# KIBAHA – MOROGORO EXPRESSWAY PPP PROJECT

## LOT 2: CHALINZE – MOROGORO (84.9 KM)

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# FEASIBILITY STUDY REPORT

## INTERNAL TA REVIEW SUMMARY

*(Pre-RFQ Issuance — Internal Use Only)*

| | |
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| **Prepared by** | Transaction Advisor — Cheil Engineering Co., Ltd. (Lead) |
| **Contract No.** | AE.001/2025-26/HQ/W/40 |
| **Contracting Authority** | TANROADS |
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This Feasibility Study Report (the "Report") is provided by the Contracting Authority (TANROADS) to Bidders solely for reference purposes in the preparation of their Proposals in connection with the Request for Proposals (RFP) for Lot 2 (Chalinze – Morogoro, 84.9 km) of the Kibaha – Morogoro Expressway PPP Project.

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Bidders are advised in particular to note that: (a) the traffic demand forecasts in this Report are based on a road network planning scenario that includes Lot 3 (Morogoro–Dodoma Expressway) as a network planning assumption only; (b) the inclusion of Lot 3 in the traffic model does not constitute a commitment by the Government of Tanzania to proceed with Lot 3; and (c) Bidders must satisfy themselves as to the robustness of the traffic and revenue assumptions for the purposes of their own financial modelling.

# 1. DOCUMENT OVERVIEW

## 1.1 Purpose

This document is an internal Transaction Advisor (TA) review summary of the Final Feasibility Study Report for Lot 2 (Chalinze – Morogoro, 84.9 km) of the Kibaha–Morogoro Expressway PPP Project. It is prepared by the TA team for internal quality assurance prior to the issuance of the Request for Qualification (RFQ) for Lot 2.

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# 2. PROJECT OVERVIEW

## 2.1 Project Description

Lot 2 forms the rear section of the Kibaha–Morogoro Expressway, connecting Chalinze to Morogoro Municipal. The project is to be procured as a greenfield DBFOMT (Design, Build, Finance, Operate, Maintain and Transfer) PPP concession of approximately 30 years (including construction period). On expiry of the concession, the asset shall be transferred to the Government of the United Republic of Tanzania.

The project road runs parallel to the existing Morogoro Road (T1) on the north side, commencing at the Chalinze Interchange (connection point with Lot 1) and terminating at the Morogoro Interchange, connecting to the T3 road north of Morogoro.

## 2.2 Key Technical Parameters

| | |
|---|---|
| **Project Section** | Chalinze – Morogoro (Lot 2) |
| **Total Length** | 84.9 km |
| **Carriageway** | 4-lane dual carriageway (2 lanes each direction) |
| **Design Speed** | 120 km/h |
| **Interchanges** | 3 nos. — Bwawani IC, Kingolwira IC, Morogoro IC |
| **Bridges** | 13 nos. (total 815 m) |
| **Vehicular Overpasses** | 9 nos. (total 515 m) |
| **Vehicular Underpasses** | 43 nos. box culvert (total 1,625 m) |
| **Toll Stations** | 4 nos. — 1 Main (Chalinze) + 3 IC Stations; Closed Toll System (CTS) |
| **Rest Areas** | 2 nos. |

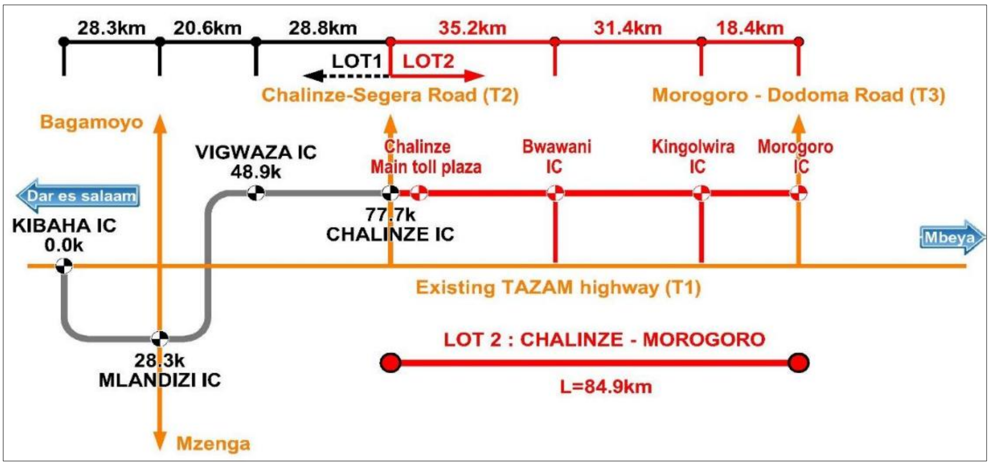
| | |
|---|---|
| **Pavement Type** | JUCP Concrete Slab — 270 mm / 40 MPa |
| **Concession Period** | 30 years (incl. construction) |
| **PPP Structure** | DBFOMT — Availability Payment Mechanism |

## 2.3 Feasibility Study Background

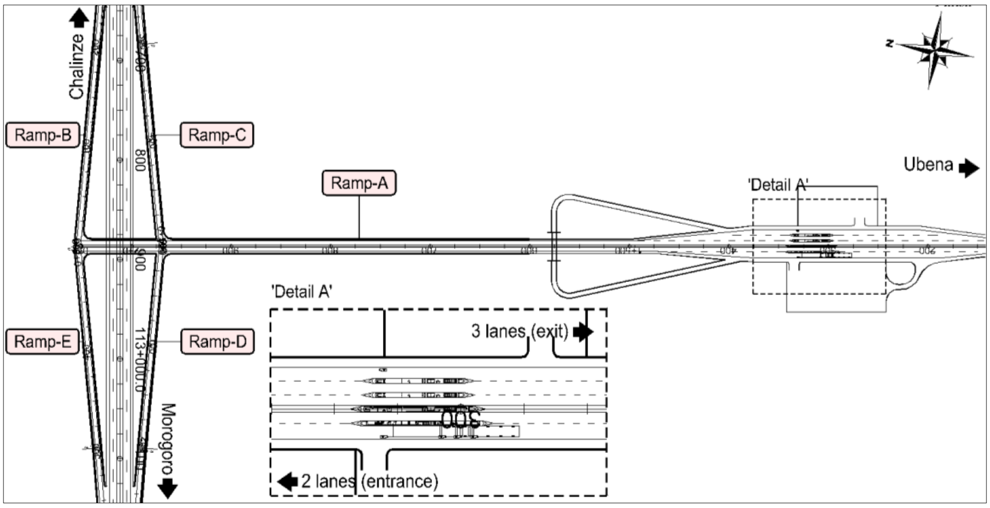
A pre-feasibility study for the Lot 2 section was conducted by TECU (TANROADS Engineering and Consulting Unit). The TA conducted a comprehensive verification and update of the TECU pre-feasibility data and prepared a full Feasibility Study covering technical, economic, commercial, financial, environmental, social, legal, and institutional assessments using HDM-4 v2.11 for economic analysis. The Final FS Report was approved by the PPP Steering Committee (PPPSC) on 20 August 2025.

*<Figure 1-1: Location map of Kibaha-Chalinze-Morogoro expressway>*

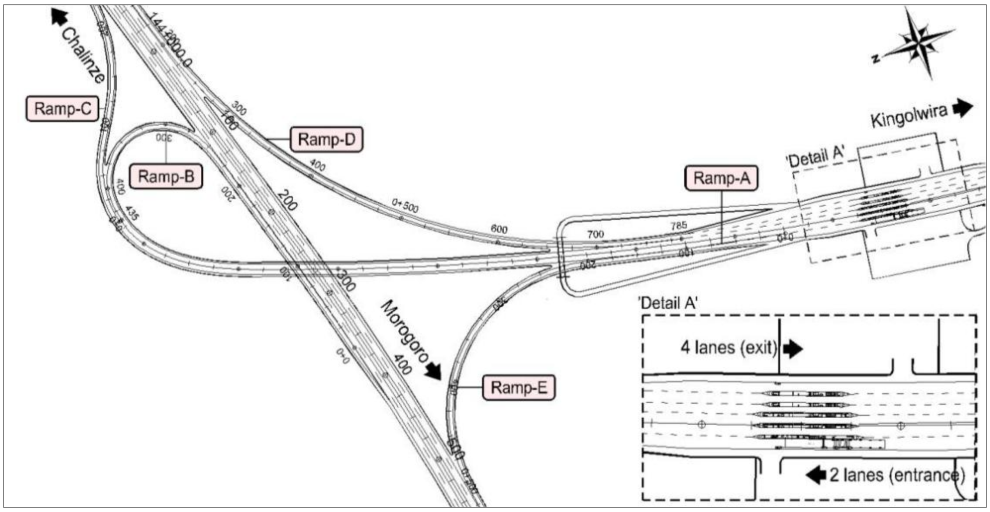

*<Figure 1-2: Location map of Interchanges>*



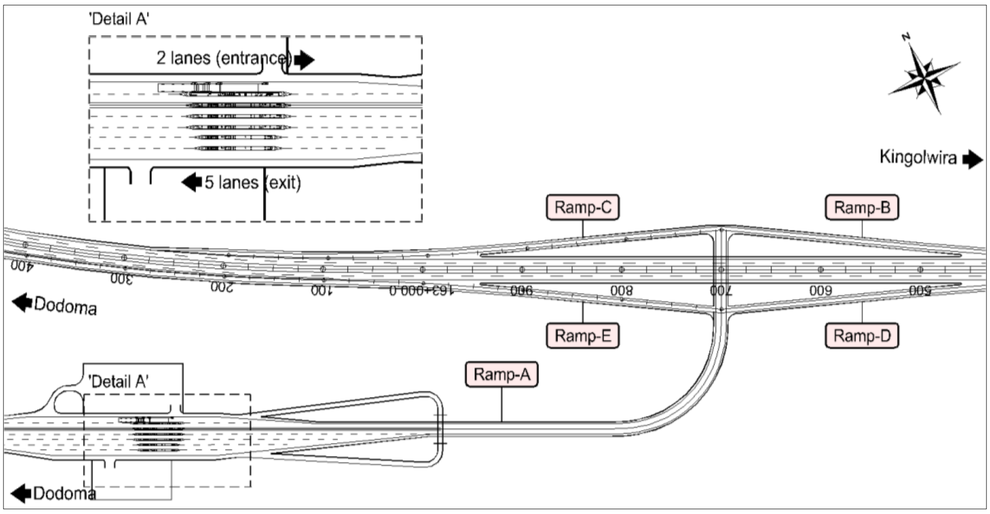
<Figure 1-3: Features of Bwawani Interchange>




<Figure 1-4: Features of Kingolwira Interchange>




<Figure 1-5: Features of Morogoro Interchange>



## 2.4 Project Location

### 2.4.1 Geographical Location

The Kibaha – Mlandizi – Chalinze - Morogoro expressway (205km) will form part of the TANZAM highway. The Lot 1 of the expressway starts from Kibaha District (TAMCO Area) in Coast region, traverses through Chalinze and Lot 2 is from Chalinze to Morogoro Municipal.

Lot 2 (Chalinze - Morogoro) of this project includes two spur roads that connects Kingorwila and Bwawani township. Lot 2 of the project starting point is at Chalinze right after traversing the existing T2 road and runs parallel to the existing Morogoro road on the North side. At Morogoro, the project road intersects with the T3 road at the north of Morogoro. It connects with the T3 road via the Morogoro Interchange, marking the end of the expressway.

*<Figure 2-1 Starting Point at Chalinze>*

*<Figure 2-2 Point of connection with the existing road in Kingolwira and Buwawani>*

*<Figure 2-3 End Point at T3 road (North of Morogoro)>*

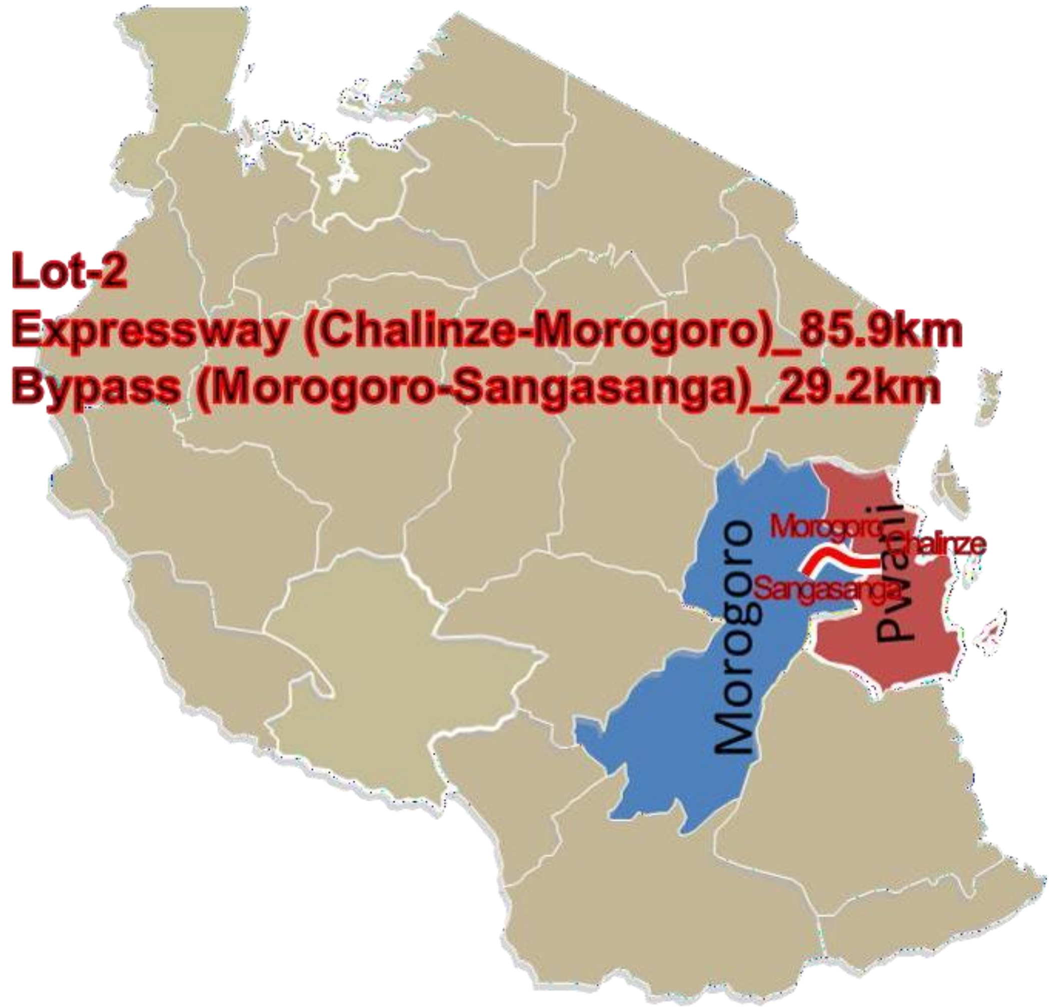
### 2.4.2 Site Suitability and Geographical location

The road project site is selected by considering its suitability in Topography, Drainage, Climates and Socio-Economic Condition. The road will be constructed along hilly and rolling terrain in coast belt rises from 180m to 625m and is dominated by sandy loam and clay which is advantageous in optimization of the design in the context of drainage, road geometry etc. The lowland areas contain rivers that discharge their water to the Indian Ocean.

The project route is parallel to the existing Morogoro road which is also advantageous due to existence of source of materials such as gravel, sand, aggregates and water from nearby borrow pits and quarries which were used during construction of the existing Morogoro road. Also, the proposed site is easily accessible through the existing Morogoro road as it will enable haulage of construction materials such as cement, reinforcement and equipment that are purchased from DSM and/or imported outside the country. On the other hand, the existence of health centres and referral hospital is another advantages to private investor in this project. The project is near to DSM city where labour force is abundant, therefore the private investor may not use more effort during mobilization of staff. All these are additional advantages to the prospective investors who may wish to develop this project under PPP arrangements.

The Project road for Lot-2 is within a part of Pwani and Morogoro regions.

*<Figure 2- 4 Location of Project road in Pwani and Morogoro region>*



### General Status of the Project Location of Pwani Region

- **Topology and Drainage**

Pwani region is on the eastern part of Tanzania mainland and a large part of the region is situated along the Indian Ocean coastal belt. It shares boarders with Tanga region in the north, Morogoro in the West, Dar es Salam region in the South east and Lindi in the South. Pwani region is near Dar es Salam city. As such, it is accessible to markets of any product.

The region is dominated by the coastal belt which rises from 0 to 100m above the sea level. These areas are covered by sand and loam soils and heavy clay waterlogged soils suitable for paddy production.

The Highland plateau in coast belt rises from 100m to 480 m and is dominated by sandy loam and clay which are suitable for vegetables and pulses cultivation.

The Lowland areas concern the bank of the rivers that discharge their water in the Indian Ocean.

The drainage system in Pwani region is based on rivers constituting the Rufiji River largely in Rufiji district, Wami River in Bagamoyo district, and Ruvu River in Kibaha and Bagamoyo districts. These rivers are used either for agricultural purposes or as source of fishing industry.

- **Climate**

The Pwani Region experiences three distinct seasons; dry season extending between May and October and two rainy seasons. The heavy rainfall covers 120 days between March and June every year. The light rainfall is received for 60 days and common from October to December each year. However, the light rainfall is very unreliable. The annual rainfall ranges from 700mm to 800mm.

High temperatures occur during December and low temperatures occur during the month of July. According to meteorological statistics the average temperature for the area is about 28 deg Celsius.

- **Regional Administrative Set-up**

The region is composed of 9 district/council split into 133 wards.

*<Table 2-4: Administrative Units in Coast Region>*

| District/Council | Wards |
|---|---|
| Bagamoyo District | 11 |
| Chalinze District | 15 |
| Kibaha District | 14 |
| Kibaha Town | 14 |
| Kisarawe District | 17 |
| Mkuranga District | 25 |
| Rufiji District | 13 |
| Mafia District | 8 |
| Kibiti District | 16 |
| Total | **133** |

*(Source: National Bureau Statistics Tanzania, 2022)*

The region covers a surface of 33,539 $km^2$ composed of 96.6% of land area and 3.4% of water surface. The region area represents 3.4% of Tanzania mainland area.

- **Population Distribution**

The population census of 2022 reveals that coast region population had a total population of 2,024,947 inhabitants in which men are 998,616 and women are 1,026,331 with an average annual growth of 6.1% distributed between the different districts as can be seen in the table below. The census results show that Mkuranga district is the most populated district with 533,033 persons followed by Chalinze district 316,759. The same distribution trend is observed on the projection of the population over the years. As can be observed in the table below, Mkuranga and Chalinze are more populous while Mafia is the least populated.

*<Table 2-5: Pwani Region Population Distribution>*

| Population (Number) | | | | |
|---|---|---|---|---|
| District | Both Sexes | Male | Female | Sex Ratio |
| Bagamoyo District | 205,478 | 101,827 | 103,651 | 98 |
| Chalinze District | 316,759 | 158,087 | 158,672 | 100 |
| Kibaha District | 123,367 | 61,220 | 62,147 | 99 |
| Kibaha Town | 265,360 | 127,155 | 138,205 | 92 |
| Kisarawe District | 159,226 | 79,892 | 79,334 | 101 |
| Mkuranga District | 533,033 | 257,483 | 257,550 | 93 |
| Rufiji District | 159,906 | 82,325 | 77,581 | 106 |
| Mafia District | 66,180 | 33,220 | 32,960 | 101 |
| Kibiti District | 195,638 | 97,407 | 98,231 | 99 |
| Pwani Region | **2,024,947** | **998,616** | **1,026,331** | **97** |

*(Source: Tanzania Bureau of Statistics 2022)*

### Economic and Land Use Pattern

The economy of Coast region is predominantly based on subsistence agriculture and fishing. In the absence of large scale farming, agriculture which covers 80% of the activities of the region is managed by smallholders. They involve more on food crops such as paddy, cassava, and vegetables than in cash crops. Cashew nuts, pineapples, mangoes and other crops are cultivated as sources of income. Livestock contributes significantly to the economy of the region. Improved cattle are source of income particularly in Kibaha. Besides Livestock, forestry products constitute important source of revenue with timber exploited in Rufiji. Fishing industry which is performed in Mafia, Bagamoyo and Mkuranga is key element on the regional economy. Mining at Bagamoyo, at a small scale supplements the regional economy.

