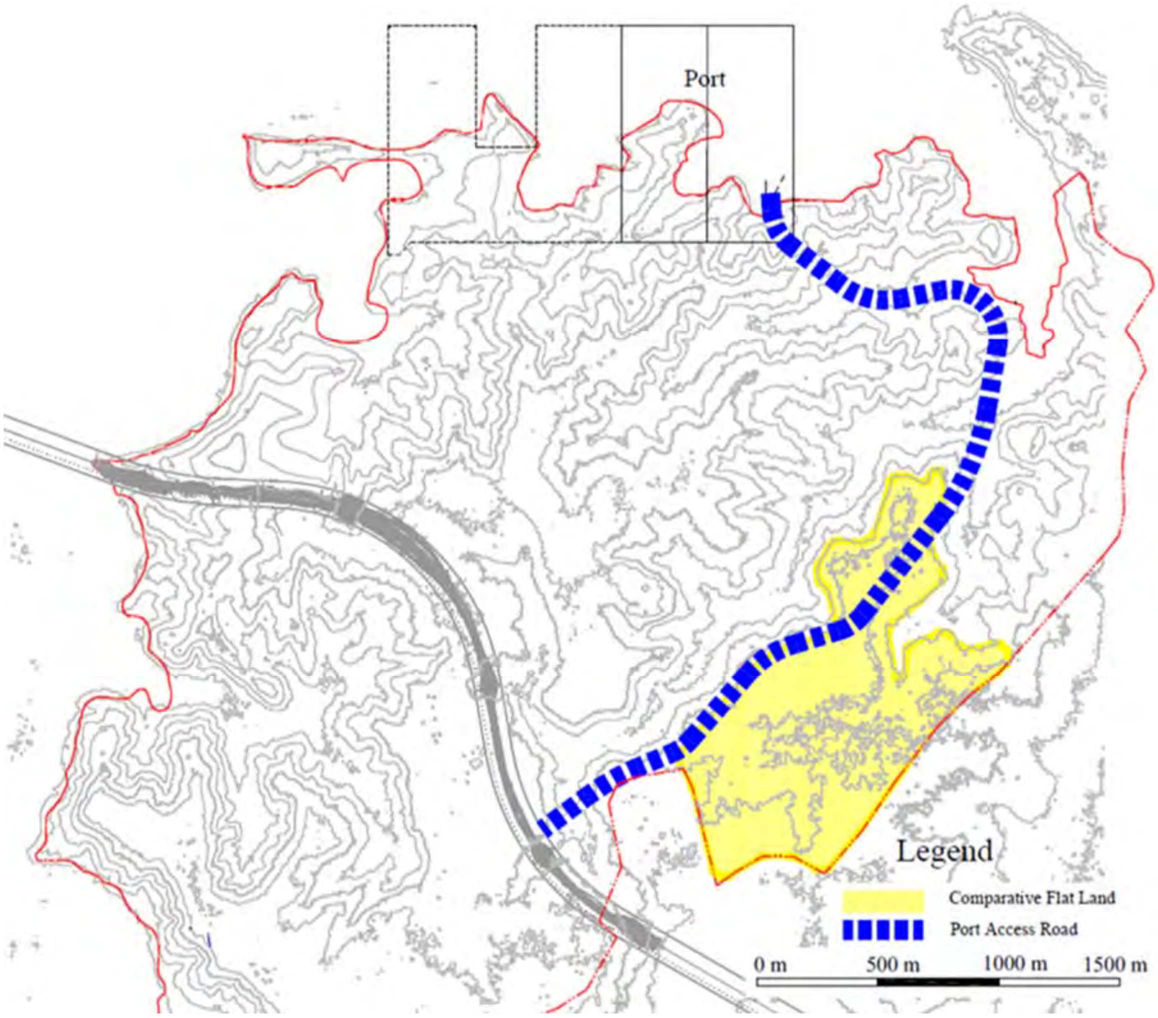
		A1	A2	B1	B2	C1	C2
Description		Straight (A to B)	Right-out (A to C)	Straight (B to A)	Merging (B to C)	Straight (C to A)	Right-in (C to B)
Traffic Volume [PCU/h]		317	658	311	238	282	232
Large size vehicle ratio [%]		42.7	73.7	25.9	35.0	34.9	17.1
Basic saturation flow rate [PCU/h]		2000	2000	2000	1800	1800	2000
Correction	Width	1.00	1.00	1.00	1.00	1.00	1.00
	Gradient	0.95	0.95	0.99	0.99	1.00	1.00
	Large size vehicle	0.77	0.66	0.85	0.80	0.80	0.89
Corrected saturation flow rate [PCU/h]		1,463	1,253	1,677	1,431	1,446	1,787
Signal cycle length [second]		60					
Clearance length [second]		5					
Effective green time	ϕ 1 [second]	12	12	12	12	12	
	ϕ 2 [second]	24	24		24	24	
	ϕ 3 [second]				9	9	9
Lane capacity [PCU/h]		878	697	335	1,073	1,085	268
Evaluation		OK	OK	OK	OK	OK	OK
Queueing length		-	86	-	-	-	41

Source: JICA Design Team

ii) Horizontal Alignment

a) Design of alignment for efficient land use along the road

Due to the steep topography, suitable land for urban land use is limited in this area. The Alignment of the SEZ main road should be designed considering efficient land use.

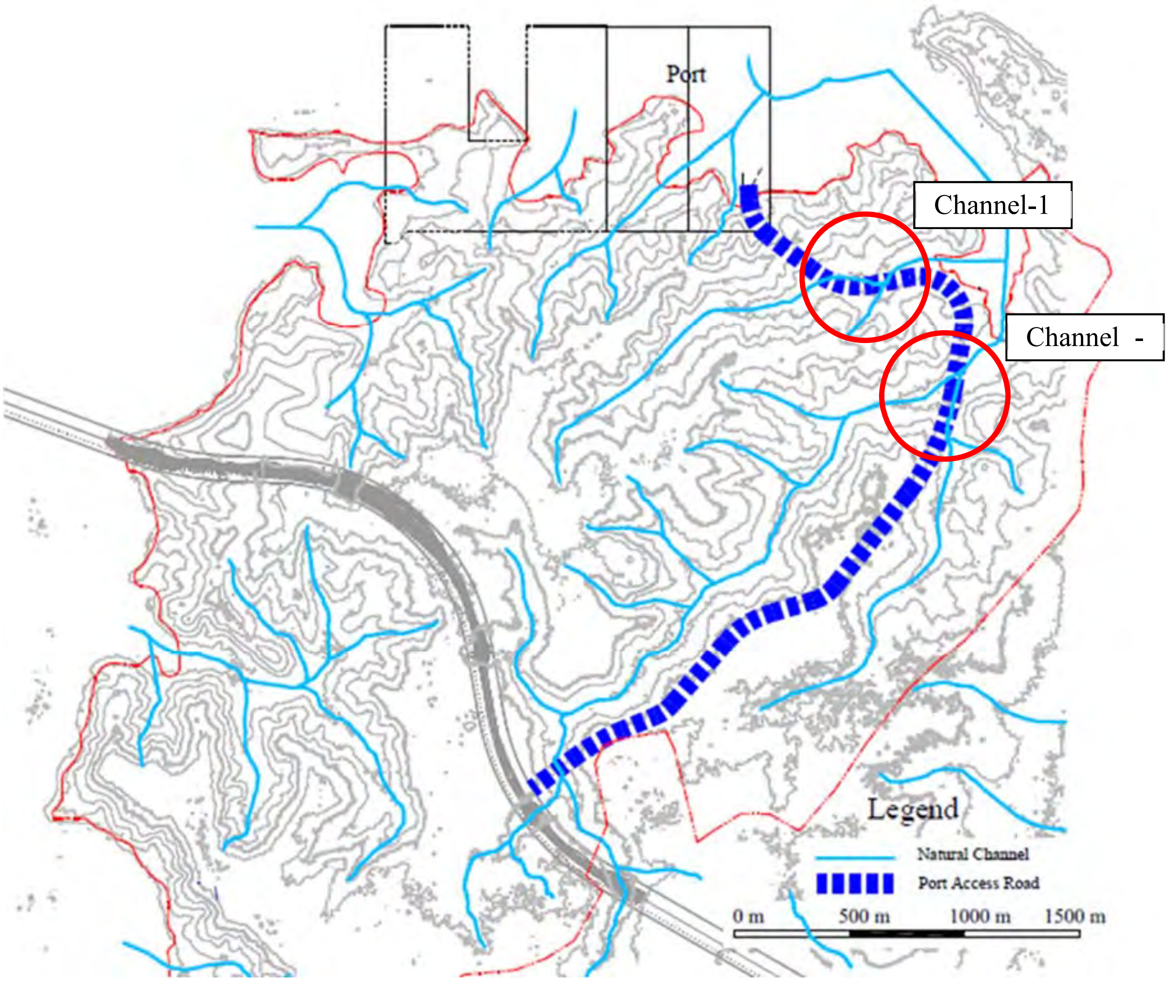


Source: JICA Design Team

Figure 8.4.33 Location of Comparative Flat Land and Draft Horizontal Alignment

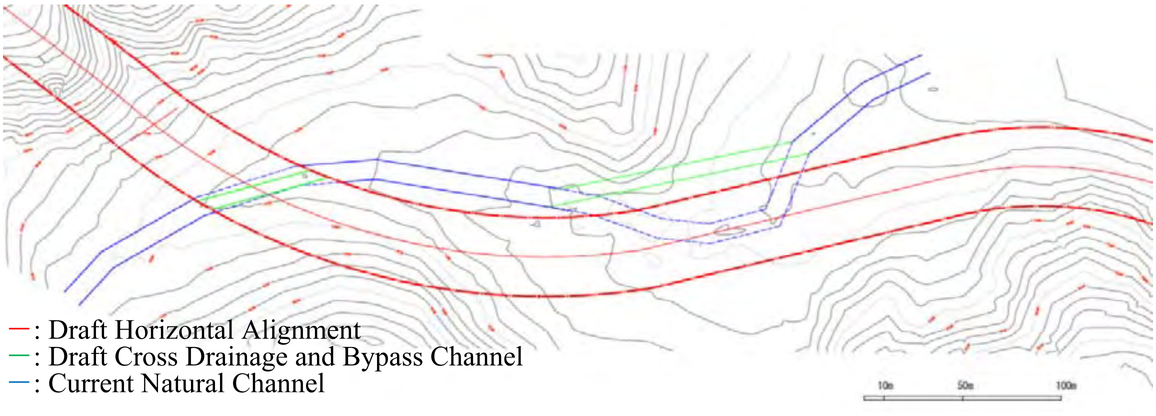
b) Reduction of cost and impact of crossing an existing open channel

The planning alignment of the SEZ main road crosses several major natural channels. In the section that crosses the channel, it is necessary to construct an underground culvert or bypass so that the channels avoid the road. The alignment of the SEZ main road should be designed considering the cost and impact of crossing an open channel and the construction of a bypass drainage.



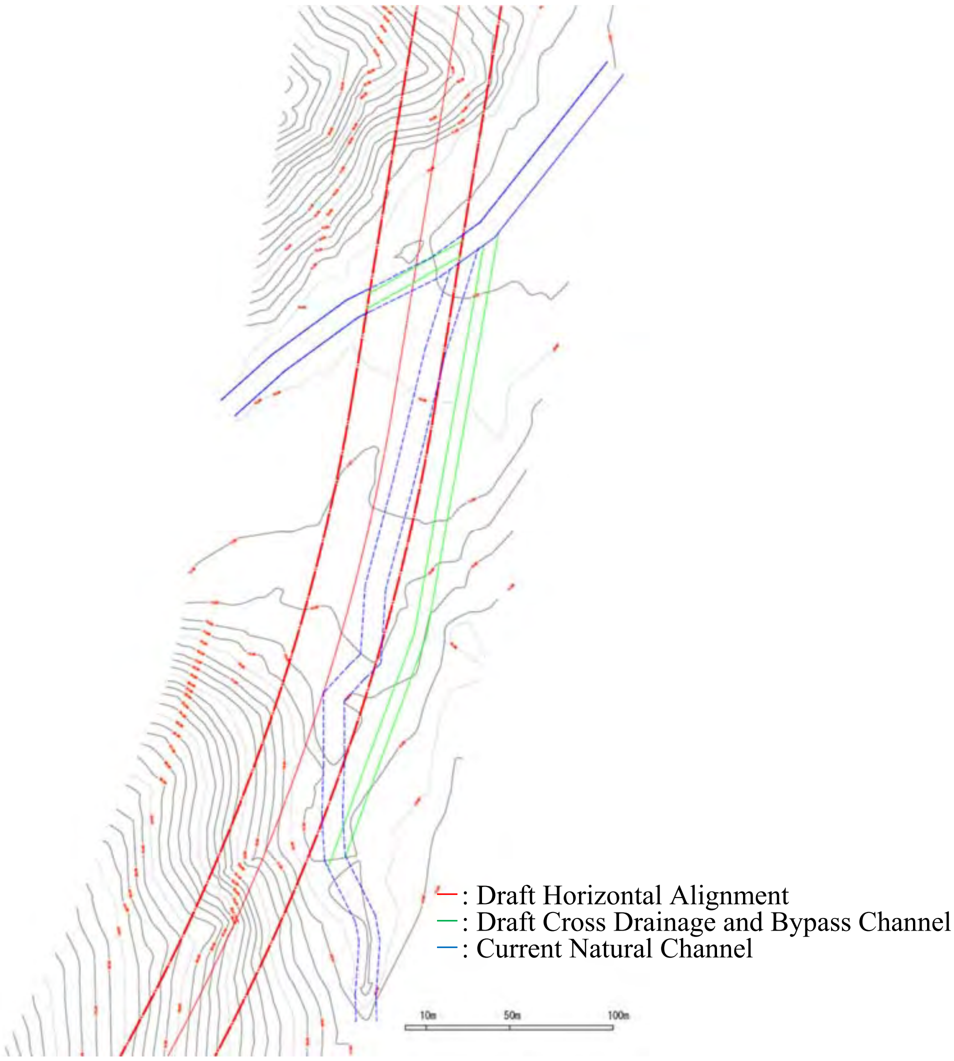
Source: JICA Design Team

Figure 8.4.34 Location of Cross Drainage and Bypass Channel along the SEZ main road



Source: JICA Design Team

Figure 8.4.35 Cross Drainage and Bypass Channel -1



Source: JICA Design Team

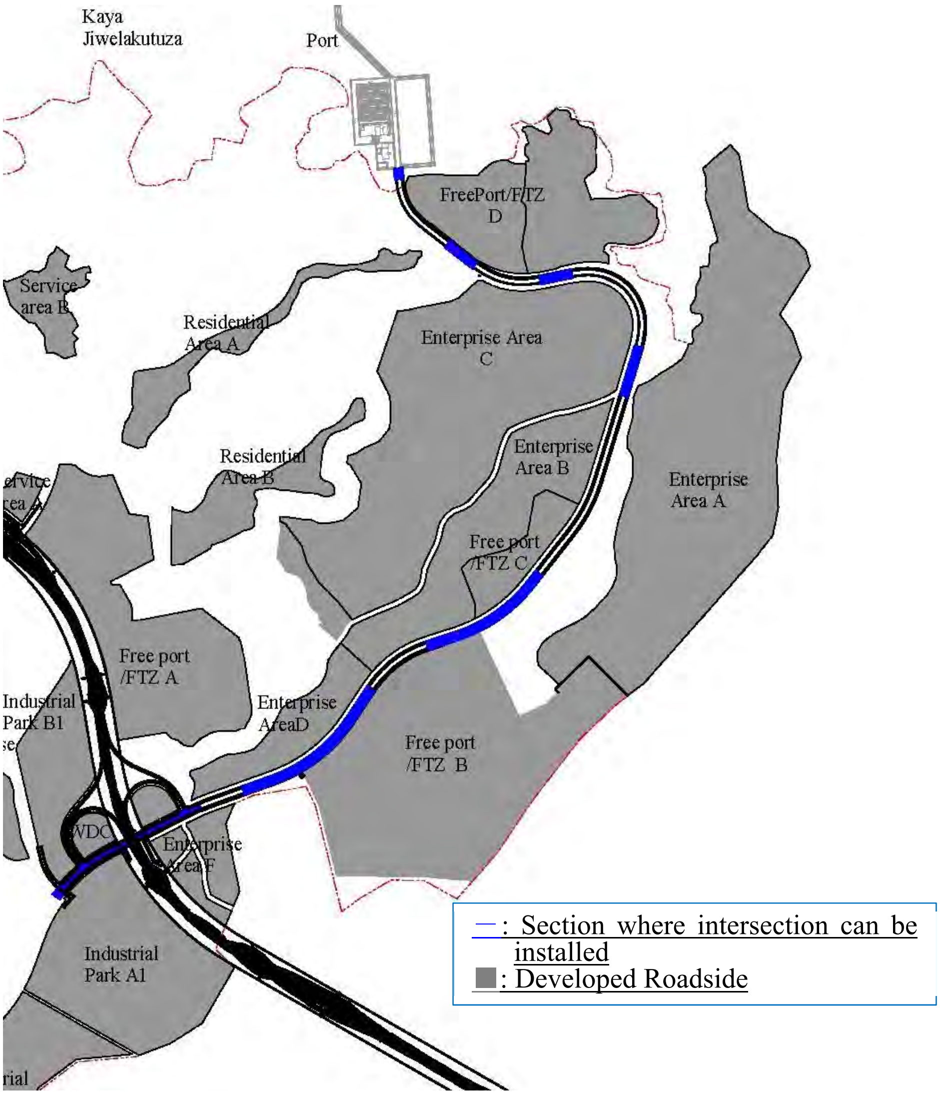
Figure 8.4.36 Cross Drainage and Bypass Channel -2

iii) Vertical Alignment

a) Adoption of gradient and crescent/sag curve radius at intersection

A small gradient is recommended for a comfortable and safe driving, especially when the passing traffic on the SEZ main road is mainly categorized as cargo. Then, the vertical alignment is basically along with current topography, and adopted smaller gradient (it should be less than 4%).

Besides, gradient near intersections should be less than 3% according to Kenyan standard. Larger vertical curve radii are also adopted near intersections. However, it is not determined where the intersections are allocated because the locations depend on each developer who will be responsible for construction of roadside zones. Figure 8.4.37 shows sections where intersections to access to roadside zones can be installed. It is determined by designed gradient and horizontal curve radii.



Source: JICA Design Team

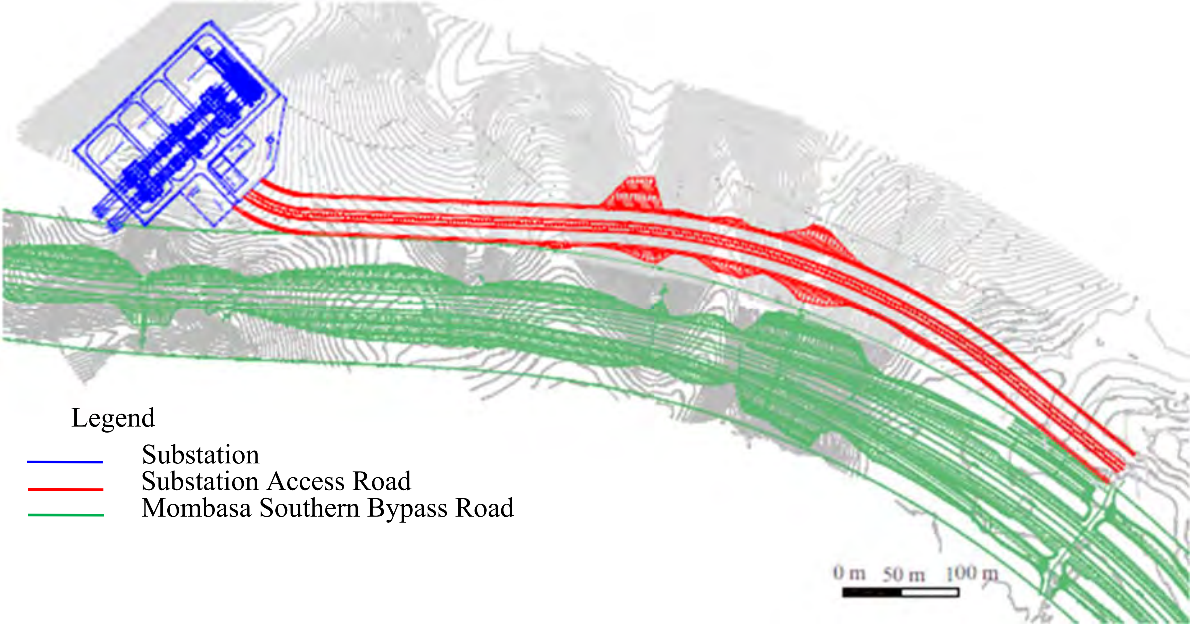
Figure 8.4.37 Proposed Location of Intersections in Mombasa SEZ M/P

(3) Substation Access Road

i) Design of Alignment to Minimize the Impacts to Residents and the Environment

Due to the steep topography of the land for construction of the substation, the access road is required to have a wide slope with cut and fill earthwork. Moreover, there is an MSBR right-of-way to the south of the substation. Horizontal and vertical alignment should be designed to avoid the MSBR. Road width should also be minimized in consideration of the existing residents and the environment.

Furthermore, the exit road over the MSBR may be constructed in coordination with the MSBR project office. In this case, a bypass of the exit road will be needed.



Source: JICA Design Team

Figure 8.4.38 Horizontal Alignment of the Substation Access Road

8.5 Water Supply

The water demand and water source, which are both available in the Mombasa Special Economic Zone (SEZ), have been reviewed. The development of new boreholes is proposed in the Tiwi Well-field by adjusting the water supply plan of Mombasa SEZ and the related water development activities by other donors in Mombasa and Kwale counties.

8.5.1 Overview

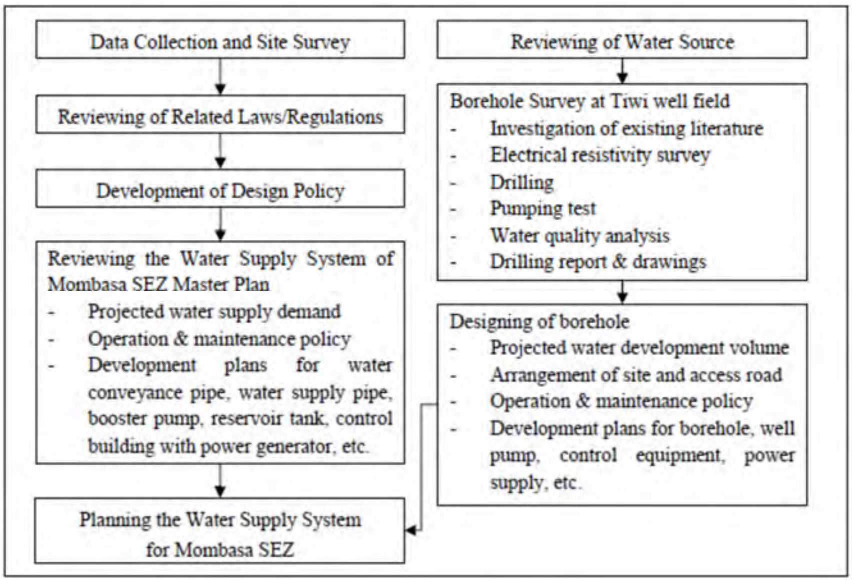
(1) Purpose of the Survey

The main purpose of this survey is to update the existing master plan by reflecting the current situation and to provide the implementation plan including preliminary design, project cost estimation, and implementation schedule for the development of water supply services in Mombasa SEZ. It is particularly important to understand the current situation of the water source. Therefore, it is necessary to collect and investigate existing literature and information that would be the basis on water source development and water supply planning (including past record and future projection of water supply volume). The main objectives are as follows:

1) To comprehend the Kenyan standard on the quality of service water by collecting the related laws and regulations, and to conduct an interview survey on related public institutions;
2) To design the borehole and the conveying water pipe based on the borehole survey;
3) To forecast the optimal capacity of water supply facilities with the water demand for each zone;
4) To conduct a preliminary design for the water supply pipe, booster pump, reservoir tank, etc.;
5) To review the existing SEZ master plan and to update it to satisfy these conditions.

(2) Methodology of the Water Supply System Design

The flow chart of water supply system design is shown in Figure 8.5.1.



Source: JICA Design Team

Figure 8.5.1 Flow Chart of Water Supply System Design

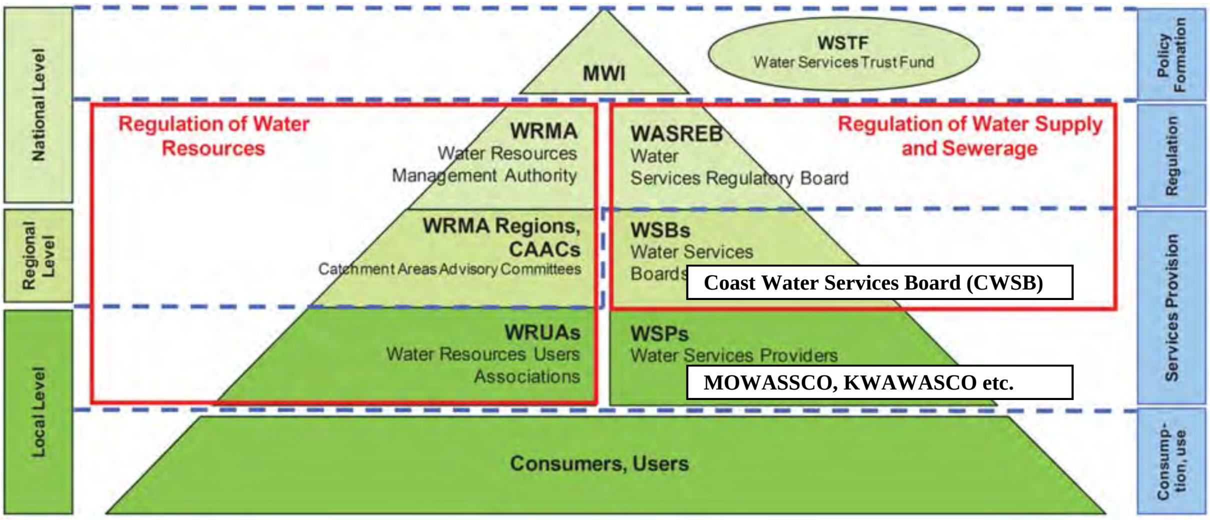
Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

8.5.2 Current Conditions and Related Project

(1) Current Conditions of Water Supply

i) Administrative Structure of Water

The existing representation of the institutional framework of the water sector under the Ministry of Water and Sanitation (MOW) is illustrated in Figure 8.5.2. The Water Services Boards (WSBs) are under the jurisdiction of MOW. The sub-regional offices of Water Services Providers (WSPs) provide water supply and sewerage management services at a sub-regional level under the regional offices of WSBs. The Coast Water Services Board (CWSB) is a parastatal under MOW, responsible for the provision of water and sewerage services in the Coast Region. The CWSB is one of the eight WSBs in Kenya, and it is covering six counties, namely; Mombasa, Kilifi, Kwale, Taita-Taveta, Lamu, and the Tana River. The CWSB does not provide services directly but through contracted WSPs. The CWSB had contracted seven WSPs to provide water and sewerage services in towns and urban centers. Examples are the Mombasa Water Supply and Sanitation Services Company (MOWASSCO) and the Kwale Water and Sewerage Company (KWAWASCO). The study on the latest situation after the New Water Act is ongoing. Thus, the latest situation is needed to be checked. (After additional study, it will be corrected.)



Source: Updated by the JICA Design Team based on the National Water Master Plan 2030 by JICA, October 2013

Figure 8.5.2 Representation of Institutional Framework of Water under MOW

ii) Current Conditions of Water Supply System

Mombasa County does not possess any big surface water sources. Therefore, it heavily depends on water sources from outside the county for its potable needs. Mombasa County is receiving water from Mzima Springs, Baricho Well-field, Marere Springs, and Tiwi Well-field. Apart from these, the county also sources its water from shallow wells or boreholes operated by private investors or NGOs. The water from these sources is salty, that it just meeting the acceptable levels. The existing water sources and storage facilities in Mombasa County are shown in Figures 8.5.3 and 8.5.4. The Kayabombo Reservoir sourced from Marere Springs and Tiwi Well-field is supplying to Likoni in the south of Mombasa. However, the current water supply volume is not enough. The following are the major water supply issues being considered:

- Insufficient water source
- Old facilities or low level of water supply infrastructure development
- Groundwater salinity
- Ground water pollution
- High Non-revenue Water (NRW) levels

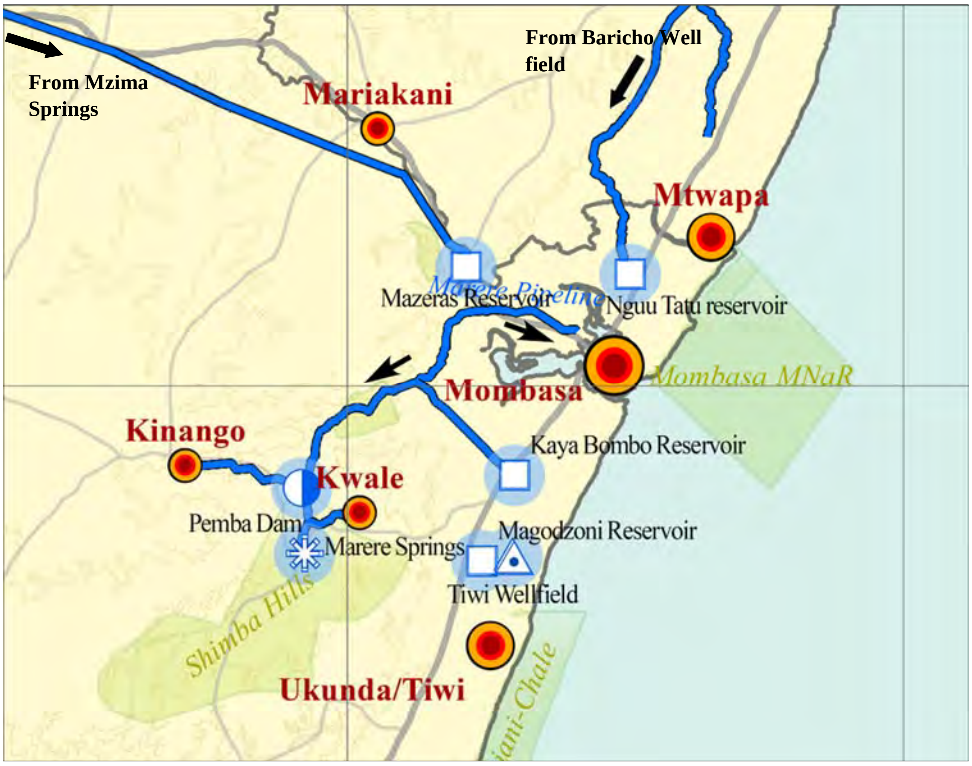
(Source: F/S Report of Water Supply M/P for Mombasa and Other Towns Within Coast Province, February 2012)

Kaya Bombo Reservoir (1,250 m^3 and 1,440 m^3)

Tiwi Borehole/Well-field

Source: JICA Design Team

Figure 8.5.3 Photo of Existing Water Supply System in Mombasa



Source: Team Updated by the JICA Design Team based on the Water Supply M/P for Mombasa by CWSB (February 2012)

Figure 8.5.4 Current Situation of Water Supply System in Mombasa

In order to secure the water source of Mombasa SEZ (Phase 1), the JICA Design Team will carry out a survey on groundwater development as follows:

- Collect and analyze the existing hydrological and hydrological geological data, and carry out a field survey;
- Perform electrical resistivity survey, select the drilling site, and formulate a well drilling plan;
- Conduct a well drilling, water quality analysis (groundwater/water environmental standard items), and pumping test (preliminary pumping test, step pumping test, continuous pumping test, recovery test);
- Create a well inventory and conduct groundwater monitoring within the work implementation period, and,
- Conduct groundwater flow analysis, calculate sustainable pump yield and formulate additional well drilling plan as necessary based on the existing data and on-site measurement data.

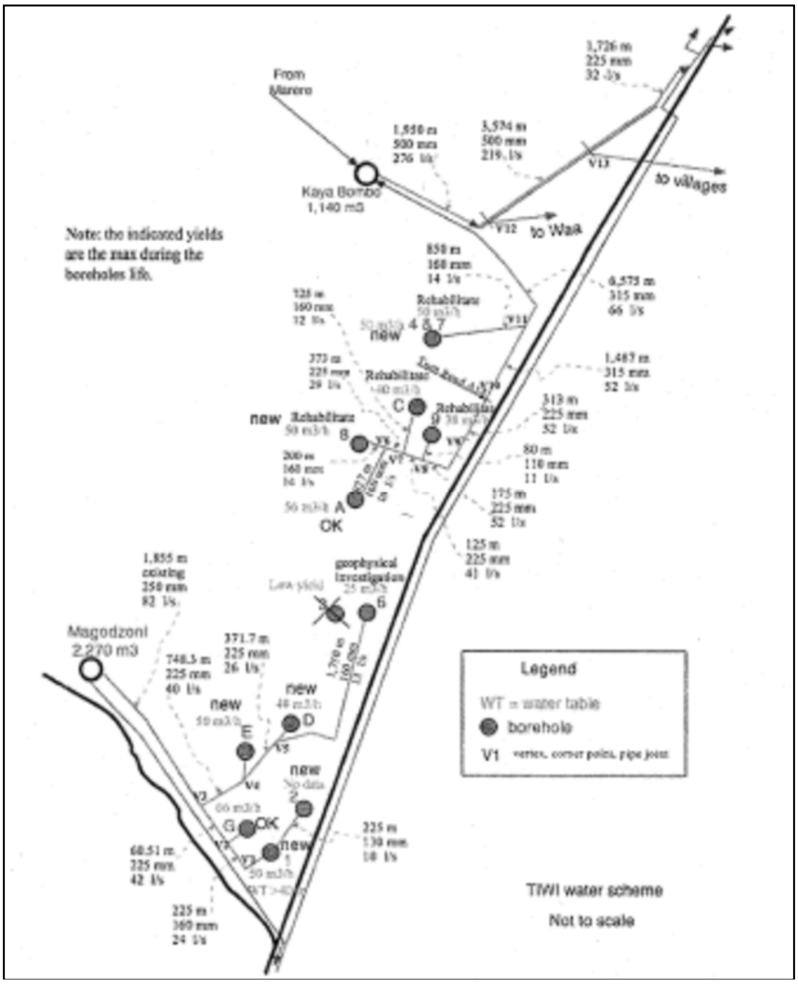
iii) Data Collection and Inspection of Tiwi Boreholes

The reported water production levels of Tiwi boreholes are shown Table 8.5.1 and Figure 8.5.5.

Table 8.5.1 Water Production of Tiwi Boreholes

Sites	Borehole	Yield, Q (m^3/hr)	Remarks
1.	6.2	12	Supply to Magodzoni
	6.1	25	Supply to Magodzoni. Has shown increased salinity
2.	D3	50	Supply to Magodzoni
3.	E	34	Supply to Magodzoni
4.	G1	60	Supply to Magodzoni
	G2	-	Not operational due to defective pump.
5.	1	50	Supply to Magodzoni
6.	2	54	Supply to Magodzoni
7.	A	50	Serves Kombani
8.	8.1	29	Supply to Kayabombo. BH 8.1 and BH 8.2 work concurrently
	8.2	20	Serves Matuga
	8.3	8	Supply to Kayabombo
9.	C	52	Supply to Kayabombo
10.	4	37	Supply to Kayabombo
	7	37	Supply to Kayabombo
11.	9	6	Supply to Kayabombo

Source: JICA Design Team (CWSB, 14 March 2017) (After additional study, it will be corrected.)