Fertile land used for agriculture activities is only a small proportion of the region. The arable land available in the region is not fully used, only 519,230ha in 1,933,224ha representing 26% of the total arable land is cultivated.

The Pwani region is an area favourable for agricultural activities with undeveloped land. From the total arable land, only 19.1% is used to cultivate crops.

Livestock activities in the Pwani region are not well developed. It is limited to traditional zebu cattle husbandry and breed which do not produce value of milk. Return on livestock is low due to lack of essential infrastructure. Nevertheless grazing areas, dips, veterinary centres, crushers, hide and skin sheds, and abattoirs are distributed throughout different districts. Cattle and goats are largely in Bagamoyo and Rufiji districts which host more than 50% of the region's livestock population excluding the poultry.

Pwani region is among the regions possessing attractive natural resources in the country. The region has 49 forest reserves out of which 10 are in Bagamoyo and 24 in Rufiji equivalent to 69% of the total regions forests. Kibaha and Bagamoyo have more land covered by forests with 99,000ha and 57,374ha respectively.

## General Status of the Project Location of Morogoro Region

- **Topology Location**

The region is located in the Mid – Eastern part of Tanzania mainland and it lies between latitudes 5° 58' and 10' south of the equator and between longitude 35° 25' and 38° 30' East Greenwich. It is bordered by seven other Regions.

To the north Morogoro region shares boarders with Arusha and Tanga regions. To the east and southeast, it shares boarders with Ruvuma and Lindi regions respectively. To the west and southwest, it shares borders with Dodoma and Iringa regions respectively

- **Climate and Topography**

Morogoro Region experiences climate of moderate temperature and rainfall. The average annual temperatures vary between 180oC to 300 oC in lowlands. The Region experiences moderate temperature of around 250 oC almost throughout the year. The warm season normally runs from July to September.

Generally, the Region experiences a bi-modal rainfall pattern with long rains between March and May and short rains between November to January. The average annual rainfall varies between 600mm and 1800mm. However, the average annual rainfall varies from year to year and between ecological zones. Moreover, the mountainous 5 topographical nature of the Region affects the patterns of the rainfall. The eastern parts of Uluguru Mountains receive very high rainfall to 2,850mm annually while the leeward sides of these mountains are generally dry receiving rains of less than 600mm per annum.

The areas experiencing least rains include Gairo and Mamboya divisions in the North of Kilosa District and Ngerengere division in Morogoro rural district. Also, the Region's climate especially that of Ulanga and Kilombero Districts in the southern parts is greatly influenced by Mahenge and Udzungwa mountain ranges which have high altitude and harbor dense forest reserves.

- **Soil and Drainage System**

Soils in the region vary according to topographical and ecological zones. In the mountainous and hilly areas the common type of soils found are mainly oxisols which are generally low in nitrogen and phosphorus. Valley and low lands are generally characterized by alluvial soils which are fertile in nature. Sandy and clay soils are common in woodlands and grasslands. Soil condition in the region favors production of various crops like maize, paddy, beans, cassava, species, sweet and Irish potatoes, amaranths, vegetables, sugarcane, simsim, cocoa, cotton, cashew nuts, etc.

There are about 143 rivers. Several rivers and tributaries originating from the mountains cut across Morogoro Region. The Region's drainage system is formed by many rivers that flow from highlands to lowlands in the valleys. The major rivers among others include Kilombero, Ruaha, Wami, Luwegu, Ruvu, Ngerengere, Mkata, Mkondoa and Mkindo.

- **Regional Administrative Set-up**

Morogoro region is divided into seven administrative districts, which are further divided into wards and villages.

*<Table 2-6: Administrative Units in Morogoro Region>*

| District | No. of Division | No. of Wards | No. of Villages |
|---|---|---|---|
| Morogoro Municipal | 1 | 29 | 0 |
| Ifakara Township | 1 | 19 | 48 |
| Kilombero | 6 | 31 | 149 |
| Kilosa | 7 | 40 | 138 |
| Malinyi | 3 | 10 | 33 |
| Mlimba | 4 | 16 | 62 |
| Mvomero | 4 | 30 | 130 |
| Ulanga | 4 | 21 | 59 |
| Gairo | 2 | 18 | 50 |
| Total | 32 | **214** | **669** |

*(Source: Compiled Data from Councils 2021)*

- **Land Use Pattern**

Morogoro region has a total area of 4,623,005 ha which is equivalent to 4.9% of the total area of Tanzania Mainland (94,278,400 ha). Most of the total land area, 1,772,597 ha (38.3 percent) is arable land used for crop cultivation followed by area used for grazing which occupied an area of 371,537 ha (8.0 percent) and area covered by forest was 330,277 (7.1 percent) of the total region's area. The remaining 2,140,625 ha (46.3 percent of total area) is both covered by water bodies and used for settlement purposes

*<Table 2-7: Land Use Pattern in Morogoro Region>*

| District | Total Land Area (Ha) | Arable (Ha) | Gazing (Ha) | Forest (Ha) | Game Reserve (Ha) |
|---|---|---|---|---|---|
| Morogoro Municipal | 53,135 | 11,844 | 291 | - | - |
| Ifakara Township | 118,471 | 61,597 | 7,998 | 22,889 | - |
| Kilombero | 506,750 | 265,147 | 36,443 | 126,630 | - |

| District | Total Land Area (Ha) | Arable (Ha) | Gazing (Ha) | Forest (Ha) | Game Reserve (Ha) |
|---|---|---|---|---|---|
| Kilosa | 1,239,370 | 536,590 | 261,203 | 0 | - |
| Malinyi | 997,990 | 105,218 | 20,845 | 27,993 | - |
| Mlimba | 458,800 | 383,884 | 3,474 | 21,029 | - |
| Mvomero | 732,500 | 199,760 | 0 | 127,820 | - |
| Ulanga | 330,859 | 97,476 | 0 | 3,828 | 7,970 |
| Gairo | 185,130 | 111,080 | 41,283 | 88 | - |
| Total | 4,623,005 | 1,772,597 | 371,537 | **330,277** | **7,970** |

*(Source: Compiled Data from Councils 2021)*

- **Population Distribution**

The 2012 Population and Housing Census shows the total population of Morogoro region in 2012 was about 2.2 million. Out of that, 71.3 percent (1.5 million) were residing in rural areas and 28.7 percent (0.6 million) resided in urban areas. Also the Census results and 2020 population projection shows that population growth rate of Morogoro region from 2012 to 2020 was 3.0 percent. In rural areas, the population growth rate was 2.1 percent while in urban areas the population growth rate was 2.9 percent. At district level, Kilosa DC is the most populated council in the region with a population of 438,175 persons in 2012 and 538,755 persons (2020 population projections) followed by Morogoro MC with population of 315,866 in 2012 and 394,528 persons (2020 population projections ). The least population of persons was observed in Malinyi DC and Ulanga DC both with 114,202 and 151,001 persons respectively in 2012. Their population increased to 142,753 and 188,751 persons in 2020 population projections. Favorable agricultural and livestock keeping opportunities in the region appears to be main drivers of this change, as population increased with more people migrating from different places to seek opportunities.

*<Table 2-8: Morogoro Region's Population Distribution>*

| Population (Number)<br>District<br>Both Sexes | | Male | Female | Sex Ratio |
|---|---|---|---|---|
| Kilosa District | 617,032 | 308,204 | 308,828 | 100 |
| Morogoro District | 387,736 | 192,252 | 195,484 | 98 |
| Morogoro Municipal | 471,409 | 226,817 | 244,592 | 93 |
| Mimba District | 292,536 | 146,947 | 145,589 | 101 |
| Ifakara Town | 290,424 | 141,023 | 149,401 | 94 |
| Ulanga District | 232,895 | 116,441 | 116,454 | 100 |
| Malinyi District | 225,126 | 111,842 | 113,284 | 99 |
| Mvomero District | 421,741 | 210,834 | 210,907 | 100 |
| Gairo District | 258,205 | 125,509 | 132,696 | 95 |
| Morogoro Region | **3,197,104** | **1,579,869** | **1,617,235** | **98** |

*(Source: Tanzania Bureau of Statistics 2022)*

## 2.5 Objective and Expected Output and Outcome

### 2.5.1 Objectives of the Project

#### Improving the level of service

- **Congestion reduction**

The current Kibaha - Morogoro section of the existing road (A7) is a single carriageway and passes through major towns which results in high congestion and low traffic flow. This project will focus on examining how congestion on this highway can be reduced. Some of the options which will be examined to reduce this congestion include analysing the impact of developing a dual carriageway and the possibility of by-passing major towns.

- **Improved quality of the road in terms of potholes reduction and smoother road**

The development and operation of the project will be undertaken by a private sector operator, who will maintain and rehabilitate the road during the concession period of the PPP. This will ensure that the condition of the road is maintained, resulting in several benefits for its users including: reduced vehicle damage and as a result reduced vehicle maintenance cost; reduced accidents caused by potholes and other road damage.

#### Improving the connectivity

- **Domestic**

This project will improve connectivity within the country which will result in several benefits including increased domestic tourism due to less travel time; improved trade by reducing delivery times and increased accessibility to the DSM port.

- **International**

The improved connectivity will further improve trade between the land locked countries (Rwanda, Uganda, Zambia, Malawi, Burundi, Zimbabwe and South Sudan) and the international market, which will ease their access to both imports and exports.

#### Reduced travel time

Less travel time will lead to increased productivity by the users of the road. This will result in reduction of direct and indirect costs as a result of congestion and time wastage on the roads. Reduced delivery and travel times will also enable business to provide better value and services to its customers. More businesses will also open up along the coast due to ease of access to the rest of the country.

### 2.5.2 Expected Outcome

From a short-term perspective, the expected outcome of this project is to reduce traffic congestion from Kibaha to Morogoro through the implementation of a four-lane dual carriageway toll expressway (205 km), and promote socio-economic development by ensuring road safety as well as vehicle operating costs.

In addition, considering from a long-term perspective, if the project road is extended to neighboring countries via Dodoma in the future, the project road will become the central axis of the national logistics flow, and Tanzania will become a central country in the East African logistics industry. From this point of view, it is important to establish a systematic implementation plan by establishing an expressway master plan covering the entire of Tanzania to select project priorities and analyse the adequacy of financial options.

### 2.5.3 Expected outputs of the Project

The expected outputs of the project will include a modern 4 lanes dual carriageway toll Expressway with a driving speed of 120km/hr, modern rest areas at intermediate locations along the route, road service level that meets international standards, interchanges and e-tolling system at entry and exist points.

### 2.5.4 Beneficiaries

Beneficiaries of the Kibaha – Chalinze – Morogoro Toll Expressway include but not limited to the following: -

- Private party will earn return on investment and improve investment profile.
- Road User will save travel time, reduce vehicles operating costs, will have alternative route, improve safety and health, and improve access to social services and increasing business profit.
- Government will improve road services, reduce congestion, increase government asset, increase revenue, employment, innovation, poverty reduction, improved productivity and promote economic developments of the nation.
- General public benefit from reduced logistic cost, improved access to social services, employment and improved social economic activities.
- Project workers will benefit from employment, training, remuneration and knowledge transfer.
- The project will increase land value and give an impetus to the real-estate sector in the surrounding areas.
- The project will reduce congestion and improve access to neighboring countries of Kenya, Uganda, Rwanda, Burundi, DRC Congo, Zambia and Malawi hence promoting investment and trade.

The project will be constructed in the new alignment where community have properties and undertaking economic activities. Therefore, implementation of the project is likely to affect economic activities and properties owned by the community surrounding the project corridor and ecosystem.

## 2.6 Identification of Needs

The domestic transportation industry in Tanzania grew 1.7 times in 5 years, from USD 2.8 billion in 2014 to USD 3.8 billion in 2018. Regarding the mode of transportation, roads play an important role in logistics transportation based on the statistics that 90% of passengers and 75% of cargo are transported by road among all modes of transport.

In 2019, the volume of cargo transported by road in Tanzania was approximately 240 million tons, an increase of more than 5% from the previous year, and over 200 million tons of cargo were transported using road annually in the last five years. These facts are analyzed that the improvement of road infrastructure for logistics flow has one of the greatest impacts on the growth of the entire industry in Tanzania.

*<Table 2-6: Current Status and Prospects of Road Freight Transportation in Tanzania>*

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| Total Volume (Million Tonnes) | 211 | 213 | 215 | 227 | 240 | 253 |
| Increase Rate (%) | 3.8 | 4.1 | 4.2 | 5.6 | 5.8 | 6.0 |

*(Source: Korea Trade-Investment Promotion Agency, DSM branch)*

In addition, according to Tanzania's Development Vision 2025 and Tanzania Five Year Development plan, investment in the infrastructure sector, especially road and rail sectors, is one of the main concerns of the Government.

Along with the growth of Tanzania's port industry, it is expected that the increase in land logistics transportation to domestic and neighboring countries will lead to the development of the road infrastructure industry connecting domestic and neighboring countries in the future. DSM Port handles 90% of Tanzania's shipping cargo volume, and 32% of customs clearance cargo is to neighboring countries. Demand for road infrastructure is expected to continue to increase due to the continuous increase in land logistics transportation to neighboring countries along with the increasing cargo throughput in Tanzania. Tanzania is planning and proceeding with a number of projects to complete road construction with neighboring countries by 2025.

The project road plays a key role in transporting logistics from DSM to neighboring countries and forms a key axis of logistics movement to inland countries. However, the current improvement of Kimara-Kibaha Road (19.7 km) to 8 lanes significantly shifted traffic congestion from the Kibaha to Morogoro road, which is a single carriage way. This has significantly affected Travelling Time and Vehicle Operations Costs (VOC). Consequently, causing delays in the transportation of agricultural goods and industrial production to reach their destinations in time, increase and unpredictable prices of goods, and denial of the general public to access social services in time.

In this regard, the implementation of the Project is an urgent task of the Government to solve the social and economic development obstacles caused by traffic congestion on the Morogoro road.

## 2.7 Development of Options

Within the framework of this project, the TA team has undertaken a comprehensive endeavor to conceptualize and assess a spectrum of options aimed at achieving an optimal blend of technical prowess and financial viability. These options were diligently compiled and communicated to the CA through an interim report, signifying a pivotal milestone in our collaborative journey. Following meticulous evaluation, the most favorable option was discerned and subsequently integrated into the comprehensive feasibility study.

Yet, our commitment to excellence did not conclude with this initial selection. The TA team, driven by an unwavering dedication to maximizing project viability, proceeded to meticulously fashion an array of options that would infuse the project with enduring positivity and resilience. The culmination of these endeavors resulted in the formulation of an optimal feasibility study—one that charts a course for sustained success.

As a testament to our holistic approach, here is a concise overview of the significant technical and financial options that the TA team formulated, scrutinized, and evaluated. Each option was crafted with an intent to harmonize innovation with pragmatic feasibility, fostering an environment where calculated risks lead to promising outcomes.

#### Enhancing Accessibility and Optimizing Traffic Demand

In the realm of infrastructure development, the dual aspirations of augmenting accessibility and harnessing the potential of traffic demand stand as foundational pillars of progress. This strategic endeavor not only strengthens connectivity but also serves as a catalyst for economic prosperity and societal advancement.

The placement of interchanges is an intricate decision, intricately intertwined with the roles they play in the broader landscape. For rural expressways that bypass smaller communities, a singular interchange may fulfill the region's needs, while more sizable communities might necessitate the establishment of multiple interchanges. The precision in pinpointing the ideal interchange locations pivots on the unique requisites of each community.

While the specifics of each situation underscore their individuality, an overarching principle guides this intricate decision-making process. It is recommended that an interchange be strategically positioned along a major thoroughfare, one that holds a pivotal role within the local road network. This strategic positioning aligns harmoniously with a broader objective: the optimization of traffic distribution.

Placing an interchange along a prominent roadway with substantial significance in the local infrastructure sets in motion a cascade of advantages. Traffic movements are streamlined, facilitating efficient transit and heightening accessibility to vital destinations. This symphony of connectivity not only fulfills the immediate needs of communities but also fosters the framework for a sustainable transportation ecosystem.

Amidst the diverse intricacies of each locality, a steadfast aspiration remains constant: the creation of an infrastructure that seamlessly synchronizes transportation with community requisites, fosters operational efficiency, and ultimately contributes to a cohesive and flourishing urban fabric.

In consonance with these principles, the TA has advocated for the incorporation of an additional interchange, identified as the Bwawani Interchange (Bwawani IC), as Option 1. This proposition, grounded in a comprehensive review of the optimal intersection intervals, seeks to elevate project efficiency and enhance user convenience, thereby augmenting accessibility to the local community. The inclusion of Bwawani IC (Option 1) effectively reduces the maximum interchange interval from the original 68.6 km to 35.2 km, significantly amplifying the expressway's accessibility.

While this proposed additional interchange entails an incremental construction cost of approximately 40 billion TZS, the ensuing benefits are projected to outweigh this investment. Forecasts indicate a prospective upsurge of about 1,300 vehicles per day in traffic flow, an enhancement that is anticipated to bolster the overall financial viability of the project. The culmination of these considerations is illustrated in Chapter 3, Technical Assessment.

#### Approaches for Ensuring Financial Affordability

In the dynamic realm of infrastructure development, achieving financial affordability stands as a pivotal cornerstone. Our mission is to meticulously construct strategies that not only ensure fiscal viability but also make the project appealing to investors across the spectrum.

To fulfill this imperative, we are engaged in the meticulous formulation of options, each meticulously designed to strike a delicate balance between financial prudence and inclusivity.

These options encompass a spectrum of considerations, ranging from funding models and cost-sharing mechanisms to revenue projections and risk mitigation strategies.

Our approach entails a comprehensive evaluation of various scenarios, accounting for diverse economic variables and stakeholder expectations. These options are not mere financial constructs; they represent a fusion of thoughtful planning, practicality, and a steadfast commitment to upholding the project's affordability.

- **Maximizing Project Efficiency through Size Optimization**

Drawing from the traffic demand projections conducted by the Technical Advisor (TA), it has been discerned that the anticipated future traffic volume for Lot 2 will be less than that of Lot 1. This shift is attributed to the redistribution of traffic flow from Chalinze to Arusha. This adjustment in traffic patterns has consequently impacted the financial viability of the project, prompting the TA team to conduct a comprehensive re-evaluation of the project's scope.

To enhance the financial feasibility of this project, the TA team has undertaken a critical assessment, identifying sections of the expressway that exhibit financial vulnerabilities. These are sections where toll revenues are notably lower in comparison to construction costs. Subsequently, the team evaluated the potential impact on the technical functionality of the highway resulting from the exclusion of these financially weak sections. This rigorous evaluation has led to the development of strategic options aimed at addressing these challenges.

This analytical process culminated in a concentrated focus on the Morogoro bypass section (from Morogoro IC to Sangasanga IC). This section emerged as a point of scrutiny due to the projected traffic volume being significantly lower in comparison to the construction costs, thereby compromising the project's financial sustainability. In response, the TA team formulated and reviewed distinct options for the Morogoro bypass section, all aimed at safeguarding the project's affordability.

The options for the Morogoro Bypass section are as follows:

- Option 1: Maintain the existing design as a 4-lane highway.
- Option 2: Downsize to a 2-lane configuration.
- Option 3: Exclude the Morogoro Bypass section from the project.

After conducting a thorough analysis of these three options, it was concluded that even if the Morogoro Bypass section were to be downsized to two lanes (option 2), achieving financial stability remained unattainable. Consequently, the TA team recommended the exclusion of the Morogoro Bypass from the project, a recommendation that received approval from the CA.

However, while the removal of the Morogoro Bypass was a result of its financial infeasibility, it is important to note that from a technical perspective, this section holds significant importance in dispersing concentrated traffic within downtown Morogoro. Recognizing this, TA advised the CA to consider carrying out the Morogoro Bypass using government funding.

Ultimately, the decision to exclude the Morogoro Bypass has significantly contributed to ensuring the project's financial robustness. Further insights into this evaluation can be found in Chapter 3, Technical Assessment.

- **Enhancing the Precision of Traffic Demand Forecasting**

The traffic demand forecasting model is intricately tied to the nuances of planning, and it is imperative to underscore the importance of comprehensive planning integration when undertaking traffic demand forecasting. Ensuring that all pertinent transportation and urban development plans are seamlessly integrated into the forecasting process is essential. Furthermore, the inclusion of plans that are not only theoretically feasible but are also actively progressing within the comprehensive planning framework can yield more precise and pragmatic traffic demand forecasting outcomes.

The selection and application of a viable plan from a multitude of proposed or ongoing plans demand significant time and effort. Moreover, altering an established traffic demand forecasting model is a task that necessitates both diligence and time investment.

However, the TA team has been attuned to the ongoing EPC+F project and the potential expansion of the project road to Dodoma. Envisioning the extension of this project's expressway to Dodoma holds the promise of connecting with the Arusha-Kibaya-Kongwa route, which is concurrently progressing under the EPC+F initiative. In such a scenario, a substantial portion of traffic previously dispersed from Chalinze to Arusha could potentially be absorbed by this extended expressway.

TA has recognized this potential and subsequently developed a traffic demand forecasting option that accounts for this scenario. The estimated toll revenue derived from this specific traffic demand forecasting option is presented within this feasibility study report as one viable option for financial analysis.

If these assumptions find validation by the CA, any resultant alterations to the traffic demand forecasting outcomes will be duly incorporated into the final feasibility study report. This demonstrates our commitment to a responsive and informed decision-making process, aligned with the dynamic shifts within the realm of transportation planning and execution.

- **Option for Payment Mechanism**

During the Interim Report stage, an annuity/availability-based payment mechanism was recommended. The Interim Report did not provide any details with respect to the structure or adjustment mechanism of the payment mechanism, as these are developed during the RFP documentation stage.

As the chosen payment mechanism can severely impact the affordability of the project to the GoT/ TANRAODS, the Transaction Advisor has considered various approaches to the payment mechanism as part of this Feasibility Study.

As a base, the Transaction Advisor assumed the payment mechanism of the Lot 1 procurement documentation whereby the Private Party is entitled to annual adjustments to local inflation and changes to the USD exchange rate on any USD debt repayments for as long as the USD debt is outstanding.

As part of the approach to ensure financial viability, the Transaction Advisor will consider alternate approaches to the payment mechanism in order to determine the most affordable solution to the GoT/TANROADS. This will be tested as part of the sensitivity analysis in Chapter 6 (Financial Assessment) and Annexure I (Value for Money Assessment) and will be presented to the CA for the selection of an optimal solution.

## 2.8 Project Administration and Institutional Capability

TANROADS has set up a project team in accordance with the requirements laid out in the PPP Act and Regulation. The particulars of the project team, headed by the project officer is shown in table below, and will be responsible for delivering the project in accordance with the PPP Act. As part of accountability, the project officer is responsible for keeping internal stakeholders appropriately engaged and informed and as such, formal minute meetings with set agendas and actions have been maintained for all key project communications.

*<Table 2-10: PPP Project Team (as per PPP Act Requirement)>*

<table>
<tr><th>Requirement</th><th colspan="2">Role</th><th>Designate</th></tr>
<tr><td>Accounting Officer</td><td colspan="2">• Appoint team, sign PPP agreement & take full responsibility</td><td>Executive Officer</td></tr>
<tr><td>Project Officer</td><td colspan="2">• Manage procurement & performance of private party</td><td>PPP Manager</td></tr>
<tr><td rowspan="10">PPP Management Team</td><td rowspan="6">Contracting Authority</td><td>PPP Manager</td><td>Eng. Elibariki C. Mkumbo</td></tr>
<tr><td colspan="2">Desk Officer</td></tr>
<tr><td colspan="2">Highway Project Engineer</td></tr>
<tr><td colspan="2">Structural Project Engineer</td></tr>
<tr><td colspan="2">Project Legal Advisor</td></tr>
<tr><td colspan="2">Project Economic Advisor</td></tr>
<tr><td colspan="3">PPP Centre</td></tr>
<tr><td colspan="3">Ministry of Finance</td></tr>
<tr><td colspan="3">Ministry of Works and Transport (Works)</td></tr>
<tr><td colspan="3">The Office of Attorney General</td></tr>
<tr><td>Transaction Advisor</td><td colspan="2">• Support the Procuring Authority in the development of the project</td><td>CHEIL Engineering Consortium</td></tr>
</table>

The project officer will manage the procurement process and ensure that the private operator who is selected is capable of operating as per the expectations particularly with regards to delivering the complex construction program and operating the expressway in accordance to the concession agreement provisions. TANROADS is also working collaboratively with the PPP Center, Ministry of Works and Transport, Ministry of Finance and Planning, PPP Unit and the Attorney General's office to review key documents at major milestones of procurement such as prequalification, concession signing and prior to financial close.

For the procurement phase, TANROADS is being supported by the transaction advisors. Post financial close, a dedicated TANRAODS projects team supported by an Independent Engineer and a project implementation unit will ensure construction and subsequent operations proceed as per expectations.

The institutional capability of institutions that are either directly affected by or will have an interest in the project are shown in the following table.

*<Table 2-11: Institutional Capability>*

| Stakeholders | Role | Responsibility |
|---|---|---|
| Ministry of Works and Transport | Project Sponsor | Ministry under which TANROADS reports to |
| Ministry of Finance and Planning | Project Guarantor | Will provide all Government of Tanzania guarantees |
| Tanzania National Roads Agency (TANROADS) -HQ and Pwani Region | Contracting Authority (CA) | Will enter into a contract for the project with successful concessionaire |
| Bank of Tanzania (BoT) | Regulator | Financial Regulator |
| National Environmental Management Council (NEMC) | Regulator | Ensuring that the project satisfies all regulated environmental and social regulations in the country |
| Tanzania Rural and Urban Roads Agency (TARURA) | Affected Party | May need to realign or relocate some of its roads to cater for the project |
| Road Fund Board | Interested Party | Funding of road projects |
| Tanzania Investment Centre (TIC) | Interested Party | Attracting foreign investors into Tanzania.<br>Provide investment information.<br>Provide guidance on Tanzanian legal, tax and other related information to investors. |
| Pwani Regional Commissioner (RC) Office | Affected Party | Regional government administration. Project area is within regional boundaries. |
| Morogoro Regional Commissioner (RC) Office | Affected Party | Regional government administration. Project area is within regional boundaries. |
| Chalinze District Council | Affected Party | District government administration. Project area is within District boundaries. |
| Morogoro District Council | Affected Party | District government administration. Project area is within District boundaries. |
| Morogoro Urban District | Affected Party | Municipal government administration.<br>Project area is within regional boundaries. |
| Ministry of Home Affairs (Kingolwira Prison) | Affected Party | Project area traverses through prison area. |
| Tanzania Electric Supply Company Limited (TANESCO) - HQ, Pwani and Morogoro Regions | Affected Party | Have infrastructure in the project area which may need to be either protected or relocated |

| Stakeholders | Role | Responsibility |
|---|---|---|
| Dar es Salaam Water Supply and Sanitation Authority (DAWASA)- Chalinze | Affected Party | Have infrastructure in the project area which may need to be either protected or relocated |
| Morogoro Water Supply and Sanitation Authority (MORUWASA) | Affected Party | Have infrastructure in the project area which may need to be either protected or relocated |
| Rural Water Supply and Sanitation Agency-Mvomero (RUWASA-Mvomero | Affected Party | Have infrastructure in the project area which may need to be either protected or relocated |
| Tanzania Zambia Pipeline Limited (TAZAMA) | Affected Party | Have infrastructure in the project area which may need to be either protected or relocated |
| Tanzania Railways Corporation (TRC) | Affected Party | Have infrastructure in the form of both SGR and MGR rail infrastructure in the project area which may need to be protected |
| Wami Ruvu Water Basin Offices | Affected Party | Capable of giving guidance on aspects of water |
| Tanzania Forest Services Agency (TFS) | Affected Party | Have a forest in the project area and will give guidance on aspects of fores |
| Tanzania Wildlife Management Authority (TAWA) | Affected Party | Have a Wildlife area in the project area and will give guidance on the implementation of the project. |
| Public Private Partnership (PPP) Steering Committee | Regulator | Reviewing and approving project feasibility study, detailed project report and design, selection of preferred bidder. |
| Planning Commission | Interested Party | Providing recommendations that influence approvals processes for developments, land use plans, and infrastructure investments, among other duties |
| Ministry Transportation | Interested Party | Responsible for Transport Policy, Planning and Coordination functions as well as oversight of Infrastructure delivery and asset management |
| Office of the Attorney General (OAG) | Interested Party | To vet PPP Agreement and issues legal opinion in regard to the project. |
| Regulatory Authorities | Regulator | To regulate services and standards. OSHA to enforce compliance of health and safety issues at working places. |
| Traffic Police | Interested Party | Enforcement of traffic safety |
| Immigration Department | Interested Party | Immigration procedures |

| Stakeholders | Role | Responsibility |
|---|---|---|
| Ministry of Health | Interested Party | Control communicable diseases |
| TAZARA, TAZAMA and TPA and ATCL | Affected/Interested Party | Sharing common interests during preparation and execution of the expressway project. |
| Tanzania Revenue Authority (TRA) | Interested Party | Provide guidance on tax related matters during execution of the expressway project, Customs clearance |
| Public Private Partnership (PPP) Centre | Interested Party | PPP agreements and advice PPP Steering Committee accordingly. |
| Professional Regulatory Bodies | Interested Party | CRB - For registration of Contractors and projects as well as monitoring Contractor's performance.<br><br>AQRB- Registration of Architects and Quantity Surveyors<br><br>ERB - Registration of Engineers and monitor performance of Engineers |
| Business Registration and Licensing Agency (BRELA) | Interested Party | Responsible for business registration |
| Local Government Authority (Municipal Council) | Affected Party | Sensitization and awareness creation to the public and issuance of building permit, land acquisition, royalty collection and collection of revenue at bus stands. |
| Ministry of Lands, Housing and Human Settlements Development (MLHHSD) | Interested Party | For land issues settlement and grant certificate of the right of Occupancy |
| Financial Institutions, Social Security Funds and Insurance Companies | Interested Party | Responsible for providing financial supports towards project implementation |
| Tenants/Business Owners/airlines | Interested Party | Involve in sharing experience and giving advices on the project |
| Development Partners | Interested Party | To support PPP projects and Capacity building |
| General Public | Interested Party | Key stakeholders and Beneficiaries of the Project |
| Consumer Associations (LATRA Consultative Council, TATOA, TABOA etc.) | Interested Party | To advocate interest of transporters and related stakeholders. |
| Tanzania Telecommunication Company Limited (TTCL) | Affected Party | Have infrastructure in the project area which may need to be either protected or relocated |

# 3. TECHNICAL ASSESSMENT

## 3.1 Overview

The purpose of this overview process is to understand the climatic and socio-economiccharacteristics of Tanzania, which shall be used in the key processes of the estimation of thetransportation demands and the analysis of the project feasibility, etc.

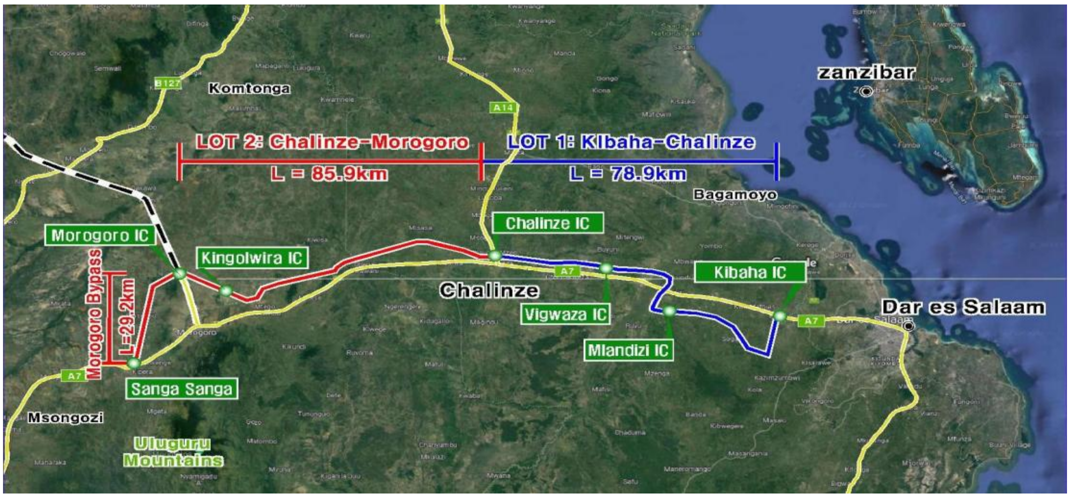
Also, it aims to review the National level plans, transportation-related plans, other relevantplans in the affected areas, and relevant local plans in a comprehensive manner and see if theyare related to the projects, reflecting into the project as necessary.

## 3.2 Verification f Topographical Survey

The road corridor of the expressway whose width is 80m and the length of 205km was definedfrom start to end. The project road starts at Kibaha Mailimoja area in Coast region and ends atMakunganya area (along Morogoro to Dodoma road) and also the project include the accessroad that runs from Sangasanga area (along Morogoro – Iringa road) to Makunganya area inMorogoro region. The route selection for this road was done by TANROADS EngineeringConsulting Unit (TECU also carried out basic and prefeasibility study on the proposed alignment.The study included Topographical Survey of the whole road that runs from Mailimoja Kibahathrough Mlandizi, Chalinze to Sangasanga in Morogoro region with total distance of 205.0Km.The selected route by TECU is depicted in the figure below.

The Government of Tanzania assigned the Transaction Advisory team to carry out theComprehensive Feasibility study of the selected project route. Under the agreement amongother things,(Task 4 of TOR) the Transaction Advisor (TA) would prepare a detailed TechnicalSurvey report depicting the whole process of which the Topographical survey of the projectroad was carried out and the results thereof. The team also will look into the status, accuracy,reliability and acceptability of the existing Topographical information. All relevant maps, plansand documents will form the part of the report.

The Transaction Advisor (TA) team has done a field reconnaissance, observations, data capture,field data processing, plan/map preparation and reporting for the purposes of verification ofcorrectness of the existing Topographical survey information. This Technical survey report givesthe detail of the whole process.




*<Figure 3-6: Location of the Project route>*

### 3.2.1 Scope of works

The scope of work is to study topographic maps, satellite images and air photographs and tocarry out site reconnaissance surveys to assess, evaluate and give recommendations onaproposed corridor by TECU for the construction of the Expressway from Kibaha to Morogoro.The activities will include:

#### Details of utility Services and other physical features

The TA will verify the collection of details of all important physical features along the alignmentdone by TECU and effect any necessary corrections. These features include buildings andstructures, monuments, burial grounds, cremation grounds, places of worship, railway lines,steam/river water mains, severs, gas/oil pipes, crossings, trees, plantations, utility services suchas electric, and telephone line (O/H & U/G) and poles, optical fibre cables (OFC). The survey willcover the entire right-of-way of the road with an allowance for possible shifting of the centralline at some of the intersections locations.

The information collected during reconnaissance and field surveys will be shown on a stripplanso that the proposed improvements can be appreciated and assessment of the extent of LandAcquisition (L.A) with L.A schedule of proposed types of utilities for relocation/removal etc.beassessed and suitable actions be initiated. Separate strip plan for each of the services involvedwill be prepared for submission to the concerned Institution.

#### Verification and Correction of Topographical Survey

The TA will verify and effect necessary corrections on the topographical surveys carried out byTECU to facilitate the location of acceptable permanent control points, centerline, drainagestructures, and computation of quantities of earthworks.

All topographic surveys undertaken by the TA will be according to the Land Surveying andMapping Standards of Tanzania, and will be recorded in standard survey filed books/electronicdata book, which will be submitted and become the property of the Client at the completion ofthe assignment.

The primary network of permanent control points will be established at a maximum interval of3,000m along the road thereafter to be distributed to a maximum of 300m as secondary points.

The TA will liaise with the Ministry responsible for lands for the existing National Grid/Datumreference beacons and benchmarks in order to establish the permanent control points. The coordinates of all intersection points will be in the Universal Transverse Mercator (UTM) systemand will be tied to the National Survey Grid, and levels related to the National Benchmarks.

Monumentation of all primary control points will be made using 12mm steel pins embedded inconcrete cast in-situ. The description cards for the control points will be prepared and submittedto the Client and detailed in the report to be submitted to the Client for future reference.

The survey of the centre line will involve verification and correction of all activities carried out byTECU to locate the road alignment on the ground and to plot it on the plan, including:

Leveling along centerline at 50m intervals for the longitudinal profile, and

Cross-section leveling at 200m internals and at any local irregularity. Cross sections are to coverat least 25m on each side of the centerline

Further, the survey will update or cover the location from the centre line of physical features likebuildings, monuments, posts, pipe lines, existing roads and railway lines, steam/river crossings,cross drainage structures etc. that are likely to affect the road construction works.

In addition, electronic copies of the topographic data saved in MS Excel and topographicdrawings in p or DWG format will be submitted in CD ROMs to the Client and become his property.

### 3.2.2 Instrumentation

Instruments used to carry out the Survey are: -

- HI-TARGET V90+ (4 No.) GPS receivers
- ProMark3 (3No.) GPS receivers
- Total station SOKKIA SET 220K (1 No.).
- Precise Automatic leveling Machines (2 No.).
- Laptop Computers.

### 3.2.3 Methodology

The LOT2 Section of the expressway runs from Chalinze to Morogoro whose total length is

84.9Km with access road of 29.2Km. The TA survey team carried out survey within this section.

**Control Survey:**

TA survey team adopted the existing survey controls at site. The LOT2 section of the expresswayhad only primary controls that were established by TECU survey team. These controls wereadopted and then re-coordinated as its network was not consistent within itself. The newlyassigned horizontal coordinates and computations involved are well presented in the Appendix

The secondary survey controls were the installed as intermediate points between any pair ofPrimary survey control points. Secondary points are made of precast concrete cubes whosedimensions are 18cm x 18cm x45cm These ground markers are named with prefix CMSC followedby increasing numeric value, i.e CMSC 001,002,003………300. CMSC stands for CHALINZE-MOROGORO SECONDARY CONTROL.

*<Figure 3-7: secondary survey control monuments >*

Before execution of Control Survey, permanent ground markers were established on the areasof interest. These marks are of two categories

- Primary control markers
- Secondary control markers

- **Monumentation and Coordination of Primary Survey Controls**

The survey monuments that were installed by TECU were adopted. These monuments werespaced at approximately 3km intervals and were named as KMGPS 10,11,12…..62

These Controls are made of cast in situ concrete fixed with 12mm iron rod at the center incasedinto 4 inch pvc pipe.

GPS survey was done following the generally accepted survey principle of “from the whole to thepart” in which case the main framework of controls was established first followed bydensification of controls within the main framework.