Source: CWSB (After additional study, it will be corrected for borehole number)

Figure 8.5.5 Location Map of Tiwi Boreholes

Based on the data collection and inspection, the important issues of concern are the following: (after additional study, these will be added to the present operation status of the boreholes corrected)

a. Salinity

It was reported that Borehole 6.1 had high salinity. The issue of water quality should be followed up with CWSB since they have a water quality-monitoring program for all the boreholes in operation.

b. WRA Monitoring Boreholes

There are some monitoring boreholes that belong to the WRA. One of them was observed at borehole 6.1. It needs to be enquired from WRA if they have any data that can be used for the study. Any available data will be analyzed.

c. Borehole Production Data

The collected data of borehole production will be compared with the yield data that was obtained during the initial test pumping to see whether there is any deviation. Information on borehole size, depth, type, and size of casings, sieves, gravel, and packing used should also be sought during the study to apply to the design of the new boreholes.

d. Land Ownership

It was established during the inspection that most of the lands at Tiwi are privately owned except for the land for the existing boreholes which was acquired by CWSB. An inquiry shall be made from CWSB regarding compensation rates that were used in the previous compensation.

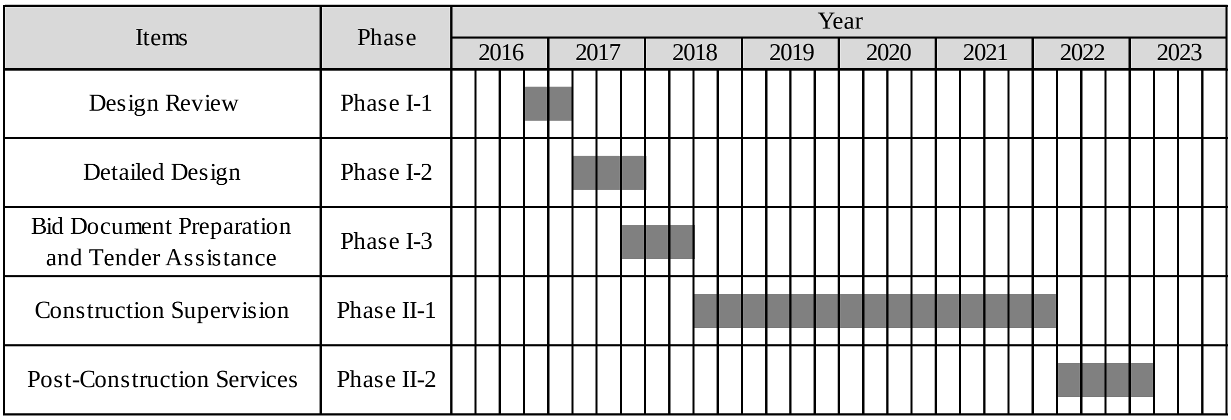
e. Sand Harvesting

It was also observed that sand harvesting is ongoing in Tiwi area and this may have a potential of degradation and adverse effects to the environment.

(2) Related Projects of Water Supply

i) Mwache Multi-Purpose Dam Project (by the World Bank)

The design review, detailed design and construction supervision for Mwache Multi-purpose Dam is an on-going project promoted by the World Bank. The dam will supply approximately 186,000 m^3/day (67.9 MCM/year) to Mombasa and Kwale counties based on allocation agreements between the counties. In the original plan, the implementation schedule of the projects is shown in Figure 8.5.6.

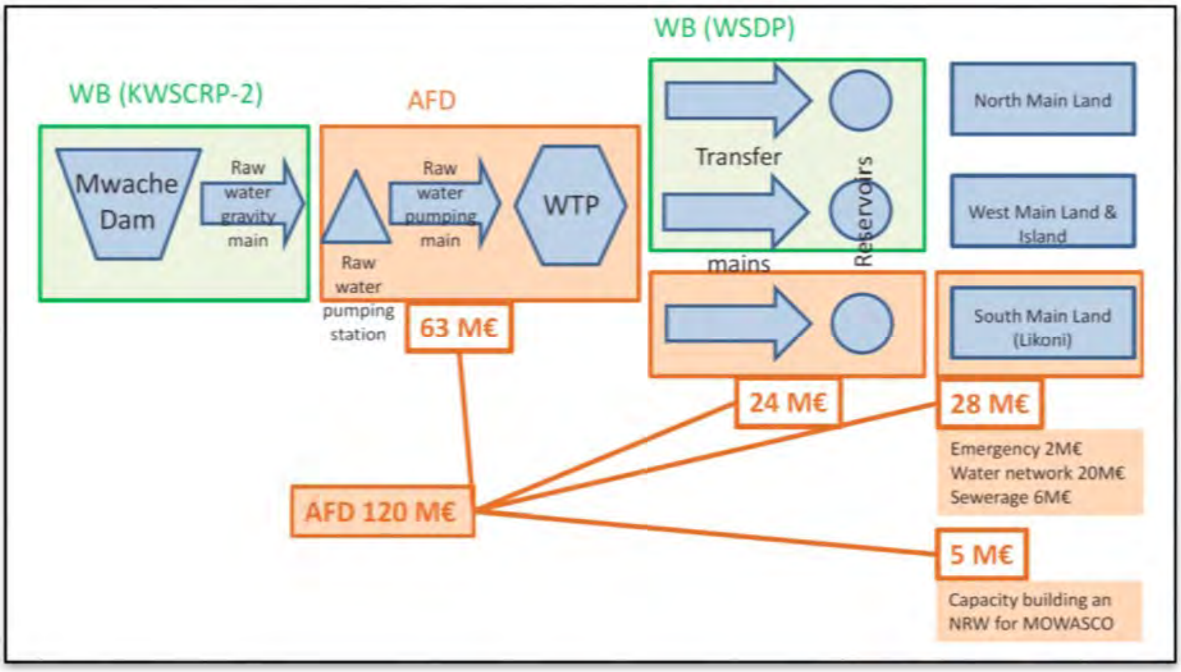


Source: Inception Report of Design Review, Detailed Design and Construction Supervision. (WB, Jan 2017)

Figure 8.5.6 Original Implementation Schedule of Mwache Dam (by the WB)

ii) Water Transmission Facilities for Kenya Coast Province Water Supply (AFD)

The project on water transmission facilities for the Kenya Coast Province water supply from the Mwache Dam is ongoing and promoted by the AFD. Based on the additional information, the outline of the allocation of each lending institution concerned and the business contents are shown in Figure 8.5.7 and Table 8.5.2 as the background of the whole Mwache Project is described in the project’s mission report.



Source: AFD (Mwache Project CKE1103 Mission Report - November 2018)

Figure 8.5.7 Assignment of Related Assistance of the Mwache Dam Project

Table 8.5.2 Summary of Related Assistance of the Mwache Dam Project

Donor Organizations	Summary of project	Fund
WB (KWSCRP-2)	• Mwache Dam (ongoing), Kwale County Development Assistance (Pilot irrigation project), intake, transmission raw water pipe	USD 200 M
AFD	• Raw water pump station, Transmission water pipe, Mwache Water Treatment Plant (EUR 63 M) • Main water supply pipe from Mwache Water Treatment Plant to southern area (including Dongo Kundu Water Reservoir Tank) (EUR 24 M) • Water pipe network project (EUR 20 M), indirect investment of improvement of sewage facilities (EUR 6 M), water supply project to Likoni area until the Mwache Project is completed (EUR 2 M) • Capacity building for MOWASCO, measures for non-revenue water, procurement of equipment (EUR 5 M)	EUR 120 M
WB (WSDP)	• As water development project two transmission water pipes and water reservoir tanks (USD 100 M) • Indirect assistance of water supply network in coastal area（USD 200 M）	USD 300M

Source: AFD (Mwache Project CKE1103 Mission Report - November 2018)

According to AFD's Mwache project mission report, the progress of the project and implementation schedule of major projects are as follows. The provisional schedule of each project is shown in Figure 8.5.8.

a）Mwache Dam

- All bids have been evaluated, and the combined evaluation report of the temporary awarded bidder is under review at the World Bank (WB).
- The letter of acceptance can only be issued once the Resettlement Action Plan (RAP, also covering the water treatment plant (WTP) site) has been approved by the WB, whose no-objection is at the moment withheld and is waiting for a revised version.
- In the case of the construction is started in April 2019, construction will be completed at the end of March 2023, and the planned ponding of the water reservoir will start in January 2023.

b）Water Treatment Plant

- The scope of works includes a raw water pumping station, a 2.6-km raw water main, a 186,000-m^3/d WTP (under design build operate conditions) with a 10,000 m^3 clear water tank.
- For the consultancy, the five technical proposals are currently under evaluation by CWSB.
- Final tender documents are expected at month 10 of the consultancy, and a contractor will be selected by the end of 2020.
- The construction period is 24 months and will be completed at the end of September 2022. Trial operations will start thereafter.

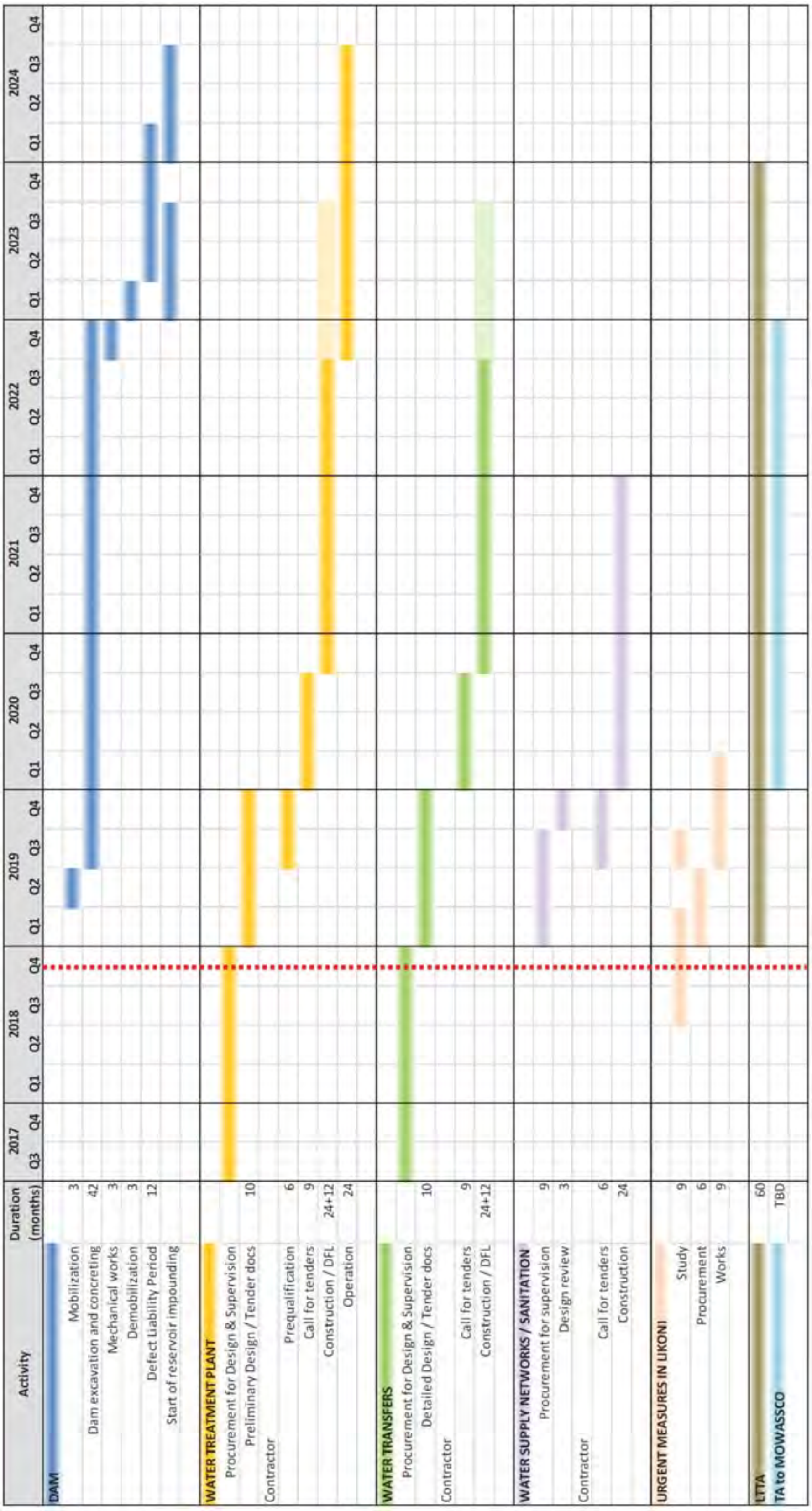
c）Transmission Water Pipe

- The temporary awarded JV consultant is pending contract negotiations.
- Once mobilized, the consultant will promptly initiate in-depth technical discussions with the consultant in charge of bridge/road design (JICA-funded Southern Bypass Project with KeNHA) to determine and do the cost adjustments necessary to accommodate a larger pipe.
- The joint support (MoWS, Mombasa County, AFD) is necessary in leading discussions with JICA and KeNHA.
- The construction period is the same as for the water treatment plant, and it will be completed at the end of September 2022.

d）Emergency Works for Likoni Area

- The JV consultant signed the short-term TA consultancy contract in June 2018, which essentially includes the hydrogeological study and feasibility study, detailed design, and tender documents for emergency actions to improve water supply in Likoni.
- The timeframe initially contemplated to get concrete results is one year, for a target additional volume of 5,000 m^3/d.
- The consultant submitted its final inception report in September 2018 and draft feasibility study on 15 October 2018.
- CWSB and AFD were not satisfied with this deliverable: lack of specific conclusions (only general), OPEX not assessed, CAPEX evaluation not backed up, narrow interpretation of ToRs, etc.

- Regarding Likoni and desalination, other sites in the public domain around the two identified ones shall be investigated (distance, depth, yield, and water quality), and economic calculations (taking into account CAPEX, energy costs, lifespan of the infrastructure, etc.) shall be carried out to define the most desirable scenario (containerized desalination, solar-powered, or not).
- The consultant will propose the following: 1) submit revised feasibility study with options, OPEX, etc., and 2) produce conceptual designs for Tiwi Well-field, detailed design for Marere Pipeline, as well as tender documents by January 2019.
- The construction period is July 2019 to the end of June 2020.



Source: AFD (Mwache Project CKE1103 Mission Report - November 2018)

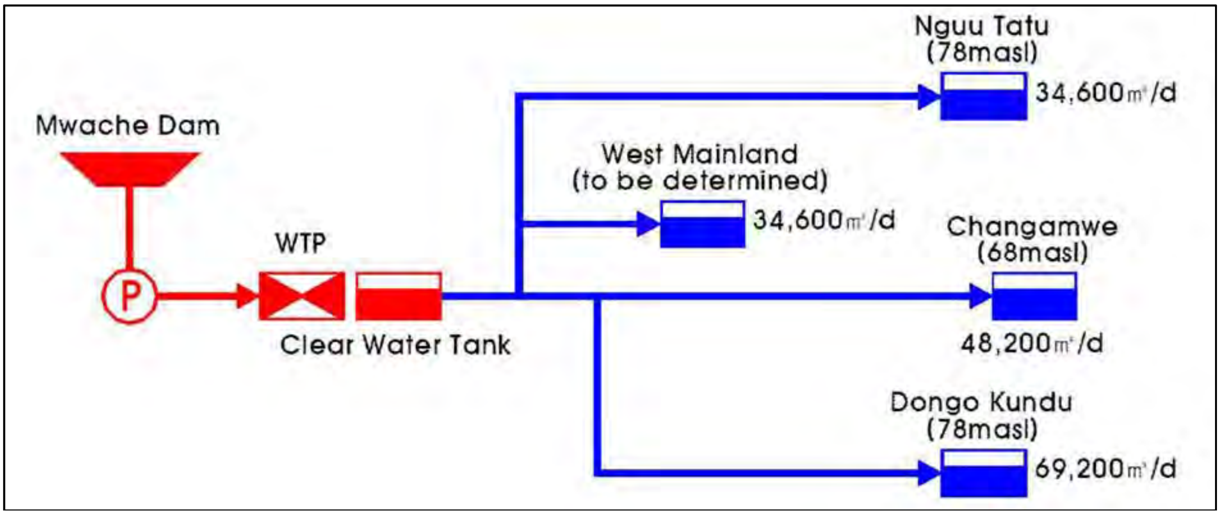
Figure 8.5.8 Tentative Schedule of Related Assistance of the Mwache Dam Project

Table 8.5.3 Water Resource Development by Phase (Water Supply Master Plan)

Phase		Immediate	Phase I	Phase II	Phase III	
Target Year		**2015**	**2020**	**2025**	**2030**	**2035**
Population Projection		3,521,284	4,130,325	4,839,196	5,669,727	6,642,798
Water Demand (m^3/d)		230,561	284,655	374,521	442,465	511,359
Existing Capacity (m^3/d)	Tiwi Boreholes	13,000	13,000	13,000	13,000	13,000
	Marere Springs	12,000	12,000	12,000	12,000	12,000
	Mzima Springs	35,000	35,000	35,000	-	-
	Baricho Well-field	83,000	83,000	83,000	68,000	68000
	Other Local	12,000	12,000	12,000	12,000	12,000
	Total Existing	155,000	155,000	155,000	105,000	105,000
Capacity Following Implementation (m^3/d)	Baricho Expansion	20,000	20,000	20,000	17,000	17,000
	Mwache Dam	-	186,000	186,000	186,000	186,000
	Baricho 2 Expansion	-	-	70,000	90,000	90,000
	Mzima 2	-	-	-	105,000	105,000
	Msambweni Well-field	-	-	-	-	20,000
	Total Available	175,000	361,000	431,000	503,000	523,000
Surplus / Deficit (m^3/d)		-55,561	76,345	56,479	60,535	11,641

Source: Feasibility Study on Water Transmission Facilities for the Kenya Coast Province Water Supply (AFD, Jan 2016)

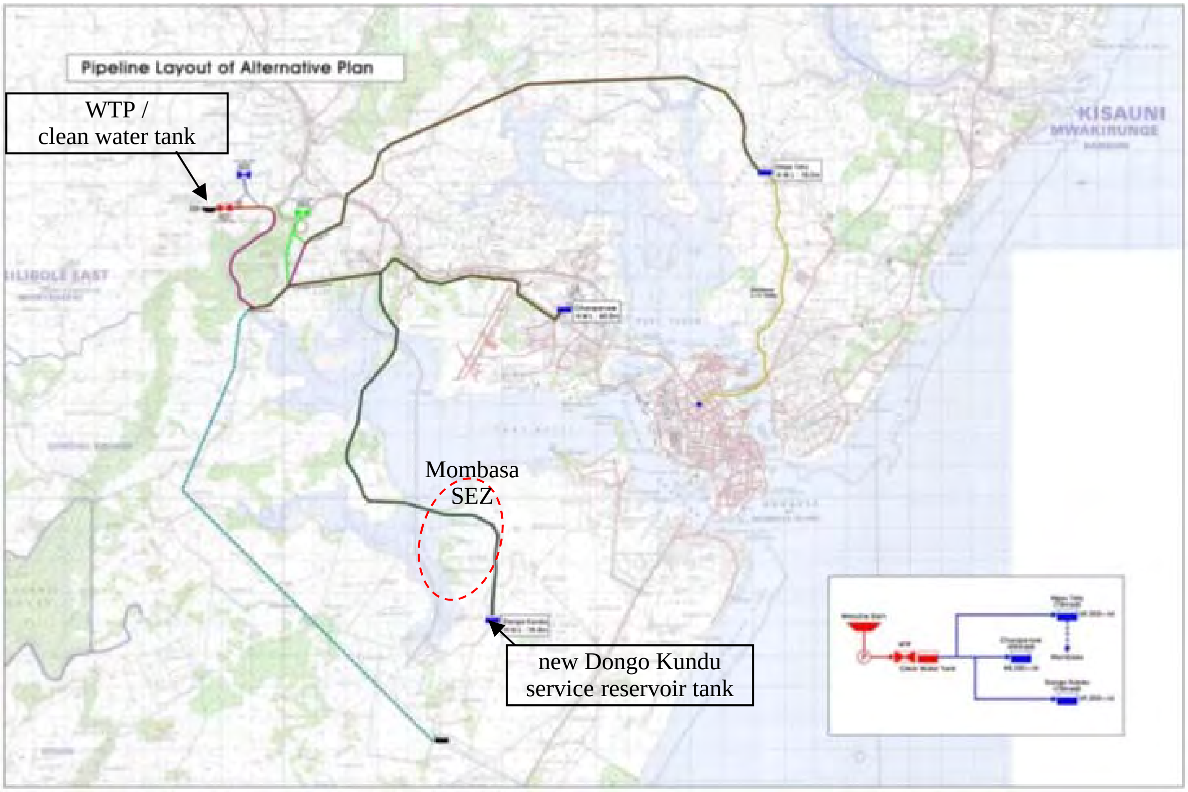
On the Mwache Dam, the three separate pipe routes are suggested from the clear water tank at WTP. These separate pipelines will transmit bulk water to main service reservoirs by gravity. Four service reservoirs are proposed for bulk water distribution to each service area. The Kaya Bombo line was changed to Dongo Kundu line based on the new Southern Bypass Road Plan (by the JICA). The new Dongo Kundu service reservoir tank (supply volume 69,200 m^3/d, tank capacity 23,000 m^3) will be located near the Mombasa SEZ. The water allocation to each service reservoir is based on the Water Supply Master Plan as shown in Figure 8.5.9 and Figure 8.5.10.



Source: Feasibility Study on Water Transmission Facilities for Kenya Coast Province Water Supply (AFD, Jan 2016)

Figure 8.5.9 Hydraulic Concept of Water Transmission Facilities (by the AFD)

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: Feasibility Study on Water Transmission Facilities for Kenya Coast Province Water Supply (AFD, Jan 2016)

Figure 8.5.10 Pipeline Layout of Water Transmission Facilities (by the AFD)

iii) Mombasa Seawater Desalination Project

The tender of feasibility study, design, build, and operate seawater desalination plants for Mombasa County is ongoing. The result of tender is not yet published. The objectives of the project are shown as follows: (this information has not been updated)

- To fill the gap of the water demand in the county which is currently at 70%
- To fulfill the water demand for the residents of the county currently at 180,000 m^3 per day

8.5.3 Borehole Development Survey in Tiwi Well-field

(1) Background and Objective of Borehole Survey in Tiwi Well-field

i) Background

Before Mwache Dam will be completed, alternative water resources should be explored in order to supply the demand of the SEZ. Based on the review of previous reports and discussions with related organizations, the Tiwi Well-field was selected as the water source for the initial stage of the SEZ.

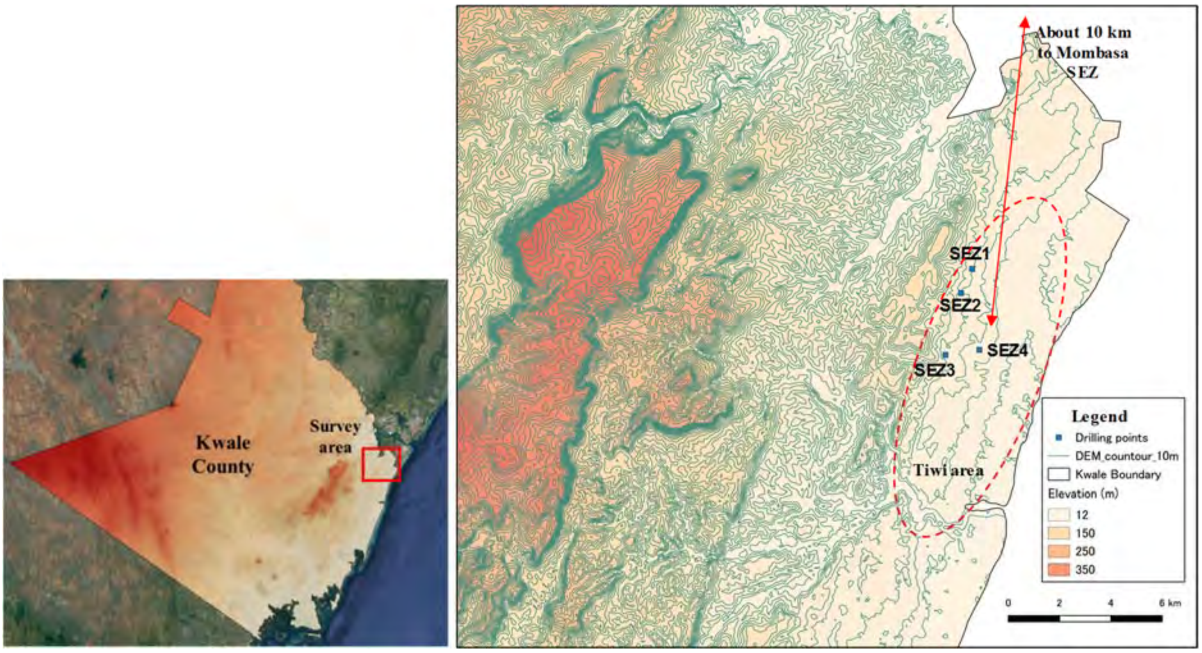
ii) Objective

The main purpose of the survey is to select the appropriate sites and obtain the permits for drilling new boreholes which can supply sufficient water resource to Mombasa SEZ at the initial stage without influence on the current water supply system in Tiwi well-field. In this survey, 1) pumping test, 2) water quality test, 3) groundwater level monitoring for each borehole, and 4) numerical simulation of sustainable groundwater development potential are implemented.

(2) Basic Information of Tiwi Well-field

i) Topography, Geology and Hydrogeology

The sites of borehole drilling in this survey are located about 30 km south from Mombasa SEZ at Tiwi Well-field in Kwale County. The area of the Tiwi aquifer is small but it is still an important groundwater source strategically. The location and topographical information of Tiwi Well-field (Tiwi area) with the proposed borehole drilling sites are shown in the map below.



Source: JICA Design Team

Figure 8.5.11 Location and Topographical Information of Tiwi Well-field

The stratigraphy of Tiwi Well-field was reported by the Joint Venture SINCAT-ATKINS in 1996. Note that 147 km^2 of Tiwi Well-field crosses the area from the Mwache River in the south to Matuga and Ngombeni in the north. The eastern boundary is on the Pleistocene coral limestone, and the western boundary is approximately 2,000 meters west from the Likoni-Ukunda road (Adams 1986). Less than 70 m thickness of back-reef lagoon sand of Pleistocene age (so-called the “Kilindini Sands”) are deposited in the well-field. Hence, the aquifer is supposed to consist of coastal limestone. However, it should be considered as a major alluvial formation because of the alluvial character, very fine to coarse sands (Mumma et al., 2011). The Tiwi aquifer is semi-confined or confined, with a rest water level 25 to 30 m below the ground. Each borehole is capable of well-water supplies although fine sands frequently contaminate the water. Transmissivity values range from 120 to 600 m^2/day, and storage coefficients from 9.3×10^{-3} to 8.0×10^{-2} (TAHAL Group 2012).

ERA	PERIOD (age)	ROCKS & SEDIMENTS DEPOSITED	LITHOLOGY	ENVIRONMENT	CLIMATE	EVENTS
CENOZOIC	Recent (0.1 mily.)	Alluvial & Coastal Beach Sands, Coastal Sand Dunes	Superficial unconsolidated sands.	Coastal and near-coastal	Present day	Gradual rise in sea level
	Pieistocene (0.2 mily.)	Coral Reef and Lagoonal Kilindini Sands	Coral limestone Unconsolidated and cemented sands & clays.	Marine, coastal and near-coastal	Pluvial and Interpluvial	Fluctuating sea level
	Pliocene (7 mily.)	Magarini Sands: Upper Lower Marafa Formation	Fine grained, red wind blown sands. Coarse quartz sands, gravels & silty clays. Sandstone/ sands/ shales	Continental Fluviatile and deltaic	Arid ↑ Wet	Extensive erosion of Mesozoic deposits Faulting
	Miocene Oligocene Eocene (58 mily.)	Baratamu Formation	Marls/ limestone/ clays & sands	Shallow water littoral	Warm	Deposition, extensive continental erosion
MESOZOIC	Cretaceous (135mily.)	Mtomku Formation: Upper Middle	Shales & limestones Shale, limestone & sandstone			Faulting?
	Jurassic (195 mily.)	Mtomku Formation: Lower Kambe Limestone Mazeras Formation: Upper Middle	Shales, siltstones & sandstones Limestones, shales & siltstones Sandstones/ Arkoses Sandstone	Marine Continental	Warm	Marine invasion of coastal plain, subsequent limestone deposition
	Triassic (225 mily.)	Mariakani Sandstone: Upper Middle Lower Maji ya Chumvi: Upper	Sandstone Sandstone Sandstone Sandstones, shales, siltstones	Deltatic and lacustrine Deltatic	Generally semi-arid	Continental subsidence to form basin of deposition
PALAEOZIC	Permian (286 mily.)	Maji ya Chumvi: Lower Taru Grits: Upper Lower	Black, shaly siltstones Arkoses/Sandstones siltstone, shales Arkoses/ Conglomerates.	Lacustrine Continental	Generally semi-arid	Downwarping of continental margin

Source: Joint Venture SINCAT-ATKINS (1996)

Figure 8.5.12 Stratigraphy of Tiwi Well-field

ii) Aquifer Structure and Groundwater Flow

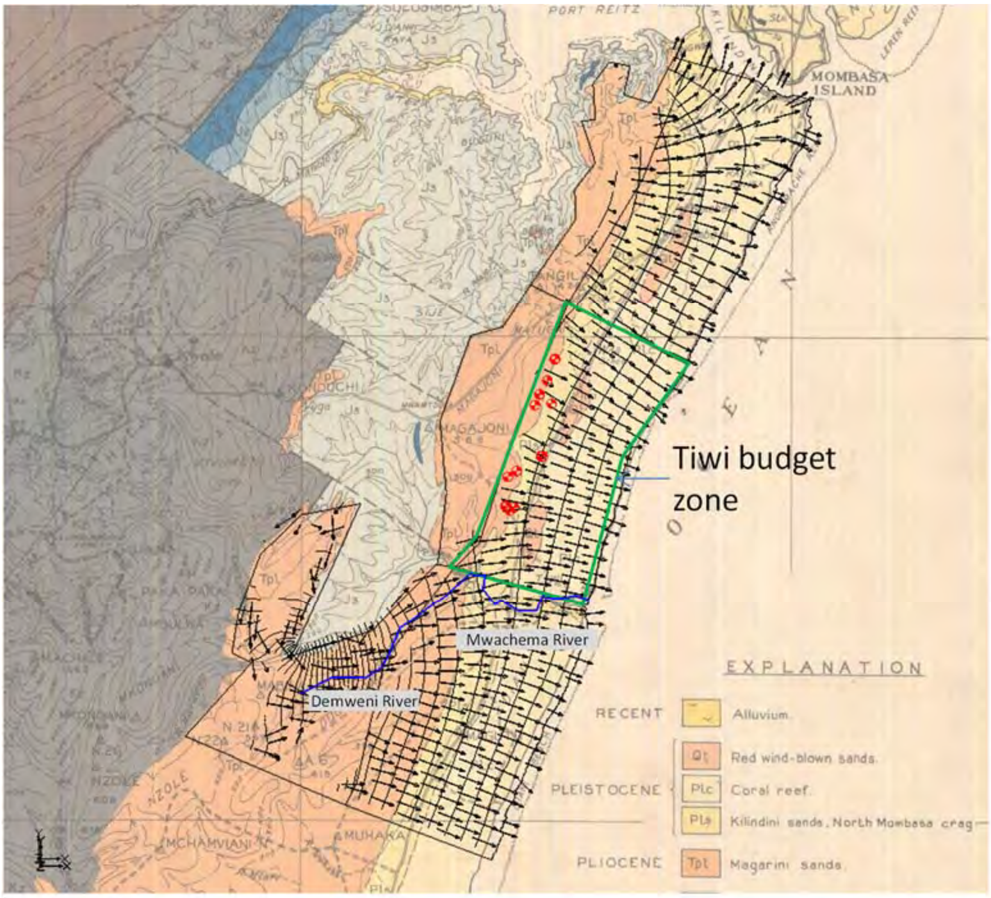
Only a few previous studies have reported about the aquifer structure of this area. On the other hand, our vertical electrical survey enables to comprehend two groundwater aquifers existence under the ground. The depth of the shallower aquifer is about 20~40 m, and the deeper one is about 60~75 m from the ground, respectively. Based on the knowledge, the aquifer structure of Tiwi Well-field can be summarized in Table 8.5.4.

Table 8.5.4 Aquifer Structure of Tiwi Well-field

Layer	Depth (-G.L.m)	Hydrogeologic condition
1	0~40	Permeable (Unconfined layer)
2	40~60	Impermeable
3	60~75	Permeable (confined layer)
4	75~80	Impermeable (Bottom layer of 3D model)

Source: JICA Design Team

There was no groundwater level simultaneous measurement has ever been carried out in Tiwi Well-field. However, the previous study of "Water Supply Master Plan for Mombasa and other Towns Within Coast Province Final Water Resource" has reported the groundwater flow system through the use of numerical simulation as shown in the figure below.



Source: Water Supply Master Plan for Mombasa and other Towns Within Coast Province Final Water Resource Report

Figure 8.5.13 Groundwater Flow System of Tiwi Well-field

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

iii) Information on the Existing Well

The previous study concluded that the current installed water supply capacity in Tiwi Well-field is approximately 13,000 m^3/day while the groundwater potential here is estimated at about 20,000 m^3/day (TAHAL Group 2012). The location and water production of existing wells are shown in Table 8.5.5, while the water quality analysis results is shown in Table 8.5.6. As shown in the table, the electrical conductivity of water from the wells is less than or equal to the Kenyan drinking water standard 2500 μS/cm. Some wells are observed to have high electrical conductivity. However, when considering wells of 1000 μS/cm or more, there was no correlation between well depth and electrical conductivity in the existing wells, and salt water penetration into existing deep wells (80 m deep) in the region was not confirmed.

Table 8.5.5 Location and Productivity of Existing Tiwi Well-field

Name	X*	Y*	Depth (m)	Production After Refurbishment (m^3/day)
Tiwi_BH1	563621	9532610	75.0	865
Tiwi_BH2	563781	9532720	85.0	1,154
Tiwi_BH4	565329	9538360	75.0	1,232
Tiwi_BH6_6.1	564800	9534660	61.4	541
Tiwi_BH7	565339	9538330	75.0	929
Tiwi_BH8	564745	9537000	75.0	391
Tiwi_BH8.2	564752	9537020	80.5	744
Tiwi_BH9	565199	9536650	80.0	216
Tiwi_BHA	564573	9536600	75.0	1,087
Tiwi_BHC	565035	9537530	64.9	1,058
Tiwi_BHD	563872	9534110	75.0	996
Tiwi_BHE	563536	9533890	75.0	1,020
Tiwi_BHG1	563447	9532780	66.5	1,262
Tiwi_BHG2	563478	9532780	75.0	1,368
Tiwi_BH6.3	564850	9534660	80.0	264
Total Production (m^3/d)				**13,127**

*Coordinate system is UTM 37S.

Source: JICA Design Team

Table 8.5.6 Groundwater Quality of Existing Tiwi Well-field

Sample Source	pH	Colour	E.C	TDS	Turbidity	Chloride	T.Alkalinity	T.Hardness	Ca^{2+}	Mg^{2+}
		Hazen	μs/cm	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l
Tiwi BH 1	7.3	2.5	1249	624.5	<5	194	294	208	81.81	1.46
Tiwi BH 2	7.6	2.5	1260	630.0	<5	151	310	182	36.45	22.45
Tiwi BH 4 & 7	6.99	2.5	796	298.0	5	121	388	190	75.33	0.98
Tiwi BH 6	7.2	2.5	1172	586.0	0	208	254	374	ND	24.40
Tiwi BH 6.1	7.4	2.5	2060	1030.0	<5	155	276	378	150.66	1.46
Tiwi BH 6.2	7.5	2.5	849	224.5	<5	73	326	126	39.69	6.83
Tiwi BH 8.1	7.2	2.5	854	227.0	<5	119	264	218	29.16	35.63
Tiwi BH 8.2	7.2	2.5	607	303.5	<5	57	224	230	32.40	36.60
Tiwi BH A	7.3	2.5	566	283.0	<5	38	250	158	42.12	13.18
Tiwi BH C	7.4	2.5	641	220.5	<5	38	290	170	27.54	24.89
Tiwi BH D3	7.4	2.5	700	350.0	<5	54	310	170	20.25	29.28
Tiwi BH E	7.2	2.5	643	321.5	<5	67	176	154	32.40	18.06
Tiwi BH G1	7.5	2.5	1246	623.0	<5	194	260	220	40.50	29.28

*Well name changed in some location due to rehabilitation

Source: JICA Design Team

(3) Result of Borehole Survey (1st phase)

i) Selection of Drilling Sites

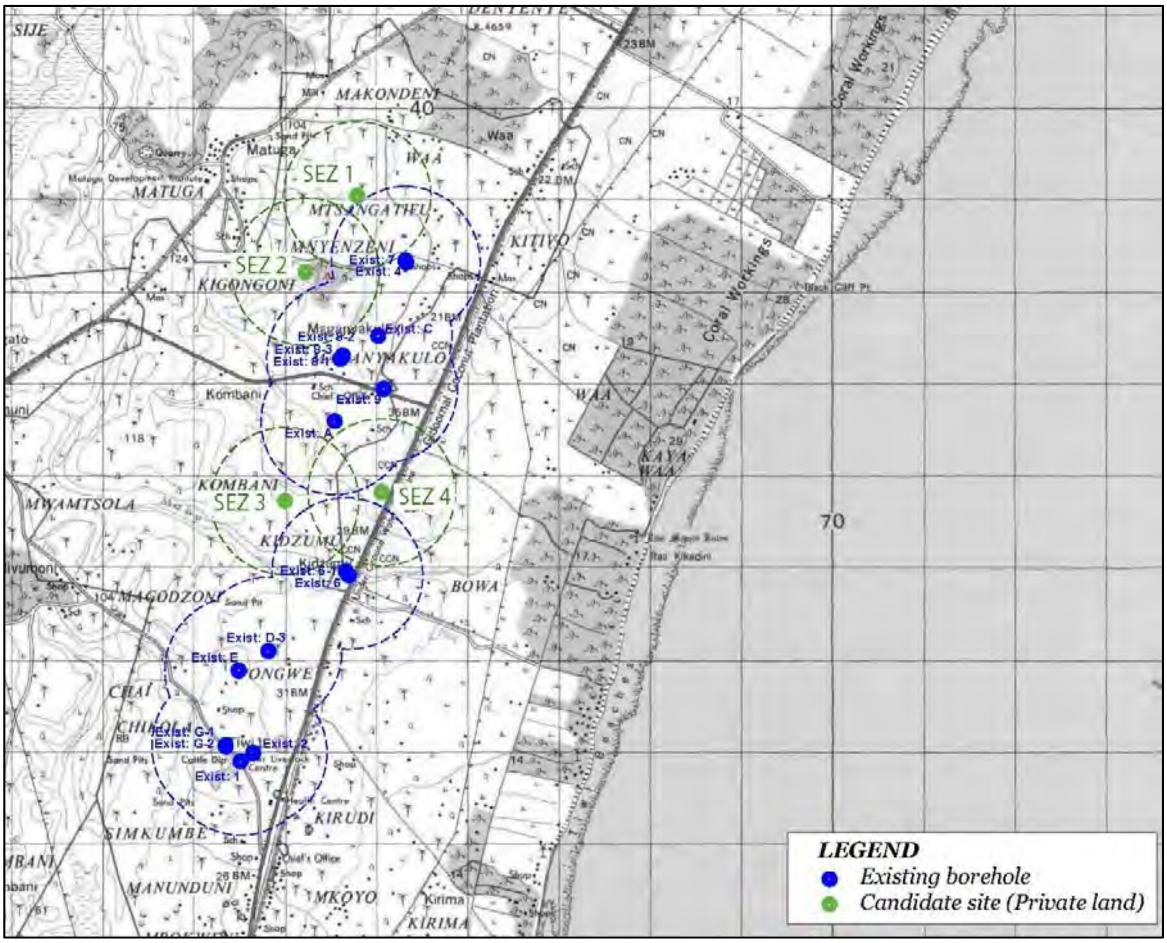
Through the use of the Vertical Electric Survey (VES) as well as taking into account the location of existing boreholes, four candidate sites for new borehole drilling have been selected. The VES results indicate that the shallow aquifer exists roughly between 20~40 m below ground level, while the deep aquifer lies between 60~75 m below ground level, which suggest a 75~80 m drilling depth for boreholes in the survey area.

Table 8.5.7 Information of Candidate Drilling Site Selected by VES

Site ID	Ownership	Borehole Location		Planned Drilling Depth (m)	Site Area
		Latitude (°)	Longitude (°)		
SEZ 1	*Private*	-4.172	39.585	75	20 m × 15 m
SEZ 2	*Private*	-4.182	39.580	80	20 m × 20 m
SEZ 3	*Private*	-4.203	39.576	80	20 m × 20 m
SEZ 4	Kwale County	-4.203	39.588	80	20 m × 20 m

Source: JICA Design Team

The locations of the new boreholes and existing boreholes are shown in Figure 8.5.14. Among the four sites, SEZ 1~SEZ 3 are located in a private land, and SEZ 4 is located in a land owned by Kwale County.



Source: JICA Design Team

Figure 8.5.14 Location of Drilling Sites

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

ii) Procedure to Obtain the Permission

For drilling new boreholes in Kenya, it is necessary to obtain a permit issued by the Water Resource Management Authority (WRMA). In order to get the permit from WRMA, application for drilling and some other related documents should be submitted. The status of those documents is shown in Table 8.5.8.

Table 8.5.8 Status of Necessary Documents for Drilling Permit

Document	Contents	Remarks
Permit Application	WRMA provides format	Developer prepares and applies.
Land Acquisition Agreement	Agreement from the land owner	SEZ 1,2 and 3: Agreement from private land owner SEZ 4: Consent letter from Kwale county
ESIA Approval	Get an approval on ESIA report	Submit to NEMA
Consent Letter	Acquire consent letter from relevant authorities for groundwater development	1) Kwale County Government Office for Water and Infrastructure 2) Mombasa Water Supply and Sanitation Company 3) Coastal Water Service Board

Source: JICA Design Team

iii) Drilling Survey

The drilling survey has been conducted at four selected locations. Drilling period, quantity, and specification are summarized in Table 8.5.9 below.

Table 8.5.9 Summary of Drilling Survey*

	SEZ-1	SEZ-2	SEZ-3	SEZ-4
Latitude (°)	-4.172	-4.182	-4.203	-4.203
Longitude (°)	39.585	39.580	39.576	39.588
Elevation	51m	50m	47m	40m
Period	2017/10/15～11/5	2017/10/13～10/14	2017/10/2～10/12	2017/10/23～10/28
Borehole depth	68 m	80 m	80 m	78 m
Depth of screen	GL-44 m～GL-62 m	GL-32 m～GL-50 m, GL-62 m～GL-74 m	GL-32 m～GL-44 m, GL-56 m～GL-74 m	GL-36 m～GL-48 m, GL-54 m～GL-72 m
Total length of screen	18 m	30 m	30 m	30 m
Casing size	8 inch* (steel)	8 inch* (steel)	8 inch* (steel)	8 inch* (steel)

* Borehole was drilled with 14 inch OD, and planned to install 10-inch uPVC casings. However due to collapsing of unconfined formation inside the wellbore, 8-inch steel casings were installed instead.

Source: JICA Design Team

iv) Pumping Test

After installation of casings, a pumping test was carried out to evaluate productivity of each well. The procedure for the pumping test is as follows.

- Pre-pumping test : to clean inside borehole, and determine discharge rate of step-drawdown
- Step-drawdown test : implement five steps test with designated discharge rate for two hours for each to evaluate productivity and determine discharge rate of constant-rate test

- Constant-rate test : pumping with designated discharge rate for 24 hours to observe stability
- Recovery test : to observe recovery of water table after constant-rate test

The results of each pumping test are summarized in the following table.

Table 8.5.10 Summary of Pumping Test*

	SEZ-1	SEZ-2	SEZ-3	SEZ-4
Period	2017/11/9～11/10	2017/10/20～10/21	2017/11/16～11/17	2017/11/11～11/12
Step-drawdown discharge rate	*	20,25, 30,40, 45 m^3/hr	20, 25, 36, 45, 55 m^3/hr	*
Constant rate	2.40 m^3/hr	36.0 m^3/hr	55.0 m^3/hr	5.50 m^3/hr
Pump depth	62.0 m	74.0 m	74.0 m	74.0 m
Static water level	47.60 m	48.50 m	43.80 m	34.88 m
Drawdown	7.96 m	11.02 m	21.23 m	34.27 m
Yield**	1.6 m^3/hr	25.2 m^3/hr	38.5 m^3/hr	3.8 m^3/hr

* Not conducted because of low discharge
** Appropriate yield is calculated with 70% of possible yield.
Source: JICA Design Team

v) Water Quality Analysis

Groundwater from each borehole has been collected and analyzed with the certain parameters. The result of the chemical analysis is summarized in the following table, which includes data of SEZ-5 and 8 of the 2nd survey.

Table 8.5.11 Result of Water Quality Analysis*

PARAMETERS	UNIT	1st phase					2nd phase		kenyan standard (drinking)*
		SEZ 1	SEZ 2	SEZ 3	SEZ 4	Lab	SEZ 5 (Lab 5)	SEZ 8 (Lab 6)	
pH	pH scale	6.94	7.27	6.66	7.23	1	6.69	7.00	6.5-8.5
Colour	mgPt/l	23.0	5.0	6.0	14.0	1	< 5	ND	50
Turbidity	NTU	8.49	ND	0.25	2.69	1		0.8	25
Total Alkalinity	mg/L	50.0	408.0	176.0	212.0	1	98.0	409.3	500
Conductivity (25°C)	μS/cm	353	999	977	727	1	776	5960	2500
Calcium	mg/L	17.8	74.4	50.4	62.4	1	11.4	40	250
Iron	mg/L	0.51	0.12	0.21	0.29	1	0.04	ND	0.3
Magnesium	mg/L	0.4	17.5	7.8	17.5	1	17.4	36.4	100
Total hardness	mg/L	46.0	258.0	158.0	228.0	1	100.0	250	500
Chlorides	mg/L	64.0	132	216.0	39.0	1	118.9	1575	250
Fluorides	mg/L	ND	0.87	0.20	0.49	1	< 1.0	0.1	1.5
Nitrates	mg/L	0.2	1.8	0.2	0.2	1		1.0	45
Nitrites	mg/L	0.004	0.001	0.003	0.016	1			-
Sulphate	mg/L	15.0	19.0	47.0	40.0	1	29.3	140	400
Free Carbon Dioxide	mg/L	202.0	14.0	26.0	274.0	1			-
Total dissolved solids	mg/L	219	619	606	451	1	388	3190	1500
Total suspension solids	mg/L	7.0	2.0	15.0	ND	1	ND	ND	-
Manganese	mg/L	0.027	0.05	0.08	0.006	1	0.07	0.2	0.1
Ammonia	mg/L	ND	ND	ND	0.25	1		0.1	0.5
Sodium	mg/L	56.8	168	403	106	2	73.28	1324	200
Potassium	mg/L	8	8	12	6	2	1.07		-
Arsenic	mg/L	< 0.01	< 0.01	< 0.01	< 0.01	3			0.05
Copper	mg/L	0.05	0	0	0.11	2	< 0.01	ND	0.1
Zinc	mg/L	0.13	0.04	0.05	0.13	2		0.1	5
Lead	mg/L	< 0.004	< 0.004	< 0.004	< 0.004	3	< 0.01		0.05
Total Coliforms Count	cfu/mL	-	Nil	-	Nil	2	10	30	10
		-	10	-	14	4			
Faecal Coliforms count	MPN/100 ml	-	Nil	-	Nil	2	-	-	Nil
		-	Nil	-	Nil	4			
Escherichia coil	cfu/mL	-	-	-	-	-	ND	ND	Nil

ND-Not Detected

* KS 05-459: Part 1:1996

Extremely High
Higher than standard value
Need to note
unmeasured

Lab 1: Kenya Water Institute (P.O.Box 60013, Nairobi)
Lab 2: Government Chemist's Department (P.O. Box 81119, Mombasa)
Lab 3: SGS Kenya Limited Laboratory Services (P.O. Box 90264, Mombasa)
Lab 4: Coast Water Service Board (P.O. Box 90417, Mombasa)
Lab 5: Pulucon, Blue Water Wells (P.O. Box 5263-01002, Thika)
Lab 6: Aqualytic Laboratories Ltd. (P.O. Box 4600-00506, Nairobi)

Source: JICA Design Team

As a result of water analysis, the groundwater of successful boreholes of SEZ-4 and 3 is not contaminated with hazardous materials. However, water sample of SEZ-1 shows a relatively high number of color, turbidity, and iron concentration. It is also observed that the chloride ion and sodium ion concentration of SEZ-3 were relatively high.

The concentrations of chloride and sodium ions in SEZ-8 greatly exceeds the drinking standard, and indicates that salinization have occurred.

In SEZ-2, 4, 5, and 8, E. coli group counts (total coliforms count) were detected. In Kenya, standards have been established for this item, but the number of coliform bacteria groups in Japan has been changed to "E. coli" because of the low index of fecal contamination. It is observed that there are no problems in water quality because fecal coliforms count or Escherichia Coli indicating fecal contamination has not been detected. On the other hand, if the Kenyan drinking standard is complied with, some kind of treatment such as disinfection or boiling is advisable.

(4) Result of Borehole Survey (2nd phase)

i) Background of Additional Drilling Survey

The drilling survey has been conducted at four sites in the Tiwi Region in 2017. The amount of water production capacity for successful boreholes is approximately 1,200 m^3/day (total) water production was found. However, the additional 800 m^3/day of the production is needed for the SEZ-project because the goal is around 2,000 m^3/day. Therefore, additional four drilling surveys for the water supply was planned in the same region. The following processes of the investigation were conducted to select the new sites:

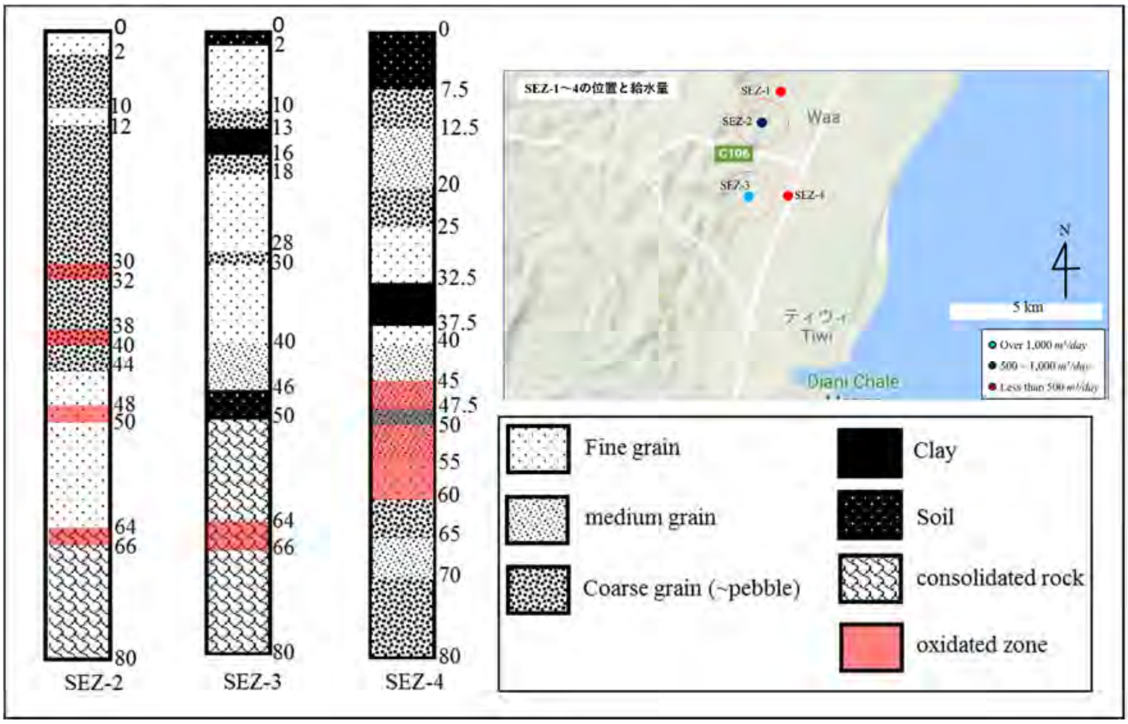
1) Review and feedback from the last study in 2017
2) Fieldwork to investigate geological structure and the topography
3) Conducting VES at six candidate-sites and some existing-boreholes that have higher ability of water supply, and the analysis.
4) Selection of four new drilling sites

1) Feedback on the latest study in 2017

To evaluate the reason of differences of yield at each borehole, the following observations were conducted:

- Sampling observation
- Comprehending quantity of water production and chloride ion concentration at all existing boreholes

Samples were obtained during the drilling survey in 2017. These were observed to make the stratigraphic column at each site to evaluate the geological structure. However, the samples at SEZ-1 were missing.

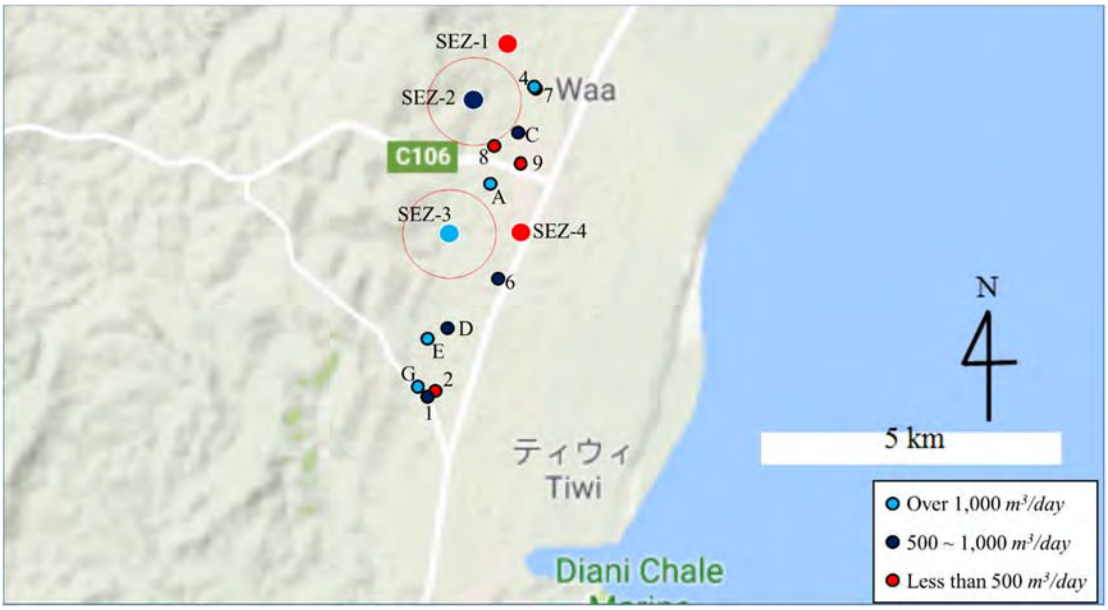


Source: JICA Design Team

Figure 8.5.15 Stratigraphic Column of SEZ-2 to 4

The Tiwi aquifer is supposed to exist at a layer of the quaternary unconsolidated deposit (Carruthers, 1985). Mainly coarse grains are deposited at SEZ-2 and 3 (comparable higher elevation), suggesting that transportation of the sediments is occurring. In addition, shale rock at the bottom layer is observed, respectively. The shale layers are relating to the late tertiary layer, suggesting that the other unconsolidated sediment layers are relating to quaternary layers and corresponded to the existence of aquifers. On the other hand, samples at SEZ-4 are consisted of fragments of carbonate rock (coral fragments) with higher muddy rate. This suggests the eustasy would be dominated in this region and the site is supposed to be paleo-lagoon. The structure of the sediments in this site would be higher filling fraction and bad-permeability, resulting in lower possibility of potential aquifer (a result of water production in SEZ-4 reveals lower potential, actually). Therefore, dominatable of the eustasy point should be avoided for drilling candidates.

The water production capacity at each existing-borehole including SEZ-boreholes is plotted to confirm the area that possesses the higher/lower quantity.

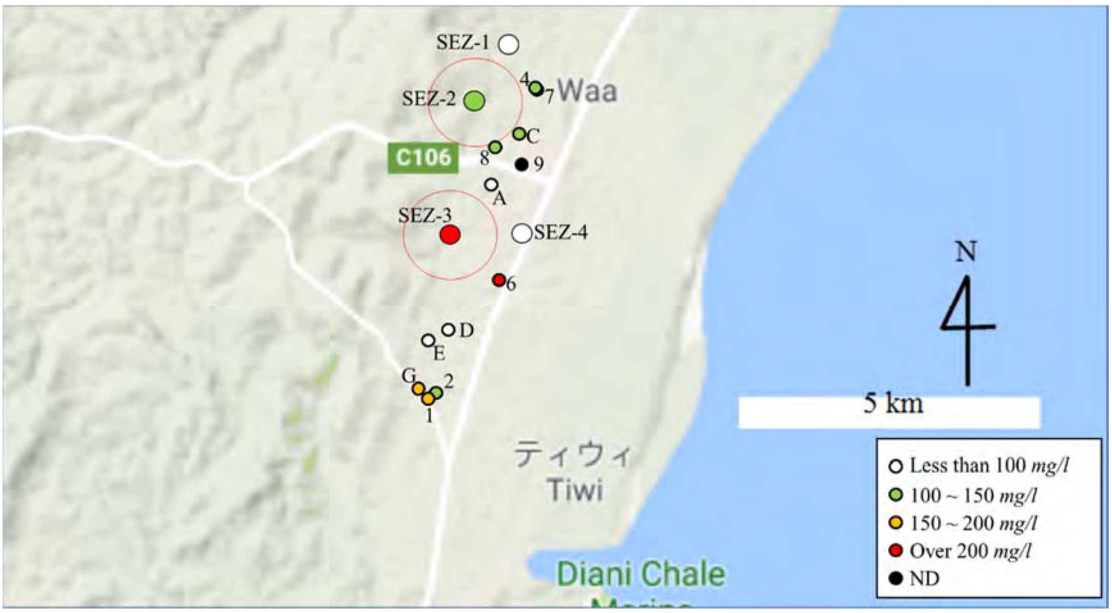


Source: JICA Design Team

Figure 8.5.16 Location of Existing Boreholes and the Quantity of Water Supply

Boreholes with higher capacity of water production are located at a higher elevation of terrace and/or paleo-river, while wells of the lower capacity are plotted in plain field at lower elevation.

The next figure shows the chloride concentration of each existing borehole which is the indication of salinization of groundwater. The plotting chloride ion elucidates areas around SEZ-3 and BH-6 should be avoided being the candidate owing to the higher concentration.



Source: JICA Design Team

Figure 8.5.17 Location of Existing Boreholes and Chloride Ion Concentration

2) Fieldwork on Geological Structure and the Topography

Conducting outcrop observation at the river side at 500 m south from SEZ-3, the sediment consists of poorly-sorted sand to coarse grain. This structure of the sediment has a lower filling factor and permeability, resulting in the possibility of a good aquifer. Therefore, the site nearby the river and paleo-river are supposed to be a better candidate to conduct the drilling survey.

In the Tiwi Region, there are many sand-harvest places that created artificial eroded land. Precipitation during the rainy season is frequently pooling at the land and forming ponds that propagate lotus flowers. The fieldwork was conducted in January 2018 during the dry season and many ponds were still found. This suggests peat deposits at the sites, and this sediment might prevent recharge of the groundwater from the surface.

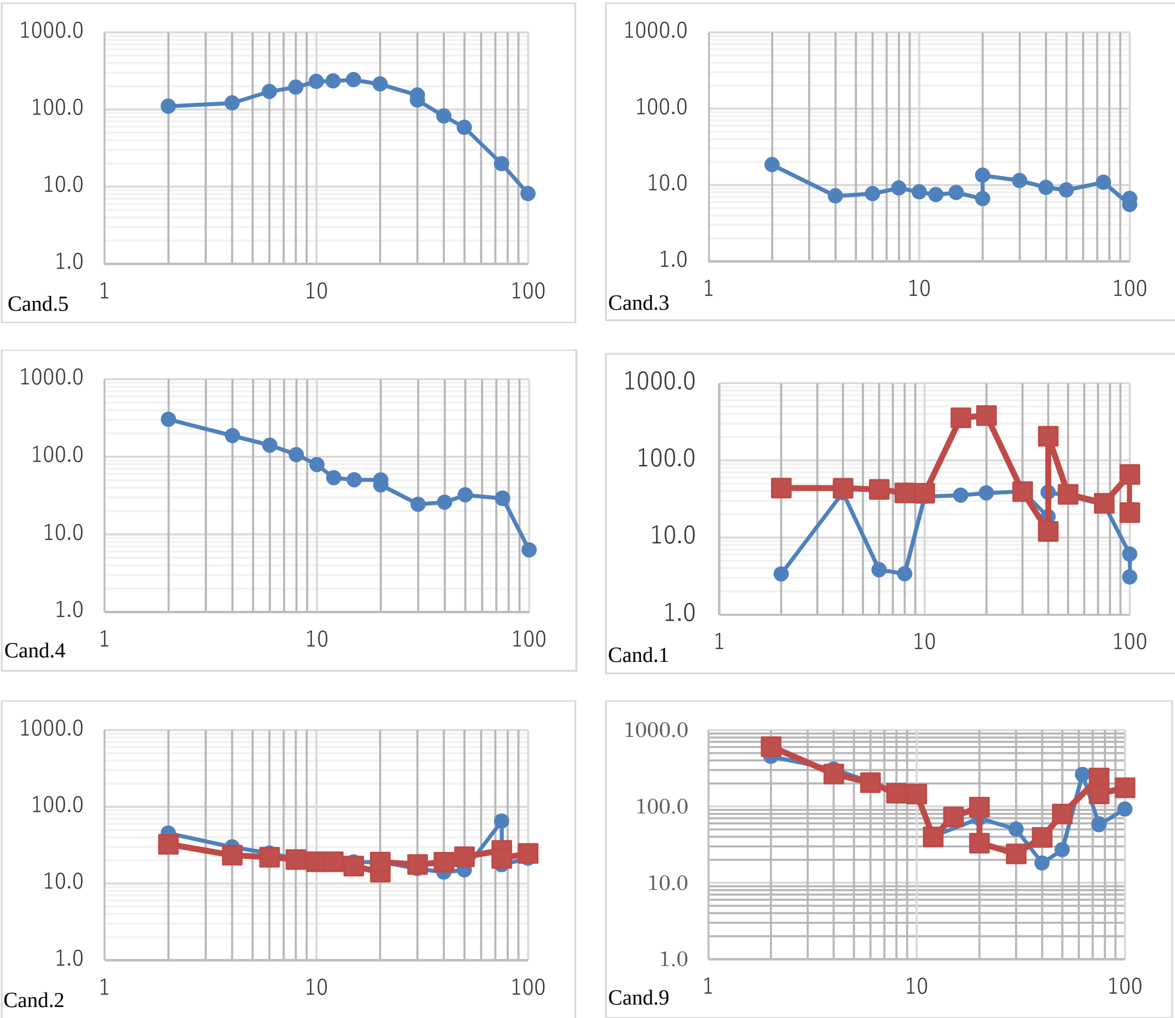
A lot of outcrops, consisting of diagenesis calcite rock (originating aragonite, or coral), were found at the eastern side from the NS-direction main road during the fieldwork. This type of rock is supposed to be solid and have lower permeability than the poorly-sorted unconsolidated sediment. Hence, the area with calcite rock should be avoided in the selection of a candidate.

3) Conducting VES and Analysis

The processes of this investigation enabled to select six candidates for the drilling survey. To identify four sites for the drilling survey, VES was conducted for each candidate site. Moreover, existing boreholes that possess higher quantity of water production were also selected to conduct the same survey to obtain the references for analysis. Following Figure 8.5.18 shows the locations of six candidates and existing boreholes followed by the result of the VES.

Source: JICA Design Team

Figure 8.5.18 Locations of Six Candidates and Existing Boreholes

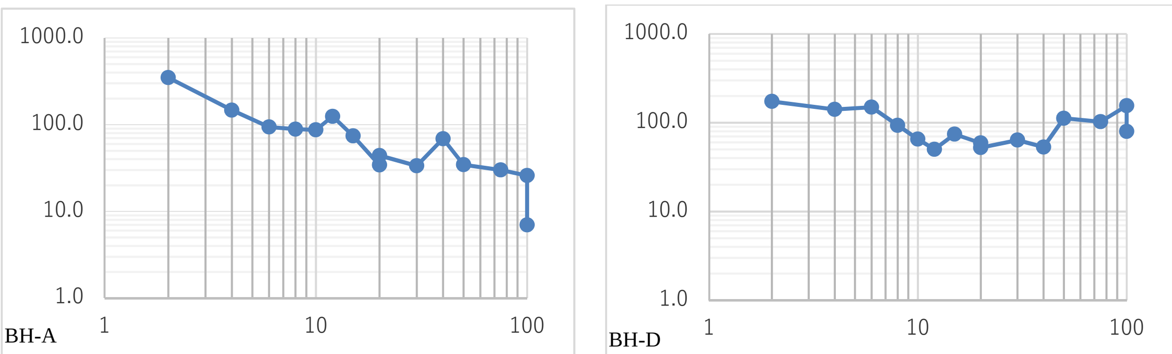


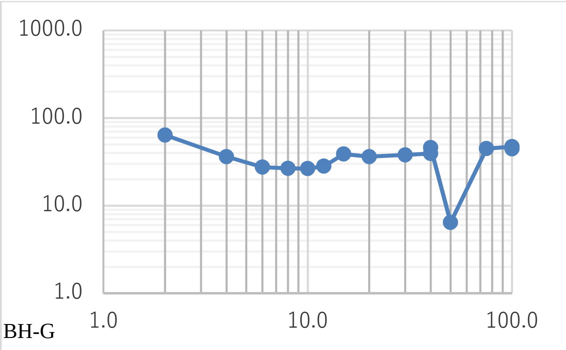
(x-axis relating to depth (m), whereas y-axis relating to value of resistivity (Ω-m))

Source: JICA Design Team

Figure 8.5.19 VES Results of Six Candidates (Ordering from Northern Side)

Candidates 1, 2, and 9 were conducted in two directions as N-S and E-S (relating to blue and orange, respectively, in the figures) whereas Candidates 3, 4, and 5 could be conducted only in one direction, owing to the geography at the site. Moreover, some existing boreholes located near the candidate sites were also selected and conducted VES as references for the analysis.





(x-axis relating to depth (m), whereas y-axis relating to value of resistivity (Ω m))

Source: JICA Design Team

Figure 8.5.20 VES Results of Existing Boreholes (Ordering Northern Side)

Table 8.5.12 below shows the summary of the analyses of the VES result of six candidates with relativity of VES results of existing boreholes.

Table 8.5.12 Summary of VES Analysis

Candidate	Results of VES Analysis	Similarity to the Results of Existing Wells
Cand. 5	Arc plot = coral stratum	N/A
Cand. 3	<10 Specific Resistance = expected thinness of strata with low permeability such as mud strata and aquifers	N/A
Cand. 4	Ideal resistivity at depths of 30 to 50 m	A
Cand. 1	<10: Built-up of mud and expectation of aquifer over 30 to 80 m	G
Cand. 2	Aquifer 30-70 m deep expected	G
Cand. 8	Indicates the presence of water at a depth of about 10 m and 20-50 m.	N/A

Source: JICA Design Team

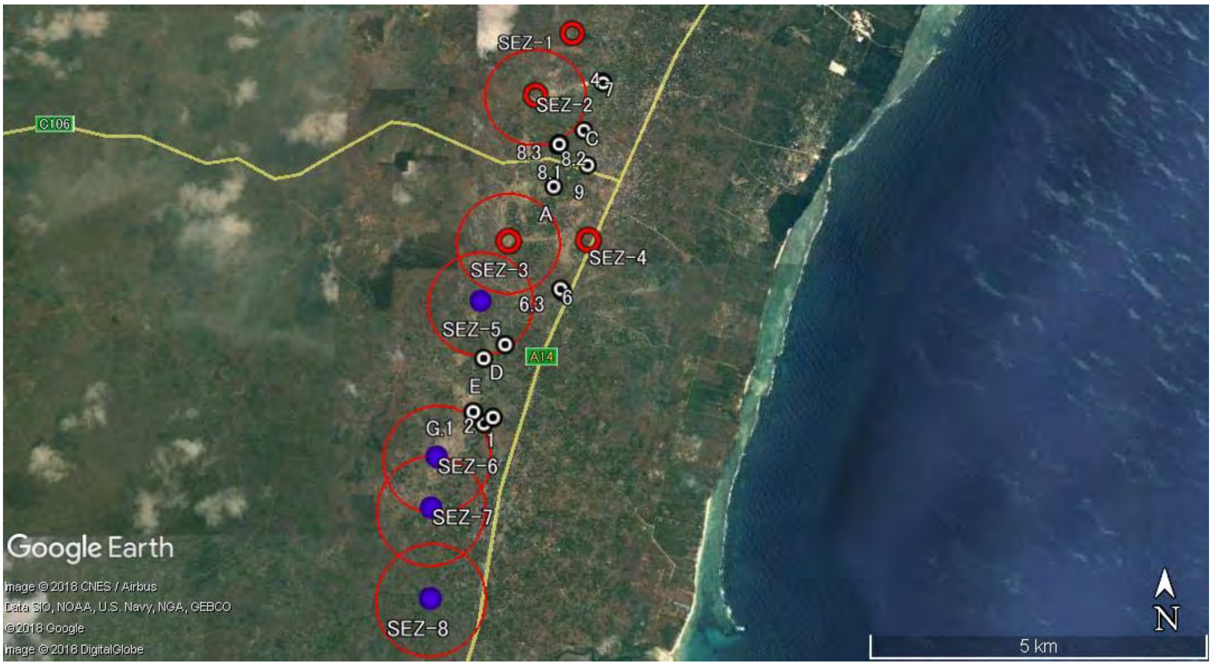
Ⅴ-4) Selection of Four New Drilling Sites

After analyzing VES data of six candidate sites, Candidates 1, 2, 4, and 9 were selected for drilling sites. The ID numbers are SEZ-6, 7, 5, and 8, respectively. General information of these drilling sites is summarized in the following table.

Table 8.5.13 Information of New Drilling Sites

Site ID	Ownership	Borehole Location		Planned Drilling Depth (m)	Site Area
		Latitude (°)	Longitude (°)		
SEZ 5	Private	-4.211	39.573	90	20 m × 20 m
SEZ 6	Private	-4.233	39.567	90	20 m × 20 m
SEZ 7	Private	-4.240	39.567	90	20 m × 20 m
SEZ 8	Private	-4.252	39.569	90	20 m × 20 m

Source: JICA Design Team



Source: JICA Design Team

Figure 8.5.21 Location of New Drilling Sites (SEZ-5-8)

ii) 2nd Drilling Survey

The results of the 2nd survey are summarized in the table below.

Of the sites subjected to the second drilling survey, only SEZ-8 initially completed all tests. The other three sites were drilled to the planned depth; however, when the casings were installed, the wells collapsed, and the finishing of the wells could not be completed. Of these three sites, SEZ-6 was judged to have failed due to a technical mistake of the drilling contractor, so re-excavation was carried out on the basis of the contract.

The location for this redrilling was selected at SEZ-5, having the farthest location from the south (SEZ-8) where signs of salinization were observed.

In addition, it was judged that it was difficult to overcome the collapse in the borehole using the materials and equipment owned and the operation technology by the contractor because it was caused by the geological condition of the target area. Therefore, in order to reduce the risk of collapse, the bit diameter was changed from 14 inches to 12 inches and the casing diameter from 10 inches to 6 inches so that the gap between the casing and the wall was increased.

SEZ-5 (second time) and SEZ-8 were drilled to the planned depth of 90 m, but drilling cuttings and rocks were accumulated by the geological collapse in the borehole when the casing was installed, and the insertion depth of the casing was 63 m and 72.5 m, respectively.

Geological logs of SEZ-5, 6, 7, and 8 are attached in the annex.