Three GPS receivers were placed on base point and other two new monuments points in staticmode. The three GPS receivers were left to collect readings enough to resolve baseline vectorsbetween themselves and hence obtain a set of GPS controls on which to base while proceedingwith further control break down throughout the road.2.1.1 Monumentation and Coordinationof Secondary Survey Controls

Secondary controls were installed at intervals between 300m to 400m. These controls are madeof precast concrete cubes and were firmly fixed on the ground at suitable locations.

*<Figure 3-8: Installed Secondary survey control markers between Chalinze and Morogoro>*

Secondary markers have been installed consist of precast concrete cubes with Aluminum screwat the center. The secondary markers have been named with prefix CMSP followed by increasingdigits eg CMSP 01,02, 03…300GPS receivers in Real Time Kinematic (RTK) mode were used toassign horizontal coordinates of the secondary survey markers that were established. Heights ofthe survey ground markers were assigned by leveling in this case precise automatic levels wereused.

Secondary Survey Controls were coordinated by using GPS receivers in RTK mode. The RTK basestation was set at one of Primary Control Point (established earlier) and the Rover was set at anySecondary Point for about 2-5 minutes to give it horizontal coordinates.

- **Details survey**

Site detail picking was performed mainly using RTK GPS especially in the open areas which wasoccasionally supplemented by total station survey in the built up areas. Details picked during thetopographical survey included but not limited to spot heights, invert levels, floor levels, accessroads, foot paths, culverts, bridges, trees, signboards, boundary fences, buildings, drainage, farmboundaries, overhead power lines and telephone poles. Others include; kerb stone, boundarywalls, gates and any other feature of interest. Detail picking and recording has been doneelectronically and thereafter downloaded into computer every day. Thus being able to avoidgross errors and blunders.

*<Figure 3-9: Taking overhead power line cables' height measurements >*


*<Figure 3-10: Detail picking at site>*

### 3.2.4 Data Processing

As explained above, GPS post processing was done using GNSS Solution software to produceprimary control points for the survey works. This was followed by Secondary Controls

coordination by using GPS receivers with RTK capability. On the other hand, leveling data havebeen reduced using Microsoft Excel spreadsheet.

The details survey results have been used to produce the topographical map of the detailspicked from site as described in the methodology. Detailed digital topographical map hasbeen produced which covers the whole project area. The same information has also beensupplied in digital format (AutoCAD format) to the client.

The maps has been drawn using AutoCAD Civil 3D software version 2018. The same nationalgrid system of coordinate used in picking topographical details have been used in drawing themap. Various colours have been used in depicting information in the map for the purpose ofenhancing readability. Whenever it was necessary cartographic generalization has been used.

A legend has been provided to the right hand side of the map to aid in interpretation ofvarious features shown in the map.

### 3.2.5 Description of Results

The TA survey team has carried out field survey as per TOR. Field data collection and then thesubsequent analysis have revealed the following:

- Some of survey control points that were established during the previous projectmissions are still good and intact. The TA survey team has installed more surveycontrols at site within the project corridor. Some of these controls are new and otherswere adopted from previous project missions. The positional values has slightlychanged and vertical values are within the acceptable accuracies and are beingusedfor survey activities currently and for future.

### 3.2.6 Verification of Topographic Survey Information

The TA survey team has carried out all necessary verifications on the correctness andreliability of previous topographical information gathered by TECU at earlier stages of theproject.

The technical checks were done on the geodetic network that was established to coordinatethe project corridor. The TA survey team checked the network in LOT2 and harmonized it withLOT1 network. This process has resulted into having a slightly different set of horizontalsurvey controls when compared the two with the list provided by TECU.

All physical and manmade features within the project corridor were picked and compared tothe details picked by TECU team. There is no significant differences between the two.

Apart from slight re-alignments at some sections, there is no significant difference betweenthe information provided by TECU and the one collected by TA team.

## 3.3 Verification of Soil and Materials Investigation

### 3.3.1 Verification of Previous Study carried by TECU

Materials investigation study from Chalinze to Morogoro were carried out in 2022 by Researchand Development Unit (RDU) working under TECU.

Investigations involved following activities:

- Sampling and laboratory testing of subgrade soils
- Identifying and testing of gravels materials
- Identifying and testing of hardstone sites
- Identifying and testing of sand sources
- Investigation of water sources

The alignment started at Chalinze (end of lot 1) as continuation of chainage from Lot 1 up to Morogoro.

#### Subgrade soils

Subgrade soils were investigated by excavation of test pits to 1m depth at intervals of 1000m.Test pits were excavated along the proposed alignment. Samples were taken and tested for:

- Particles size distribution
- Atterberg limits
- Linear shrinkage
- Compaction tests
- CBR tests

Investigation concluded that, most of the subgrade soils were dominated with clayey SAND,sandy CLAY and silty SAND. It also noted occasions of gravelly materials.

- **Classification of subgrade**

Alignment soils were divided into eleven homogeneous sections from Chalinze to Morogororoad section. These homogeneous sections.

*<Table 3-13: Summary of homogeneous section from previous study>*

| Name | Location (km) | Length (km) | CBR design | Subgrade class |
|---|---|---|---|---|
| Section 1 | 78.8 to 84.8 | 6 | 3 | S3 expansi vesoils |
| Section 2 | 84.8 to 92.8 | 8 | 16.7 | S15 |
| Section 3 | 92.8 to 110.8 | 18 | 7.4 | S7 with someproblem soils |
| Section 4 | 110.8 to 112.8 | 2 | 52.4 | S15 |
| Section 5 | 112.8 to 146 | 33.2 | 7.3 | S7 |
| Section 6 | 146 to 156 | 10 | 15.7 | S15 |

| Name | Location (km) | Length (km) | CBR design | Subgrade class |
|---|---|---|---|---|
| Section 7 | 156 to 162 | 6 | 4.5 | S3 with someproblem soils |
| Section 8 | 162 to 166 | 4 | 20.5 | S15 |
| Section 9 | 166 to 175 | 9 | 10 | S7 |
| Section 10 | 175 to 190 | 15 | 21.4 | S15 |
| Section 11 | 190 to 193.732 | 3.732 | 8.5 | S7 |

Problem soils such as those with low strength and/or expansive soils were identified in somelocations.

*<Table 3-14 : Areas identified as containing problem soils from previous study>*

| SN | Location | Length (km) | CBR | WeightedPlasticity Index | Remark |
|---|---|---|---|---|---|
| 1 | 78.8 to 84.8 | 6 | 3 – 4 | 27 – 29 | Potentially expansive |
| 2 | 101.8 to 103.8 | 2 | 1 – 3 | 38 | Low strength andpotentially expansive |
| 3 | 157 to 159 | 2 | 3 – 6 | 21 – 29 | Potentially expansive |

Total of 9km were identified as having problem soils. Extended investigations to determinedegree of expansiveness was conducted for soils with potential to being expansive. Testsindicated presence of expansive soils with degree of expansiveness ranging from 31 to 65%.The specifications (PMDM) categorise these as medium to high degree of expansiveness.

- **Treatments for subgrade with problem soils**

Treatments for subgrade with low strength soils were not outlined specifically rather it wasreferred to treatments for expansive soils. Expansive soils were identified by computing theirweighted plasticity index, PIw whereas materials with higher than 20 were classified asexpansive soils.

It was noted that most of areas classified as having expansive soils were also having CBR ofless than 3 termed low strength subgrades. Proposed treatments for expansive soils were toexcavate and replace 600mm with minimum cover dependent on the height of embankmentfill whereas for embankment of less than 2m minimum cover of 1m was proposed whileproviding slope of 1:4 was required when the embankment exceeds 2m.

- **Locations with rocks outcrops**

Rocks outcrops were encountered in some of the locations. These were visually identified, nosample or testing of hardness, weathering was conducted.

These outcrops were observed between station 170+000 and 173+000 (place known as mguluwa ndege hills) extending a two-kilometre length and from station 176+000 and 176+500, halfa kilometre length.

### Materials for construction

Proposed and potential sources for construction materials were identified and investigated forsuitability.

- **Gravels sources**

Several gravel sources were identified and sampled by excavation of 2m test pits.Representative samples were subjected to following laboratory tests:

- Particles size distribution
- Atterberg limits
- Linear shrinkage
- Compaction tests
- CBR tests

It was stated that the results of the laboratory tests have at least CBR of 15% and some borrowareas have as high as 45% suitable for subbase layer.

*<Table 3-15: Quality and quantities for proposed gravel borrow areas>*

| Name | Location (km) | Offset | Quality | Quantity, $m^3$ |
|---|---|---|---|---|
| BP 06 Chang'ombe | 87+100 RHS | 4.7km from Msolwa – Msoga junction alongTanzam Highway | G25 | 1,310,000 |
| BP 05 Gezaulole | 97+600RHS | 7.6km from UbenaZomozi | G25 | 2,100,000 |
| BP 04 Maseyu | 124+000LHS | 250m from proposedroad | G25 | 675,000 |
| BP 03 Lukonde/Mikese | 139+800LHS | 9km from Tanzamhighway | G25 | 450,000 |
| BP 02 Mwidu | 105+700RHS | 2.9km from Tanzamhighway | G45 | 324,000 |
| BP 01 Mzumbe | 190+000RHS | 2.5km from Mzumbejunction | G25 | 300,000 |

- **Hardstone sources**

Two sources of hard stone were identified and sampled. Tests conducted to ascertain itssuitability included:

- Ten Percent Fine Value at dry and wet conditions (TFV dry and TFV wet)
- Aggregate Crushing Value (ACV)
- Aggregate Impact Value (AIV)
- Los Angeles Abrasion Test (LAA)
- Bitumen Affinity
- Relative Density and Water Absorption
- Sodium Sulphate Soundness (SSS)

The sources were at Lugoba in Coast Region and Mafuru in Morogoro Region. Lugoba source

has been utilised for upgrading and construction of Dar es Salaam and Coast roads. Testindicated that the source is suitable for concrete works. Test results for Mafuru stones hasshown to satisfy quality requirements for concrete works.

- **Sand sources**

It was reported that two sources were identified and investigated. These sources wereSangasanga bridge at 800m left side from station 114+500 and Samunge/Mafuru at 0.3kmleft side of station 140+000.

Test results indicated both these sources were having slightly low fines content andtheirgrading curves were plotted marginally outside of BS 822 specified envelope. However, it waspointed out that with minor adjustment by blending with other sources the sources can beconsidered for usage.

- **Water sources**

One water source at Ngerengere River was identified and sampled. The tests indicatedthatthe source meet requirements for construction works.

### 3.6.2. Investigation of Subgrade Soils

&**General**

An investigation of alignment soils was conducted by sampling from excavated test pits andperforming both field identification and laboratory classification. The results were used tocharacterise the project road into homogeneous sections and determination of design CBR foridentified sections.

- **Field Investigation and Testing**

Existing subgrade investigations comprised of:

- Visual assessment of the existing subgrade soils for planning of test pit sampling
- Test pit excavations with subsoil layer description and sampling of existing subgradelayers.

The following sections describe the investigations carried out and provide summaries of theresults obtained. An investigation on the existing alignment was carried out by excavating testpits and performing laboratory testing to the retrieved soil samples. Test pits of 1.0m depthwere excavated at an average interval of 1000m.

&**Laboratory Testing**

Existing subgrade soil samples were subjected to the following laboratory tests for thedetermination of various soil characteristics:

- Particle size distribution
- Atterberg limits including linear shrinkage
- Compaction tests for determination of moisture/density relationship
- CBR tests after 4 days soaking

Tests listed in Table below have been carried out on the subgrade materials.

*<Table 3-16: Subgrade materials>*

| Test Description | CML Reference | International Standard |
|---|---|---|
| Liquid Limit | CML 1.2 | BS 1377: Part 2 – 1990 |
| Plastic Limit and Plasticity Index | CML 1.3 | BS 1377: Part 2 – 1990 |
| Linear Shrinkage and Shrinkage Limit | CML 1.4 | BS 1377: Part 2 – 1990 |
| Particle Size Distribution (Wet sieving) | CML 1.7 | BS 1377: Part 2 – 1990 |
| Compaction (BS Heavy) | CML 1.9 | BS 1377: Part 4 – 1990 |
| CBR (three-point method) | CML 1.11 | BS 1377: Part 4 – 1990 |
| Bulk Density and Particle Density | CML 2.2 | BS 812: Part 2 – 1995 |

- **Soil Classification**

Subgrade properties for existing road alignment are characterised by clay and silty sandmaterials with intermediate plasticity. In accordance with AASHTO soil classification system,the subgrade materials are dominated with finer materials with plasticity greater than 10.Non-plastic materials were encountered in isolated areas. Subgrade is dominated with groupA-7-6 and A-6 and to lesser extends subgroups A-2-4 and A-2-6 existed. Isolated sections withsubgroup A-1-b, A-3 and A-4 were encountered in isolated locations.

*<Table 3-17: Soil Classification along Chalinze – Morogoro Road section>*

| Location | Grading | | | | | GM | GC | LL | PL | PI | PIw | LS | MDD | OMC | CBR at %MDD | | | Swell | AASHTO classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 28 | 5 | 2 | 0.425 | 0.075 | | | % | % | % | % | % | kg/m$^3$ | % | 90 | 93 | 95 | % | |
| 79+000 | 100 | 98 | 96 | 87 | 42 | 0.75 | 12.7 | 55 | 24 | 31 | 27.0 | 12 | 1903 | 13 | 2 | 3 | 5 | 0.4 | A-7-6 (7) |
| 80+000 | 100 | 98 | 97 | 90 | 78 | 0.35 | 9.8 | 56 | 24 | 32 | 28.8 | 16 | 1985 | 11 | 2 | 3 | 3 | 0.7 | A-7-6 (25) |
| 81+000 | 100 | 100 | 100 | 95 | 90 | 0.15 | 5.0 | 51 | 22 | 29 | 27.6 | 14 | 1870 | 9.8 | 2 | 2 | 3 | 0.8 | A-7-6 (28) |
| 82+000 | 100 | 80 | 64 | 59 | 51 | 1.26 | 32.8 | 48 | 26 | 22 | 13.0 | 14 | 1998 | 11 | 3 | 5 | 9 | 0.6 | A-7-6 (8) |
| 83+000 | 100 | 100 | 100 | 85 | 49 | 0.66 | 15.0 | 40 | 20 | 20 | 17.0 | 12 | 1990 | 15 | 5 | 8 | 12 | 0.1 | A-6 (6) |
| 84+000 | 100 | 100 | 99 | 90 | 84 | 0.27 | 10.0 | 38 | 13 | 25 | 22.5 | 13 | 2008 | 12 | 1 | 2 | 4 | 0.5 | A-6 (19) |
| 85+000 | 100 | 99 | 98 | 93 | 85 | 0.24 | 6.9 | 45 | 22 | 23 | 21.4 | 12 | 1966 | 8.5 | 2 | 4 | 5 | 1.2 | A-7-6 (20) |
| 86+000 | 100 | 96 | 85 | 44 | 28 | 1.43 | 53.8 | 39 | 18 | 21 | 9.2 | 11 | 1990 | 10 | 12 | 17 | 22 | 0.7 | A-2-6 (0) |
| 88+000 | 100 | 52 | 45 | 21 | 9 | 2.25 | 41.1 | 18 | NP | NP | 0.0 | 9 | 2210 | 8 | 18 | 25 | 48 | 0.3 | A-1-a (0) |
| 90+000 | 100 | 100 | 99 | 75 | 49 | 0.77 | 25.0 | 34 | 19 | 15 | 11.3 | 10 | 2109 | 12 | 2 | 6 | 10 | 0.2 | A-6 (4) |
| 92+000 | 100 | 100 | 100 | 76 | 21 | 1.03 | 24.0 | 30 | 11 | 19 | 14.4 | 12 | 2112 | 9 | 7 | 12 | 18 | 0.6 | A-2-6 (0) |
| 94+000 | 100 | 99 | 93 | 78 | 42 | 0.87 | 21.8 | 34 | 16 | 18 | 14.0 | 8 | 1986 | 8 | 3 | 8 | 11 | 0.08 | A-6 (3) |
| 96+000 | 100 | 100 | 100 | 68 | 43 | 0.89 | 32.0 | 27 | 14 | 13 | 8.8 | 7 | 2076 | 8.5 | 5 | 9 | 12 | 0.4 | A-6 (1) |
| 98+000 | 100 | 100 | 100 | 83 | 49 | 0.68 | 17.0 | 42 | 21 | 21 | 17.4 | 7 | 1985 | 10 | 2 | 5 | 9 | 0.6 | A-7-6 (6) |
| 100+000 | 100 | 100 | 100 | 87 | 36 | 0.77 | 13.0 | 38 | 16 | 22 | 19.1 | 12 | 1978 | 12 | 5 | 9 | 13 | 0.3 | A-6 (2) |
| 102+000 | 100 | 96 | 93 | 65 | 38 | 1.04 | 33.6 | 57 | 12 | 45 | 29.3 | 15 | 1992 | 9.5 | 1 | 3 | 4 | 1.3 | A-7-6 (8) |
| 103+000 | 100 | 98 | 97 | 72 | 37 | 0.94 | 27.4 | 39 | 13 | 26 | 18.7 | 12 | 1975 | 9 | 7 | 8 | 12 | 0.07 | A-6 (3) |
| 104+000 | 100 | 100 | 99 | 66 | 22 | 1.13 | 34.0 | 21 | 11 | 10 | 6.6 | 6 | 1870 | 1 | 3 | 4 | 12 | 1.2 | A-2-4 (0) |

| Location | Grading | | | | | GM | GC | LL | PL | PI | PIw | LS | MDD | OMC | CBR at %MDD | | | Swell | AASHTO classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 28 | 5 | 2 | 0.425 | 0.075 | | | % | % | % | % | % | kg/m$^3$ | % | 90 | 93 | 95 | % | |
| 106+000 | 100 | 100 | 98 | 75 | 28 | 0.99 | 25.0 | 19 | NP | NP | 0.0 | 2 | 1890 | 12 | 12 | 19 | 32 | 0.09 | A-2-4 (0) |
| 108+000 | 100 | 88 | 75 | 53 | 45 | 1.27 | 41.4 | 28 | 12 | 16 | 8.5 | 7 | 1970 | 9 | 5 | 7 | 12 | 0.2 | A-6 (3) |
| 110+000 | 100 | 99 | 99 | 83 | 52 | 0.66 | 16.8 | 23 | 8 | 15 | 12.5 | 9 | 2024 | 8 | 3 | 7 | 13 | 1.1 | A-6 (3) |
| 112+000 | 100 | 99 | 98 | 57 | 13 | 1.32 | 42.6 | 27 | 17 | 10 | 5.7 | 7 | 1932 | 12 | 13 | 18 | 37 | 0.6 | A-2-4 (0) |
| 114+000 | 100 | 98 | 93 | 63 | 43 | 1.01 | 36.3 | 28 | 12 | 16 | 10.1 | 4 | 1980 | 9.6 | 1 | 2 | 4 | 1.3 | A-6 (2) |
| 116+000 | 100 | 100 | 99 | 71 | 49 | 0.81 | 29.0 | 37 | 21 | 16 | 11.4 | 8 | 2045 | 7 | 11 | 14 | 23 | 0.04 | A-6 (4) |
| 117+000 | 100 | 98 | 87 | 63 | 45 | 1.05 | 36.3 | 28 | 11 | 17 | 10.7 | 9 | 1990 | 8.5 | 6 | 15 | 18 | 0.03 | A-6 (3) |
| 118+000 | 100 | 100 | 100 | 77 | 30 | 0.93 | 23.0 | 21 | 10 | 11 | 8.5 | 1.4 | 1996 | 8.5 | 12 | 16 | 24 | 0.17 | A-2-6 (0) |
| 119+000 | 100 | 99 | 98 | 77 | 49 | 0.76 | 22.8 | 31 | 12 | 19 | 14.6 | 10 | 2022 | 11 | 3 | 9 | 13 | 0.09 | A-6 (5) |
| 120+000 | 100 | 100 | 99 | 86 | 52 | 0.63 | 14.0 | 43 | 22 | 21 | 18.1 | 10 | 1997 | 9 | 3 | 7 | 9 | 1.2 | A-7-6 (7) |
| 121+000 | 100 | 99 | 97 | 89 | 75 | 0.39 | 10.9 | 44 | 26 | 18 | 16.0 | 12 | 1951 | 8.2 | 1 | 3 | 9 | 0.5 | A-7-6 (13) |
| 122+000 | 100 | 100 | 100 | 87 | 80 | 0.33 | 13.0 | 35 | 19 | 16 | 13.9 | 10 | 1860 | 9.5 | 13 | 19 | 32 | 0.04 | A-6 (11) |
| 123+000 | 100 | 100 | 84 | 63 | 37 | 1.16 | 37.0 | 32 | 15 | 17 | 10.7 | 9 | 1895 | 9.5 | 6 | 11 | 16 | 0.23 | A-6 (1) |
| 124+000 | 100 | 97 | 95 | 71 | 53 | 0.81 | 28.1 | 48 | 24 | 24 | 17.0 | 13 | 1806 | 13 | 3 | 4 | 8 | 0.6 | A-7-6 (9) |
| 125+000 | 100 | 99 | 97 | 90 | 41 | 0.72 | 9.9 | 42 | 26 | 16 | 14.4 | 13 | 1845 | 10 | 5 | 8 | 12 | 0.3 | A-7-6 (2) |
| 126+000 | 100 | 95 | 94 | 80 | 60 | 0.66 | 19.0 | 38 | 24 | 14 | 11.2 | 10 | 1905 | 12 | 5 | 6 | 13 | 0.2 | A-6 (6) |
| 127+000 | 100 | 97 | 93 | 58 | 36 | 1.13 | 40.7 | 37 | 16 | 21 | 12.2 | 11 | 1870 | 11 | 9 | 13 | 18 | 0.8 | A-6 (2) |