Table 8.5.14 Summary of the 2nd Drilling Survey

	SEZ-5（1st）	SEZ-5（2nd）	SEZ-6	SEZ-7	SEZ-8
Latitude (°)	-4.211	-4.211	-4.233	-4.240	-4.252
Longitude (°)	39.573	39.573	39.567	39.567	39.569
Elevation	42 m	42 m	27 m	35 m	27 m
Period	2018/9/18～9/24	2019/1/16～1/22	2018/9/10～9/16	2018/9/4 ～ 9/15	2017/10/23 ～ 10/28
Borehole depth	90 m	90 m	90 m	90 m	90 m
Bit size	12 inches	12 inches	14 inches	14 inches	12 inches
Depth of screen	-	GL -30-33 m, 36-42 m, 45-51 m, 57-60 m	-	-	GL-12.5-15.5 m, 18.5-21.5 m, 24.5-30.5 m, 36.5-39.5 m, 42.5-48.5 m, 51.5-54.5 m, 60.5-63.5 m
Total length of screen	-	18 m	-	-	27 m
Casing size	-	6 inch* (uPVC)	-	-	8 inch* (uPVC)
Depth of well	-	GL-63 m	-	-	GL-72.5 m

* Borehole was drilled with 14 inches lod, and planned to install 10-inch uPVC casings. However due to collapsing of unconfined formation inside the wellbore, smaller size of casings was installed instead.

Source: JICA Design Team

iii) Pumping Test

The capacity of the aquifer was evaluated by the pumping test in SEZ-5 and SEA-8 where the casings were successfully inserted. The procedure of the pumping test is the same as that of the first phase.

It should be noted that the measured value of the yield water volume depends on the capacity of the pumps that can be procured locally by the subcontractor, and neither of the following has reached the limit pumped water volume. Therefore, it can be considered that the possible pumping capacity is adequate.

Table 8.5.15 Summary of Pumping Test (2nd phase)

	SEZ-5	SEZ-8
Period	2019/2/13～2/15	2018/10/17～10/19
Step-drawdown discharge rate	42,44,46,48,50 m^3/hr	52,54,56,58,60 m^3/hr
Constant rate	50.0 m^3/hr	60.0 m^3/hr
Pump depth	58.0 m	58.0 m
Static water level	45.01 m	22.22 m
Drawdown	2.32 m	6.36 m
Dynamic water level	47.33 m	28.56 m
Yield*	35.0 m^3/hr	42.0 m^3/hr

* Appropriate yield is calculated with 70% of possible yield.

Source: JICA Design Team

iv) Water Quality Analysis

Result of analysis of SEZ-5 and 8 is summarized in the same table of the result of the 1st phase.

v) Summary of Drilling Survey

Groundwater of each borehole has been collected and analyzed with the following parameters. The result of chemical analysis is summarized in the following table, which includes the data of SEZ-5 and 8 of the 2nd survey.

Table 8.5.16 Summary of Drilling Survey

Item	SEZ-1	SEZ-2	SEZ-3	SEZ-4
Drilling survey	Excavate to 68 m (14")	Excavate to 80 m (14")	Excavate to 80 m (14")	Excavate to 78 m (14")
Casing insertion	8-inch (steel)	8-inch (steel)	8-inch (steel)	8-inch (steel)
Pumping test Appropriate yield	1.6 m^3/hr	25.2 m^3/hr	38.5 m^3/hr	3.8 m^3/hr
Quality test of water	Compliance with drinking standards	Compliance with drinking standards	Sodium ion concentration slightly higher but available (403 mg/liter, standard 200 mg/liter)	Compliance with drinking standards
Evaluation of water s wells	Do not use because the amount of water is small.	Successful well	Successful well	Do not use because of low water volume (donated to communities)

Item	SEZ-5 (2nd)	SEZ-6	SEZ-7	SEZ-8
Drilling survey	Excavate to 90 m (12")	Drilling to a planned depth of 90 m also failed due to underground trouble (14")	Excavation completed to the planned depth of 90 m (14")	Excavation completed to the planned depth of 90 m (12")
Casing Insertion	6" uPVC to GL-63 m	Inserted up to around 63 m, but failed due to the occurrence of a trouble in the pit.	Interruption due to collapsible formation (10" uPVC) >45 m	8" uPVC to GL-72.5m
Pumping test	35 m^3/hr	Not implemented	Not implemented	48 m^3/hr
Quality test of water	Compliance with drinking standards	Not implemented	Not implemented	Contains much higher salinity than the drinking standard (chloride ion: 1,575 mg/liter; standard: 250 mg/liter)
Evaluation of water supply wells	Successful well	Wells failed due to defective construction, and re-excavation is in progress at the SEZ-5 site.	Casing cannot be inserted. Failed well	Not applicable for drinking due to high salinity.

* Appropriate yield is calculated with 70 % of possible yield.
Source: JICA Design Team

(5) Numerical Simulation of Groundwater Flow System

i) Objective of Groundwater Numerical Simulation

As the Tiwi Well-filed is located in the coastal area, the salinization pollution problem may occur in the well due to over-pumping. Furthermore, besides the borehole drilled by this survey, there are still other pumping wells distributed in this area. The well interference problem may also happen if an inappropriate

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

pumping rate is set in those new boreholes, which may induce groundwater level decline and quality deterioration in other wells.

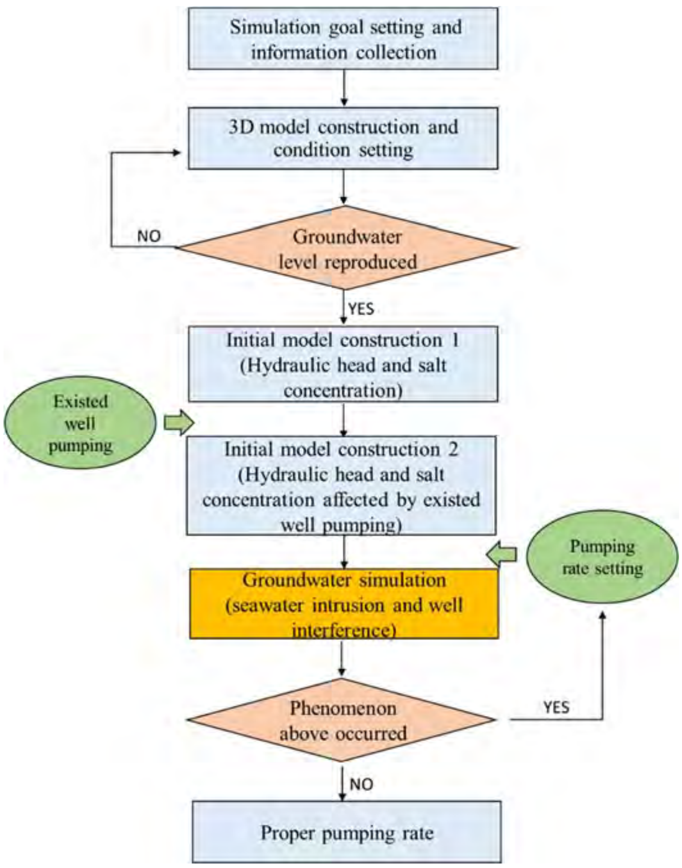
In order to prevent the problems above from happening, a numerical simulation 3D model will be used for estimating the proper pumping rate in the new borehole.

ii) Method

Finite element method will be used in a 3D model to simulate the groundwater flow system in target area. In the model, non-steady state groundwater flow will be calculated considering the groundwater movement and material transport. FEFLOW (DHI) will be used for the 3D model construction and simulation.

By now, the drilling surveys in six sites (SEZ-1~5 and SEZ-8) have been completed, and information such as layer permeability and static groundwater level has also been obtained through the survey. The results of the pumping test on drilling boreholes showed that the water supply capacity is low in SEZ-1 and SEZ-4 which cannot be used as pumping wells. On SEZ-8, although enough pumping rate has been confirmed, the saline concentration is too high; thus, the water of this well also cannot be used as pumping well. Therefore, only three pumping wells (SEZ-2, SEZ-3 and SEZ-5) will be considered in the model.

The flow of numerical simulation is shown in the figure below.



Source: JICA Design Team

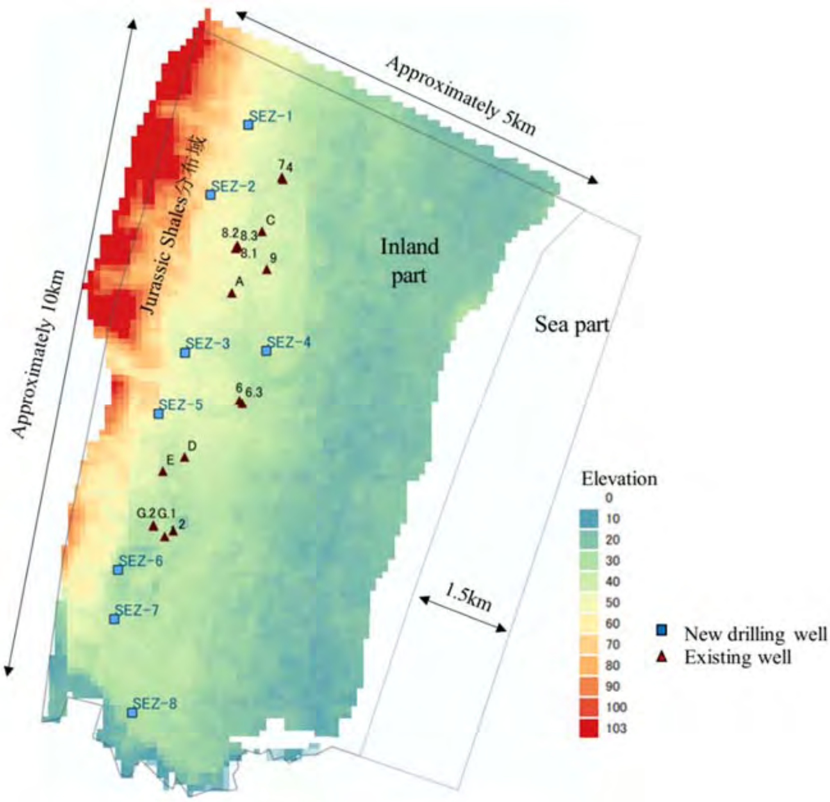
Figure 8.5.22 Flow of Numerical Simulation

iii) Model Construction and Conditions Setting

- Model Overview

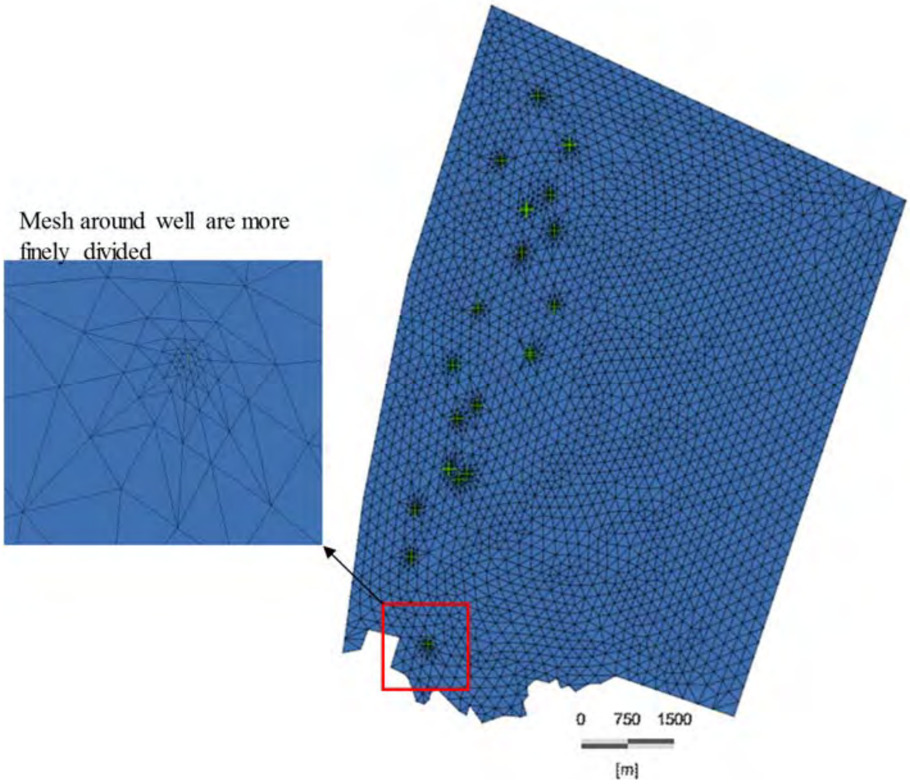
The simulation area is shown in the figure below, which is about 10 km × 5 km. In this analysis, in order to simulate the saltwater intrusion from the sea to the inland side, the coastal boundary of the analysis range is extended to the seaside by 1.5 km, and the expanded part is given the salt concentration of the sea. Jurassic Shales is set as the western boundary, while the river in the south is set as the southern boundary.

Irregular meshes are generated by the meshing tool in FEFLOW. The distance between the mesh nodes is approximately 150 m, but in order to reproduce the change of the groundwater level in more detail, the mesh around the pumping well have been divided more finely. Meshes generated by FEFLOW is shown in Figure 8.5.23.



Source: JICA Design Team

Figure 8.5.23 Analysis Area of Numerical Simulation

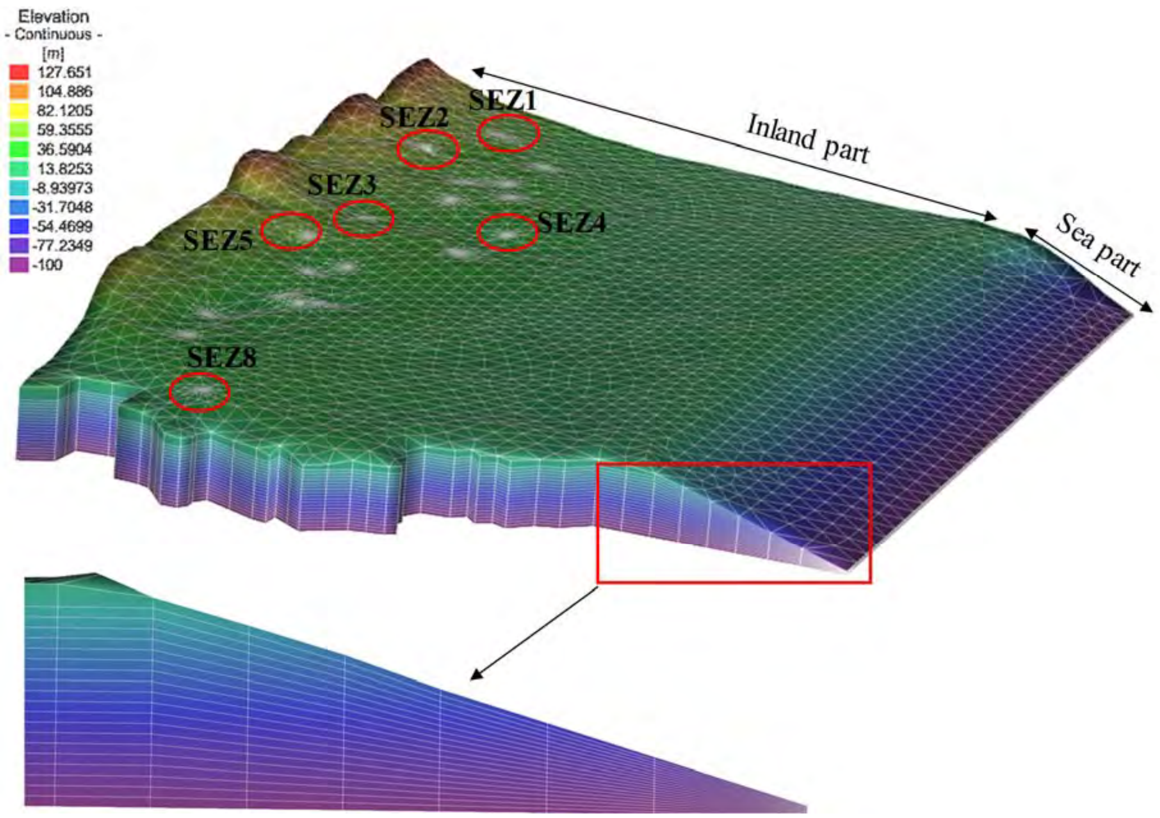


Source: JICA Design Team

Figure 8.5.24 Mesh Structure in the Model

- 3D modelling

After completing the mesh generation, the model will be extended from 2D to 3D model. Initially, elevation of the surface and bottom layer is set at 0 m and 100 m, and the thickness of each layer is set at 5 m. After that, the actual elevation value will be given to the surface layer, and the layer thickness of the ocean part will be modified accordingly to the seafloor topography (See Figure 8.5.25 below).



Source: JICA Design Team

Figure 8.5.25 Structure of 3D Modelling

- Layer and physical property value setting

According to the information collected from the geological samples during borehole drilling as well as existing report, it is estimated that the formation in the survey area is composed of layers with good permeability of up to 100 m depth, so the stratum of the entire model is assumed to be the aquifer.

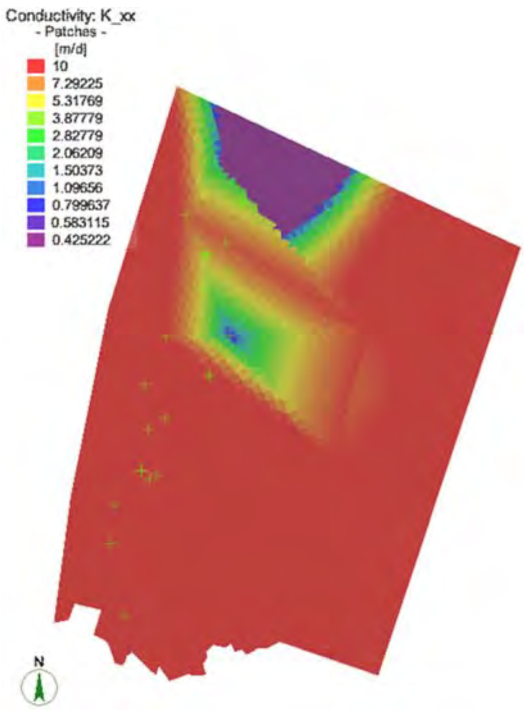
At the stage of the initial model construction 1, the permeability coefficient of the aquifer is calculated using the Akima Linear interpolation method based on estimated value through the pumping test. The permeability coefficient in each site is shown in table below. Although SEZ-3 and 8 show high permeability, since the number of total drilling sites are not enough to represent the whole survey area, the relatively high value that may only represent the situation in a very limited area is not suitable to be used directly in the model. Thus, for the permeability coefficient in these two sites, it was decided not to use the pumping test data but to use a general value of 10 m/day for the Tiwi aquifer reported by previous studies.

Table 8.5.17 Calculated Permeability Coefficient and the Values Used in the Model

Site	Permeability Coefficient (m/day)	Values Used in the Model (m/day)
SEZ-1	1.60	1.60
SEZ-2	8.66	8.66
SEZ-3	31.61	10
SEZ-4	0.43	0.43
SEZ-5	142.87	10

Source: JICA Design Team

The distribution of the permeability coefficient in the horizontal direction calculated by interpolation method is shown in Figure 8.5.26. As a provisional value, the permeability coefficient in the vertical direction is set at 1/10 of that in horizontal direction.

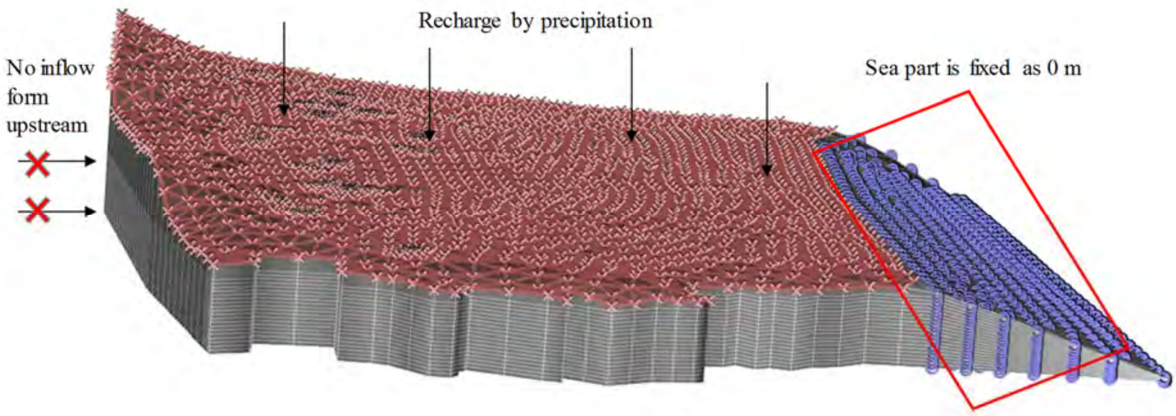


Source: JICA Design Team

Figure 8.5.26 Distribution of Permeability Coefficient by Interpolation Method

- ➢ Hydraulic head boundary and recharge condition

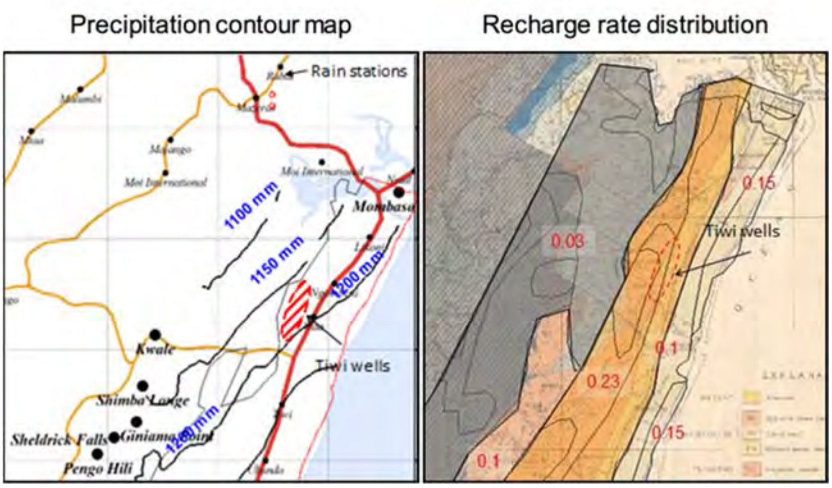
At the stage of initial model construction, the hydraulic head boundary and the recharge condition are set as shown in Figure 8.5.27.



Source: JICA Design Team

Figure 8.5.27 Hydraulic Head Boundary and Recharge Condition Setting

The groundwater recharge amount in the survey area is calculated to be approximately 980 mm/a (precipitation) × 0.03 (recharge rate) = 29.4 mm/a according to previous studies.



Source: TAHAL Group 2012

Figure 8.5.28 Precipitation Contour Map and Recharge Rate Distribution in Tiwi

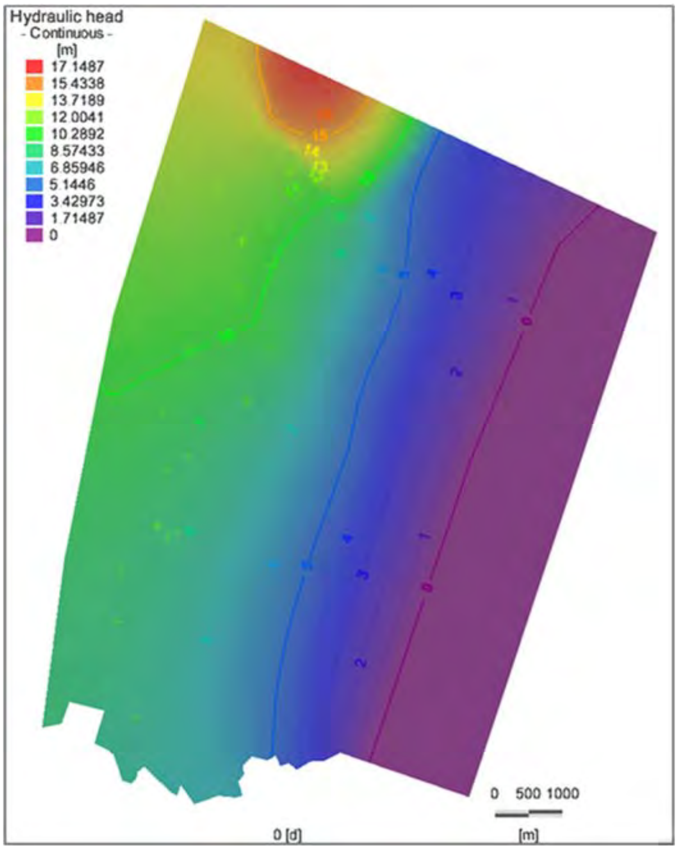
At the stage of the 3D model construction, the precipitation recharge rate has been adjusted to 18.25 mm/a (0.0005 m/day) which could roughly reproduce the groundwater level in SEZ-2 (north side) and SEZ8 (south side) (Table 8.5.18). The initial groundwater contour map is shown in Figure 8.5.29.

After determining the recharge rate, the initial model construction 1 and 2 will be done.

Table 8.5.18 Calculated Permeability Coefficient and the Values Used in the Model

Site	Ground Surface Elevation (m)	Observed Static Groundwater Level (G.L.-m)	Observed Static Groundwater Level (m)	Calculated Groundwater Level (m)
SEZ-2	63.0508	48.50	14.5508	11.9138
SEZ-8	29.2021	22.81	6.3921	6.69566

Source: JICA Design Team



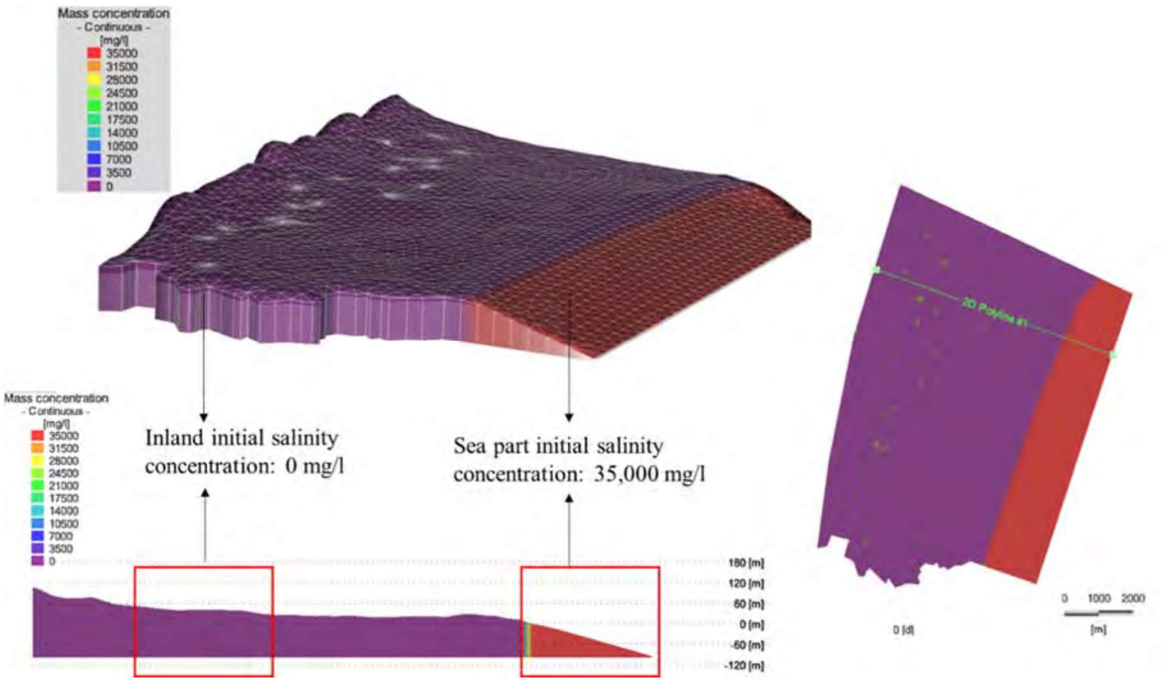
Source: JICA Design Team

Figure 8.5.29 Initial Groundwater Contour Map in Tiwi Area

iv) Initial Model Construction 1 and 2

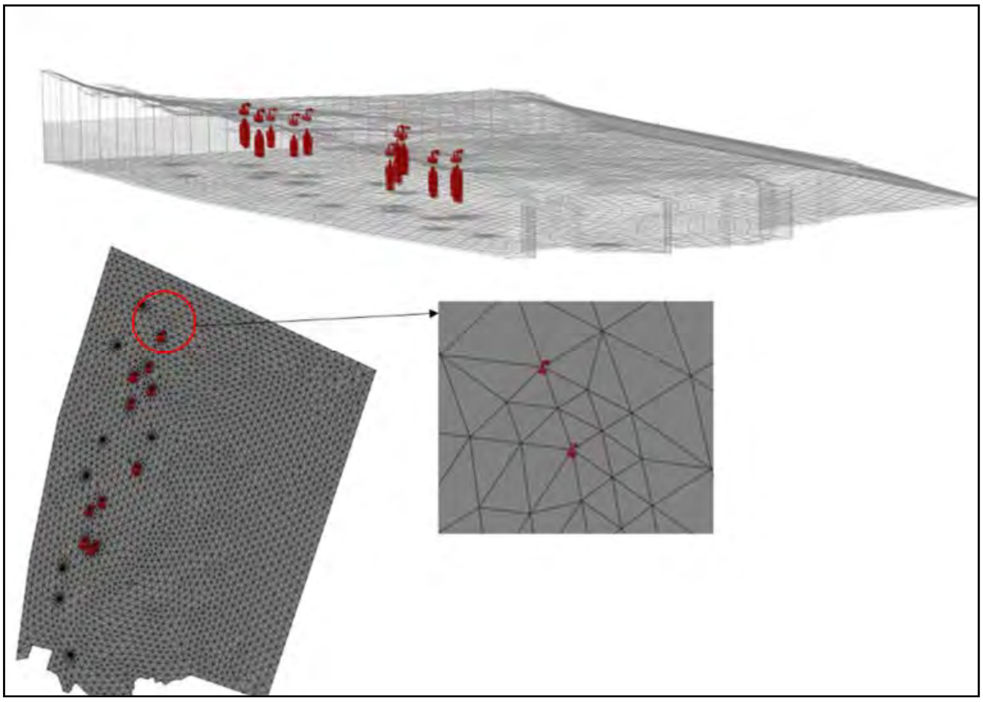
After setting the necessary parameters, in the process of building the initial model, conditions like the initial salt concentration distribution and existing well configuration should be provided to the model. As shown in Figure 8.5.30, initial salt concentration of the sea part was set at 35,000 mg/L and that of the inland part was set at 0 mg/L. Meshes around the wells have already been finely divided, and the existing well will be configured in the center of those meshes.

Pumping rate and well depth have been set as shown in table below. It should be noted that the pumping rate measured are those taken after the rehabilitation of existing wells, so the groundwater level distribution calculated by the model may be different from the current actual situation in Tiwi area.



Source: JICA Design Team

Figure 8.5.30 Setting of the Initial Concentration Distribution



Source: JICA Design Team

Figure 8.5.31 Configuration of the Existing Well

Table 8.5.19 Configuration Information of Existing Well

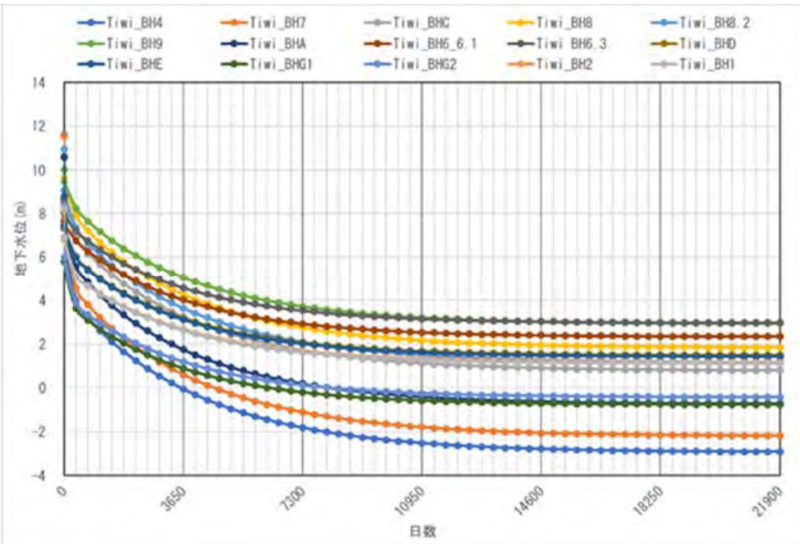
Name	X*	Y*	Depth (m)	Model depth (m)	Production after refurbishment (m³/day)
Tiwi_BH1	563621	9532610	75	75	865
Tiwi_BH2	563781	9532720	85	85	1,154
Tiwi_BH4	565329	9538360	75	75	1,232
Tiwi_BH6_6.1	564800	9534660	61.4	60	541
Tiwi_BH7	565339	9538330	75	75	929
Tiwi_BH8	564745	9537000	75	80	391
Tiwi_BH8.2	564752	9537020	80.5	80	744
Tiwi_BH9	565199	9536650	80	80	216
Tiwi_BHA	564573	9536600	75	75	1,087
Tiwi_BHC	565035	9537530	64.9	65	1,058
Tiwi_BHD	563872	9534110	75	75	996
Tiwi_BHE	563536	9533890	75	75	1,020
Tiwi_BHG1	563447	9532780	66.5	65	1,262
Tiwi_BHG2	563478	9532780	75	75	1,368
Tiwi BH6.3	564850	9534660	80	80	264

Source: JICA Design Team

The construction of the initial model is completed after setting the parameters above. The initial model will be calculated for enough years until the groundwater level in existing wells are stable. After that, new drilled wells will be additionally configured into the model, and the model will be recalculated including the discussion if the seawater intrusion and well interference have occurred or not.

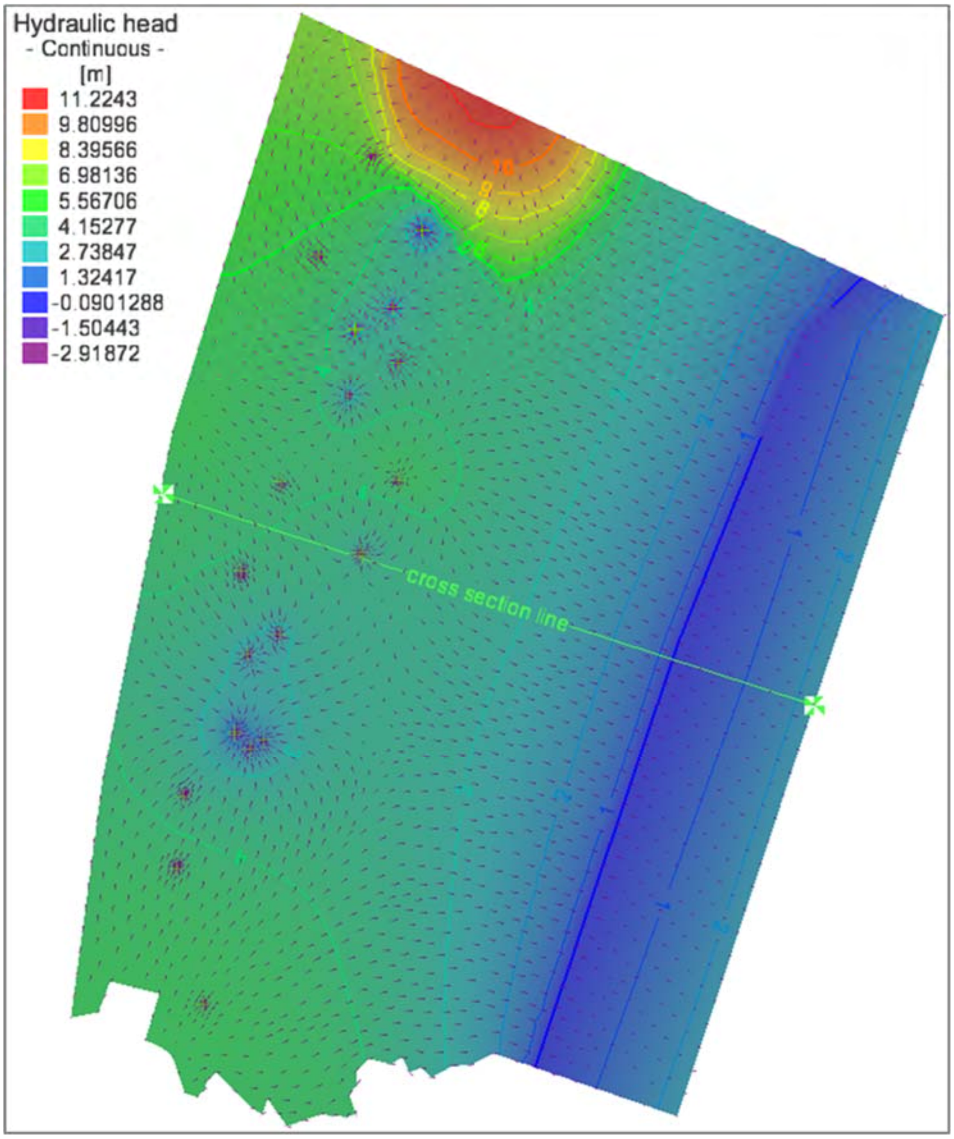
v) Results of Initial Model and Discussion

Groundwater level changes of existing wells calculated for 60 years are shown in the figure below. The figure shows that groundwater level decreases gradually since the initial status, and after about 40 years, it can be found to become state. Therefore, it can be considered that the model has reached a new equilibrium status after 60 years. The groundwater level and flow map are shown in the figure below.



Source: JICA Design Team

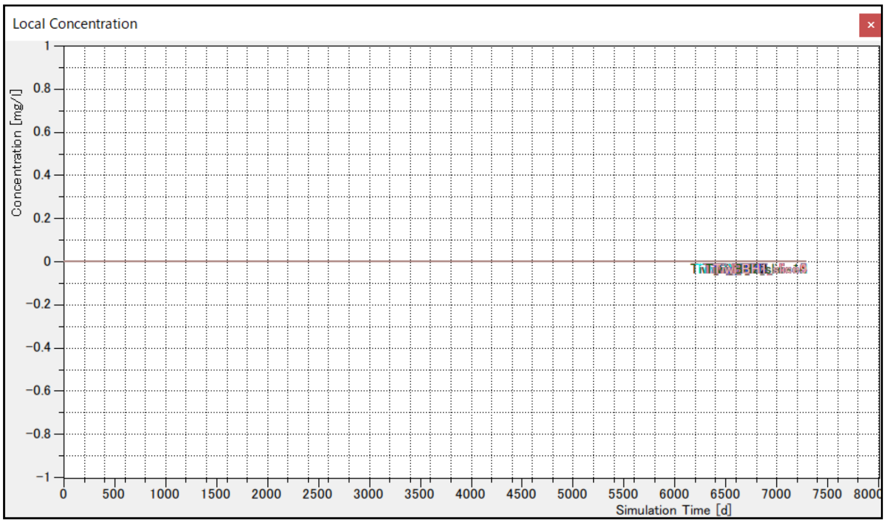
Figure 8.5.32 Groundwater Level Change of Existing Well (60 years)



Source: JICA Design Team

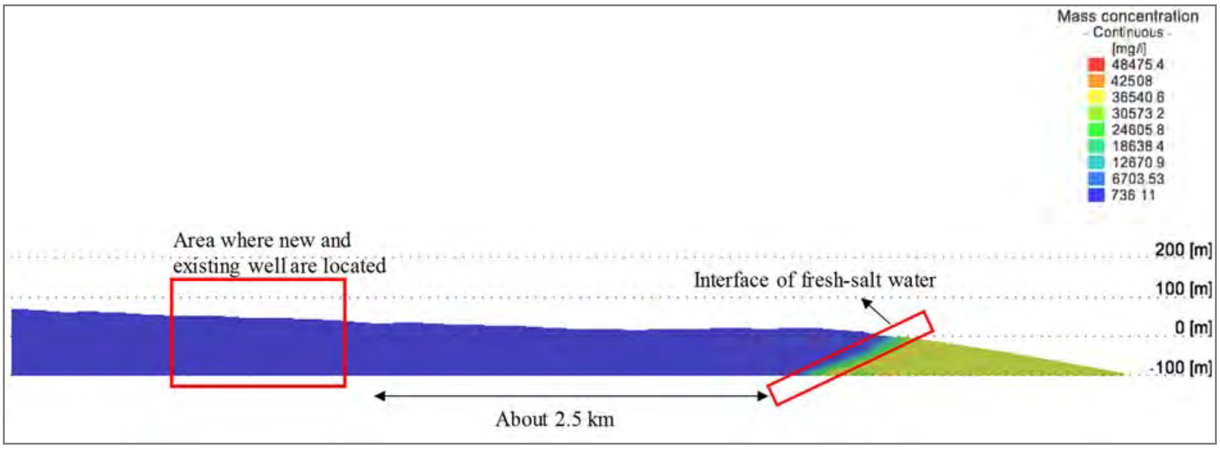
Figure 8.5.33 Groundwater Level and Flow Map After 60-years Pumping by Existing Well

Salt concentration changes during the 60 years in the existing wells, and their distribution in the cross-section line (see cross section line in Figure 8.5.35) are shown in figure below. The figures indicated that sea water intrusion did not occur during these 60 years as there are no changes in salt concentration of the existing wells.



Source: JICA Design Team

Figure 8.5.34 Salt Concentration Change in Existing Well (40th ~60th year)



Source: JICA Design Team

Figure 8.5.35 Salt Concentration Distribution in Cross-section Line

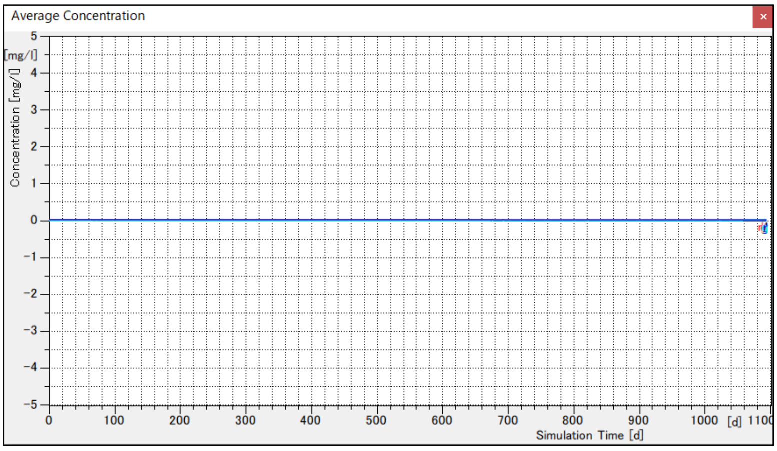
vi) Results of the Calculation of Sea Water Intrusion and Well Inference Caused by New Drilling Wells

Information of the new drilled wells added to the model calculated for 60 years are shown in the table below. After configuration of the new drilled wells, the model has been calculated for three more years. The salt concentration changes of existing and new wells during these three years are shown in Figure 8.5.36. The results show that even after adding three new wells to the model, the sea water intrusion still did not occur.

Table 8.5.20 Configuration Information of New Drilled Well

Site	Casing Diameter (inch)	Depth (m)	Planned Pumping Rate (m^3/day)
SEZ-2	8	80	460
SEZ-3	8	80	700
SEZ-5	6	90	630

Source: JICA Design Team



Source: JICA Design Team

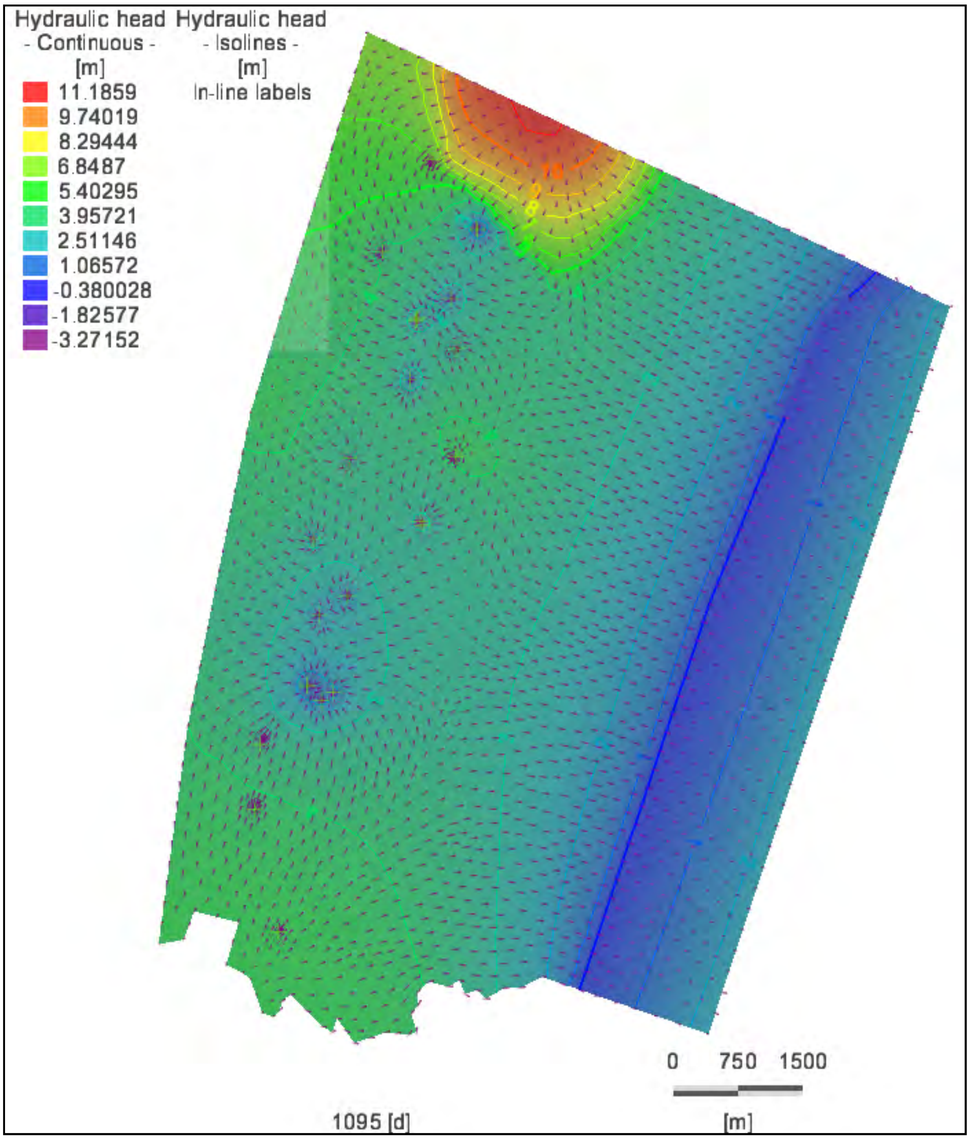
Figure 8.5.36 Salt Concentration Change in Existing and New Drilled Well (3 years)

Groundwater level decrease of existing wells after three years adding the new drilled well is shown in the table below. The results show that due to the pumping of new drilled wells, groundwater level of existing wells decreased 0.2 ~ 0.5 m after three years. However, comparing with the groundwater level decrease of the existing wells from initial status to their stable status (60 years), the decrease caused by the new drilled wells can be considered as a minor and the effects acceptable. Groundwater level and flow map after three years adding new drilled wells are shown in Figure 8.5.37.

Table 8.5.21 Groundwater Decrease of Existing Well Due to Pumping of New Drilled Wells

Location	Initial (1)	60 year (2)	63 years (3)	Decreased due to new well (3)-(2)	Total decrease (2)-(1)
Tiwi_BH1	6.93	1.12	0.92	-0.20	-5.81
Tiwi_BH2	6.83	1.17	0.97	-0.21	-5.66
Tiwi_BH4	7.34	-2.92	-3.27	-0.35	-10.26
Tiwi_BH6_6.1	7.64	2.35	1.96	-0.39	-5.29
Tiwi BH6.3	8.00	2.98	2.62	-0.37	-5.02
Tiwi_BH7	7.76	-2.18	-2.52	-0.34	-9.94
Tiwi_BH8	9.65	1.85	1.45	-0.40	-7.80
Tiwi_BH8.2	9.11	1.19	0.77	-0.42	-7.92
Tiwi_BH9	9.49	2.96	2.65	-0.30	-6.53
Tiwi_BHA	7.36	-0.70	-1.18	-0.48	-8.06
Tiwi_BHC	8.71	0.80	0.44	-0.36	-7.91
Tiwi_BHD	7.35	1.50	1.11	-0.39	-5.85
Tiwi_BHE	7.47	1.43	1.07	-0.36	-6.03
Tiwi_BHG1	5.81	-0.75	-0.99	-0.24	-6.56
Tiwi_BHG2	5.99	-0.42	-0.64	-0.23	-6.40

Source: JICA Design Team



Source: JICA Design Team

Figure 8.5.37 Groundwater Level and Flow Map After Adding New Drilled Well (3 years)

The simulation of groundwater salt concentration and groundwater level has been conducted based on the information collected during this survey. The results show that the pumping rate setting in the new drilled well is suitable to be used as a water resource for three years.

8.5.4 Basic Design Policy

(1) Review of the Water Demand of Mombasa SEZ

In the Mombasa SEZ Master Plan, the unit water consumption was based on Kenyan standards, the criteria of the detailed design report for the Mombasa Port Development Project (D/D Criteria), and the Japanese standards. However, since the water resource for the SEZ is limited, unit water consumption has been updated according to the following concerns:

1) Change of development area

The development area for each land use is updated because of the update on the land use plan which is shown in Clause 8.2. The total development area of the Phase 1 area shrunk from 389 ha, in the existing SEZ M/P, to 230 ha in the updated plan. The total development area of the final stage is 818 ha.

2) Change of expected industries for the SEZ

Because of the limitation of the water resource, industries with low water usage are selected. The expected industries are discussed.

a) The highest prioritized industries with low water consumption:

- Printing
- Metal products
- Transportation equipment
- Logistics (including warehousing industry)
- Tourism

b) The second highest prioritized industries with medium water consumption:

Although industries in this category also have a big potential on the SEZ, there is a possibility that these will be adopted as expected industries if the water consumption of specific tenants is low.

- Agricultural crop processing
- Clothing
- Rubber
- Plastics

However, these expected industries for the SEZ shall be updated through business planning based on the interview survey and SEZ development policy by the MoI.

3) Change of unit amount of water consumption

Based on the expected industries selected above, the unit amount of water consumption for the industrial park is updated to "40 m^3/d*ha". As other item, the rate of NRW is presumed to be 10% taking into account water leakage. The unit amount for each land use is shown below:

Table 8.5.22 Updating of Unit Amount of Water Consumption of Each Land Use

Land Use		Unit Amount		Remarks
		Adopted in SEZ M/P	**Adopted in this Mission**	
1	Port	Total 480 m^3/d		Calculated in the SEZ M/P for Port
2	Free port/Free trade zone A/B/C	20 m^3/d*ha		
3	Free port/Free trade zone D	1.5 m^3/d*ha		
4	Industrial park	**100 m^3/d*ha**	**40 m^3/d*ha**	Low water consumption industries
5	MICE area	25 m^3/d*head		
6	Tourism parks	0.6 m^3/d*bed		

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Land Use		Unit Amount		Remarks
		Adopted in SEZ M/P	Adopted in this Mission	
7	Service area	25 m³/d* head		
8	Transmission line	-		
9	Enterprise area (A/B/C)	20 m³/d*ha		
10	Enterprise area (D~J)	20 m³/d*ha		
11	Residential area E	250 m³/d*ha		for high class housing
12	Residential area A/B/C/D	150 m³/d*ha		for middle class housing
13	Mombasa southern bypass road	-		
14	Port access road 1/2	-		
15	Utility (SS, WDC, utility area)	0.6 m³/d*ha		
16	Main drainage network area	-		
-	Other (Non-Revenue Water: 10% of the above water demand)	-	**10% of demand**	Water leakage is included

Source: JICA Design Team

The water demand of the Mombasa SEZ was updated considering the above considerations. Although the total daily average water demand in the SEZ M/P was 24,700 m^3/day, the updated water demand is reduced to about 15,600 m^3/day, which is shown in Table 8.5.23.

Table 8.5.23 Updated Water Demand for Mombasa SEZ

Land Use Zone		Development Area (ha)				Number of Workers /				Water Demand (m^3/day)			
		Phase 1	Phase 2	Phase 3	Total	Phase 1	Phase 2	Phase 3	Total	Phase 1	Phase 2	Phase 3	Total
1	Port	15.0	15.0	15.0	45.0	500	500	500	1,500	160	160	160	480
2	Free port/Free trade zone A/B/C	67.1	7.6	39.5	114.2	3,355	380	1,975	5,710	1,342	152	790	2,284
3	Free port/Free trade zone D	13.3	0.0	19.2	32.5	50	0	50	100	20	0	29	49
4	Industrial park	35.2	63.4	13.9	112.5	3,520	6,340	1,390	11,250	1,408	2,536	556	4,500
5	MICE area	0.0	2.2	0.0	2.2	0	660	0	660	0	67	0	67
6	Tourism parks	0.0	49.0	0.0	49.0	0	980	0	980	0	720	1,632	2,352
7	Service area	0.0	8.8	0.0	8.8	0	880	0	880	0	22	0	22
8	Transmission line	15.4	0.0	0.0	15.4	-	-	-	0	-	-	-	0
9	Enterprise area (A/B/C) *	0.0	128.1	0.0	128.1	0	6,401	0	6,401	0	2,562	0	2,562
10	Enterprise area (D~J) *	0.0	23.9	23.8	47.7	0	1,686	1,193	2,879	0	478	476	954
11	Residential area E	0.0	0.0	9.9	9.9	0	0	1,188	1,188	0	0	297	297
12	Residential area A/B/C/D	0.0	29.1	0.0	29.1	0	3,492	0	3,492	0	524	0	524
13	Mombasa southern bypass road	-	-	-	-	-	-	-	-	-	-	-	-
14	Port access road 1/2	18.7	0.0	5.6	24.3	-	-	-	0	-	-	-	0
15	Utility (SS, WDC, utility area)	3.0	12.5	0.0	15.5	40	100	0	140	2	8	0	10
16	Main drainage network area	26.1	0.0	0.0	26.1	-	-	-	0	-	-	-	0
-	Other (Non-Revenue Water) 10%	-	-	-	-	-	-	-	-	294	723	394	1,411
Total		**193.8**	**339.6**	**126.9**	**660.3**	**7,465**	**21,419**	**6,296**	**35,180**	**3,226**	**7,952**	**4,334**	**15,512**

Note: Enterprise area has a steep slope. On the demand forecast, the area of excluding slope was used as available.
Source: JICA Design Team

4) Water volume for planning facilities

In this project, three values of water volume for planning facilities are set in consideration of various water supply facilities.

- Daily average supply water volume: Generally, it is applied to fiscal planning and reservoir design as basic data of water supply planning.

- Daily maximum supply water volume: Generally, it shows the water supply capacity, and it is applied to the design for water intake and for WTP.
- Hourly maximum supply water volume: Generally, it is applied to design of water distribution facilities such as water distribution pipes.

The water volume for planning facilities is as shown in Table 8.5.24.

Table 8.5.24 Water Volume for Planning Facilities

Categories	Phase1	Phase2	Phase3	Total	Fluctuation
Daily average supply water volume	3,226	7,952	4,334	15,512	1.00
Daily maximum supply water volume	4,033	9,940	5,418	19,391	1.25
Hourly maximum supply water volume	8,066	19,880	10,836	38,782	2.00

Source: JICA Design Team

The other water resource is needed to ensure the initial stage while waiting for the water supply from the Mwache Dam. The alternative water resource (Tiwi Well-field) is proposed in Clause 8.5.4 (2). The appropriate yield of well (70% of the possible yield, for 24 hours a day operation) is about 2,300 m^3/day as follows.

- Well SEZ-2: 25.2 m^3/hour (604.8 m^3/day)
- Well SEZ-3: 38.5 m^3/hour (924.0 m^3/day)
- Well SEZ-5: 35.0 m^3/hour (840.0 m^3/day)

Phase 1 is further divided into three stages, and the targeted development year is adopted as Stage 1 (2023), Stage 2 (2026), and Stage 3 (2030).

Regarding the water initial demand, since the capacity of the well water resource is limited at the Tiwi boreholes, it is planned that full water demand of Phase 1 (4,100 m^3/day) will not be fully supplied, a part of the demand is covered initially from Stage 2. As a result of this consideration, the water demand at Stage 2 is estimated to be about 2,000 m^3/day. The calculation process of water demand for the staging plan of Phase 1 is shown in Table 8.5.25.

Table 8.5.25 Estimated Water Demand of Phase 1 (Staging Plan)

	Land Use Zone	Staging Plan for Phase 1 (ha)				Water Demand for Phase 1			
		Stage 1 (2023)	Stage 2 (2026)	Stage 3 (2030)	Total	Stage 1 (2023)	Stage 2 (2026)	Stage 3 (2030)	Total
1	Port	15.0	0.0	0.0	15.0	160	0	0	160
2	Free port/Free trade zone A/B/C	19.0	44.0	4.1	67.1	380	880	82	1,342
3	Free port/Free trade zone D	13.3	0.0	0.0	13.3	20	0	0	20
4	Industrial park	0.0	0.0	35.2	35.2	0	0	1,408	1,408
5	MICE area	0.0	0.0	0.0	0.0	0	0	0	0
6	Tourism parks	0.0	0.0	0.0	0.0	0	0	0	0
7	Service area	0.0	0.0	0.0	0.0	0	0	0	0
8	Transmission line	15.4	0.0	0.0	15.4	-	-	-	0
9	Enterprise area (A/B/C) *	0.0	0.0	0.0	0.0	0	0	0	0
10	Enterprise area (D~J) *	0.0	0.0	0.0	0.0	0	0	0	0
11	Residential area E	0.0	0.0	0.0	0.0	0	0	0	0
12	Residential area A/B/C/D	0.0	0.0	0.0	0.0	0	0	0	0
13	Mombasa southern bypass road	-	-	-	0.0	-	-	-	-
14	Port access road 1/2	18.7	0.0	0.0	18.7	-	-	-	0
15	Utility (SS, WDC, utility area)	3.0	0.0	0.0	3.0	2	0	0	2
16	Main drainage network area	26.1	0.0	0.0	26.1	-	-	-	0
-	Other (Non-Revenue Water) 10%	-	-	-	0.0	57	88	149	294
	Total	**110.5**	**44.0**	**39.3**	**193.8**	**619**	**968**	**1,639**	**3,226**
Note) Daily maximum water volume = Daily maximum water volume x1.25				factor	1.25	774	1,210	2,049	4,033
				round		774	1,984	4,033	-
				cumulative		**800**	**2,000**	**4,100**	-

Source: JICA Design Team

In accordance with the review of the land use plan of Mombasa SEZ, the candidate sites of the Water Distribution Center (WDC) were compared and reviewed. The basic conditions for selecting a location of WDC are as follows:

- 1st: Select the highest ground in the area
- 2nd: Consider for land use plan and location of receiving point (power/water)
- 3rd: Consider for economy and maintainability of water distribution pipeline

Reasons for selecting a location site of WDC:

5) Case-1: SEZ M/P Review

As the policy of selecting the location of the WDC at the Mombasa SEZ M/P, the land is not the highest ground (GL+46 m), but it is a location that takes into consideration the 2nd condition, and the location of utility facilities (power plant/substation, WDC) at one place both being beside the receiving point. This aimed for the streamline of traffic lines related to the operation and maintenance of utility facilities.

6) Case-2: 1st Proposal (PR1)

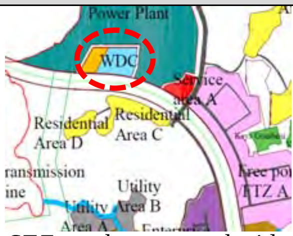
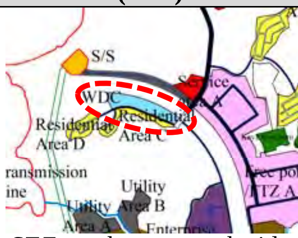
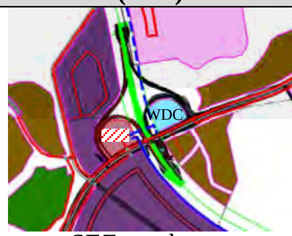
The proposed location of Case-2 is at the south side of the substation at a place on higher ground (GL+61 m) considering water supply efficiency. On the other hand, the location is difficult to be accessed for land developing because of the narrow pathways and steep slope. Also, it is necessary to construct a new access road to the proposed WDC because there is no road construction on SEZ Phase 1.

7) Case-3: 2nd Proposal (PR2)

The proposed location of Case-3 is a little lower on the ground (GL+56m) than Case-2. The space of flat land can be arranged sufficiently in the road junction. Also, the length of water supply pipe from the Tiwi Well-field is shorter than the other cases in the stage of SEZ Phase 1, and it satisfies the conditions No. 2 and 3.

The proposed location of Case-3 was finally selected in this study, and the comparative review of the location of WDC is shown in Table 8.5.26.

Table 8.5.26 Comparative Review of Location of Water Distribution Center

Case		Case-1: SEZ M/P Review	Case-2: 1st Proposal (PR1)	Case-3: 2nd Proposal (PR2)
Location Map of Water Distribution Center		 SEZ northwest, south side of Southern bypass	 SEZ northwest, south side of southern bypass	 SEZ southeast, inside junction
Summary of WDC		Land ground level: +46 m Elevated tank height: 35 m	Land ground level: +61 m Elevated tank height: 20 m	Land ground level: +56 m Elevated tank height: 25 m
Layout Condition of WDC		・Since there is not any topo-survey, detailed design of land-filling for the site was not done, but the location has a steep sloping ground. ・Similarly, at the entrance, construction of an approach road that requires large sloping is required.	・The site is constructed at the height of 2 levels in the considered land use (The approach road to WDC affects the residential area) ・Availability is low due to the narrow site ・Since the existing road cannot be used for an approach road to the existing residential area, it is necessary to construct a provisional road.	・Enough land area can be secured ・Since there is an access road and there is a height difference (7.25 m), an approach road (about 100 m sloping) is needed inside the site ・Entrance of the WDC can be constructed at the SEZ (phase 1). ・Length of water pipeline can be shortened for the SEZ (phase 1・Stage 2)
Cost	Phase1 ①Well, Transmission pipe ②WDC ③Distribution pipe	**USD 6,737,600** ①USD 3,125,484 (L=25,370 m) ②USD 1,321,625 (V=2,850 m^3) ③USD 2,290,491 (L=7,010 m)	**USD 6,411,756** ①USD 3,072,907 (L=24,950 m) ②USD 1,306,932 (V=2,850 m^3) ③USD 2,031,917 (L=7,335 m)	**USD 5,158,670** ①USD 2,759,951 (L=22,450 m) ②USD 1,311,830 (V=2,850 m^3) ③USD 1,086,889 (L=6,915 m)
	Phase2,3	**USD 4,898,801** ① - ②USD 1,774,218 (V=2,850 m^3 x 2) ③USD 3,124,583 (L=22,295 m)	**USD 4,907,183** ① - ②USD 1,759,526 (V=2,850 m^3 x 2) ③USD 3,147,658 (L=22,640 m)	**USD 5,113,782** ① - ②USD 1,852,415 (V=2,850 m^3 x 2) ③USD 3,261,367 (L=22,510 m)
	Total (Phase1,2,3)	**USD 11,636,401** ①USD 3,125,484 ②USD 3,095,843 ③USD 5,415,074	**USD 11,318,939** ①USD 3,072,907 ②USD 3,066,457 ③USD 5,179,575	**USD 10,272,452** ①USD 2,759,951 ②USD 3,164,245 ③USD 4,348,256

Case	Case-1: SEZ M/P Review	Case-2: 1st Proposal (PR1)	Case-3: 2nd Proposal (PR2)
Traffic Accessibility	Approach from substation access road. However, although KETRACO, the project entity of the substation, had requested that the substation access road should be for their road only. So, due to the entry and exit of personnel related to the water supply facilities adjustment is necessary.	Approach from existing road. It is necessary to widen and improve the existing roads, but generally there is no problem.	Approach from harbor access road. In order to bring it closer to the lamp entrance, it is limited to the entrance position and the structure layout of the water reservoir tank. However, the traffic volume does not have a big impact for 10 PCU/day.
Impact on EIA · RAP (Phase 1)	It is unnecessary to provide some lands for water distribution pipe from the tank to the port access road. In the case that the approach road can be shared with the substation access road, there is no complication.	It is necessary to provide some lands for the water distribution pipe from the tank to the port access road. W: 5 m × L: 50 m = 25 m^2 It is necessary to revise the existing road (about 140 m).	Because it is within the project scope of the port access road, additional land acquisition for phase 1 is unnecessary. The approach from the southern bypass cannot be constructed until the lamp development by the port project is done, but the traffic volume is extremely small, and the influence on the existing road is also small.

Note: Exchange rate: JPY 1 = KSh 1.095, USD 1 = KSh 102.091(2017 year)

Source: JICA Design Team

(1) Proposed the Development of Tiwi Boreholes for SEZ (Phase 1 / Stage 2)

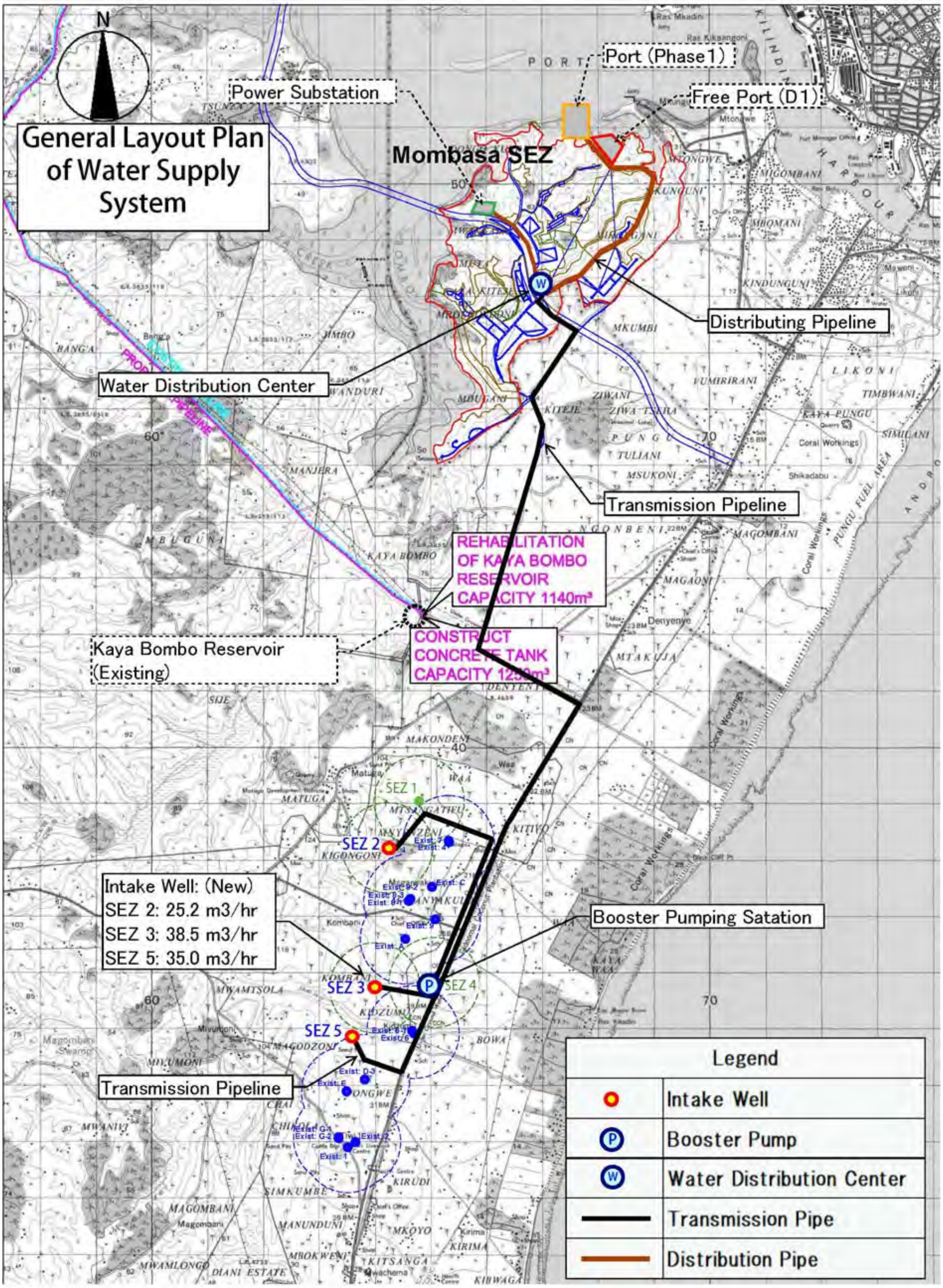
The outline of well facilities and water supply facilities to be developed for SEZ Phase 1 (Stage 2: planned water supply amount of 2,000 m^3/day) is shown in Table 8.5.27. And, the layout plan of the water supply facilities is shown in Figure 8.5.38.