| Location | Grading | | | | | GM | GC | LL | PL | PI | PIw | LS | MDD | OMC | CBR at %MDD | | | Swell | AASHTO classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 28 | 5 | 2 | 0.425 | 0.075 | | | % | % | % | % | % | $kg/m^3$ | % | 90 | 93 | 95 | % | |
| 128+000 | 100 | 100 | 100 | 90 | 51 | 0.59 | 10.0 | 34 | 24 | 10 | 9.0 | 4 | 2115 | 6.8 | 8 | 14 | 17 | 0.3 | A-4 (2) |
| 129+000 | 100 | 100 | 100 | 87 | 69 | 0.44 | 13.0 | 36 | 21 | 15 | 13.1 | 9 | 1990 | 12 | 3 | 5 | 9 | 1.3 | A-6 (8) |
| 130+000 | 100 | 100 | 99 | 89 | 62 | 0.50 | 11.0 | 36 | 19 | 17 | 15.1 | 7 | 1960 | 11 | 3 | 6 | 11 | 0.1 | A-6 (8) |
| 131+000 | 100 | 99 | 98 | 89 | 44 | 0.69 | 10.9 | 41 | 22 | 19 | 16.9 | 11 | 1880 | 11.5 | 5 | 7 | 14 | 0.3 | A-7-6 (4) |
| 132+000 | 100 | 97 | 96 | 83 | 51 | 0.70 | 16.5 | 39 | 26 | 13 | 10.8 | 9.5 | 1906 | 13 | 4 | 7 | 11 | 0.3 | A-6 (4) |
| 133+000 | 100 | 99 | 96 | 87 | 42 | 0.75 | 12.9 | 30 | 15 | 15 | 13.1 | 7 | 2045 | 9 | 3 | 8 | 10 | 0.2 | A-6 (2) |
| 134+000 | 100 | 99 | 96 | 86 | 63 | 0.55 | 13.9 | 16 | NP | NP | 0.0 | 4 | 2120 | 11 | 9 | 12 | 21 | 0.3 | A-4 (0) |
| 135+000 | 100 | 94 | 91 | 83 | 61 | 0.65 | 16.0 | 29 | 13 | 16 | 13.3 | 10 | 2210 | 12 | 5 | 10 | 13 | 0.25 | A-6 (6) |
| 136+000 | 100 | 100 | 100 | 78 | 56 | 0.66 | 22.0 | 37 | 16 | 21 | 16.4 | 9 | 2110 | 10.5 | 5 | 11 | 13 | 0.17 | A-6 (8) |
| 138+000 | 100 | 100 | 99 | 76 | 38 | 0.87 | 24.0 | 32 | 21 | 11 | 8.4 | 9 | 1885 | 12.5 | 9 | 13 | 34 | 0.2 | A-6 (0) |
| 140+000 | 100 | 99 | 94 | 56 | 17 | 1.33 | 43.6 | 23 | NP | NP | 0.0 | 8 | 2035 | 9.5 | 5 | 12 | 33 | 0.25 | A-2-4 (0) |
| 142+000 | 100 | 100 | 99 | 81 | 58 | 0.62 | 19.0 | 41 | 21 | 20 | 16.2 | 12 | 1986 | 10 | 2 | 3 | 7 | 0.1 | A-7-6 (9) |
| 144+000 | 100 | 100 | 100 | 74 | 41 | 0.85 | 26.0 | 27 | 19 | 8 | 5.9 | 5 | 1995 | 10 | 3 | 12 | 22 | 0.2 | A-4 (0) |
| 146+000 | 100 | 100 | 99 | 77 | 35 | 0.89 | 23.0 | 28 | 16 | 12 | 9.2 | 4 | 2010 | 7 | 5 | 12 | 19 | 0.4 | A-2-6 (0) |
| 148+000 | 100 | 100 | 100 | 79 | 23 | 0.98 | 21.0 | 13 | NP | NP | 0.0 | 1.4 | 2046 | 9.5 | 12 | 18 | 36 | 0.01 | A-2-4 (0) |
| 150+000 | 100 | 100 | 100 | 89 | 55 | 0.56 | 11.0 | 28 | 15 | 13 | 11.6 | 10 | 2160 | 5.5 | 4 | 7 | 14 | 0.35 | A-6 (4) |
| 152+000 | 100 | 100 | 100 | 75 | 10 | 1.15 | 25.0 | 18 | NP | NP | 0.0 | 1.4 | 2150 | 8 | 13 | 18 | 39 | 0.1 | A-3 (0) |
| 154+000 | 100 | 100 | 100 | 87 | 33 | 0.80 | 13.0 | 32 | 21 | 11 | 9.6 | 5 | 2100 | 12 | 5 | 12 | 18 | 0.5 | A-2-6 (0) |
| 156+000 | 100 | 100 | 98 | 77 | 22 | 1.03 | 23.0 | 12 | NP | NP | 0.0 | 3 | 2045 | 12 | 12 | 17 | 40 | 0.8 | A-2-4 (0) |

| Location | Grading | | | | | GM | GC | LL | PL | PI | PIw | LS | MDD | OMC | CBR at %MDD | | | Swell | AASHTO classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 28 | 5 | 2 | 0.425 | 0.075 | | | % | % | % | % | % | kg/m$^3$ | % | 90 | 93 | 95 | % | |
| 157+000 | 100 | 100 | 99 | 74 | 45 | 0.82 | 26.0 | 46 | 14 | 32 | 23.7 | 12.5 | 1887 | 11 | 2 | 4 | 5 | 0.8 | A-7-6 (8) |
| 158+000 | 100 | 98 | 95 | 76 | 37 | 0.92 | 23.5 | 46 | 27 | 19 | 14.4 | 12.9 | 1940 | 14 | 2 | 6 | 12 | 0.74 | A-7-6 (2) |
| 159+000 | 100 | 100 | 99 | 93 | 64 | 0.44 | 7.0 | 57 | 22 | 35 | 32.6 | 14.3 | 1789 | 17 | 0 | 1 | 2 | 0.3 | A-7-6 (20) |
| 160+000 | 100 | 99 | 98 | 87 | 64 | 0.51 | 12.9 | 45 | 24 | 21 | 18.3 | 8.5 | 1897 | 13 | 1 | 3 | 6 | 0.5 | A-7-6 (11) |
| 161+000 | 100 | 100 | 100 | 88 | 42 | 0.70 | 12.0 | 34 | 14 | 20 | 17.6 | 9.5 | 1887 | 11 | 2 | 5 | 9 | 1.1 | A-6 (3) |
| 162+000 | 100 | 100 | 99 | 80 | 51 | 0.70 | 20.0 | 37 | 16 | 21 | 16.8 | 11.4 | 1960 | 7.9 | 1 | 3 | 6 | 0.95 | A-6 (6) |

- **Subgrade Strength Properties**

  It was observed that the subgrade from station 86+000 to 92+000 and 106+000 to 156+000were sensitive to degree of compaction. Soils in these sections were having higher increaseof CBR strength on compaction efforts of between 93% and 95% of MDD. The increaseissignificant at these compaction efforts. Converse is also true, with less compaction effort (i.e.,90%) the CBR strength attained is much lower and not proportion to the efforts expended.It is therefore recommended to compact at higher degrees in order to achieve desiredstrength.

&**Problem Soils**

Problem soils can be described as unfavourable soils which cannot be used for subgradeconstruction. During investigation, soils susceptible to be problematic were observed at variouslocations. Samples were collected for further studies to ascertain their true nature and behaviour.Such soils are:

- Low strength soils (CBR <3)
- Expansive soils
- Dispersive soils and erodible soils
- Saline soils or presence of saline water
- Collapsible soils
- Micaceous soils

- **Low Strength Soils**

  In accordance with PMDM, the low strength soil is defined as soils having CBR of less than 3%at 100% of MDD BS Light. Soil strength obtained at 90% of MDD under BS Heavy compactionefforts which is equivalent to 100% of MDD under BS Light compaction effort were checkedif they fall below 3%.

  These soils are classified as problem soils and should be treated separately from othersections. The table below shows a summary of subgrade properties.

*<Table 3-18: Location with materials having CBR less than 3 at 100% MDD of BS light>*

| Location | CBR | PI | Percentage passing (mm) | | PIw |
|---|---|---|---|---|---|
| | % | % | 0.425 | 0.075 | % |
| **79+000** | 2 | 31 | 87 | 42 | 27.0 |
| **80+000** | 2 | 32 | 90 | 78 | 28.8 |
| **81+000** | 2 | 29 | 95 | 90 | 27.6 |
| **84+000** | 1 | 25 | 90 | 84 | 22.5 |
| **85+000** | 2 | 23 | 93 | 85 | 21.4 |
| **90+000** | 2 | 15 | 75 | 49 | 11.3 |
| **98+000** | 2 | 21 | 83 | 49 | 17.4 |
| **102+000** | 1 | 45 | 65 | 38 | 29.3 |

| Location | CBR | PI | Percentage passing (mm) | | PIw |
|---|---|---|---|---|---|
| | % | % | 0.425 | 0.075 | % |
| 114+000 | 1 | 16 | 63 | 43 | 10.1 |
| 121+000 | 1 | 18 | 89 | 75 | 16.0 |
| 142+000 | 2 | 20 | 81 | 58 | 16.2 |
| 157+000 | 2 | 32 | 74 | 45 | 23.7 |
| 158+000 | 2 | 19 | 76 | 37 | 14.4 |
| 159+000 | 0 | 32 | 93 | 64 | 32.6 |
| 160+000 | 1 | 21 | 87 | 64 | 18.3 |
| 161+000 | 2 | 20 | 88 | 42 | 17.6 |
| 162+000 | 1 | 21 | 80 | 51 | 16.8 |

Laboratory test results show presence of low strength soils at various locations. Longeststretches being between:

*<Table 3-19: Sections identified as having low strength soils>*

| SN | Start | End | Length (km) |
|---|---|---|---|
| 1 | 79+000 | 81+500 | 2.5 |
| 2 | 83+500 | 85+500 | 2.0 |
| 3 | 89+000 | 91+000 | 2.0 |
| 4 | 97+000 | 99+000 | 2.0 |
| 5 | 101+000 | 102+500 | 1.5 |
| 6 | 113+000 | 115+000 | 2.0 |
| 7 | 120+500 | 121+500 | 1.0 |
| 8 | 141+500 | 143+000 | 2.0 |
| 9 | 156+500 | 162+000 | 5.5 |

Soils in these sections should be removed by at least 300mm below formation level andreplaced with suitable fill followed by improved subgrade layers.

- **Expansive Soils**

Field assessment on the centreline soils were carried out to determine any indications ofexpansive soils. Soils in alignment were found to be sandy soils with some gravels. However,initial assessment of the subgrade soils indicated presence of expansive soil by havingweighed plasticity index of more than 20 at some locations.

*<Table 3-20: Locations with materials having PIw greater than 20>*

| Location | PI | <0.425mm | $PI_W$ |
|---|---|---|---|
| 79+000 | 31 | 87 | 27.0 |
| 80+000 | 32 | 90 | 28.8 |
| 81+000 | 29 | 95 | 27.6 |
| 84+000 | 25 | 90 | 22.5 |
| 85+000 | 23 | 93 | 21.4 |
| 102+000 | 45 | 65 | 29.3 |
| 157+000 | 32 | 74 | 23.7 |
| 159+000 | 35 | 93 | 32.6 |

Extended investigations were conducted to determine the degree of expansiveness of thesesoils. The investigations include testing for Shrinkage Limit and calculation of expansiveness($\varepsilon_{ex}$) using the following formula.

$$\varepsilon_{ex}=2.4w_p - 3.9w_s + 32.5$$

- Where:
- $w_p$ = plastic limit tested on fraction <425μm and weighted to actual content ofparticles <425μm
- $w_s$ = shrinkage limit tested on fraction <425μm and weighted to actual contentof particles <425μm

- **Treatment for expansive soils**

Generally expansive soils should be excavated and replaced with suitable fill wherever theyare encountered. Special treatment depending on embankment cover above expansive soilsis given hereunder:

*<Table 3-21: Recommended treatment for expansive soils>*

| Degree of expansiveness | Methods for construction over expansive soils |
|---|---|
| Low | • Sealed shoulders<br>• Side slopes should be 1:6 or flatter |
| Medium | • Sealed shoulders<br>• Side slope should be 1:6 or flatter<br>• Minimum earth cover of 1m |
| High | • Excavate and replace 0.6m of expansive soils<br>• Minimum earthworks cover 1m<br>• Side slope 1:6 or flatter<br>• Minimum shoulder width 2m |

Where embankment is 2m or higher, the side slope can be made of 1:4 or flatter

Where excavation of expansive soils is required (i.e., high expansiveness), the excavatedmaterials should be temporarily stockpiled latter to be used for side fill to make embankmentslope to 1:6. Embankment should be constructed with compacted slope of 1:2 or flatterbefore covering with excavated materials to 1:6 side slope.

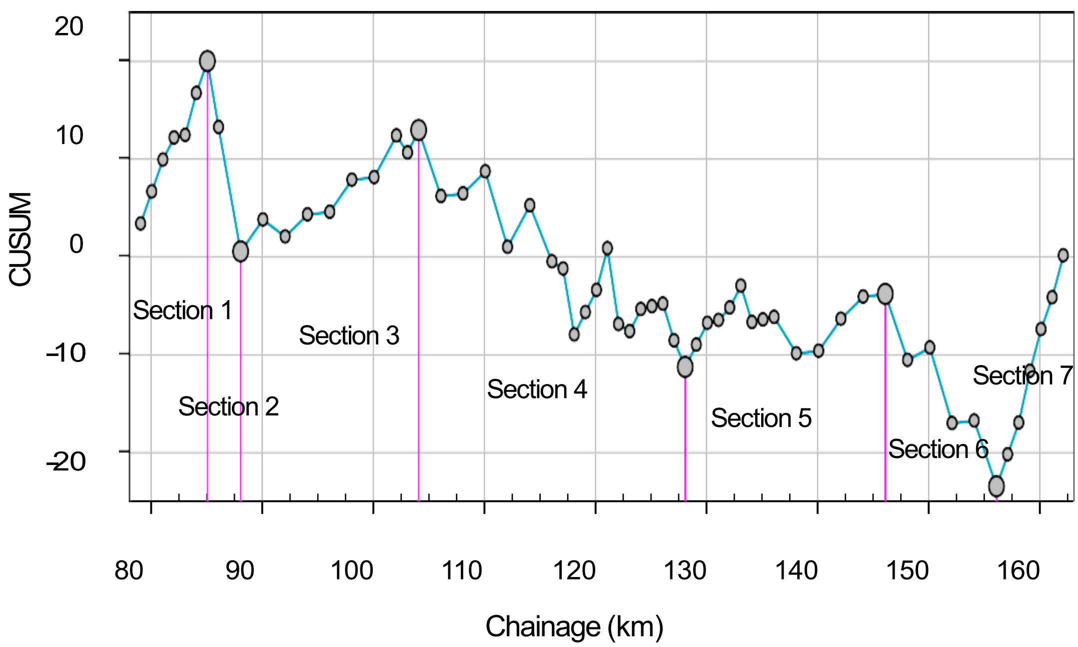
&**Homogeneous Sections**

Cumulative sums of CBR strength were plotted against location to determine areas with similarcharacteristics. The 90 percentiles of CBR for a section was taken as CBR design for that section.

- **Subgrade along Chalinze – Morogoro Road Section**

  The subgrade soils were demarcated in seven homogeneous sections. However, thesesections can be combined to longer sections provided that they are categorised in samesubgrade class. Areas categorised as having problem soils were identified and assessedindependent of identified homogeneous sections. Special treatments were recommended inthese areas.

*<Figure 3-11: Homogeneous sections in a CUSUM against distance plot>*




Properties and classification of identified homogeneous sections. CBR values after four dayssoaking was used to determine CBR design for identified homogeneous sections. TheCBRdesign was used to categorise the section into subgrade class.

*<Table 3-22: Summary of initial identified homogeneous sections>*

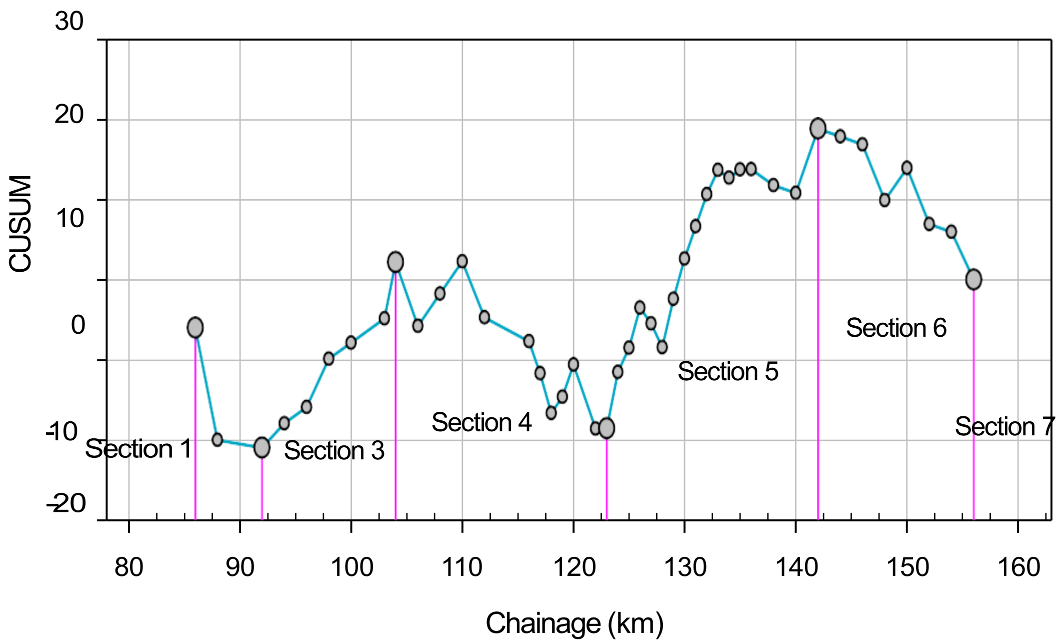
| Name | Location | Length (km) | CBR design | Subgrade class |
|---|---|---|---|---|
| Section 1 | 79+000 to 85+500 | 6.5 | 2 | Problem soil |
| Section 2 | 85+500 to 88+500 | 3 | 12 | S7 |
| Section 3 | 88+500 to 104+500 | 16 | 2 | Problem soil |
| Section 4 | 104+500 to 128+500 | 24 | 3 | S3 |
| Section 5 | 128+500 to 146+500 | 18 | 3 | S3 |
| Section 6 | 146+500 to 156+000 | 9.5 | 4 | S3 |
| Section 7 | 156+000 to 162+000 | 6 | 1 | Problem soil |

Initial investigation shows that homogeneous sections with problem soils were at section 1,section 3 and section 7 with total length of 28.5km.