Table 8.5.27 Outline of Water Supply Facilities on Phase 1 (Stage 2)

No.	Contents of Facilities	Unit	Remarks
A	Intake Well （Well Pump：appropriate yield SEZ-2: 25.2 m^3/hr, SEZ-3: 38.5 m^3/hr, SEZ-5: 35.0 m^3/hr, Gantry crane, Administration Building, Piping and Valve etc.）	3	
B	Transmission Pipeline （From Well to Pump stations: Transmission Pipe and Valve etc.）	About 9.8 km	
C	Booster Pump （Underground Tank 50 m^3、Booster Pump, Administration Building, Piping and Valve etc.）	1	
D	Transmission Pipeline （From to Pump station to WDC、Transmission Pipe and Valve etc.	About 5.7 km	
E	Water Distribution Center （Reservoir tank 1,000 m^3、Water Tank 10 m^3、Administration Building, Pumping facilities, Piping and Valve etc.）	1	
F	Distribution Pipeline （Target facilities of Stage 2, Piping and Valve etc.）	About 6.5 km (Included SS)	4.2 km 2.3 km
G	Other Facilities （Other Piping and Valves, Water meter, Water kiosk, etc.）	1 set	Adjusting

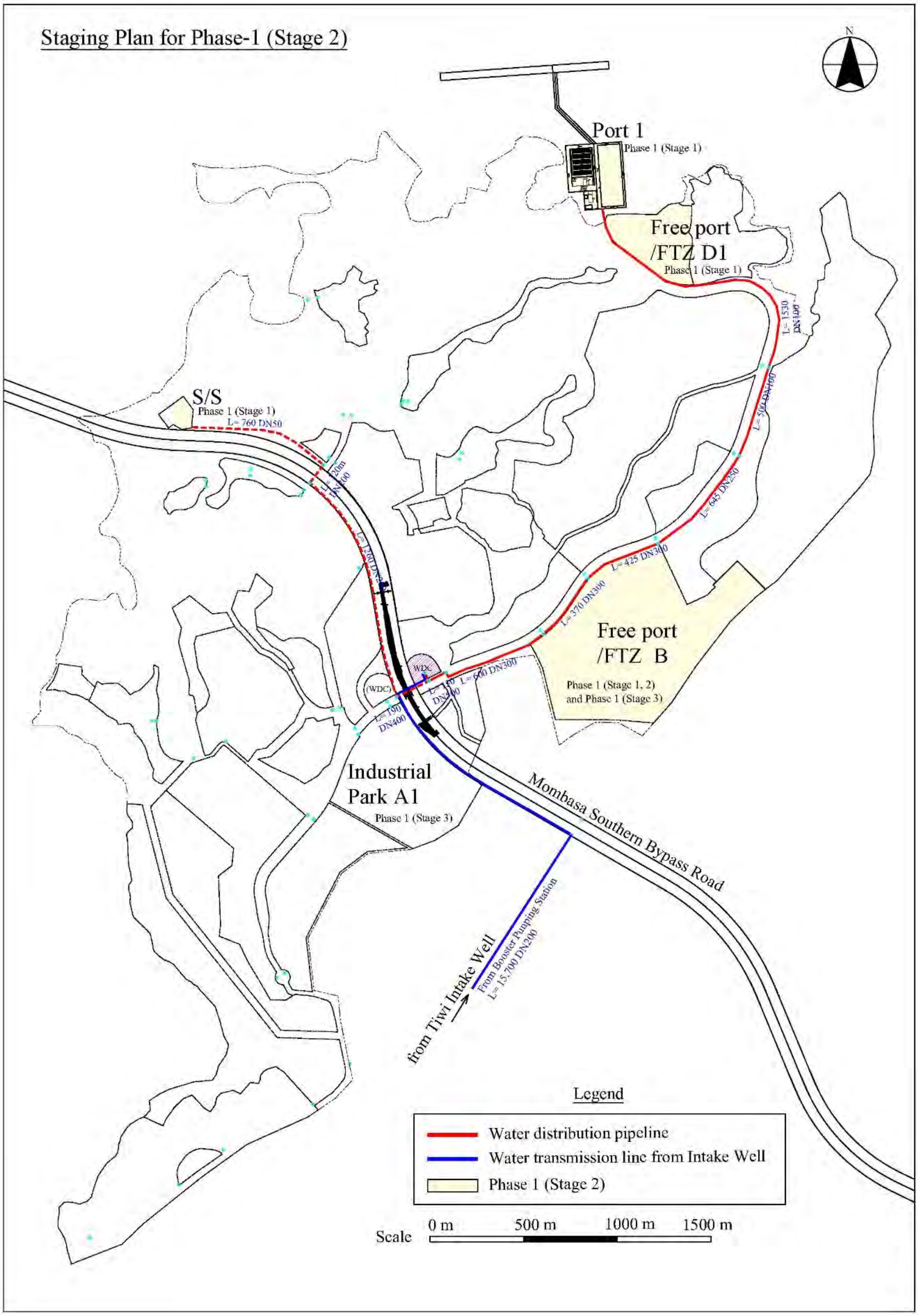
Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: JICA Design Team

Figure 8.5.38 General Layout Plan of Water Supply System on Phase1 (Stage 2)



Source: JICA Design Team

Figure 8.5.39 Water Distribution Pipeline in SEZ on Phase 1 (Stage2)

8.6 Sewerage

8.6.1 Overview

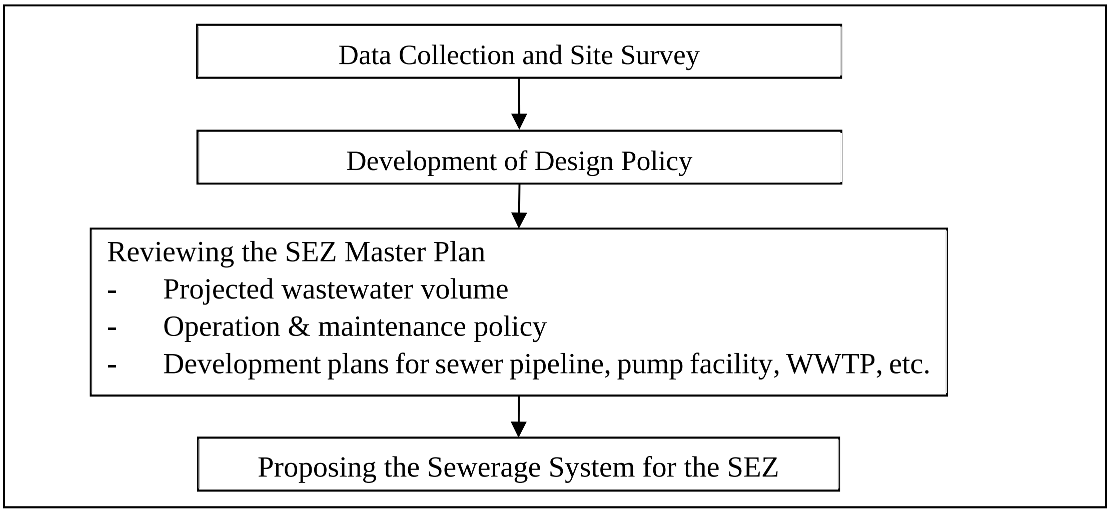
(1) Objective of the Survey

The main purpose of this survey is to update the existing master plan by reflecting the current situation and by providing an implementation plan, which includes the basic design for the development of sewerage services in Mombasa Special Economic Zone (SEZ). The goal is to improve the quality of the effluent, the Indian Ocean, and the groundwater and to safeguard the health of residents living in the surrounding areas. The main objectives are listed as follows:

- To comprehend the Kenyan standard on the discharge liquid by collecting related laws and regulations and by conducting an interview survey to related public institutions;
- To forecast the optimal capacity of a wastewater treatment facility with selected sewerage systems for each area; and,
- To review and update the existing SEZ master plan to satisfy current conditions.

(2) Methodology of the Sewerage System Design

The flowchart of sewerage design is shown in Figure 8.6.1.



Source: JICA Design Team

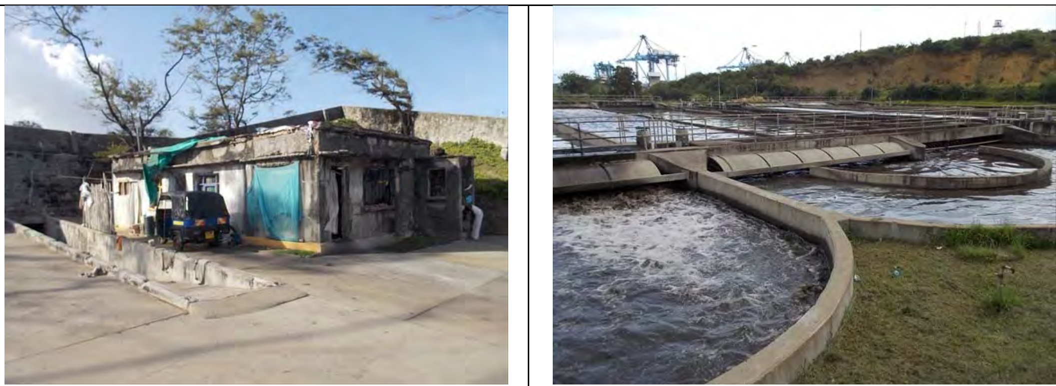
Figure 8.6.1 Flow Chart of Sewerage System Design

8.6.2 Current Conditions and Related Project

The existing sewer piping network in Mombasa County covers only a limited area of the Mombasa Island and parts of Mainland West. Mainland North and Mainland South do not have sewerage systems as of now. In Mombasa County, two wastewater treatment plants (WWTPs) are located in Kizingo and in Kipevu, and these existing WWTPs are not fully functioning. Details of the WWTPs are provided as follows:

- The Kizingo WWTP is located on a golf course on the east coast. It is an underground type plant constructed 20 years ago with a design capacity of 10,000 m^3/day. However, the plant is currently non-functional because of equipment failure. Therefore, all polluted water and sewage from the urbanized area were discharged into the Indian Ocean without undergoing any treatment.

- The Kipevu WWTP is located in Mainland West. The design capacity is 17,100 m^3/day, but it receives only 6,000 to 7,000 m^3 of wastewater per day coming from Changamwe, Port Reitz, Magongo, and Jomvu area. The development of the sewer network is insufficient because of fund shortage. In addition, highly-polluted wastewater is discharged without any treatment from factories in the covered area, which makes the treatment capacity of the WWTP lower. Current conditions of the existing facilities are shown in Figure 8.6.2.



Kizingo WWTP (Non-functional)	Kipevu WWTP (Capacity: 17,100 m^3/day)

Source: JICA Design Team

Figure 8.6.2 Photo of Kizingo WWTP and Kipevu WWTP

Source: JICA Design Team

Figure 8.6.3 Location of Existing WWTPs

There is no related development project of the sewerage system in Mombasa SEZ as of now. There is no identified project on the development of a sewerage system for Mombasa SEZ in the Waste Water Master Plan for Mombasa nor Selected Towns within the Coast Region (2015, CWSB). Thus, the development of a new sewerage system is indispensable for Mombasa SEZ development. Community toilets, public toilets, and septic tanks with soak pits are important projects for safe sanitation of expected workers and residents.

8.6.3 Basic Design Policy

It is necessary that the quality of wastewater discharged from the SEZ conforms to the standards in Kenya. The design concept of the sewerage system plan for the SEZ will follow the major concept in the current Mombasa SEZ Master Plan.

(1) For Each Zone Developer

The zone developer should ensure that the quality of wastewater discharged from its own area meets the Kenyan standards. The industrial park zone developer can have its own common separated sewer system with WWTP or obligate the enterprise or factory to have its own private pre-WWTP to ensure compliance with the discharge water quality. Also, for the other zone developer that will construct the building structure (e.g., housing, hotel, office tower), it shall meet the Kenyan Building Code and related standards to have a septic tank and/or proper treatment system. At the discharge point for each zone, it will be necessary to install a hand-hole and/or pit where samples can be taken by relevant authority of water/environment management to monitor the water quality.

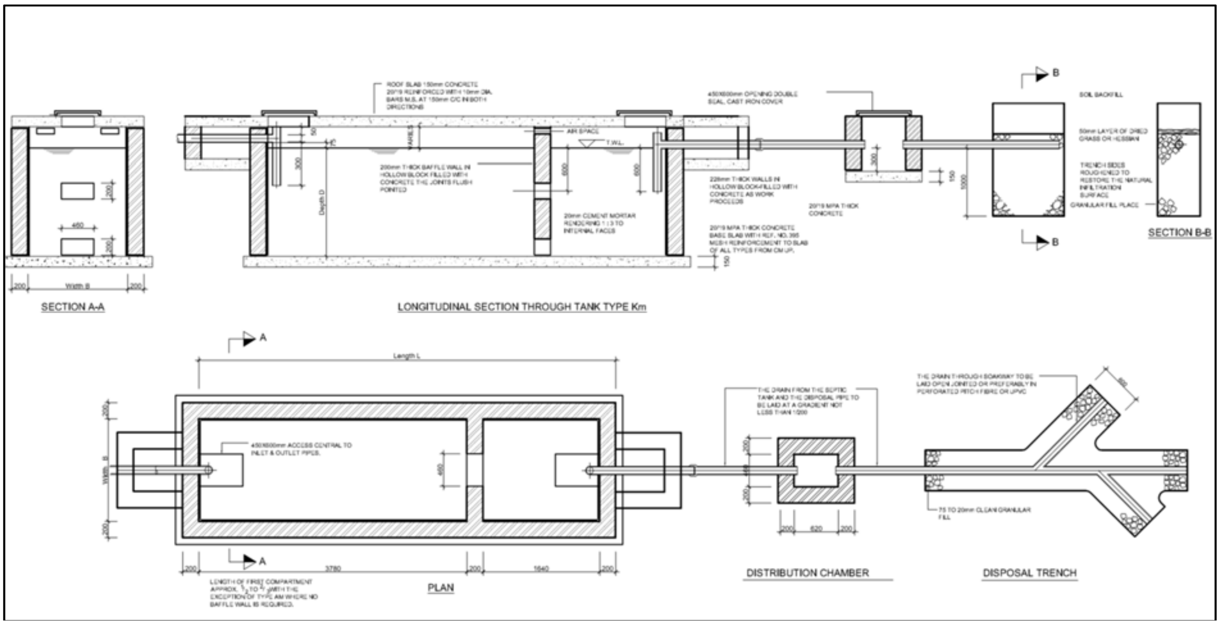
(2) For Enterprise

The enterprise shall follow all the regulations applied to the handling of wastewater discharge in the internal regulation of the zone developer.

(3) For Tenant and Residents

The tenants and residents shall follow all the guidelines/rules of utilization applied to the handling of sanitary facilities, septic tanks, and sewerage systems of each zone. A sample drawing of a septic tank in Mombasa is shown in Figure 8.6.4.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: CWSB

Figure 8.6.4 Sample Drawing of Septic Tank in Mombasa

(4) Issue of Concern for Design of Sewerage System

- Collecting the guidelines or practice manual on sewerage systems in Kenya.
- Clarifying the sewer developers and operators for each zone.
- Checking the discharge destination and carry-out means of sludge.

8.7 Drainage

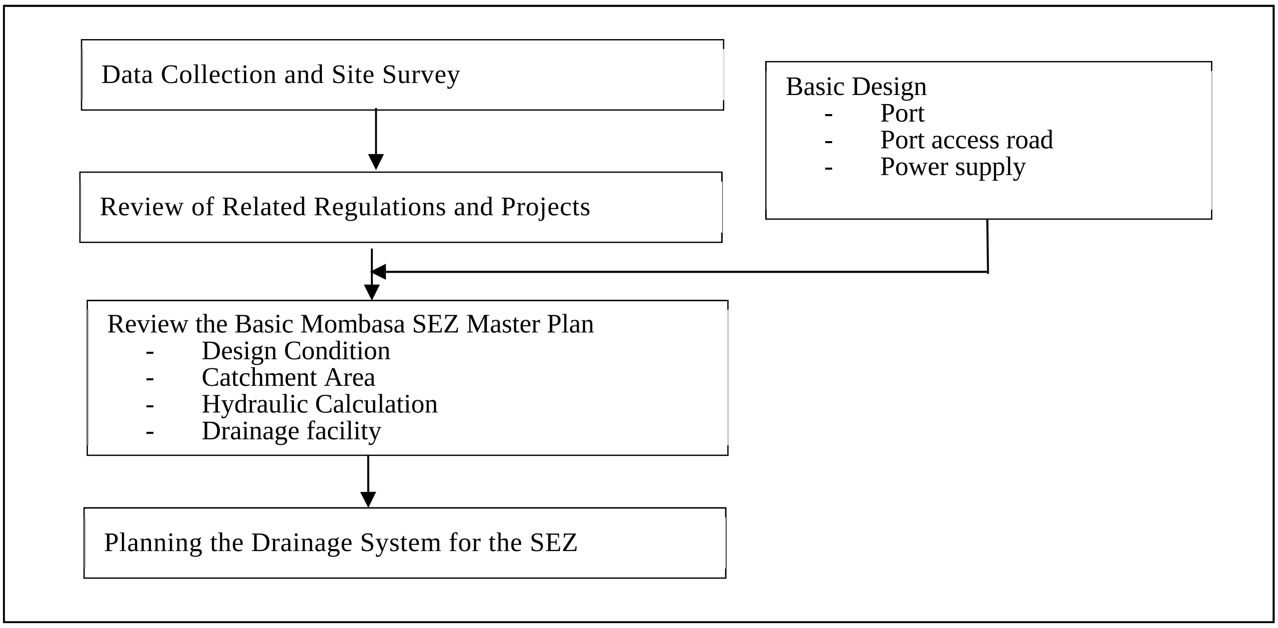
8.7.1 Overview

(1) Objective of the Survey

The objectives of this survey are (1) to update the drainage plan of the Mombasa SEZ Master Plan and (2) to provide the basic design as a Japanese ODA loan's component. The targeted area of the basic design is Phase 1 of the SEZ; however, the drainage system of the entire SEZ area should be updated to make the plan more economical and technically effective.

(2) Methodology of the Drainage Design

The flowchart of drainage design is shown in Figure 8.7.1.



Source: JICA Design Team

Figure 8.7.1 Flowchart of Drainage Design

8.7.2 Current Conditions and Related Projects

(1) Current Conditions

The rainfall pattern in Mombasa is characterized by two distinct long and short seasons corresponding to changes in the monsoon winds. The long rains occur in April to June with an average rainfall of 1,040 mm and which correspond to the southeastern monsoon winds. The short rains start towards the end of October and last until December and correspond to the comparatively dry north eastern monsoons, with an average rainfall of 240 mm. The annual average rainfall for the county is 640 mm.

The Mombasa SEZ area has many hills and valleys, but it has no big river and no rainwater drainage facilities. Since undeveloped green areas and farmlands occupy the area, most of the rainwater permeates the ground and the rest flows out to the surface. During heavy rains in the area, rainwater flows downstream through the unpaved channel as shown in Figure 8.7.2. A few concrete culverts are developed for crossing under roads as shown in Figure 8.7.3. Surface water does not flow during sunny days.

Source: JICA Design Team

Figure 8.7.2 Current Channel

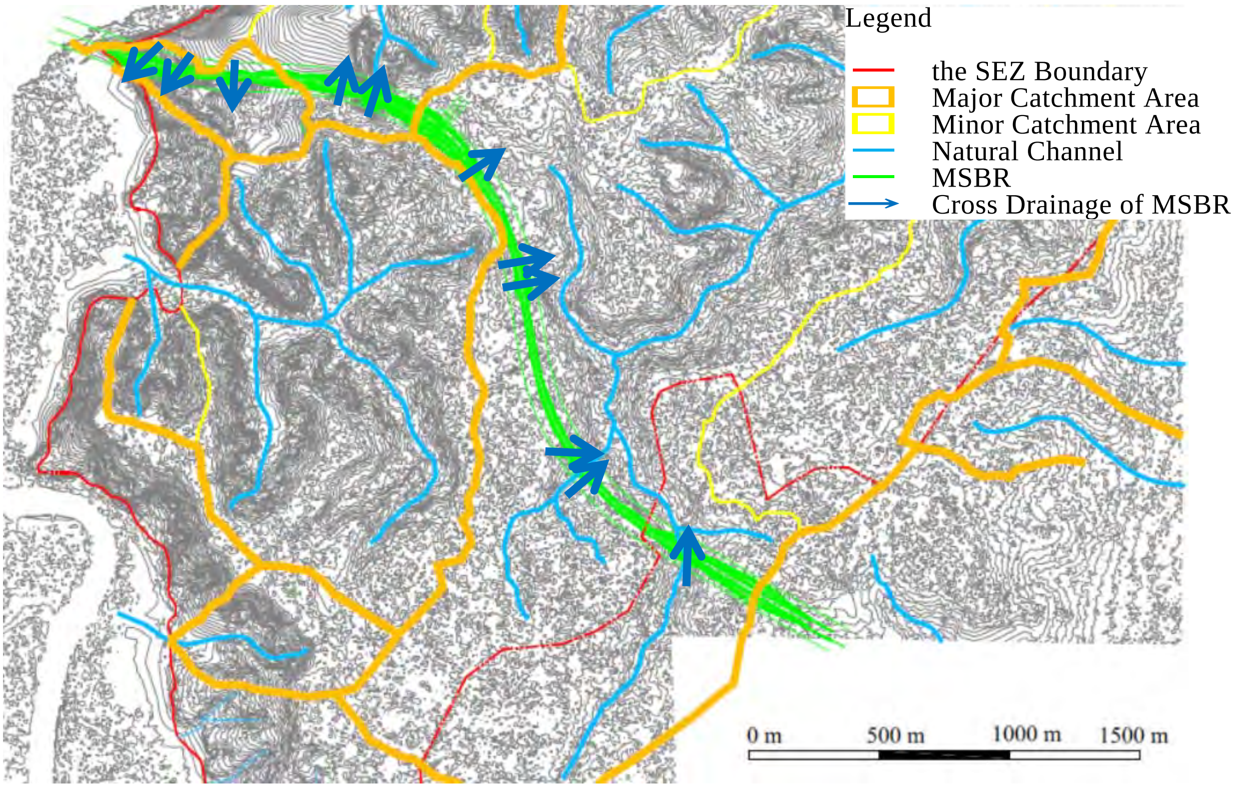
Source: JICA Design Team

Figure 8.7.3 Current Cross Drainage

(2) Related Projects

i) Mombasa Southern Bypass Road Project

Package 3 of the Mombasa Southern Bypass Road (MSBR) Project is scheduled to start construction in early 2018 and will continue for two years. The current catchment area will be changed after the construction of MSBR because the area is divided. The locations of the planned cross drainages are shown in Figure 8.7.4.



Source: Mombasa SEZ Master Plan

Figure 8.7.4 Cross Points of Drainage under the Southern Bypass Road

The catchment area, which was planned in the SEZ Master Plan, needs to be updated in line with this change by the MSBR development project.

8.7.3 Basic Design Policy

(1) Design Condition

Stormwater removal for the development of the SEZ is significantly important for safety management and economic efficiency. A gravity drainage system is designed, which is often applied for various development projects. The peak runoff at any given point in the project is calculated using the following rational formula.

Table 8.7.1 Design Condition of Drainage System

Item	Design Condition	Remark
Rainfall intensity	$I = a / (t + b)^n$ where; I : rainfall intensity (mm/hour) t : duration time (hours) a : constant as 61.2 for 5-year period b : constant as 0.33 for East Africa n : index as 0.8 for coastal regions	Refer to the Mombasa Stormwater Master Plan
Return period	5-year return for minor culverts 25-year return for major culverts 50-year return for box culverts 100-year return for bridges	
Time of concentration	$t_c=t_i+t_t$ where; t_c : time of concentration t_i : time of inlet t_t : time of travel	
Inlet time	t_i=5 minutes (steep urban area)	
Travel time	$t_t=L/V$ where; L: drainage length (m) V: flow velocity of drainage (m/s)	
Runoff calculation	Rational method $Q=0.28*CIA$ where; C: runoff coefficient I: rainfall intensity (mm/hour) A: area (km^2)	
Runoff coefficient	0.70: Port, FTZ, Enterprise Area, Industrial Park, WDC, Substaion, Utility Area, Service Area 0.50: Residential Area 0.40: Tourism Park, Transmission Line 0.30: Reserve Area	Refer to the Design Manual for Roads and Bridges 2nd Draft Part 2 Drainage Design
Hydraulic design formula	Manning's formula $Q=AV$ $V=(1/n) \times R^{2/3} \times I^{1/2}$ where, Q: drainage flow rate (m^3/s) A: cross-sectional area of drainage (m^2) V: velocity (m/s) R: hydraulic mean radius n: roughness coefficient of drainage	

Item	Design Condition	Remark
	I: hydraulic gradient (-)	
Velocity	Minimum: 0.8 m/s (for self-cleansing) Maximum: 3.0 m/s (for safety and avoiding damage)	
Margin quantity	Margin quantity (height) of open channel: 0.2d (Effective height is 80% of the depth of water)	Refer to the design guidelines for sewerage facility (JSWA in Japan)
Roughness coefficient	Open channel (Dressed stone in mortar, Brick): n=0.015 Culvert, Pipe (Concrete): n=0.012	Refer to the Design Manual for Roads and Bridges 2nd Draft Part 2 Drainage Design

Source: JICA Design Team

i) Rainfall Intensity

a) Mombasa Stormwater Master Plan (2011)

The rainfall intensity from the Mombasa Stormwater Master Plan (2011) is applied also on the Mombasa Gate City Master Plan. The formula of rainfall intensity is shown in Table 8.7.2.

Table 8.7.2 Rainfall Intensity in the Mombasa Gate City Master Plan

Items	Contents				
Design Storm Frequency (Return Periods)	5-year return for minor culverts 25-year return for major culverts 50-year return for box culverts 100-year return for bridges				
Rainfall Intensity for Mombasa $I = a / (t + b)^n$ t : duration time (hours) a, b, n : constant/index	Constant/ index	5-year	10-year	25-year	50-year
	a	61.2	71.6	85.3	95.7
	b	0.33	0.33	0.33	0.33
	n	0.8	0.8	0.8	0.8

Source: Study and Development of Mombasa Stormwater Masterplan

b) Second Draft of Road Design Guidelines for Urban Roads (2001)

The rainfall intensity from the 2nd draft of Road Design Guidelines for Urban Roads (2001) was applied in the Mombasa SEZ Master Plan. The formula of rainfall intensity which was proposed for developments in the SEZ is presented as follows:

$$I=\{1700\cdot\log(n.R) - 3000\} / (t +20)$$

where n: design return period (years) : adopted as 5-year return

R: annual rainfall (mm) : adopted as 1,648.2 mm

(maximum annual rainfall at Moi International Airport Meteorological Station)

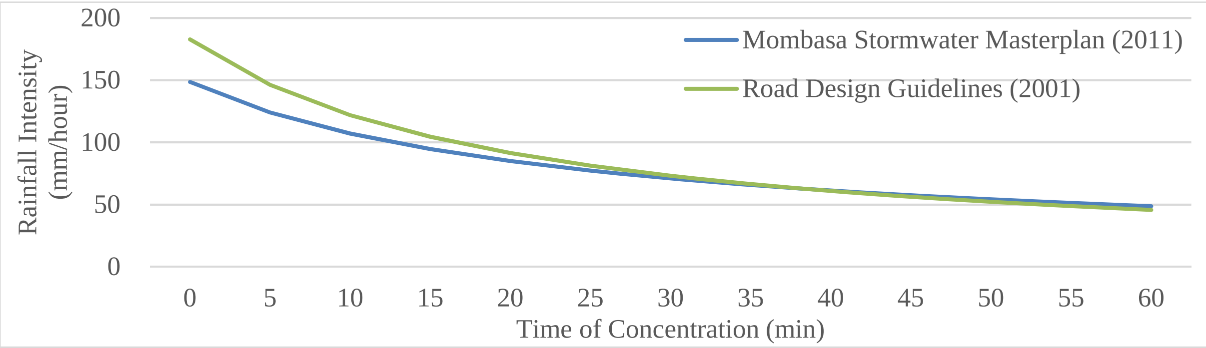
t: concentration time (min): $t=t_1+t_2$

Table 8.7.3 and Figure 8.7.5 show calculation results by two described formulas. It is suitable to apply the formula of the Mombasa Stormwater Master Plan because it is a later study and it adopts a larger rainfall intensity at a 5-year return period of 60 minutes compared with the Road Design Guidelines.

Table 8.7.3 Rainfall Intensities at 5-Year Return Period by Formulas in Kenya

Manuals in Kenya	Duration (min)						
	0	10	20	30	40	50	60
Mombasa Stormwater Master plan (2011)	148.6	107.1	85.0	71.0	61.4	54.2	48.7
Road Design Guidelines (2001)	182.9	121.9	91.4	73.1	61.0	52.2	45.7

Source: JICA Design Team (mm/hour)



Source: JICA Design Team

Figure 8.7.5 Rainfall Intensity at 5-Year Return Period by Formulas in Kenya

ii) Time of Concentration

The time of concentration (t_c) consists of an inlet time or overland flow time (t_i) plus the time of travel (t_t) in a storm sewer, paved gutter, roadside drainage ditch, drainage channel, or other drainage facilities. The time of concentration is calculated as follows:

$t_c = t_i + t_t$

where t_c = time of concentration in minutes

t_i = initial, inlet, or overland flow time in minutes

t_t = travel time in ditch, channel, gutter, storm sewer, etc., in minutes

The Mombasa Stormwater Master Plan defines an inlet time as shown in Table 8.7.4. The topography of the SEZ is steep and its land use mainly consists of industrial park and FTZ. According to the master plan, the inlet time adopted is 5 minutes for steep urban areas and wide roads while 10 minutes for normal urban areas and industrial and warehousing areas. With consideration of safety against unexpected rainfall caused by current climate change, it is suitable to adopt 5 minutes in the Design Mission.

Table 8.7.4 Inlet Time for Different Drainage Areas

Description of the Area	Inlet Time
Steep urban area	5 minutes
Normal urban area	10 minutes
Wide road	5 minutes
Industrial & warehousing area	10 minutes

Source: Study and Development of Mombasa Stormwater Master Plan

iii) Runoff Coefficient

Table 8.7.5 shows runoff coefficients in two manuals.

Table 8.7.5 Categories for Land Use in Kenyan Drainage Manuals

Land Use in the SEZ	Mombasa Stormwater Masterplan		Design Manual for Roads and Bridges 2nd Draft Part 2 Drainage Design	
	Description of Area	Runoff Coefficient	Description of Area	Runoff Coefficient
Port	Industrial	0.40 – 0.50	Industrial (light areas)	0.50 – 0.80
FTZ				
Enterprise Area				
Industrial Park			Industrial (heavy areas)	0.60 – 0.90
Residential	Residential (high density)	0.30 – 0.50	Residential (multi units, detached)	0.40 – 0.60
WDC/Substation/ Utility Area	Public Purpose	0.20 – 0.50	Business (downtown area)	0.70 – 0.95
Service Area	District Centres	0.40 – 0.60		
Tourism Park	Parks, gardens, sports grounds, etc	0.10 – 0.25	Playgrounds	0.20 – 0.40
Transmission Line				
Reserve Area	Undeveloped, bush or forest	0.01 – 0.20	Unimproved areas	0.10 – 0.30
Current Land Use				
MSBR	(None)	–	(None)	–

Source: JICA Design Team

In the drainage design, it is better to adopt larger coefficients with consideration of the importance of the SEZ's functions. Adopted runoff coefficients are shown in Table 8.7.6.

Table 8.7.6 Adopted Runoff Coefficient for the SEZ

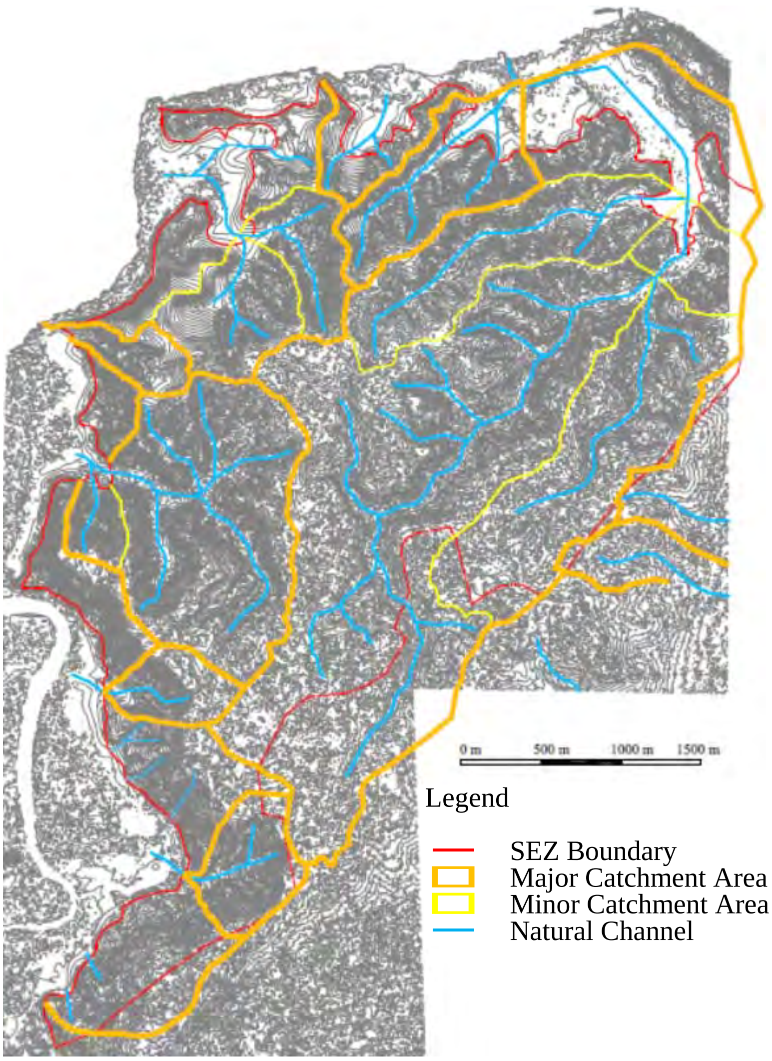
Land Use in the SEZ	Adopted Runoff Coefficient	Design Manual for Roads and Bridges 2nd Draft Part 2 Drainage Design	
		Description of Area	Runoff Coefficient
Port	0.70	Industrial (light areas)	0.50 – 0.80
FTZ			
Enterprise Area			
Industrial Park		Industrial (heavy areas)	0.60 – 0.90
WDC/Substation/Utility Area		Business (downtown area)	0.70 – 0.95
Service Area			
Residential	0.50	Residential (multi units, detached)	0.40 – 0.60
Tourism Park	0.40	Playgrounds	0.20 – 0.40
Transmission Line			
Reserve land	0.30	Unimproved areas	0.10 – 0.30
Road	0.90	(referred to Road Design Manual)	

Source: JICA Design Team

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

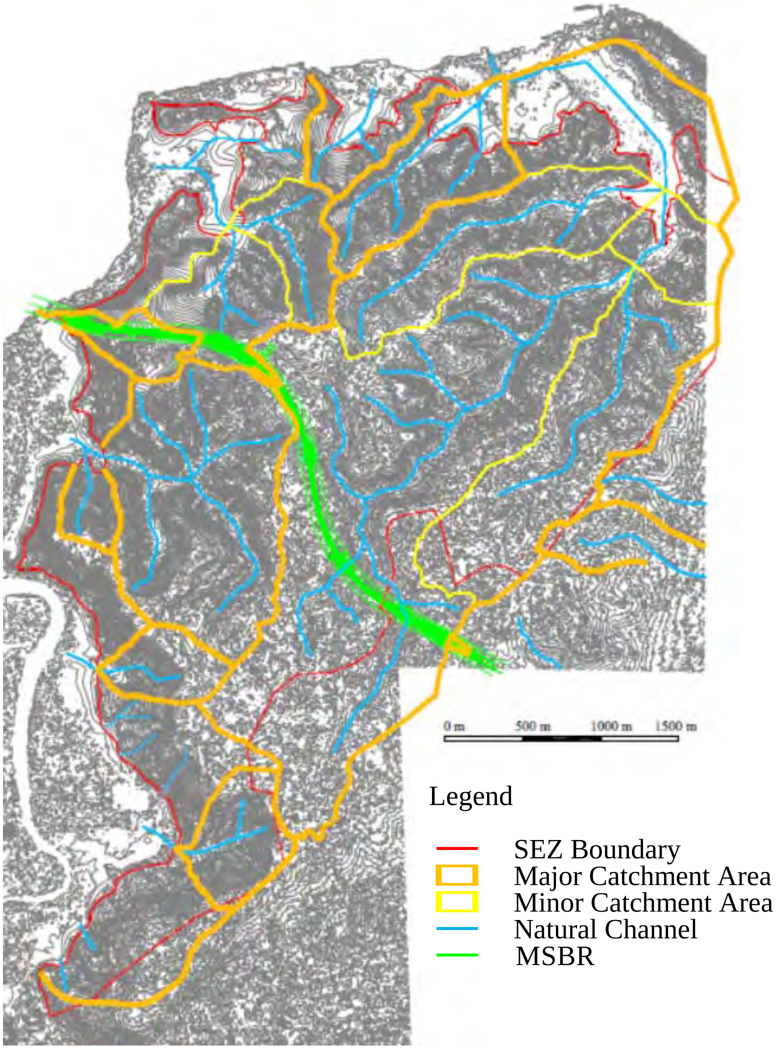
(2) Current Catchment Area

The current catchment area is shown in Figure 8.7.6. After the MSBR construction, the catchment area will be changed as shown in Figure 8.7.7. Due to a large catchment area of 827 ha located northeast, huge drain facilities are needed. The drainage should be planned with consideration of efficiency and safety.



Source: JICA Design Team

Figure 8.7.6 Current Catchment Area Before MSBR Construction

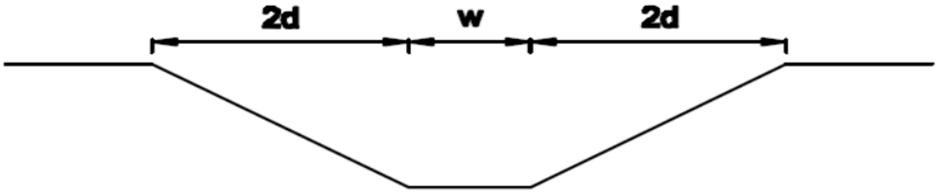


Source: JICA Design Team

Figure 8.7.7 Revised Current Catchment Area After MSBR Construction

(3) Drainage Facility

Major channels are designed as V-shaped as shown in Figure 8.7.8. The major channels run through reserve areas, which are undeveloped areas. The loose slope of the channel is H:V=2:1 which does not require reinforced concrete structure. By adopting this design, construction and management cost can be saved.



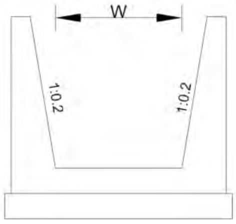
Source: Design Manual for Roads and Bridges 2nd Draft Part 2 Drainage Design

Figure 8.7.8 V-Shape Drain (H:V=2:1)

Meanwhile, side ditches along roads are designed as U-shaped, as shown in Figure 8.7.9 and Figure 8.7.10, to provide a large area for roadside land use. The slope of the channel is H:V = 1:1 or H:V = 1:2, depending

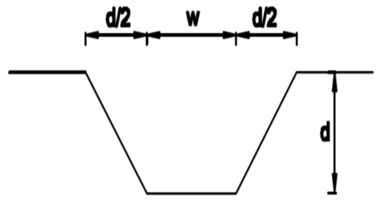
Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

on their widths. The maximum width of a U-shape drain with slope H:V=1:1 and without reinforcement is 1,000 mm.



Source: JICA Design Team

Figure 8.7.9 U-Shape Drain (H:V=1:1)



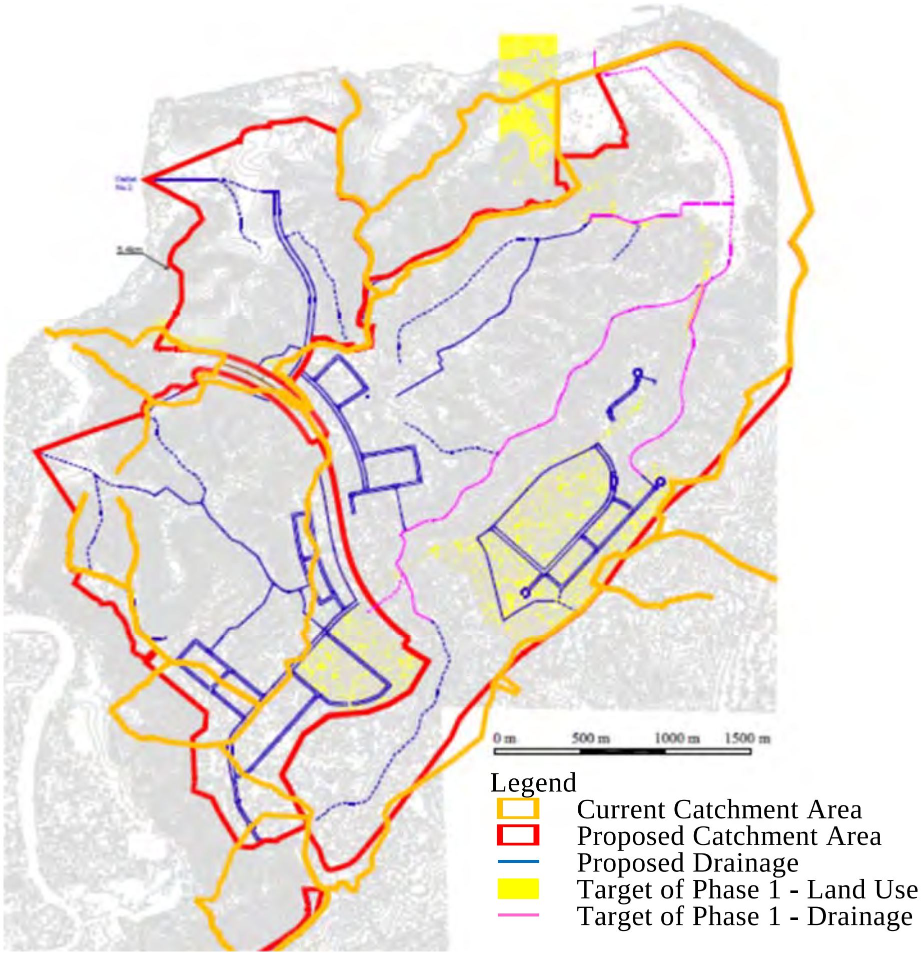
Source: Design Manual for Roads and Bridges
2nd Draft Part 2 Drainage Design

Figure 8.7.10 U-Shape Drain (H:V=1:2)

8.7.4 Consideration of Design

(1) Revision based on the Phasing Development Plan

In the drainage planning of the Mombasa SEZ Master Plan, the current catchment area would be changed by consideration of earthwork on a whole of the industrial park as shown in Figure 8.7.11. However, because the target of Phase 1 development does not include the entire industrial park, it is impossible to let runoff from the target of Phase 1 development flow into the proposed are in the Mombasa SEZ Master Plan.



Source: JICA Design Team

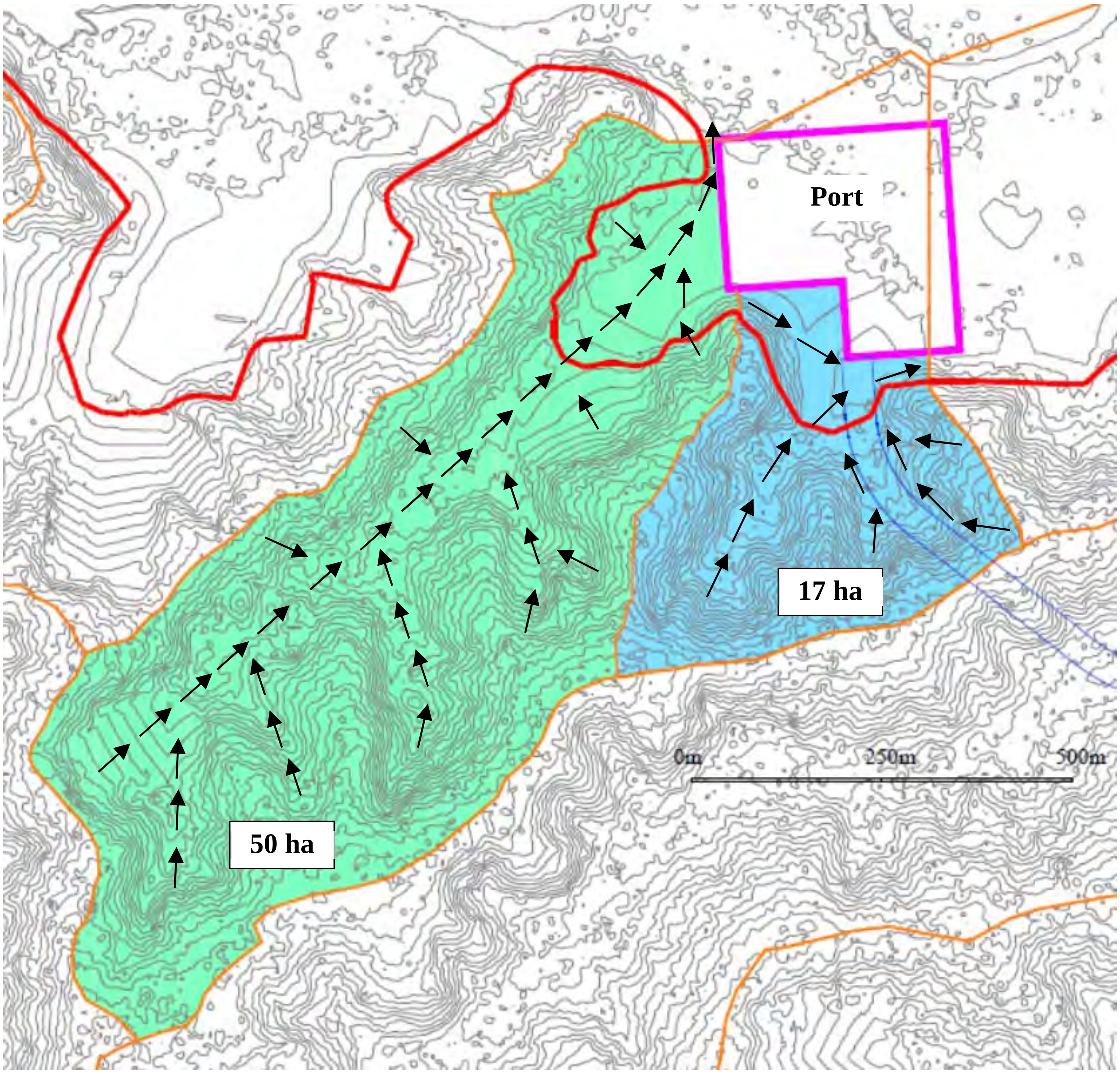
Figure 8.7.11 Change of Catchment Area Proposed in the Mombasa SEZ M/P

Thus, a planned catchment area proposed in the Mombasa SEZ Master Plan should be updated according to not only the revision of the current catchment area by the MSBR construction but also the phasing development plan.

(2) Revision based on the Basic Designs

i) Port

According to the progress of a basic design for the port, the yard is located in the center of the catchment area and the drainage route is narrow. A concrete structure specifically designed to prevent erosion should be developed. The detail of the structure will be determined as a result of the port basic design.



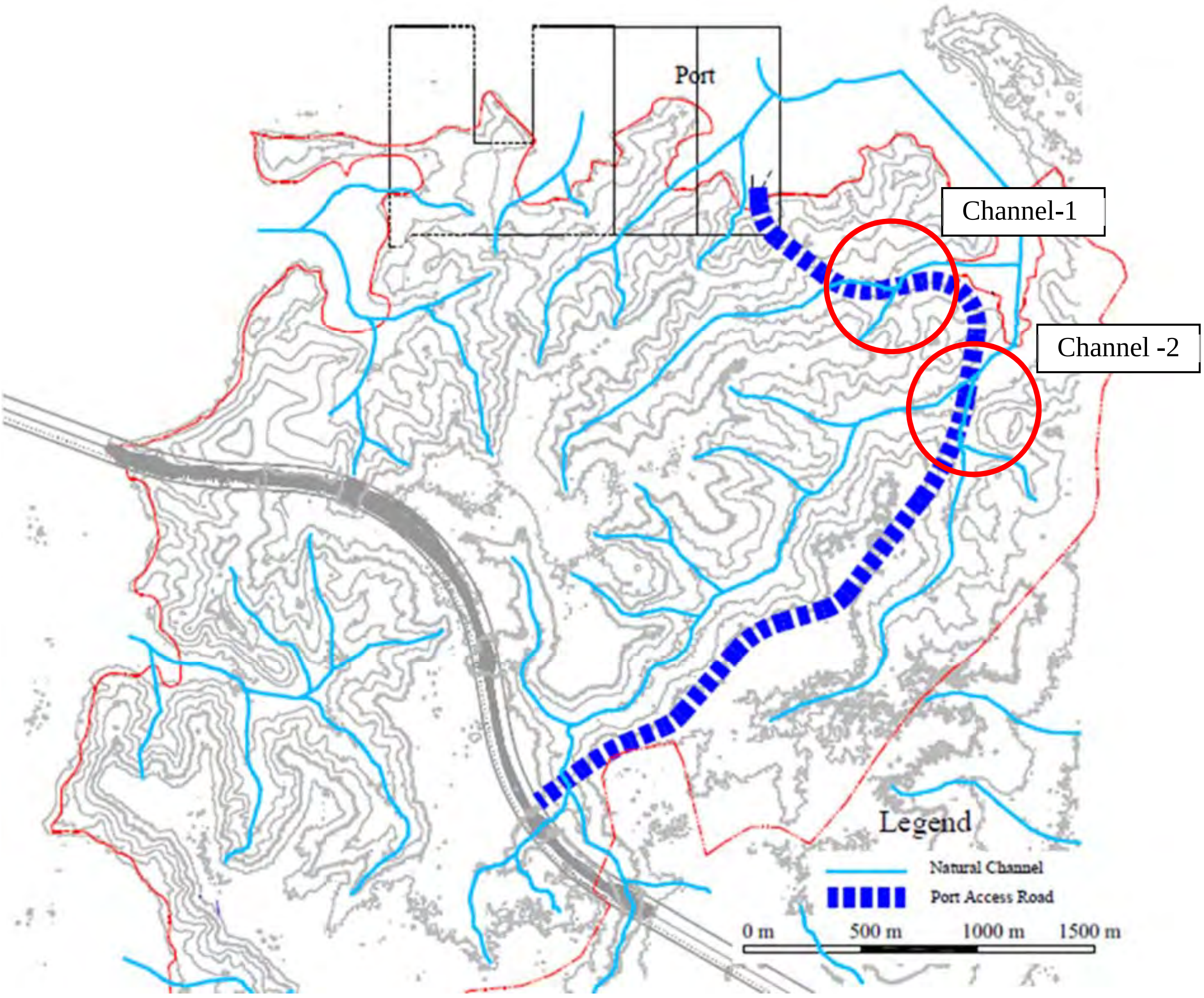
Source: JICA Design Team

Figure 8.7.12 Catchment Area at the Port

ii) Port Access Road

Based on the basic design for the port access road, the alignment crosses several planned major drainage routes. Due to difficulty in the reconstruction of cross drainages under the port access road, the primary function of these major drainages should be thoroughly considered for the future development plan of the SEZ.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: JICA Design Team

Figure 8.7.13 Location of Cross Drainage and Bypass Channel along the Port Access Road

(3) Comparison of Drain Shape between the SEZ Master Plan and the Updated Plan

According to the Mombasa SEZ Master Plan, the width of the largest V-shape channel was calculated as 14.5 m. As a result of drainage analysis, the reduction of a sectional area of the V-shape channel is not required in the reserve area, but it is possible that the U-shape drain is applied in order to reduce cut slope and for the effective use of the FTZ. Table 8.7.7 shows a comparison of the cross-sectional areas of V-shape and U-shape drains. The width of the drainage channels can be reduced by adopting a U-shape channel.

Table 8.7.7 Comparison of V-shape and U-shape Channel

Size	Image	Cross-sectional Area of Water
V 14500/6500 x 2000		15.52 m^2
U 11000/9000 x 2000		15.68 m^2

Source: JICA Design Team

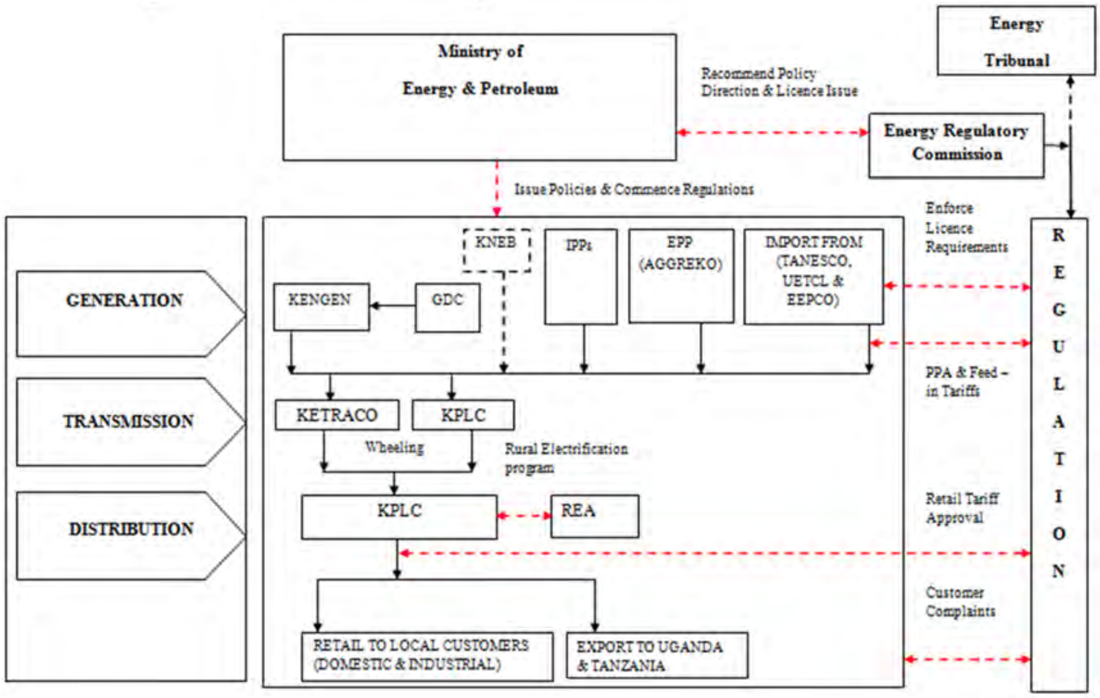
8.8 Power Supply

8.8.1 Overview

The power sector of Kenya is under the jurisdiction of the Ministry of Energy and Petroleum (MoEP). The sector includes Kenya Power Generating Company (KenGen), Kenya Power (KPLC), independent power producers (IPPs), Kenya Electricity Transmission Company (KETRACO), Geothermal Development Company (GDC), and Rural Electricity Authority (REA). The Energy Regulation Commission (ERC) supervises the sector as an independent regulatory body.

- MoEP is responsible for establishing the national energy policy and the rural electrification plan, setting the direction for the growth of the electrical power sector and making a long-term vision for the sector.
- KETRACO is responsible to develop, own, and operate power systems of 132 kV and above.
- KenGen was renamed from KPLC in 2011. It is responsible for the generation at off-grid stations, power purchase, transmission, and distribution and retail sales in Kenya. KenGen conducts electricity distribution from power systems of 132 kV or less.

The scheme of the power sector is shown in Figure 8.8.1 below.



Source: KETRACO

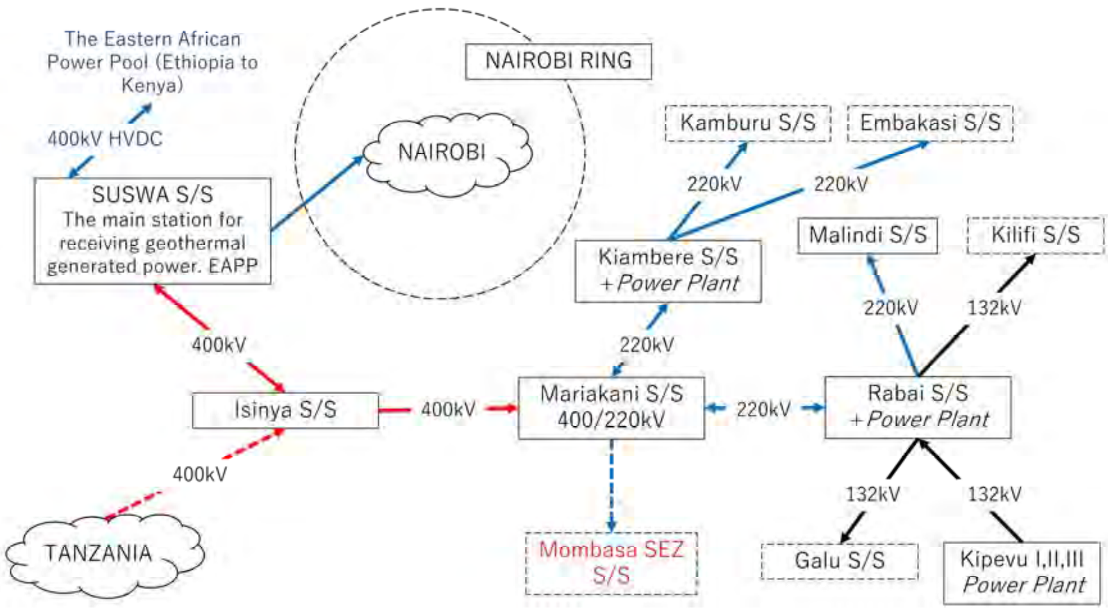
Figure 8.8.1 Institutional Structure in the Kenya's Electricity Sector

8.8.2 Current Conditions

Power is supplied to the said surrounding area by means of 132-kV transmission lines from Rabai Substation, which is being supplied by the 220/132/33 kV Rabai Power Plant and the Kipevu I, II, III power plants. There are no 132-kV nor 220-kV power systems in the Mombasa SEZ area. Since the load of the Coast Province will be increased favorably, the existing 132-kV network will not meet the load

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

demands. The existing grid network for the surrounding area of the Mombasa SEZ is shown in Figure 8.8.2.



Source: JICA Design Team

Figure 8.8.2 Existing Grid Network for the Surrounding Area of Mombasa SEZ

8.8.3 Basic Design Policy

The Mombasa SEZ is a Special Economic Zone which will be a gathering point of various industries, and it is required that sufficient power supply consisting of state-of-the-art facilities can be provided.

The reliability of the power supply system depends not only on each component, but also on the entire system. In general, to ensure reliability, it is a solution that allows the exclusive use of 132 kV transmission lines for Mombasa SEZ, provided that the power plant supplying the power continues to operate.

The reliability of the 220 kV system is higher than that of the 132 kV system due to its simple configuration. Even if a failure occurs, the safety side controls the situation, and fail-safe control prevents the worst case and controls the power supply to the entire system.

In order to increase power transmission capacity and improve reliability, it is recommended to adopt a 220 kV transmission line to supply the electricity to the SEZ area. This construction is officially recommended by MoEP.

Design concepts of the power supply system in the Mombasa SEZ are shown as follows:

- Power supply facilities shall be constructed in the initial stage to provide sufficient power supply to tenants.
- The power supply system shall be highly reliable and flexible at the time of extension.
- Construction cost shall be reduced as much as possible.

(1) Application Code and Standard

The design, specification, installation test, and inspection of all electrical equipment shall comply with the current editions and any supplements of the following publications:

- International Electro-Technical Commission (IEC);
- Kenya Power and Lighting Company (Kenya Power) Technical Standard;
- Kenya Electricity Transmission Company (KETRACO) Technical Standard;
- Kenya National Transmission Grid Code (KNTGC);
- Japanese Industrial Standards (JIS); and
- Other local electrical rules and regulations.

(2) Voltage of Power Supply System

The system voltages applied to the transmission line, substation, and distribution line follow the IEC standard value of voltage at the customer's point of supply, with tolerance limits as indicated below.

Table 8.8.1 System Voltages Applied for Transmission Line and Substation

Nominal System Voltage kV-RMs	Maximum kV-RMs
220	245

Source: JICA Design Team

The system voltages applied to the distribution line and substations are as follows:

- 33 kV ± 10%, three-phase, and 50 Hz
- 415/240 V, TN – CS system

(3) Frequency and Power Factor

- System frequency: 50 Hz ± 2%
- Power factor: ≥ 0.9;

(4) Fault Levels

The minimum design short circuit ratings for the electricity network in Kenya are given below.

- 31.5 kA/3 s for 220 kV
- 25 kA/1s for 33 kV

8.8.4 Design Conditions

(1) Design Condition

Unless otherwise specifically stated in the report or technical specification, any equipment, component, and assembly shall be designed for the following service conditions:

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Site altitude above sea level:	Below 1,000 m
Seismic coefficient:	0.15
Maximum temperature:	40 °C
Minimum temperature:	-1 °C
Design point temperature:	25 °C
Maximum operating temperature of conductor:	80 °C
Pressure at sea level:	1.013 bar (1 atmosphere)
Design relative humidity (RH):	78%
Basic wind pressure (140 km/h zone):	950 N/m^2
Creepage distance:	31 mm/kV
Basic wind speed:	39m/s (3s gust)
Pollution degree:	Level 4

(2) Contingency Criteria

Power supply facilities for the Mombasa SEZ should maintain N-1 redundancy for all transmission and major distribution components. The N-1 criteria require that all loads be restored if any single component fails.

One of the indexes in electrical supply reliability is appraised with N-1 conditions. The conditions state that power supply should be guaranteed in the event that one of the electrical components, such as a transmission line or a transformer, is out of services. For this supplying plan, N-1 conditions will be applied to guarantee reliability. In the development of power supply for the SEZ, the following criteria are applied for the design:

Table 8.8.2 Criteria and Strategy

Criteria	Strategy
Degree of reliability of electric supply of 220 kV transmission line.	To secure 220-kV transmission lines comprising at least two circuits. This capacity is sufficient to allow supply of the whole demand through one circuit. This will ensure continuous power supply even if one of the transmission lines is damaged.
To achieve safety, reliable, easy maintenance	To install a standby transformer to ensure continuous power supply even if one of the transformers fails.
To achieve future expansion	To install a double-circuit distribution system inside the SEZ.

Source: JICA Design Team

(3) Electrical Clearance

The electrical minimum clearance of equipment shall be designed based on the IEC standard or national standard shown below.

Table 8.8.3 Electrical Clearance

No.	Nominal System Voltage	220 kV	33 kV
1	Minimum clearance between live metal and earth (mm)	2,100	400
2	Minimum clearance between live metal (mm)	2,100	400
3	Minimum safety clearance between ground and the nearest point not at earth potential of an insulator (mm)	2,500	2,500
4	Minimum safety clearance - Ground clearance (mm)	7,000	3,700
5	Minimum insulator creep age distance (at rated voltage between phases) mm/kV	31	31
6	Minimum safety clearance of phase-to-phase voltage (mm)	2,700	500

Source: JICA Design Team

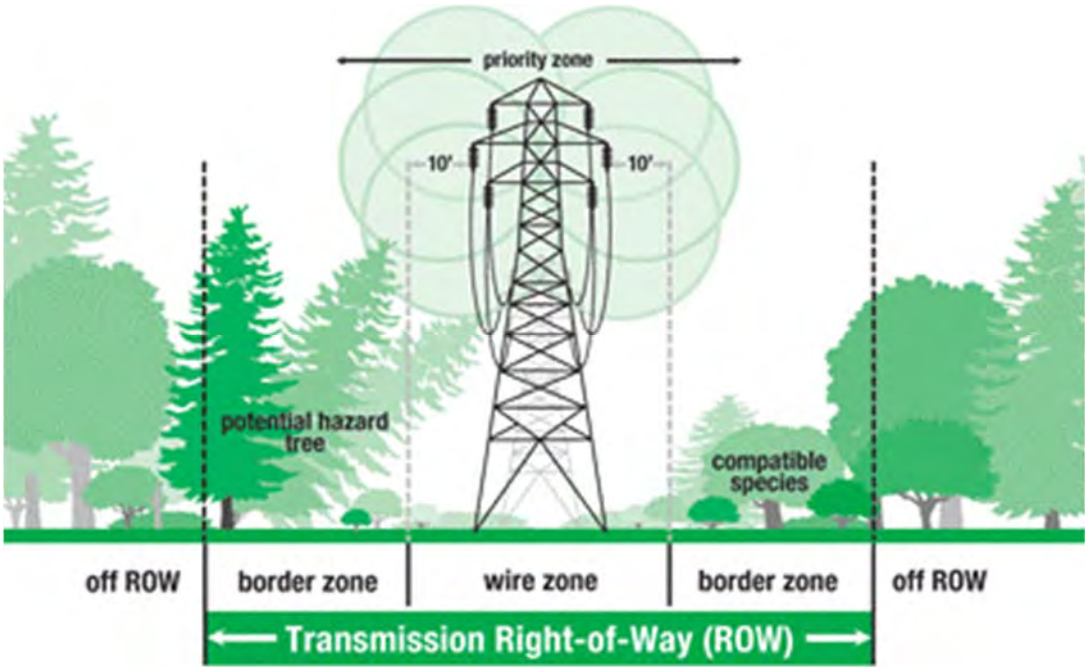
These conditions are in compliance with IEC standards and have been confirmed by the MOE.

(4) Minimum passage separation distance of overhead transmission line

The right-of-way (ROW) in the transmission line is defined as land set at two paths of the center of the transmission line. ROW is also named as "transmission corridor" or "way-leave".

Safety is one of the essential factors in the transmission line development and ROW provides necessary landscape arrangement.

There are several voltage levels of lines maintained and the width of the transmission line corridor (ROW) changes due to voltage levels. The ROW of 220-kV transmission lines should be nearly 40 m, or 20 m on either side from the center of 220-kV transmission lines. The transmission line corridor (ROW) changes with the voltage grade of the transmission line. A way-leave is an ROW over the land of another. This ROW is for carrying sewer, drain, power line, or pipeline into, over, or under lands, so installation of them may interfere with the existing buildings.



Source: Kenya Electricity Transmission Co., Ltd. (KETRACO)

Figure 8.8.3 Right-of -Way or Way-leave of Power Transmission Line

(5) Power Demand Projection

Initially, the demand projection was carried out for 848.1 ha of land in the Mombasa SEZ area, which includes the Project Study Area (Phase 1) comprising 102.35 ha, as shown in Table 8.1.4. These calculations helped determine the demand for the Mombasa SEZ.

The JICA Design Team reviewed the electricity demand from the existing SEZ Master Plan under the change of the land use plan.

As a result, the development area is expected to be 618.7 ha for the whole Mombasa SEZ area, which includes the Project Study Area (Phase 1) comprising 150.3 ha, as presented in Table 8.8.4.

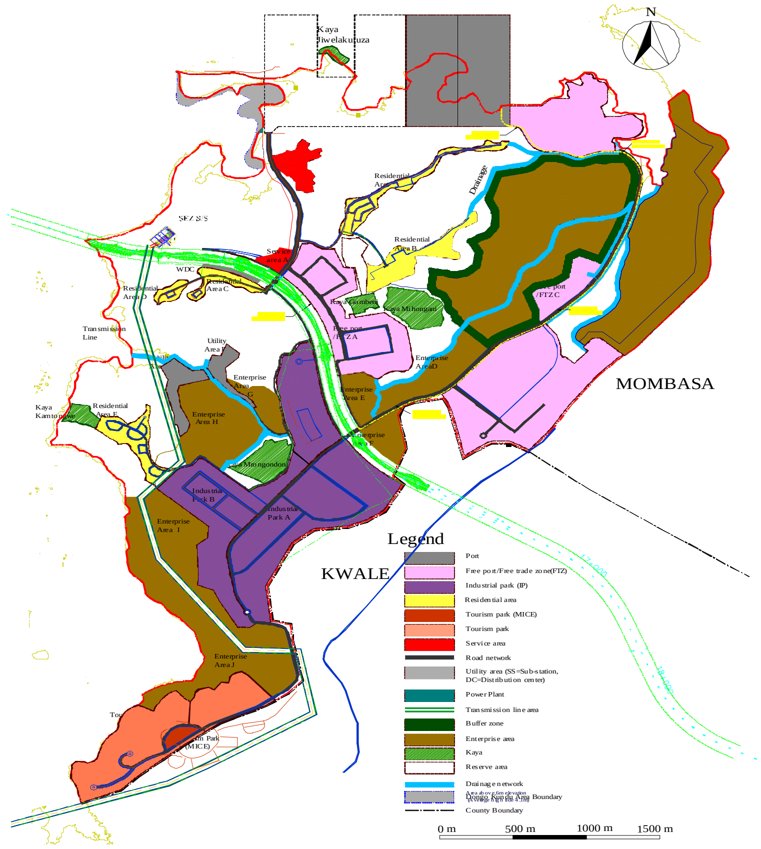
These calculations allowed the demand for the Mombasa SEZ to be determined.

Table 8.8.4 Power Demand Forecast of Mombasa SEZ

Land Use Zone	Development Area (ha)			Unit Power Demand	Power Demand (kVA)		
	Phase 1	Future	Total	kVA/ha	Phase 1	Future	Total
	(P1)	(F)	(T)	(U)	(P1*U)	(F*U)	(T*U)
No.1							
Port1	15.0		15.0	173	2,595		2,595
Port2		15.0	15.0	173		2,595	2,595
FTZ B	67.1		67.1	140	9,394		9,394
FTZ C		7.6	7.6	140		1,064	1,064
FTZ D1	13.3		13.3	114	1,516		1,516
FTZ D2		19.2	19.2	114		2,189	2,189
Enterprise area C		38.1	38.1	140		5,327	5,327
Port Access road	18.7		18.7	30	561		561
Subtotal	**114.1**	**79.9**	**194.0**	**1,024**	**14,066**	**11,175**	**25,241**
No.2							
Industrial Park A1	35.2		35.2	400	14,080		14,080
Industrial Park A2		27.4	27.4	400		10,960	10,960
WDC 1	1.0		1.0	30	30		30
WDC 2		1.0	1.0	30		30	30
S/S		2.0	2.0	30		60	60
Subtotal	**36.2**	**30.4**	**66.6**	**890**	**14,110**	**11,050**	**25,160**
No.3							
Port3		15.0	15.0	173		2,595	2,595
FTZ A		39.5	39.5	140		5,530	5,530
Enterprise area A		70.6	70.6	140		9,878	9,878
Enterprise area B		19.4	19.4	140		2,715	2,715
Enterprise area D		6.9	6.9	140		966	966
Residential A		10.4	10.4	105		1,092	1,092
Residential B		11.4	11.4	105		1,197	1,197
Service area A		1.9	1.9	100		190	190
Service area B		6.9	6.9	100		690	690
Port Access road 2		5.6	5.6	30		168	168
Subtotal	**0.0**	**187.6**	**187.6**	**1,173**	**0**	**25,021**	**25,021**

No.4							
Enterprise area G		3.8	3.8	140		529	529
Industrial Park B1		36.0	36.0	400		14,400	14,400
Industrial Park B2		13.9	13.9	400		5,560	5,560
Residential C		4.9	4.9	105		515	515
Residential D		2.4	2.4	105		252	252
Subtotal	**0.0**	**61.0**	**61.0**	**1,150**	**0**	**21,256**	**21,256**
No.5							
Enterprise area H		13.2	13.2	140		1,841	1,841
Enterprise area I		5.6	5.6	140		787	787
Enterprise area J		18.2	18.2	140		2,554	2,554
Residential E		9.9	9.9	105		1,040	1,040
Tourism Park		49.0	49.0	14		686	686
MICE		2.2	2.2	140		308	308
Utility Area A		7.1	7.1	30		213	213
Utility Area B		4.4	4.4	30		132	132
Subtotal	**0.0**	**109.6**	**109.6**	**739**	**0**	**7,560**	**7,560**
Total	**150.3**	**468.4**	**618.7**	**4,976**	**28,176**	**76,061**	**104,238**
Approx. MVA					**28**	**76**	**104**

Source: JICA Design Team



Source: JICA Design Team

Figure 8.8.4 Land Use Map of Mombasa SEZ

The recommended capacity installation for the project study area (Phase-1) is 75 MVA x 2 units (one unit for standby), and the total capacity installation for the whole SEZ area is 75 MVA x 3 units (one unit for standby). In addition, each transformer shall be regularly maintained.

8.8.5 Considerations on the Basic Design

(1) Outline of Power Supply System Plan

The phased development of power supply facilities for the Mombasa SEZ is shown in Table 8.8.5. This is dependent on the estimated power demand of the Mombasa SEZ, growing from 28 MVA in the first year (Phase-1) of operation to a total of 104 MVA in the next years for the whole Mombasa SEZ area. The outline of the development scenario is proposed as shown below.

Table 8.8.5 Phased Development of Power Supply

No.	Supplying Amount (Total)	Development Scenario
Phase-1	28 MVA	It is required that the initial power supply facilities for SEZ be ready when the Mombasa SEZ starts operation. In accordance with Phase 1 development, install a 75 MVA transformer. In addition, it is necessary to install one additional unit for backup
Future	76 MVA (Total of 104 MVA)	One more transformer should be installed to meet the basic principle of n-1 security.

Source: JICA Design Team

(2) 220-kV Transmission Line from Mariakani Substation and Mombasa SEZ Substation

i) Extension of two bays at the 220-kV switchyard in Mariakani Substation

The 400/220-kV Mariakani Substation (S/S) is under another contract or is part of the Mombasa-Nairobi Transmission Line Project. The plan views of the Mariakani S/S and its surroundings are shown in Figure 8.8.5 and Figure 8.8.6.

The 220-kV bus is ready to be upgraded and additional 220-kV switch bays of two outgoing feeders will be added at the 220-kV switchyard.