Considering that, areas with low strength CBR (CBR <3) require special treatments to improvethem before construction of embankment, identified homogeneous sections were re-examined to exclude areas with low strength CBR.

After isolating (masking) areas with low strengths CBR within a section, method of cumulativesum was used to determine and demarcate homogeneous sections and subgradeclassification of these corrected homogeneous sections were determined corresponding torespective compaction efforts.

*<Figure 3-12: Homogeneous sections in a CUSUM against distance plot for CBR strength>*




Seven sections with homogeneous properties were identified. Section 1 and section 7 wereisolated as they were classified as having problem soils. These will need special treatment.

*<Table 3-23: Summary of the adjusted homogeneous sections>*

| Name | Location | Length (km) | CBR design | Subgrade class |
|---|---|---|---|---|
| Section 1 | 79+000 to 85+500 | 6.5 | 2 | Problem soil |
| Section 2 | 85+500 to 92+500 | 7.0 | 13 | S7 |
| Section 3 | 92+500 to 104+500 | 12 | 5 | S3 |
| Section 4 | 104+500 to 123+500 | 19 | 7 | S7 |
| Section 5 | 123+500 to 142+500 | 19 | 5 | S3 |
| Section 6 | 142+500 to 156+500 | 14 | 10 | S7 |
| Section 7 | 156+500 to 162+000 | 5.5 | 1 | Problem soil |

Following adjustments made to homogeneous sections, the subgrade was classified intoproblem soils, S3 and S7. Subgrade with problem soils require special treatments beforeimprovement and construction of embankment.

### 3.6.3 Materials Investigations

&General

Material investigations have been carried out at a substantial distance from the projectarea.Factors like human settlements, geology of area and environmental restrictions have madeitdifficult to locate borrow area to within short distances from the project area. All efforts weremade to locate the sources as close to project area as possible so as to reduce costs associatedwith haulage distances.

The investigations include sources of natural granular material for fill, subbase and base (borrowareas) and sources of hard stones to be used for crushed aggregate base, asphalt mixes and forconcrete works. Other sources of materials include fine aggregates (sand) to be used for concreteworks and water sources for various usage in construction works.

- **Sources for Gravel Materials**

Materials with a minimum CBR of 15% will be needed for the subgrade construction and othergood materials will be needed for areas requiring normal fill.

Three gravel sources were identified and investigated for their suitability and approximateavailable quantities. Test pits were excavated at locations with possible extensions.Soil/gravel identification were done in the field while classification was done after laboratoryresults were obtained.

Following laboratory tests were performed to the retrieved representative soil samples:

- Particle size distribution (Sieve analysis)
- Atterberg Limits (Plastic Limits, Liquid Limit)
- Linear shrinkage
- Compaction test (Moisture-density relationship)
- CBR (after 4 days soak)

Tests were carried out in accordance with Central Materials Laboratory Manual 2000. Testsresults of the materials samples from the identified sources have shown that the materialshave good quality for road construction.

*<Table 3-24: Potentials gravel materials estimated quantities>*

| SN | Name | Location | Offset distance (km) | Position | Estimatedq uantities, $m^3$ |
|---|---|---|---|---|---|
| 1 | Chang'ombe | 87+100 | 4.7km from Msolwa – Msoga junction | 421847, 9268202 | 800,000 |
| 2 | Mdaula | 90+000 | 0.8km from MorogoroRoad | 415985, 9270073 | 150,000 |
| 3 | Mwidu | 106+000 | 2.5km from MorogoroRoad | 400069, 9270073 | 400,000 |

| SN | Name | Location | Offset distance (km) | Position | Estimatedq uantities, m$^3$ |
|---|---|---|---|---|---|
| 4 | Gezaulole | 118+200 | 3km from Morogoro Road | 392792, 9265735 | 2,100,000 |
| 5 | Maseyu | 124+000 | 0.3km from roadalignment | 384405, 9264000 | 675,000 |
| 6 | Lukonde/Kiroka | 136+000 | 9km from Dar – MorogoroRoad | 379550, 9248335 | 450,000 |
| 7 | Mikese | 137+000 | 0.2km from proposedalignment | 372857, 9258124 | 350,000 |
| 8 | Mkambarani | 142+300 | 0.6km from proposedalignment | 369029, 9257106 | 200,000 |
| 9 | Lue | 18+000 | 2.5km from proposedalignment at station18+000 Bypass | 343964, 9247343 | 500,000 |
| 10 | Bwilingu | 88+000 | 0.5km from proposedalignment | 418845, 9267093 | 350,000 |
| 11 | Mgama | 132+000 | 0.75km from proposedalignment | 376116, 9261608 | 350,000 |
| 12 | Mzumbe IringaRoad | 190+000 | 0.2km from Iringa Roadfrom station 2+400 | 338275, 9236172 | 250,000 |
| 13 | Mzumbe | 190+000 | 2.5km from Mzumbejunction from station25+000 | 341111, 9240494 | 300,000 |

Following AASHTO classification methods for soils, most of the identified sources falls underA-2-6 group, whereas two sources were classified as A-6 and one as A-2-7. Generally, thematerials contain fines less than 35% and having PI exceeding 10 and LL less than 40.

*<Table 3-25: Indicator and consistency tests and soil classification for gravel sources>*

| Name | Grading (percentage passing, %) | | | | | | Atterberg limits | | | | AASHTO Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 5 | 2 | 0.425 | 0.075 | GM | LL | PL | PI | LS | |
| Chang'ombe | 65 | 64 | 58 | 45 | 21 | 1.8 | 21 | 8 | 13 | 4.3 | A-2-6 |
| Mdaula | 84 | 73 | 56 | 28 | 16 | 2.0 | 39 | 25 | 14 | 4.0 | A-2-6 |
| Mwidu | 86 | 69 | 51 | 30 | 21 | 2.0 | 41 | 23 | 18 | 9.3 | A-2-7 |
| Gezaulole | 96 | 85 | 68 | 50 | 38 | 1.4 | 38 | 22 | 16 | 6.3 | A-6 |
| Maseyu | 61 | 50 | 42 | 32 | 14 | 2.1 | 25 | 14 | 11 | 5.0 | A-2-6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Lukonde/Kiroka | 66 | 54 | 44 | 16 | 4 | 2.4 | 28 | 11 | 17 | 3.0 | A-2-6 |
| Mikese | 85 | 76 | 64 | 42 | 21 | 1.7 | 32 | 19 | 13 | 9.3 | A-2-6 |
| Mkambarani | 99 | 98 | 97 | 82 | 50 | 0.7 | 35 | 17 | 18 | 7.0 | A-6 |
| Lue | 100 | 98 | 93 | 52 | 16 | 1.4 | 27 | 13 | 14 | 5.9 | A-2-6 |

| Name | Grading (percentage passing, %) | | | | | | Atterberg limits | | | | AASHTO Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 5 | 2 | 0.425 | 0.075 | GM | LL | PL | PI | LS | |
| Bwilingu | 56 | 46 | 40 | 28 | 9 | 2.2 | 33 | 20 | 13 | 5.7 | A-2-6 |
| Mgama | 64 | 47 | 37 | 24 | 13 | 2.3 | 36 | 19 | 17 | 3.2 | A-2-6 |
| MzumbeIringa Road | 43 | 35 | 33 | 30 | 15 | 2.2 | 40 | 18 | 22 | 11.0 | A-2-6 |
| Mzumbe | 55 | 46 | 39 | 24 | 7 | 2.3 | 39 | 14 | 25 | 12.1 | A-2-6 |

Following PMDM classification for gravels, most of the identified sources were classified asG15, whereas two sources were classified as G45 and other two as G7.

*<Table 3-26: Strength properties and classification of gravel sources*

| Name | MDD | OMC | CBR at %MDD | | | Swell | PMDM Classification |
|---|---|---|---|---|---|---|---|
| | kg/m³ | % | 90 | 93 | 95 | % | |
| Chang'ombe | 2090 | 9.8 | 9 | 15 | 28 | 0.1 | G25 |
| Mdaula | 2230 | 6.8 | 13 | 19 | 27 | 0.1 | G25 |
| Mwidu | 2000 | 11.0 | 36 | 40 | 47 | 0.0 | G45 |
| Gezaulole | 1900 | 13.4 | 12 | 18 | 25 | 0.1 | G25 |
| Maseyu | 2011 | 12 | 14 | 21 | 30 | 0.1 | G25 |
| Lukonde/Kiroka | 2010 | 10.6 | 16 | 18 | 31 | 0.1 | G25 |
| Mikese | 1880 | 12.5 | 28 | 40 | 67 | 0.0 | G45 |
| Mkambarani | 1890 | 10.6 | 11 | 16 | 20 | 0.0 | G15 |
| Lue | 2037 | 10.0 | 13 | 18 | 26 | 0.0 | G25 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bwilingu | 1990 | 11.0 | 9 | 14 | 17 | 0.1 | G15 |
| Mgama | 1790 | 15.8 | 18 | 33 | 48 | 0.0 | G45 |
| Mzumbelr inga Road | 2070 | 9.0 | 19 | 20 | 22 | 0.0 | G15 |
| Mzumbe | 2030 | 9.5 | 11 | 19 | 25 | 0.1 | G25 |

- **Rock Sources**

Potential rock quarries were identified, sampled and tested for physical parameters. Crushedrock materials are required for concrete works, base course layers, production of stones forrock fill sections and for surface wearing course. One source at Lugoba quarry wasinvestigated.

Crushed rock samples from this quarry site were taken for laboratory testing. The followingtests were carried out on the samples to ascertain their strength and physical properties.

- Ten Percent Fine Value at dry and wet conditions (TFV $_{dry}$ and TFV $_{wet}$)
- Aggregate Crushing Value (ACV)
- Aggregate Impact Value (AIV)
- Los Angeles Abrasion Test (LAA)
- Bitumen Affinity
- Relative Density and Water Absorption
- Sodium Sulphate Soundness (SSS)

The quarry is located at Lugoba area in Bagamoyo District. The source is about 20km awayfrom the project area at an offset distance of 3km from Chalinze-Msata road. Stones were ofgranite type formed during Karroo formation; they are composed of fine to medium particleswith no cleavage.

The source has been used to supply crushed aggregates used for concrete and asphalt worksfor various building and road projects in Dar es Salaam. It is estimated that the source canyield more than 900,000m3 of crushed aggregates. Rock samples taken from this source weretested for suitability in bituminous surfacing works.

Other sources as Maseyu, Lue and Mafuru were identified and investigated for suitability inconstruction works.

*<Table 3-27: Strength test and other physical properties of sampled stone>*

| Test Description | Unit | Lugoba | Maseyu | Lue | Mafuru |
|---|---|---|---|---|---|
| TFV dry | kN | 187 | 184 | 220 | 130 |
| TFV soaked | kN | 155 | 160 | 190 | 94 |
| Ratio TFVsoaked/dry | % | 83 | 87 | 86 | 72 |

| | | | | | |
|---|---|---|---|---|---|
| ACV | % | 19.6 | 20.7 | 17.5 | 19.5 |
| LAA | % | 28.7 | 29.2 | 26.4 | 30.9 |
| SSS | % | 2.2 | 2.7 | 1.9 | 4.1 |
| Relative Density | | 2.895 | 2.848 | 2.804 | 2.818 |
| Water Absorption | % | 0.41 | 0.35 | 0.34 | 0.58 |

According to PMDM, the aggregates from Lugoba, Maseyu and Lue sources meet therequirements for base course pavement layer and surfacing while those from Mafuru sourcedid not satisfy requirements for TFV soaked for surfacing layer and base of CRR. However, they satisfy requirements for base with CRS materials.

- **Sand Sources**

Sand materials are required for concrete works and sometimes to be used as drainage filtermaterials. Potential sand sources were identified and investigated for their suitability forconcrete works.

*<Table 3-28: Summary of results for sand materials>*

| SN | Name | Location | Offsetdistance(km) | Percentage passing (%) | | FM | Quantity |
|---|---|---|---|---|---|---|---|
| | | | | 2.36 | 0.075 | | m3 |
| 1 | Misugusugu | 17+000 | 4 | 99.8 | 1.9 | 2.02 | 150,000 |
| 2 | Mpiji | 0+000 | 8 | 99.1 | 0.4 | 2.16 | 75,000 |
| 3 | Vikawe | 0+000 | 10 | 99.3 | 0.5 | 1.93 | 85,000 |
| 4 | Vikunge | 13+000 | 2 | 100 | 1.0 | 1.95 | 100,000 |
| 5 | Boko Mlemela | 4+000 | 6 | 100 | 0.9 | 2.04 | 50,000 |
| 6 | Matuli | 79+000 | 30 | 99.9 | 1.8 | 2.16 | 100,000 |

The grading of these sources was checked to comply with grading specification for aggregatesfrom natural sources for concrete as specified in BS 882 and BS EN 12620.

- **Water Sources**

Water for construction near the project road is very scarce and limited in quantity.Ngerengere River a perennial source was sampled. Other water streams are seasonal.

The following chemical tests were conducted on water sample collected from this potentialsource.

- pH value
- Chloride content
- Sulphate content

An evaluation of water quality from this source towards its applicability in construction workswas carried out. Results are summarised below:

| Test Description | Unit | Results |
|---|---|---|
| pH | | 7.82 |
| Chloride content | mg/l | 92.0 |
| Sulphate content | mg/l | 75.9 |
| Electrical conductivity | µS/cm | 835 |

According to limits set by DIN 4030 for attack of concrete from water, soil and gases, thiswater source is suitable for concrete works.

- **Other sources of water**

Due to scarcity of water near to the project, it is advised to consider constructing coffer damsat strategic intervals to harvest rain water during wet seasons.

Other possible source of water is through water supply authority (DAWASA and MORUWASA).The utility water systems were supplying the villages along Chalinze to Morogoro town.During construction period, an agreement could be made with the Utility to tap water atvarious locations and supply the project.

Drilling boreholes as an alternative source of water should be considered. Historical recordsshow that water table is found at shallow depth (30 to 50m) on areas surrounding the projectarea.

&**Sources of Manufactured Materials**

Manufactured materials for road construction should be tested prior to usage. Availability ofthose sources have been checked:

- **Cement**

Cement can be sources from factories like Twiga Cement, Tanga Cement, Rhino Cement orLake Cement. Other suppliers like Dangote cement and Lucky cement are reliable.

- **Bitumen and Bituminous mixes**

Bitumen and bituminous mixes can be imported from abroad. Bitumen properties need to bechecked against requirements for various types before it is accepted in construction.

- **Reinforcement Steel**

Reinforcement steel for structural works is available in the country. Several factories likeKamal steel, MI Steel are known for producing good quality reinforcements.

## 3.7. Preliminary Drainage Studies and Surveys

This feasibility report for the drainage structures had been done in consideration of the terms ofreference, nature of the study area/site and the relevant standards and design manualsacceptable within Tanzania. Also keeping in mind, the economic viability/justification as carriedout in the economic analysis report of Chalinze-Morogoro Expressway Standard Toll Road

### 3.7.1 Drainage Studies and Surveys

&**Field Survey**

The exercise to conduct field survey was conducted on 14th to 15th March 2023 andsubsequently another site visit was conducted on 27May to 28 May 2023 by a team of Drainageand Structural Engineer, Hydrologist and Surveyor. The team carried out visual condition surveys,general assessment and detailed surveys of all crossing rivers, streams, valley and longitudinalterrain for drainage structures. Various positions/locations of drainage structures such as pipeand box culverts, bridges, median drains, side drains, etc. have been surveyed at sites as part ofthe assignment. During the field survey, general assessment and both visual assessment anddetailed surveys of all crossing rivers, streams, ponds and valley to determine the hydrauliccapacity of particular locations, initial determination of the structural requirements. Most of thedata taken at site have formed basis for the preliminary design and recommendations madeinthis report.

The preliminary design has generally been carried out in consideration to the terms of reference,nature of the site and the relevant standards and design manuals acceptable within Tanzania.Inventory for all locations which require drainage structures had been done for the entireproposed expressway standard road project and proposal for the drainage structures is given asstipulated in relevant sections and appendices.

*<Table 3-29: Simplified Formulas for Calculation of Discharge Capacity of Culverts (inlet control)>*

| Type | Discharge Capacity Q (m3/s) | | |
|---|---|---|---|
| | Hw/D=1.00 | Hw/D=1.25 | Hw/D=1.50 |
| Concrete Pipe | 1.3 x $D^{2.5}$ | 1.9 x $D^{2.5}$ | 2.2 x $D^{2.5}$ |
| Corrugated Metal Pipe | 1.1 x $D^{2.5}$ | 1.6 x $D^{2.5}$ | 1.8 x $D^{2.5}$ |
| Box Culvert | 1.5 x B x $H^{1.5}$ | 2.1 x B x $H^{1.5}$ | 2.5 x B x $H^{1.5}$ |
| D: diameter of a pipe culvert (m)<br>H: height of a box culvert (m) | B: width of a box culvert (m)<br>$H_W$: headwater height (m) | | |

### 3.7.2 General Overview - Summary of Drainage Structures

&**Bridges**

In view of their construction simplicity and cost effectiveness, Concrete T-Beam bridges havebeen recommended and adopted for use as apart from other advantages, quality localcontractors are conversant with their construction techniques hence with the magnitude andnature of this project, they can participate in the bid and offer both competitive rates and qualityjobs at lower costs compared to international contractors.

There will be a total of 4 major bridges proposed as presented in tables below.

*<Table 3-30: Summaries of Proposed Major Bridges along the project road >*

| Structure | Size | Span | Location | Total Number |
|---|---|---|---|---|
| | Msolwa Bridge: 30m (L) x 28.3m (W) | 1nos | K 86+928.5 | 1 |
| | Ngerengere River Bridge1: 40m (L) x 28.3m (W) | 1nos | K116+140 | 1 |

| | | | | |
|---|---|---|---|---|
| MajorBridges | Ngerengere River Bridge2:100m (L) x 28.3m (W) | 3nos | K116+335 | 1 |
| | Ngerengere River Bridge3: 60m (L) x 28.3m (W) | 2nos | K122+510 | 1 |
| | Ngerengere River Bridge4:100m (L) x 28.3m (W) | 2nos | K144+602.5 | 1 |
| | **Total** | | | **5** |

&**Box culverts**

In this preliminary drainage studies and surveys stage the concrete box culverts have beengrouped into five standard sizes which include singles and multiples of 2.0m x 2.0m, 3.0m x 2.0m,4.0m x 2.0m, 4.0m x 3.0m, 5.0m x 2.0m, 5.0m x 2.5m, 5.0m x 3.0m and 5.0m x 4.0m. A totalnumber of thirty-eight (38) box culverts are proposed to be installed in the entire proposedexpressway standard toll road stretch as summarized below.