The scope of work at the Mariakani S/S under the Mombasa SEZ project will include the following:

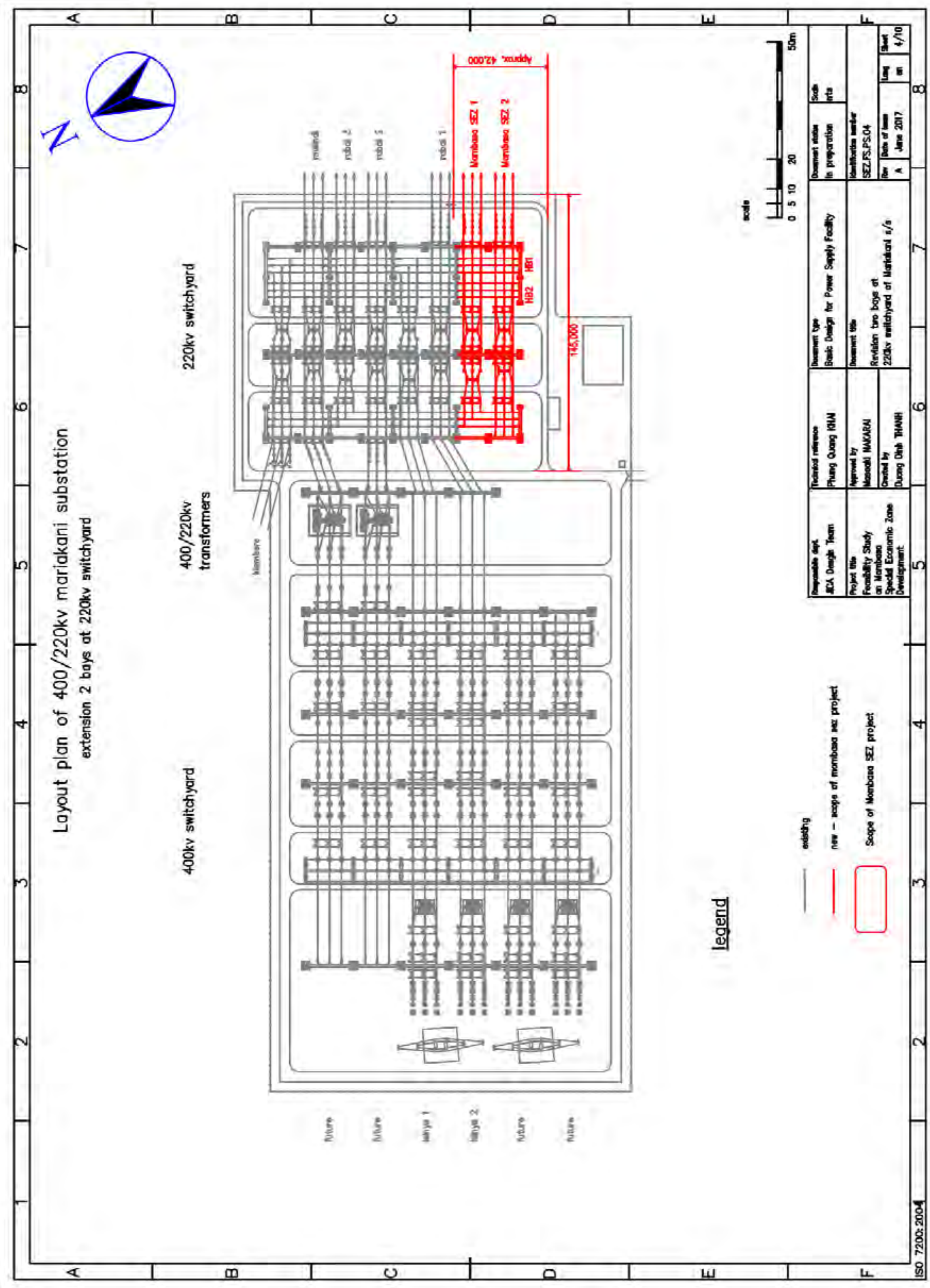
1) Ensure that power supply is 200 MVA or more by KETRACO,
2) The earthing method to be used shall be the neutral point direct grounding method,
3) Installation of 220 kV outdoor equipment and its auxiliary equipment,
4) Control and protection system,
5) SCADA metering system, and
6) Domestic network telecommunications via optical fiber composite overhead ground wire (OPGW) from the SEZ substation.

In the KETRACO control room inside the Mariakani S/S, the auxiliary equipment of the Mombasa SEZ project is installed together with the KETRACO control board.

The installation area of the auxiliary equipment is about 120 m^2, and the installation space is secured by KETRACO during the planning stage.

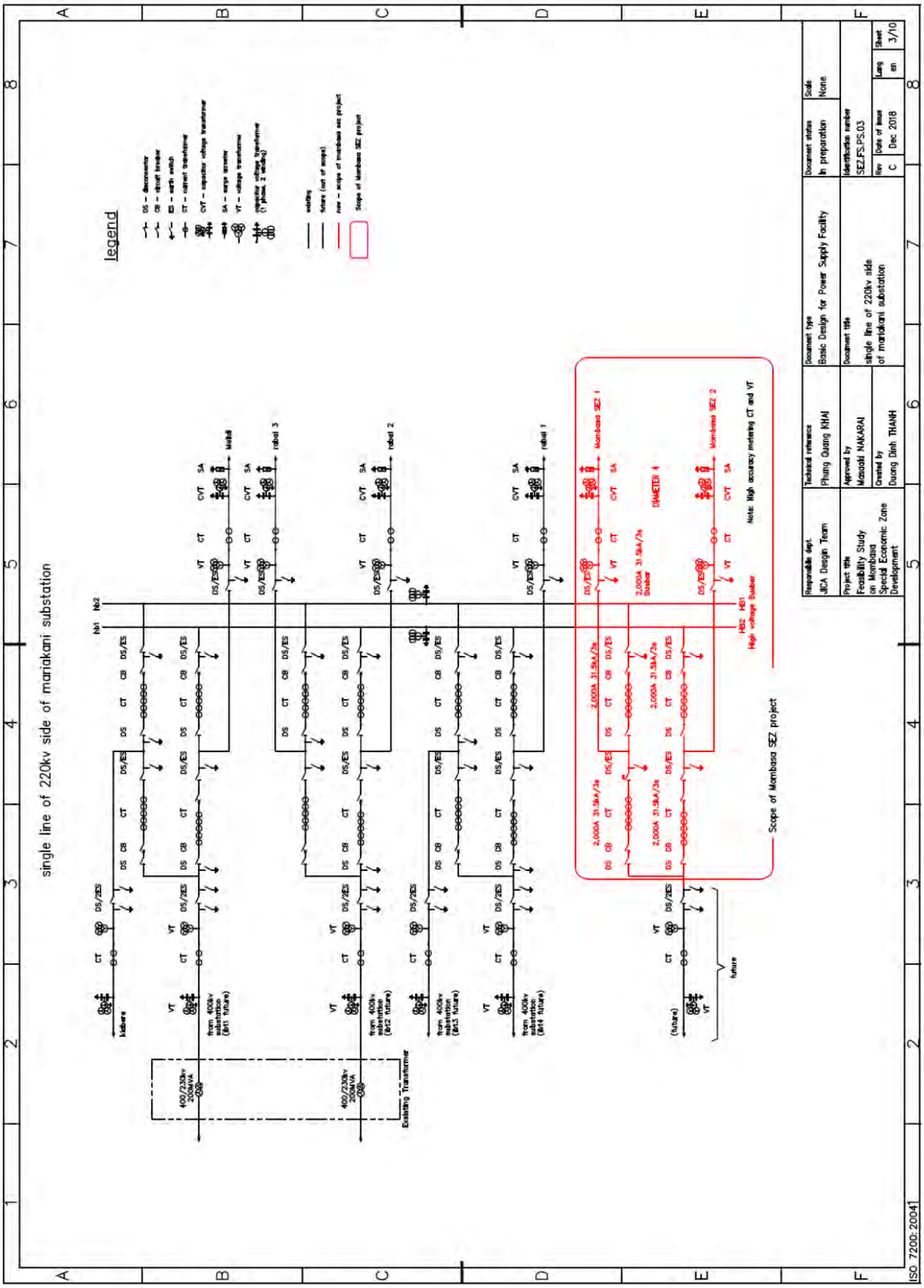
- 220 kV protection control panels
- Communication and SCADA system equipment- DC 48 V battery system and switchboards
- DC 110 V battery system and switchboards
- Inverter panels for the substation

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: Kenya Electricity Transmission Co., Ltd. (KETRACO)

Figure 8.8.5 Layout Plan at 220 kV Switchyard in Mariakani Substation



Source: Kenya Electricity Transmission Co., Ltd. (KETRACO)

Figure 8.8.6 220 kV Single Line Diagram in Mariakani Substation

ii) 220-kV Transmission Line from Mariakani S/S to SEZ S/S

1) Power Transmission Path

It was confirmed that KETRACO is to secure 200 MVA for power supply from Mariakani S/S to Mombasa SEZ S/S.

In addition, the transmission line system transmits electricity to the Mombasa SEZ S/S from the Mariakani S/S with a transmission voltage of 220 kV and two lines (neutral direct grounding system).

The plan of the 220-kV transmission line route from Mariakani S/S to SEZ S/S is shown in Figure 8.8.8.

2) Steel Tower

The steel tower is designed with a lattice structure to increase its strength.

The plan of the structure of the steel tower is shown in Figure 8.8.7. The steel tower case has two 220-kV lines with lattice structure.

3) Power Transmission Line

For transmission lines, we will consider conventional ACSR (Aluminum Conductor Steel Reinforced) and LL-ACSR (low-loss Aluminum Conductor Steel Reinforced) with low transmission loss.

ACSR CANARY is compared with LL-ACSR, a typical example of low loss wire, in the following table "Table 8.8.6 Comparison Table of Conductor type for transmission line (Canary equivalent)".

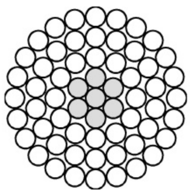
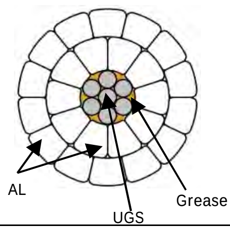
The main features of ACSR and LL-ACSR are as follows.

a) For current capacity, the current value corresponding to the CANARY operating temperature of 80 ° C. On the other hand, the temperature is 74 ° C in LL-ACSR, and the capacity of LL-ACSR is larger.

b) The electrical resistance can reduce transmission loss by about 20% because LL-ACSR is about 20% less than ACSR.

c) The outer diameter is the same in LL- ACSR and ACSR, and the wire weight is slightly larger in LL- ACSR.

Table 8.8.6 Comparison Table of Conductor type for transmission line(Canary equivalent)

Conductor type	Conventional ACSR	Typical LL-ACSR
Drawing of cross section		
Conductor size [mm^2]	515	620
Strand composition [pc/mm]	AL 24/3.28, AL 18/3.28 AL 12/3.28,ST 7/3.28	AL 14/5.49, AL 10/5.52 ST 7/3.0 （UGS）
Outer diameter [mm]	29.5	29.5
Cross-section [mm^2]	AL 456.3、ST 59.15 Total: 515.5	AL 570.7、ST 49.48 Total: 620.2
Weight [kg/km]	1,726	1,966
Tensile strength [kN]	141	168

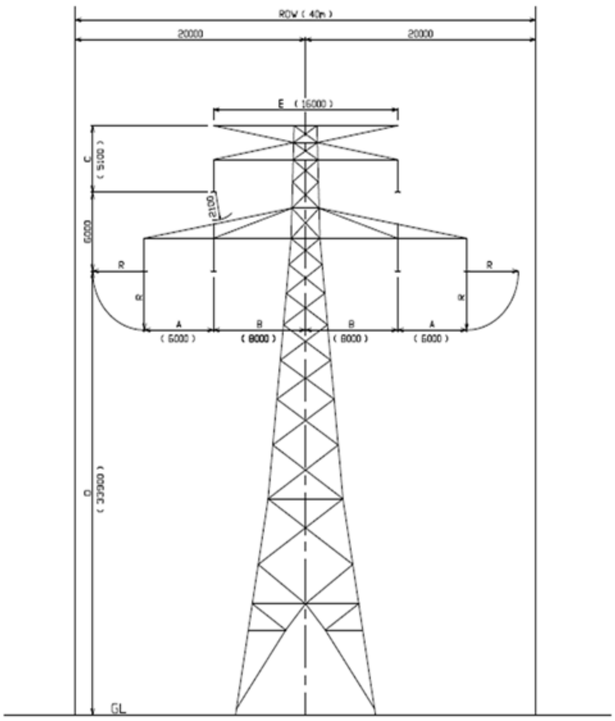
Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc

Conductor type	Conventional ACSR	Typical LL-ACSR
DC resistance [20 ℃、Ω/km]	0.0632	0.0504
Current capacity [A] (wire temp.)	753 (80 ℃)	753 (74.4 ℃)
Estimated cost	100%	200%

Source: Maker data

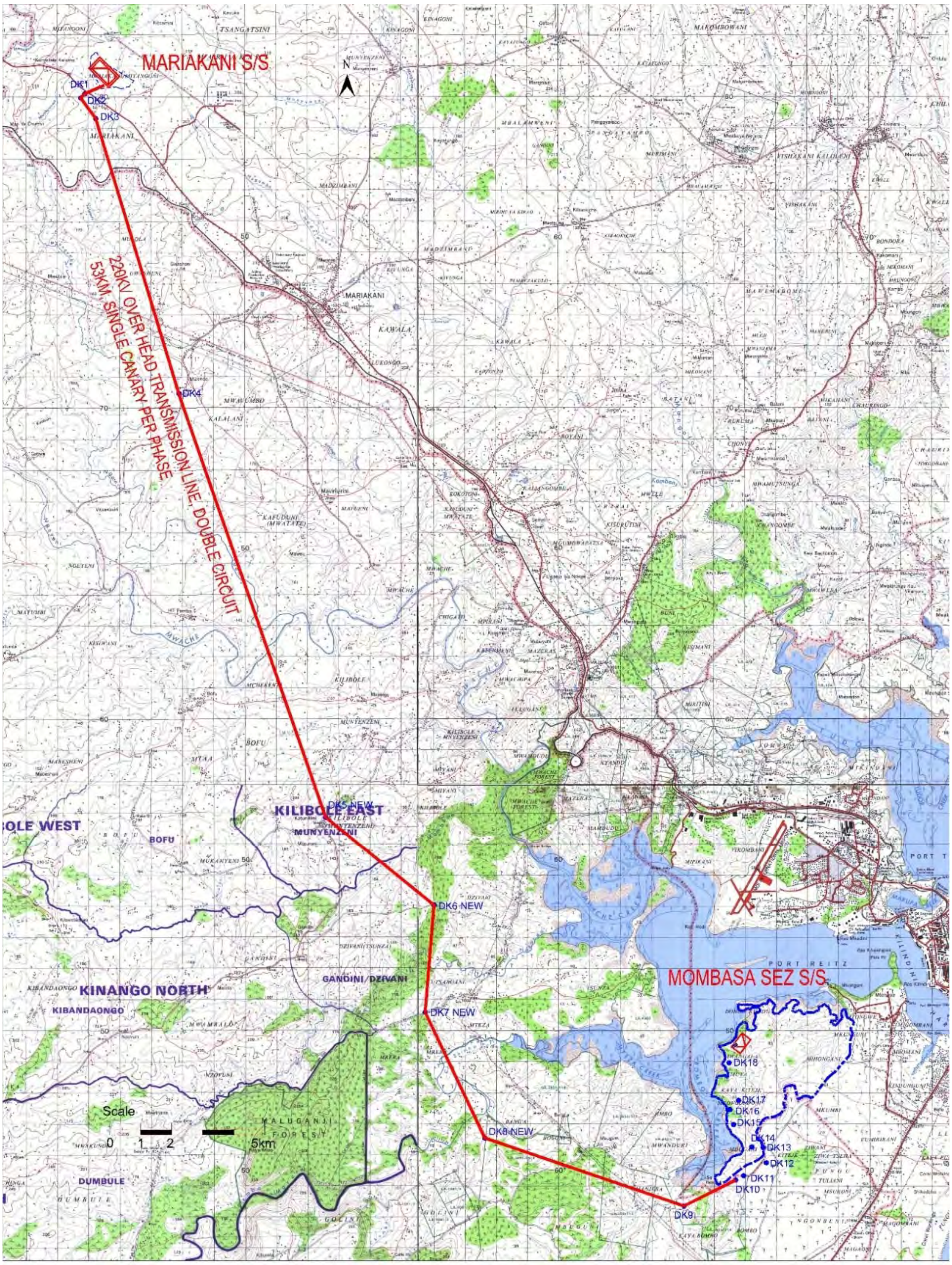
It can reduce power transmission loss by about 20%, and is effective in preventing global warming. Therefore, LL-ACSR shall be adopted.

Although the initial cost of LL-ACSR is higher than that of ACSR, it is expected that equivalent reductions can be achieved in about 20 years due to the reduction of transmission loss.



Source: The turnkey project of 400 kV and 220 kV transmission lines by KETRAKO

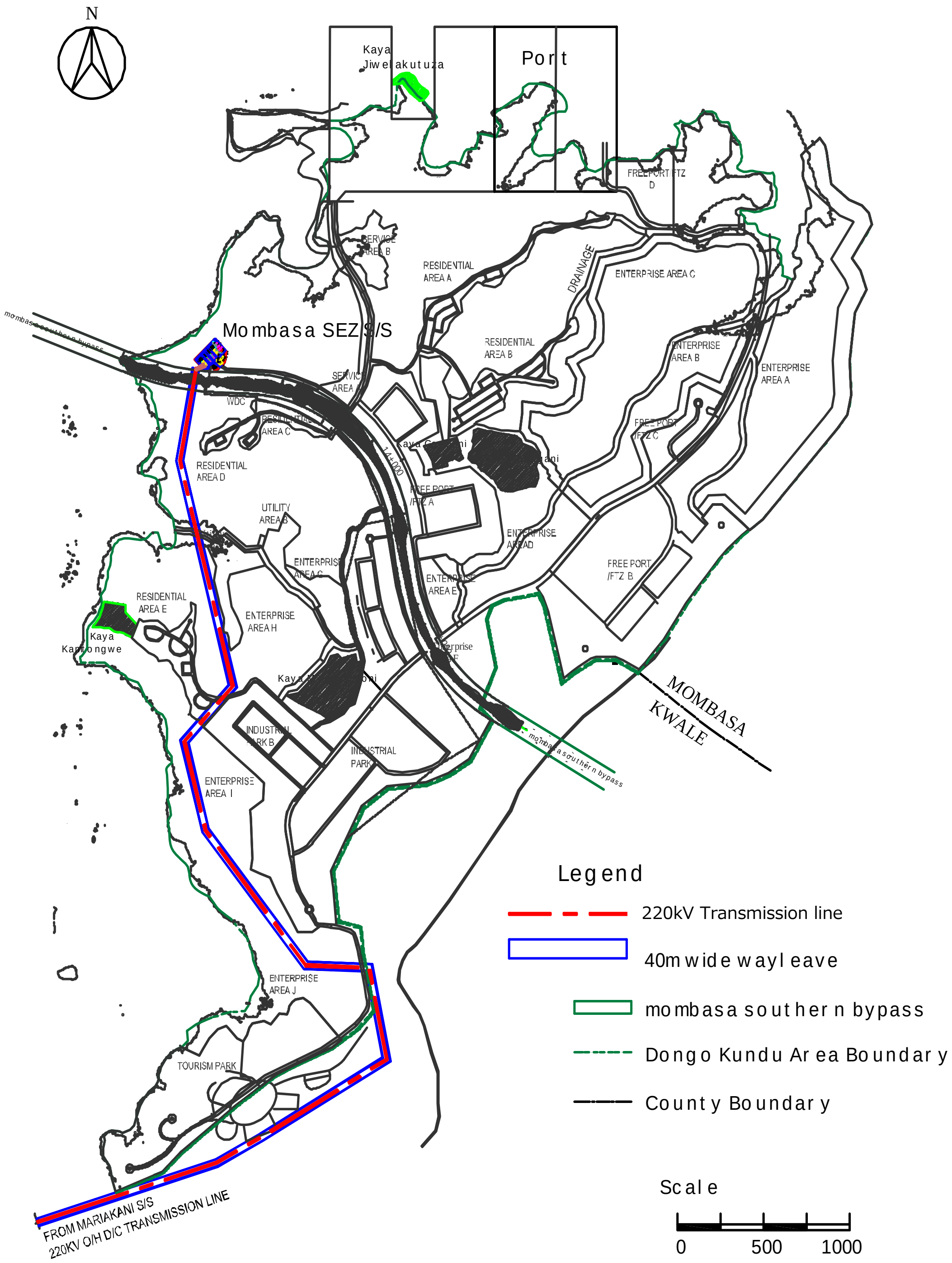
Figure 8.8.7 Example of 220-kV Double Circuit Lattice Steel Tower



Source: JICA Design Team

Figure 8.8.8 Proposed 220-kV Transmisison Line from Mariakani S/S to Mombasa SEZ S/S

Figure 8.8.8 shows the selected route area which was based on the existing study of a 400-kV transmission line that was conducted by KETRACO for the canceled 400-kV Mariakani-Dongo Kundu Project. The image below shows the route following the revised power corridor with some minor regiments to void the Kayas area inside the SEZ.



Source: JICA Design Team

Figure 8.8.9 Transmission Line inside the SEZ Area

Table 8.8.7 Specification and Quantity of Equipment for Transmission Line

Facilities to be Installed	Specification	Quantity
220 kV outlet, switching facility at Mariakani substation	245 kV-2,000 A-31.5 kA/3 s	2 bays
220-kV transmission line	220 kV overhead line, double circuit, single canary equivalent LL-ACSR per phase with OPGW, using of lattice steel tower	Approx. length: 53 km
Miscellaneous		1 lot

Source: JICA Design Team

During construction, delivery access for construction machinery, equipment materials, and tools would be through existing rural roads for the most part of the selected route towards the south and through the Mombasa-Nairobi Main Road (A109) towards the north. There are no obvious major environmental concerns observed in this line route.

(3) Proposed Mombasa SEZ S/S

To cover the demand projected for the Mombasa SEZ area, the Mombasa SEZ S/S comprising two units of 75 MVA transformers should be installed adjacent to the Mombasa Southern Bypass Road. Y-Y type is adopted as windings of transformer according to KETRACO's standard.

The power distribution system is described as follows:

a) Transformers will be operated separately to meet the power demand developed by Mombasa SEZ. development.

b) Parallel operation of the transformer is not carried out simultaneously with the switching of the transformer.

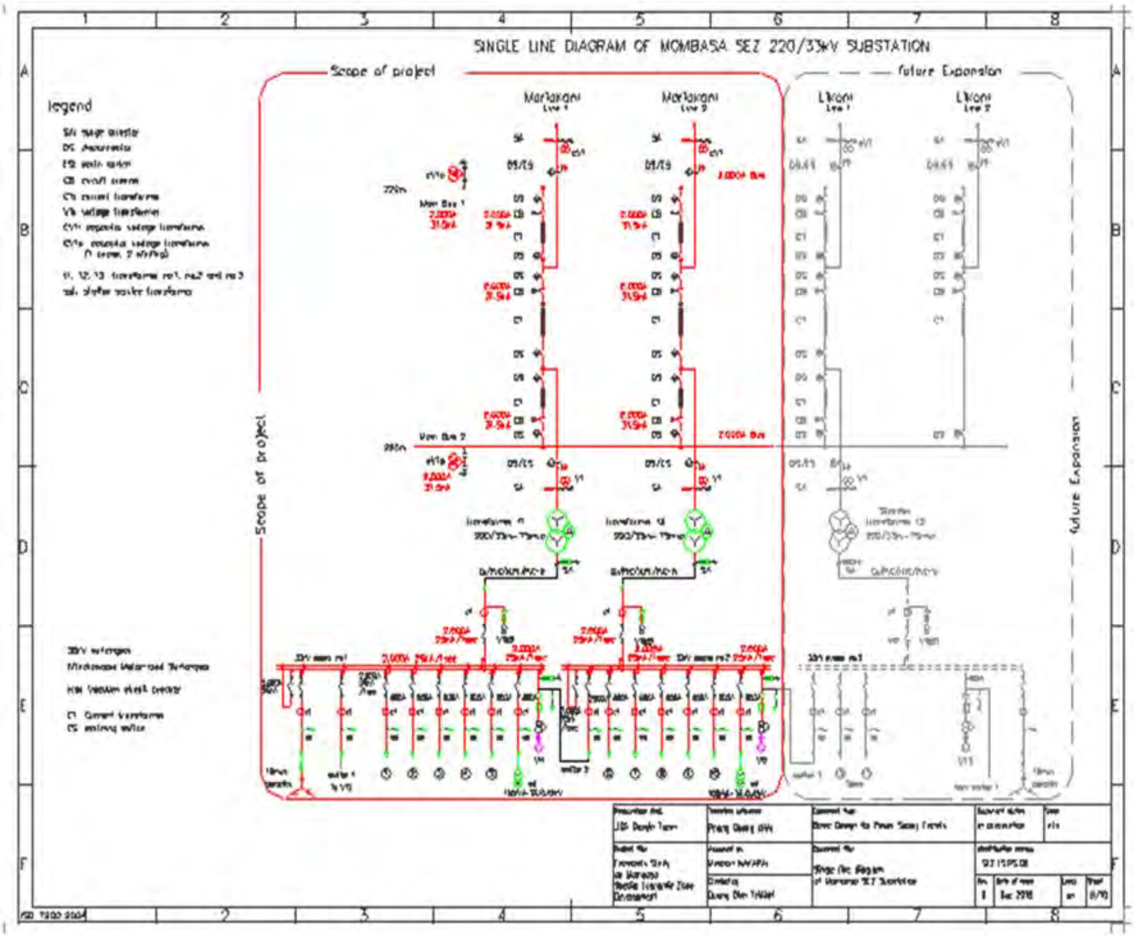
c) The 33-kV distribution system is separated into two systems. The bus bar is a double bus to ensure safety.

d) The line switching system is implemented at the time of maintenance or failure of the feeder line.

e) Power is supplied from the other line by the bus tie switch.

The configuration of electrical equipment for Mombasa SEZ S/S is applied circuit breaker and single line diagram as shown in Figure 8.8.10.

Nippon Koei Co., Ltd.
The Overseas Coastal Area Development Institute of Japan
Koei Research & Consulting Inc



Source: JICA Design Team

Figure 8.8.10 Single Diagram of 220/33 kV Mombasa SEZ S/S

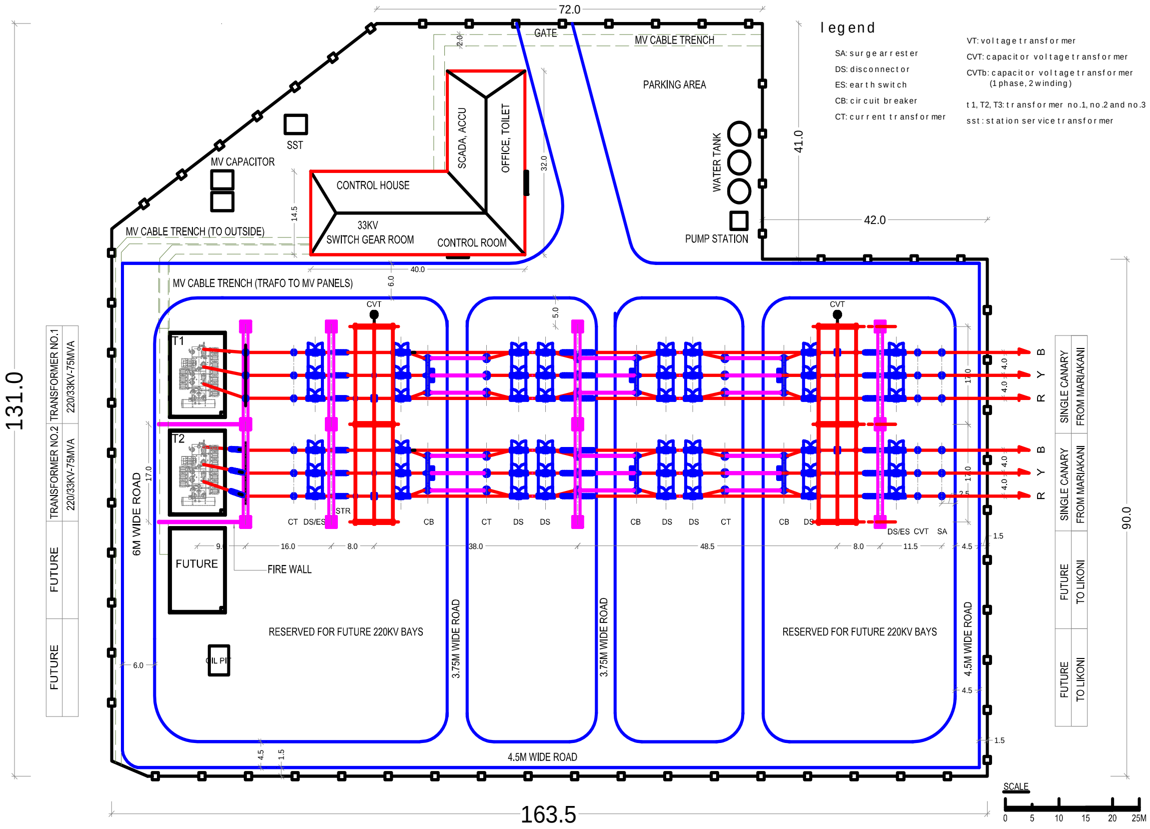
Specification and quantity of equipment is shown in Table 8.8.8.

Table 8.8.8 Specification and Quantity of Equipment for Mombasa SEZ S/S

Facilities to be Installed	Specification	Quantity
Power transformer	220/33 kV – 75 MVA	2 units
Switchyard 220 kV: 1 diameter include 3 circuit breakers, 8 disconnecting switches, surge arrester... for 1 incoming feeder and 1 transformer feeder with breaker and half configuration	245 kV-2000A-31.5 kA/3 s 3 phases, outdoor type	2 diameters
33 kV distribution cubicles: 2 incoming feeders, 10 outgoing feeders, 2 sectionalized feeders, 2 auxiliary transformer feeders, 2 voltage transformer feeders and 2 sets capacitor feeders 18 MVAr included outdoor capacitor	33 kV, 3 phases GIS - Gas-insulated switchgear, indoor-use. Incoming and bus section 2000sA, outgoing 800sA.	1 lot
Control house, civil works, control and protection system, SCADA, telecommunication, fire system, auxiliary system, etc.		1 lot
Miscellaneous		1 lot

Source: JICA Design Team

The layout plan of the substation is shown in Figure 8.8.11 which realizes as enough space for two future expansion bays (2 diameters). Design dimension for the Mombasa SEZ S/S is approximately 18,800 m^2 (largest size 160 m×130 m).



Source: JICA Design Team

Figure 8.8.11 Plan View of 220/33 kV Mombasa SEZ Substation

(4) 33-kV Distribution Lines

There is a two-feeder distribution system from the SEZ S/S to the Phase-1 District. The distribution system passes through Mombasa Southern Bypass and ports access roadside.

One feeder distributes to the port, FTZ D1, FTZ B, and the other feeds power to the industrial Park A1 and port access road are included in the scope of project.

Table 8.8.9 Specification and Quantity of 33-kV Distribution Lines (Phase-1)

Facilities to be Installed	Specification	Quantity
Power cable from 33 kV GIS cabinet to the first pole	Copper, XLPE cable	Approx. 2 km
Cable accessory		1 lot
Distribution lines	33 kV overhead line, dual circuit, Single conductor LL-ACSR Wolf equivalent, concrete poles	Approx. 7 km
Miscellaneous		1 lot

Source: JICA Design Team

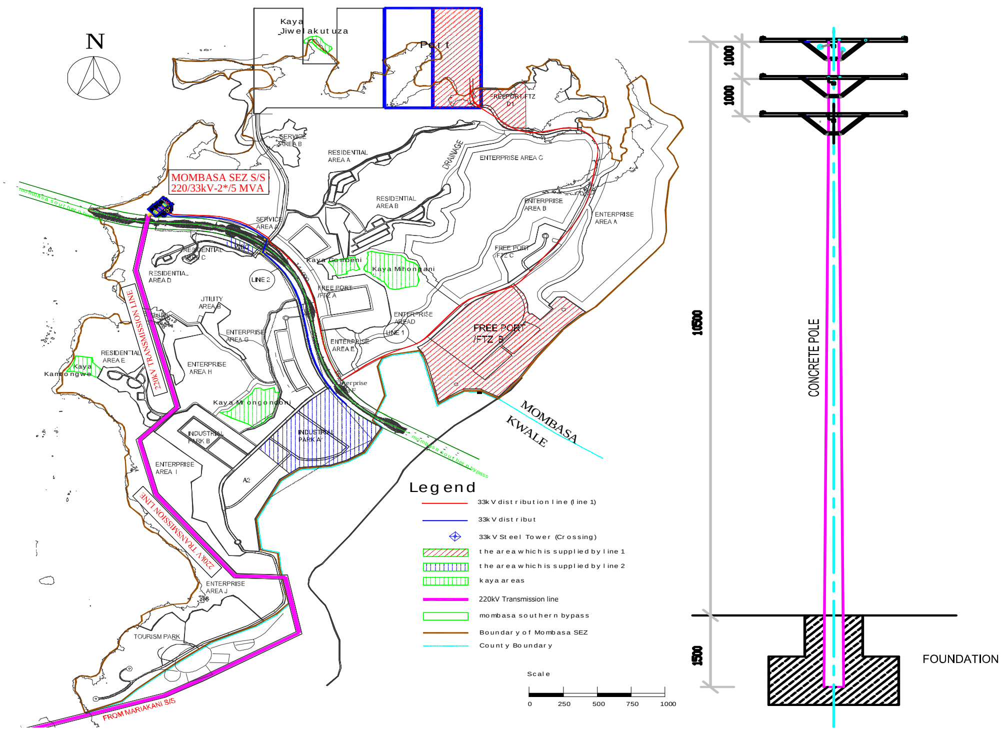
Installations for underground cables using copper conductor XLPE insulated from the medium voltage switchboards that are located in the control house to the service area along the road. From the first concrete poles, two system lines of two 33-kV circuits along with other infrastructures should be wired to following the distribution area.

1) Port, FTZ D1, FTZ B
2) Industrial Park A1

The conductor to be installed applies to the specification of ACSR 150 mm^2 which has a code name of “Wolf”. The concrete pole for a 33-kV line is typically designed according to Kenyan standards. ACSR Wolf recommends LL-ACSR to reduce loss because 33kV distribution line current value of overhead transmission line increases with load current. However, the strength of the support should be taken into consideration as the wire's own weight increases. The installation of a 33-kV concrete pole will be carried out in consideration of KPLC and the passage rights enumerated below:

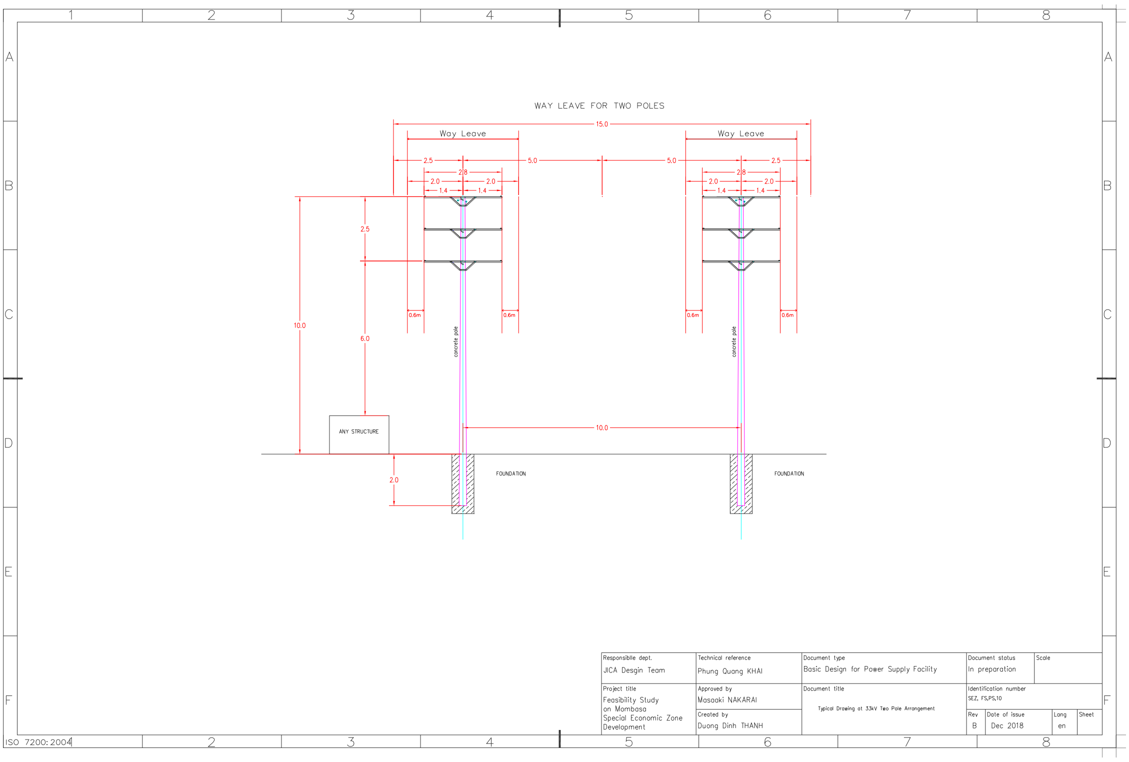
1) When there is one concrete pole: 4 m
2) In the case of two concrete poles: 10 m
3) Distance from road: approximately 3 m

Concrete pillars have corresponding environmental effects, such as forest in the building, in the city, and in the suburbs. Therefore, it is recommended to keep the separation distance of conductors.
Figures 8.8.12 and 8.8.13 show the 33-kV distribution plan and the design of the concrete pole ROW.



Source: JICA Design Team

Figure 8.8.12 Plan of 33 kV Distribution Lines and Typical Concrete Pole



Source: JICA Design Team

Figure 8.8.13 33 kV Concrete Pole ROW