*<Table 3-31: Summary of Proposed Drainage Cross box culverts along the project road >*

| Structure | size | Total Number |
|---|---|---|
| Concreteb ox culverts | 2.0m x 1.0m Single Cell | 1 |
| | 2.0m x 2.0m Single Cell | 5 |
| | 2.0m x 2.0m Double cells | - |
| | 3.0m x 2.0m Single Cell | 3 |
| | 3.0m x 2.0m Double Cells | 1 |
| | 3.0m x 2.0m Triple cells | 1 |
| | 4.0m x 2.0m Single Cell | 2 |
| | 4.0m x 2.0m Double Cells | 3 |
| | 4.0m x 3.0m Single Cell | 1 |
| | 4.0m x 3.0m Double Cells | 2 |
| | 5.0m x 2.0m Tetra Cells | 1 |
| | 5.0m x 2.5m Double Cells | 2 |
| | 5.0m x 3.0m Single Cell | 3 |
| | 5.0m x 3.0m Double Cells | 3 |
| | 5.0m x 3.0m Triple Cells | 4 |
| | 5.0m x 4.0m Double Cells | 1 |
| | 5.0m x 4.0m Triple Cells | 1 |
| TOTAL | | 34 |

## 3.8. Preliminary Hydrological Survey and Analysis

### 3.8.1 Background

The chapter summarizes observations and findings made on the basis of the review of existingreports and data, consultant reconnaissance and detailed inventory of proposed route(expressway standard toll road) and surveys of the rivers/streams and valley crossing theexpressway. Useful data in this study includes DEM maps, Topographic maps, climatic data(rainfall and temperature) and gauged rivers flow data. The above-mentioned data wereinstrumental for preparation of models for hydrological survey and analysis as well as hydraulicdesign. Other information such as land use, topography, soil characteristics and river/channelconditions has been considered on analysis. The applied flood models were used in accordanceto conditions and assumptions which produce accurate results.

Recommendations are made based on Employer's requirements, design principles, methods,criteria and standards applied in the drainage elements and design criteria.

### 3.8.2 Terms of Reference

The Terms of Reference (ToR) require hydrological and hydraulic studies and analysis to becarried out along the road section (Chalinze -Morogoro/LOT-2) with an aim of determiningdesign peak flood/ discharges across the project road. The peak flow through the river/streamwill be estimated for a return period of 100 years for the proposed bridge, 50 years for otherbridges and box culverts and 25 years for other structures using generally acceptable standardprocedures such as the Rational method for catchments between 1.0 sq km or where drainageflow distance is less than 1 km and the "Transport Road Research Laboratory (TRRL) East AfricanFlood Model" for catchments larger than 1.0 sq km but less than 200 sq km.

Update or investigate channel stability; scour depth and bank stability, maximum flood level andhydraulic opening of the structures to accommodate maximum flow anticipated with a provisionfor adequate free board.

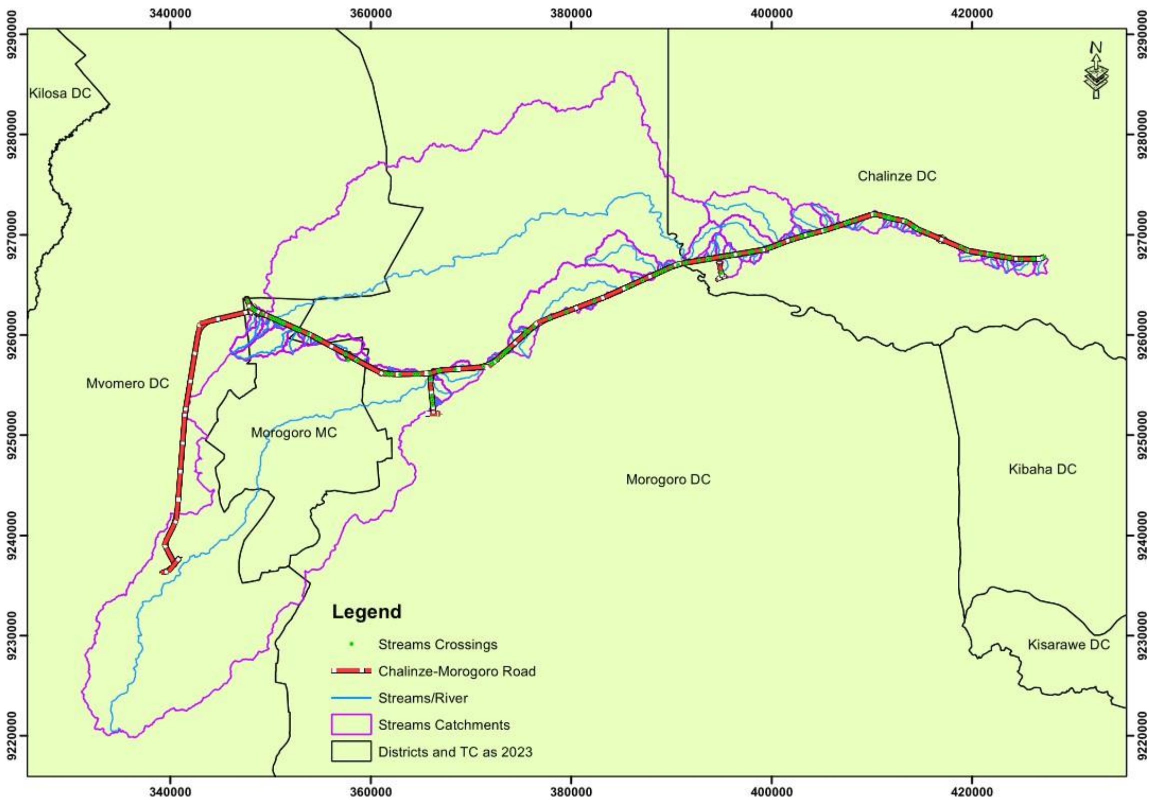
Study topographical maps and aerial photographs to define the catchment areas along theapproved alignment. Rainfall intensity, run-off duration/intensity relationship, catchments runoff characteristics and the channel slopes/discharge characteristics for each catchment area willbe determined based on the available aerial photographs, topographic maps and fieldinvestigations as necessary

The rainfall-runoff relationships and catchment characteristics for each catchment aredetermined based on climatic data (rainfall data and temperature), topographic maps, soil mapsand field investigations and then be used in the Rational Method, "Transport Road ResearchLaboratory (TRRL) East African Flood Model (TRRL-EAFM) and other appropriate internationallyacceptable hydrological models to estimate design peak floods.

In additional to the topographic maps, the Digital Elevation Model-DEM and ArcGIS data havealso been used to establish the catchment's characteristics to cross check with the topographicmap's information.

### 3.8.3 Project Location

The project road is located in both Coast region (Chalinze district) and Morogoro region(Morogoro district, Morogoro Municipal, Mvomero District). The project road starts at "Chalinzetown and transverses at Morogoro Dc, Morogororo Municipal and ends at Mvomero district (Lot2). The study road (Lot-2) and its catchments actually fall within Coast and Morogoro regions and cover a total length of about 84.9 km. The large part of project road fall within Morogoro region(Morogoro Dc and Morogoro municipal districts) and remaining part is in Coast region (Chalinze).The details and locations of all streams/Rivers and channels including their catchment areas asdetermined from the topographical maps of 1:50,000 scale and digital maps using ArcGIS 10.6,are presented in Appendix 1. The approach including the analysis of the required hydraulicstructures of all drainage outlets along the project road are discussed in details in this report.Moreover, the road under study and its draining catchments are well presented in the figurebelow in terms of their administrative areas.




*<Figure 3-13: Location of project road (study area)>*

### 3.8.4 Hydrology and Drainage objectives

The primary objective of the hydrology study/ investigations for the project road has been todetermine the peak discharges of the watercourses at the bridge/culvert sites and evaluate thefunctioning of the existing cross-drainage structures along the road alignment.

The assessment of the rivers/streams crossing the project road has been carried out. Theinformation has been collected and analyzed in respect of all relevant aspects including soilcharacteristics, land-use pattern, soil cover and drainage characteristics of the river/streamcatchments. The information has been analyzed using Flood models to generate flood estimatesfor different return periods at crossing bridges and culverts sites.

The drainage pattern of the project road (Lot 2) and catchments for the rivers/streams which arewithin Morogoro & Coast region, fall into Indian Ocean drainage system which consists of bothpermanent and seasonal rivers /streams. Largely permanent Rivers includes Ngerengere Riverwhere some of the tributaries of project roads drain to. This major river forms a part of the large basin known as WAMIRUVU River basin.

The above drainage systems form part of major drainage systems in Tanzania, which is dividedinto five major drainage systems according to the hydrological year book 2010-2019 Volume1of March 2020 by Ministry of Water. The five major drainage systems are the Indian OceanDrainage

System; the Internal Drainage to Lakes Eyasi, Natron and Bubu Depression Complex;the Internal Drainage to Lake Rukwa; the Atlantic Ocean Drainage and the Mediterranean SeaDrainage system. These systems have further been divided into nine river and lake basins forease of management of the country water resources on a River-Basin basis.

Hydrometrically, the project road is gauged at Ngerengere River and has two river gaugingstations which are falling within the road under study. These gauging stations are maintained insuch a way that reliable data are recorded. These stations include Ngerengere river at Migudeand Ngerengere river at Kingolwira stations. Rainfall within the study area is covering Two majorstations which are Chalinze & Morogoro rainfall station maintained by TMA (TanzaniaMetrological Agency). Other used rainfall station such as Mtibwa rainfall station were out ofproject road (Lot 2) but their influence reflected to the project area in terms of rainfall andtemperatures. The hydrology and drainage of the project road consists seasonal rivers,permanent rivers and waterways cruising through stretches of the project area. The largely Riveris Ngerengee River where some of the tributaries of project roads drain to which further runsdown stream to the Major Ruvu river and empty its water to the Indian Ocean.

### 3.8.5 Hydrology's role on Hydraulic Design

In the context of hydraulic design, hydrological study and analysis provides estimates of floodmagnitudes as a result of precipitation. These estimates consider processes in a watershed thattransform precipitation to runoff and transport water through the system to a project's location.For the design of drainage structure, the following requirements were considered:

- Selection of desired level of protection, specified in terms of probability of capacityexceedance.
- Finding the corresponding flow rate and/or volume, computing in many cases thecorresponding water surface elevation.

The above requirements were then considered as a basis for design. In the design of facilitiessuch as storm drain systems, culverts, and bridges, design floods were considered in terms ofpeak runoff or discharge in cubic meters per second. For systems that are designed to controlthe volume of runoff, or where flood routing through culverts or bridges is used, the dischargeper time is of interest, thus, depending on the needs of a particular project, the hydrology studyprovides the following:

- A flow rate for which the probability of exceedance is specified.
- A volume of water expected with a specified storm duration, for which the probability ofexceedance is specified
- A hydrograph-flow rate as a function of time-for a specified probability of exceedance.Thisprovides information about peak, volume, and timing of runoff level of protection desired.

These results are obtained through statistical analysis of historical observations or throughempirical or conceptual models of the relevant watershed and channel processes

### 3.8.6. Data Collection and Processing

The degree of accuracy of the flood estimates made depended on the quantity and quality of theavailable data. The hydro-meteorological information available in the study area is fairly goodfor rainfall and few gauged rivers. The gauged river (Ngerengere River) along the project roadwhich give a reasonable flow per area ratio has been considered on estimation of peak dischargeof watershed on the project road.

&**Topographic and Soil Maps**

The Topographical maps with scale 1:50,000 of the United Republic of Tanzania and Soil Mapshave been used for the hydrological study. Subsections below present the list of topographicalmaps within the project road and some which are not within the project road, but covered thewatershed which drain to the project road. The soil maps were referred from the TRRL FloodModel of East Africa by D. Fides and Pavement and Materials Design Manual, 1999, for Tanzania.

- **Topographical Maps**

  The following topographic sheets have been used for catchments delineation and extractionof catchments characteristics:

*<Table 3-32: Series of Maps used to extract information>*

| S/No. | Name of Map | Sheet No | Scale | Status of Map |
|---|---|---|---|---|
| 1 | Dakawa | 166/4 | 1:50,000 | Original Copy |
| 2 | Kwedirema | 167/3 | 1:50,000 | Original Copy |
| 3 | Msata | 167/4 | 1:50,000 | Original Copy |
| 4 | Lutindi | 182/2 | 1:50,000 | Original Copy |
| 5 | Kimamba | 182/3 | 1:50,000 | Original Copy |
| 6 | Mkata | 182/4 | 1:50,000 | Original Copy |
| 7 | Nguru ya Ndege | 183/1 | 1:50,000 | Original Copy |
| 8 | Mkono wa Mara | 183/2 | 1:50,000 | Original Copy |
| 9 | Morogoro | 183/3 | 1:50,000 | Original Copy |
| 10 | Kingulwira | 183/4 | 1:50,000 | Original Copy |
| 11 | Ubenazomozi | 184/1 | 1:50,000 | Original Copy |
| 12 | Chalinze | 184/2 | 1:50,000 | Original Copy |
| 13 | Ngerengeere | 184/3 | 1:50,000 | Original Copy |
| 14 | Maginda | 184/4 | 1:50,000 | Original Copy |
| 15 | Mlandizi | 185/1 | 1:50,000 | Original Copy |
| 16 | Yombo | 185/2 | 1:50,000 | Original Copy |
| 17 | Ruvu | 185/3 | 1:50,000 | Original Copy |
| 18 | Soga | 185/4 | 1:50,000 | Original Copy |

| | | | | |
|---|---|---|---|---|
| 19 | Doma | 2200/1 | 1:50,000 | Original Copy |
| 20 | Msongozi | 200/2 | 1:50,000 | Original Copy |
| 21 | Mgeta | 201/1 | 1:50,000 | Original Copy |

The demarcations of the watershed for the drainage structures were marked ontopographical maps and hydrological characteristics such as catchment's area (km2), soiltypes, land-use, land-cover, basin slopes, vegetation type, watercourse length, etc. wereestablished and used as inputs in flood models for further analysis of peak discharges.

- **Soil Maps**

The soil maps were referred from the TRRL Flood Model of East Africa by D. Fides andPavement and Materials Design Manual, 1999, for Tanzania. The TRRL Flood Model ofEastAfrica classify soils in three categories namely well-drained soils, slightly impeded soils andpoorly drained soils.

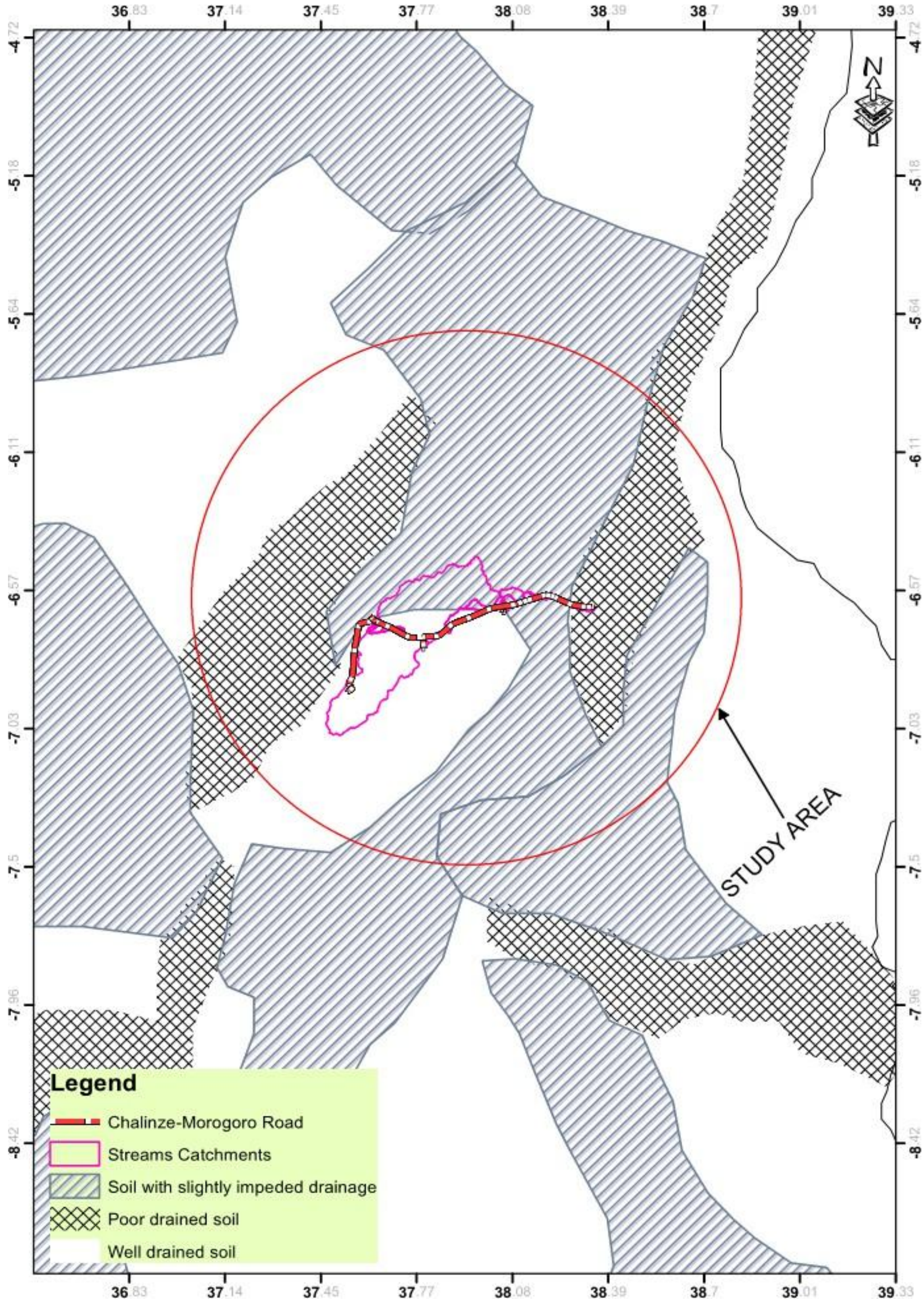
&**Soil, Land Cover/Vegetation and Land Use**

The soil type in the study area is completely dominated by well-drained soil and slightly impededsoil with portion of poorly drained soils. This type of soil comprises of sand soils, sandy loam soils,well drained and heavy clay waterlogged soils, however the large portion in which the roadpasses is dominated by sand-clay, sandy loam soil and expansive soils in some few areas.Thisfield observation concurs with the East African Soil Map which suggest that almost the entireproject area lies in the soil which is classified as well-drained soil and that of slightly impeded soilwith small portion of poor drained soils.

The natural vegetation of the study area generally comprises of short grasses, coastal swamps,shrubs, scattered trees and dense forests to some segments of the road. After first four (4km)From Chalinze town (Start point) the proposed road transverse on a forest/bush area andwoodland up to 7 kilometers before crossing the chalinze-Msolwa Road. After crossing theChalinze-Msolwa road via overpass, the road continue through short grass covers with the mixedsisal & maize farming areas and encounters occasional wooded on hills. Some clusters of treesoccur along the river valleys and swamps.

The project road traverses through villages/towns which are mainly flat, rolling and hilly whichresults to the flow mainly toward their footings then later forms streams and tributaries crossingthe study road. Land uses include cultivation of several crops which require heavy rainfall andlight rainfall. The crops which require heavy rainfall include paddy and maize. The small-holderfarmers cultivate crops that require less moisture such as sisal, pulses and vegetables. The smallholder farmers also engage in tree crop cultivation of oranges, mangoes, cashew nuts andbanana. Livestock keeping is practiced on same areas mainly the areas of Chalinze and Morogorodc.

*< Figure 3-14: Soil characteristics in the study area>*



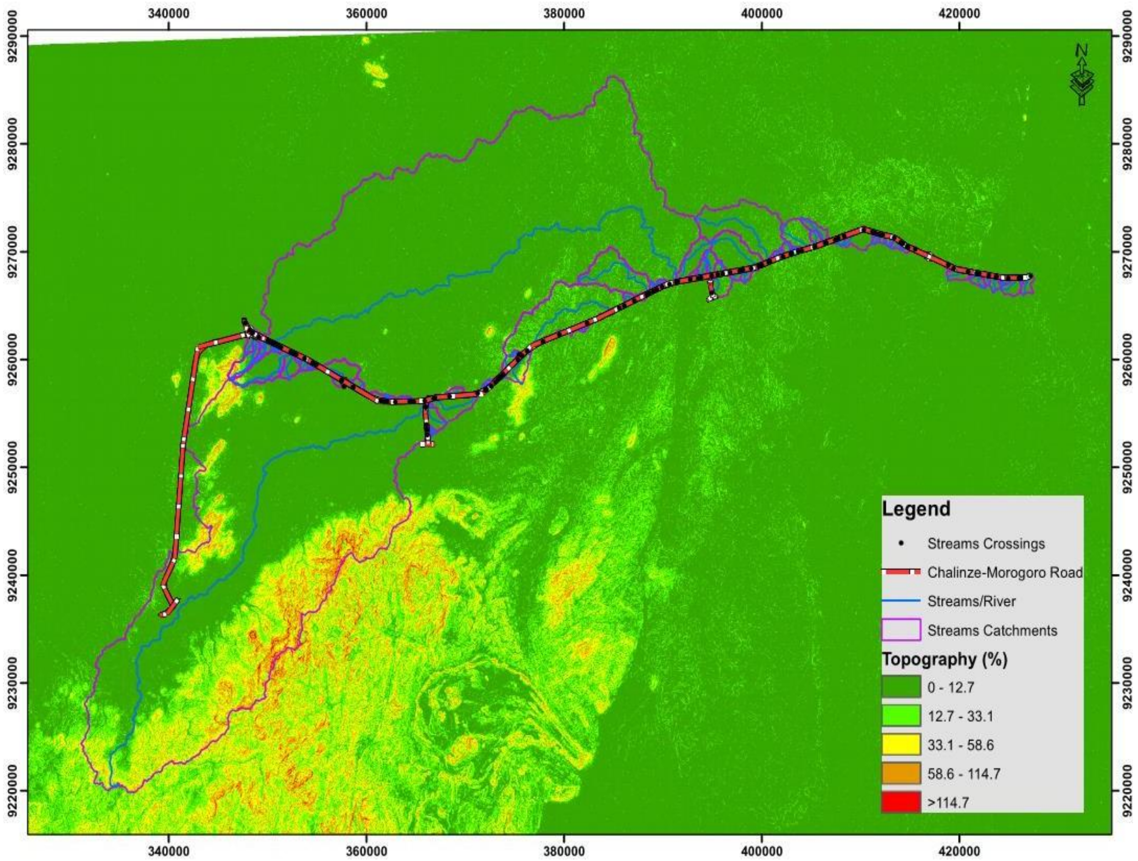

Topography, Drainage and Landform

The road under study lies between 2616m above sea level and 13m above sea level where itincludes the area covered by the watershed which drains to the existing rivers within the studyarea. The topography of the study area consists of flat areas at the foot of hills and mountains.The hills and mountains are located in the upper catchment which potentially forms thetributaries which drains the project road. The hill/mountains are elevated at up to about 2616mabove sea level, while the road elevation ranges from about 13m to 614m.

The large portion of the road and the river catchments can be classified as Moderate flat land(Slope 1%-4%), rolling (4%-10%) hilly (10%-20%) and mountainous (>20). Relatively, there arefew areas which consist of very flat slope (<1%) Slope. The Road experience rolling terrain atChalinze areas (Project start point) though there is existence of rolling at the mid segment of theproject road (Lot 2) at Kingolwira area. The presence of these Hills and Mountains result intosteep gradients for some of the river stream channels.

The study area is generally drained by the one major river (Ngerengere River) and its tributaries.The Ngerengere River and its headwater tributaries rise on the eastern slopes of the UluguruMountains and descend steeply to a plain 200 meters above sea level eastern foot of massif.Thereafter it meanders north east to reach the coast in a swampy estuary north Bagamoyo. Mostof tributaries within Ngerengere catchment eventually join with Ruvu River at their downstreams which then empties their water into the Indian Ocean.

*<Figure 3-15: Topography and Drainage pattern of study area>*



&**Climate**

Generally, the project roads (Chalinze – Morogoro Expressway) share the climate of two regionswhich are Coast region and Morogoro region. In Coast region the project roads transverses inChalinze district while in Morogoro region the project roads transverses in Morogoro RuralDistrict, Morogoro Municipal and Mvomero district.

Two key features show the climate of the Coast region where part of project road transversesincludes temperatures and rainfall. According to meteorological statistics the averagetemperature in Coast region is 28oC. The region experiences the average annual rainfall of 800mm as minimum and 1000 mm as maximum per year. The heavy rainfall falls between Marchand June every year and spread throughout the region. The light rainfall is received commonlyfrom October to December each year, however, it doesn't cover the whole region and isunreliable.

Two key features show the climate of the Morogoro region where part of project road transverseincludes temperatures and rainfall. The annual rainfall ranges from 600mm in low lands to1200mm in the highland plateau. However, there are areas which experience exceptionaldroughts (with less than 600mm of rainfall and these areas is together with the East of MorogoroRural District). The mean annual temperatures vary with altitude from the valley bottom to themountain top. The average annual temperature varies between 18oC on the mountains to 30oCin river valleys. In most parts of the region, the average temperatures are almost uniform at 25oC.The coolest months are May, June and July, while the hottest months are September andOctober.

&**Rainfall Data**

Rainfall and runoff are significant constitute of sources of water for recharge of ground in thewatershed. Rainfall is a major primary source of recharge into the ground. Surface waterisavailable in the watershed from runoff and meets in the rivers, streams or in surface waterbodies. The runoff in a watershed is affected by geomorphologic factors, particularly; land usechange affects the runoff volume and the runoff rate significantly. Hydro-meteorological andhydrological data have an important role in the drainage structures design.

In order to carry out a balanced evaluation of crossing peak discharges for different returnperiods, available data regarding rainfalls/peak discharges have been collected and assessedfrom the following hydrometrical stations (sources):

*<Table 3-33: Rainfall stations in study road>*

| S/No. | Name of Station | District of Occurance | Source of Data | Location | Year |
|---|---|---|---|---|---|
| 1 | Morogoro RainfallStation | MorogoroMunicipal | TanzaniaMeteorological Agency (TMA) | 6o 50' S<br>37o 39' E<br>526 m | 1980 to 2022 |
| 2 | Mtibwa RainfallStation | Mvomero | TanzaniaMeteorological Agency (TMA) | 6o 08' S<br>37o 39' E<br>457 m | 1980 to 2020 |
| 3 | Chalinze | Chalinze | TanzaniaMeteorological Agency (TMA) | 6.61S<br>38.3E | 1980 to 2020 |

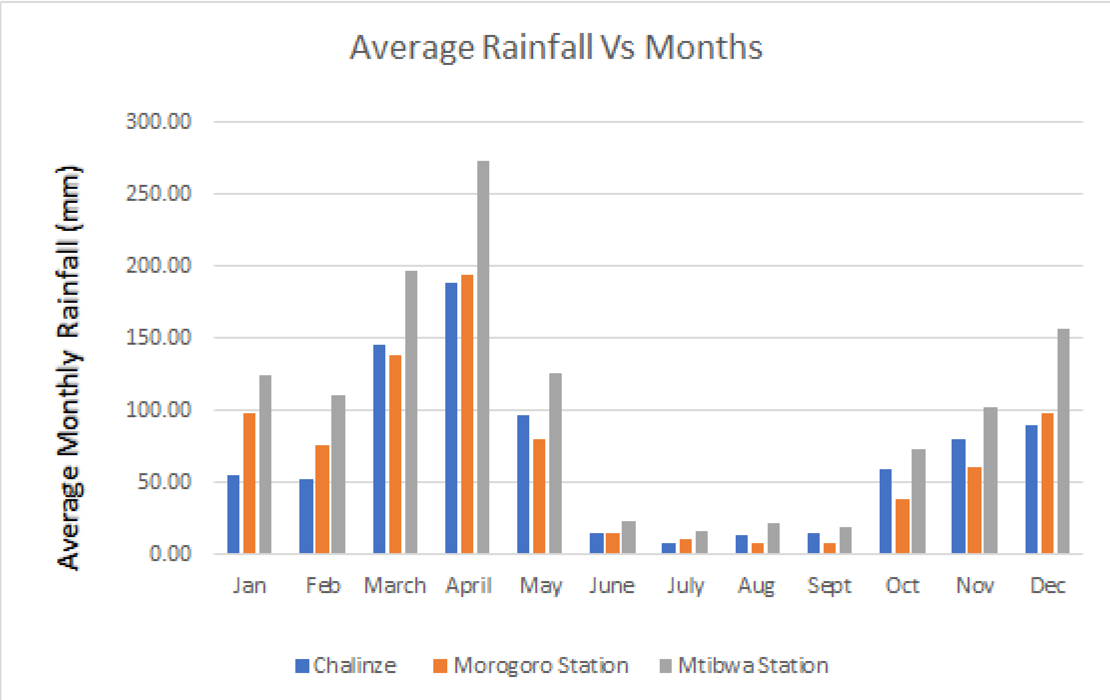
The averages of the monthly total rainfalls (mm) for selected three rainfall stations in the studyarea, namely Chalinze, Morogoro, and Mtibwa stations are presented below.

*<Table 3-34: Averages of the Monthly total rainfalls and Regional Averages>*

| Months | Chalinze | Morogoro Station | Mtibwa Station | Reg. Averages |
|---|---|---|---|---|
| Jan | 55.93 | 98.7 | 124.27 | 92.97 |
| Feb | 53.01 | 76.68 | 111.16 | 80.28 |
| March | 145.46 | 139.03 | 196.56 | 160.35 |
| April | 188.81 | 194.34 | 273.15 | 218.77 |
| May | 96.58 | 80.84 | 125.82 | 101.08 |
| June | 15.56 | 15.63 | 23.23 | 18.14 |
| July | 7.89 | 11.08 | 16.59 | 11.85 |
| Aug | 13.66 | 8.64 | 21.7 | 14.67 |
| Sept | 15.14 | 7.7 | 19.56 | 14.13 |
| Oct | 59.23 | 38.86 | 73.98 | 57.36 |
| Nov | 80.96 | 61.59 | 102.89 | 81.81 |
| Dec | 89.75 | 97.95 | 156.66 | 114.79 |

The distribution of these station rainfalls together with the Regional Averages is shown in theFigure below

*<Figure 3-16: Distribution of the Averages of the Monthly Total Rainfalls>*




The hottest period occurs between September and February and the coldest period occurs between May and August.

The temperature ranges are generally as shown in the Table below.

*<Table 3-35: The Temperature Ranges in the Study Area>*

| Temperature Level | Range |
|---|---|
| Maximum Air Temperature | 28°C – 30°C |
| Minimum Air Temperature | 17.2°C - 22°C |
| Mean annual Air Temperature | 25°C |

&**Rainfall Analysis**

- **Data Assignment**

The rainfall data obtained in the above stations are between years 1980 to 2020. These dataare for Average Total Monthly Rainfall, Rainfall Intensity, Average Monthly Temperatures, anddata showing Monthly 24hrs rainfall are also included. The data collected were used torepresent the rainfall pattern within project road areas assuming that the variation in rainfalltrend is minimal keeping in mind that 1980 to 2020 was a long period to simulate thereasonable rainfall trend within these areas.

- **Maximum Daily Rainfall and Analysis for Different Return Periods**

The data has been used in the frequency analysis of the annual maximum daily rainfalls. Therecords indicate that the heavy rainfalls occur mainly during the wet season from Novemberto May, the situation which is typical to that in the tropical areas. The sample size available of30 to 40 years as found in the three stations was considered indicative especial for Chalinzerainfall station, Morogoro rainfall station and Mtibwa rainfall station, analyzed and the resultscompared to the recommendation given in the TRRL flood Model for East Africa to get thereasonable and sound value to yield the most probable estimates.

- **Variability in space-Area reduction factor**

For a given catchment, the average rainfall depth depends on the size of the catchment area.The average rainfall depth over the catchment's area was calculated from the point rainfallmultiplied by an area reduction factor ARF. For this project, the following equation recommended in the "TRRL Report No. 623 –Prediction of Storm Rainfall in EastAfrica-by D. Fiddes and others" has been applied:

$$\text{Area Reduction Factor, ARF} = 1 - k * T^{-1/3} * A^{1/2}$$

$$ARF = 1 - 0.04 * t^{-1/3} * A^{1/2}$$

T: Rainfall duration (in hours)A: Catchments area (in km$^2$)

- **Variability in time-Rainfall Ratio**

As a basis for determination of critical rainfall duration and the corresponding intensity, therainfall depth corresponding to the duration t was calculated as a proportion of the total dailyrainfall R24 through multiplication with the rainfall ratio RRt:

$$RR_T = \frac{T}{24} * \left(\frac{(b+24)}{(b+T)}\right)^n$$

The following values have been used in the present study: b=0.33, and for Coastal stationsn=0.76, and Luguru zone stations n=0.85, corresponding to the results recommended inthe“TRRL Report No. 623 –Prediction of Storm Rainfall in East Africa-by D. Fiddes and others”

The rain duration and the corresponding rainfall depth were determined individually for allcatchments, using the duration that gives the highest peak flood for each catchment.However, recommendations of rainfall duration as presented in TRRL Report No. 623 havebeen used in catchments.

- **Detailed Analysis and Observations**

In order to establish the design value of annual maximum point rainfall, the widely acceptedprobabilistic method “Gumbel” for Extreme value distributions has been used to extrapolatethe data using linearization and distribution techniques. The standard linear-regressiontechniques were used to find the lines of best-fit explaining the relationship between stormrainfall and the recurrence interval. The result of the frequency analysis of the annualmaximum daily rainfall at the stations for different return periods, are summarized in tablesbelow.

*<Table 3-36: Chalinze Rainfall station annual maximum daily rainfall value Vs Period by GumbelMethod>*

| Return Periods (Yrs) | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 66.76 | 80.76 | 90.28 | 99.3 | 102.2 | 111.4 | 119.9 |

*<Table 3-37: Morogoro Rainfall station annual maximum daily rainfall value Vs Period by GumbelMethod>*

| Return Periods (Yrs) | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 60.98 | 77.72 | 88.81 | 99.45 | 102.82 | 113.21 | 123.53 |

*<Table 3-38: Mtibwa Rainfall station annual maximum daily rainfall value Vs Period by Gumbel Method>*

| Return Periods (Yrs) | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 90.07 | 127.83 | 152.85 | 176.84 | 184.45 | 207.87 | 231.14 |

The daily maximum rainfall values computed using TRRL 706: The East African Flood model,1976 are summarized in Table below

*<Table 3-39: Annual maximum daily rainfall value Vs Period by TRRL Method (E.A) Inland stations>*

| Return Periods (Yrs) | 2 | 5 | 10 | 20 | 25 | 50 |
|---|---|---|---|---|---|---|
| Rainfall (mm) | 75 | 123 | - | 146.03 | 168.75 | 187.5 |

*<Table 3-40: Annual maximum daily rainfall value Vs Period by TRRL Method (E.A) Inland stations>*

| Return Periods (Yrs) | 2 | 10 | 20 | 25 | 50 | 100 |
|---|---|---|---|---|---|---|
| Rainfall (mm) | 70 | 114.8 | - | 136.29 | 157.5 | 175.0 |

The observation from analysis above show that the 24hrs point rainfall values by the twomethods (Gumbel and TRRL 706) are almost identical in spite of some variation in values forthe different return periods by the TRRL: 706 and values in identified rainfall stations. In thisrespect where TRRL values are not used Chalinze rainfall station's values have been put intotask.

In the design process for the peak discharges, the use of values from the two approaches havebeen assigned into two different flood models used, that is, those in Table above used by theGumbel method, and those in Table above for TRRL flood model for East Africa (TRRL-EastAfrican Flood Model). This was done just in view of the requirement source inputs of eachflood model.

The observation from analysis above show that the estimates obtained using the GumbelMethod for the return period between 10 to 100 years for chalinze rainfall station are loweras compared with the estimates by the TRRL-East African Flood Model especially for Tableabove. The reason for such difference could have been due to the sample size of between 30years duration obtained for the station, gaps in the data and sometimes due to unavailabilityof the data for the critical rainfall months within the weather/rainfall station.

- **Effect of Climate change on Rainfall distribution**

  Currently the world is greatly affected by variation in climate change that influencethehydrological cycle. Also with the growing recognition of global climate change as per IPCCreport of 2022, the study has accounted the climate change effect by increasing 15% for thedesign storm. Hence the final design storm at 100, 50 and 25 years will be added with thepercentage increase in discharge due to this factor for structure safety.

### 3.8.7 Preliminary Hydrological Analysis

&**Approach on hydrological analysis**

The aim of the hydrological survey was to determine flood runoff at locations where rivers,stream and valley/channels cross proposed route for the expressway standard toll road. Theanalysis entailed the determination of catchment characteristics, determination of rainfallintensity-duration for appropriate return periods and calculation of design floods for theindividual catchment areas. The approach has been to:

- Estimation of peak floods from catchments upstream of proposed route for the expresswaystandard toll road;
- Propose new hydraulic structures that will safely pass the design peak floods across theproposed expressway standard toll road without overtopping the embankment.

&**Methodology on hydrological analysis**

The consultant (TA) located the project road on Google map followed by identification of thetopographic sheets' numbers in which the project road falls on and twenty-one (21) topographicsheets were identified. The topographic sheets where the project road falls on covered the extended catchment area of the streams crossing the project road.

The digital elevation models, DEM (30mx30m) of the study area were processed withGISsoftware (ArcGIS-10.6) to supplement information from the topographic sheets. The reason forhaving two source of information (topographic sheet and Digital Elevation Model) was toovercome some of the limitations which exist on topographic sheets. Such limitations ontopographic sheets were the fact that topographical maps were too old, resolution is too courseand some are in black and white. These limitations made the delineation process and extractionother required catchments characteristics difficult. Combining these two data sets providedacross checking mechanism aiming at achieving good quality results.

In additional to the data above, the consultant completed reconnaissance field survey andcollection of data which included the major rivers/stream inventory and field observations(topography coverage, soil and land use etc)

&**Delineation of catchments and their characteristics**

The objective of adopting topographical maps and DEM (Digital Elevation Model) as primarysource of data has been to delineate and characterize the catchments draining all rivers, streamsand channels crossing the project road and to estimate associated catchment parameters, suchas catchment area and channel lengths. Before delineating the catchments for all rivers/streamscrossing, it was necessary to overlay coordinates of the proposed routes into topographicalsheets geo-referenced in Arc GIS software. Other parameters which were determined from thetopographical map analysis included stream elevation at start and at road crossing, therivers/stream slope and catchment slopes. These parameters, together with other variables suchas rainfall, land use and soil parameters were used as inputs data in the computerized floodestimation models for hydrological analysis and appropriate design of road hydraulic drainagestructures.

For all smaller streams and runoff crossing points which were not visible on the topographicalsheet and satellite images (DEM), a different method was used to identify them. Throughfieldreconnaissance sizes of crossing structures were proposed according to MoW standard as wellas engineering judgement.

The delineation process was based on two approaches as described below:

- **Delineation Using Paper Topographical Maps**

  The task in processing topographical maps was to identify the road within the maps. Itwasfollowed by electronic delineating of catchments for all of the rivers and streams/valleyscrossing the road using the DEM. After delineation, selected electronically delineatedcatchment were measured using a digital Planimeter (PLACOM KP-90N), for confirmation ofthe accuracy of the method. Other parameters such as channel length were electronicallyextracted from the attribute table of the ArcGIS software for each of the catchmentdelineated. The catchment delineation using DEM and or Landsat is as discussed in the nextsub section.

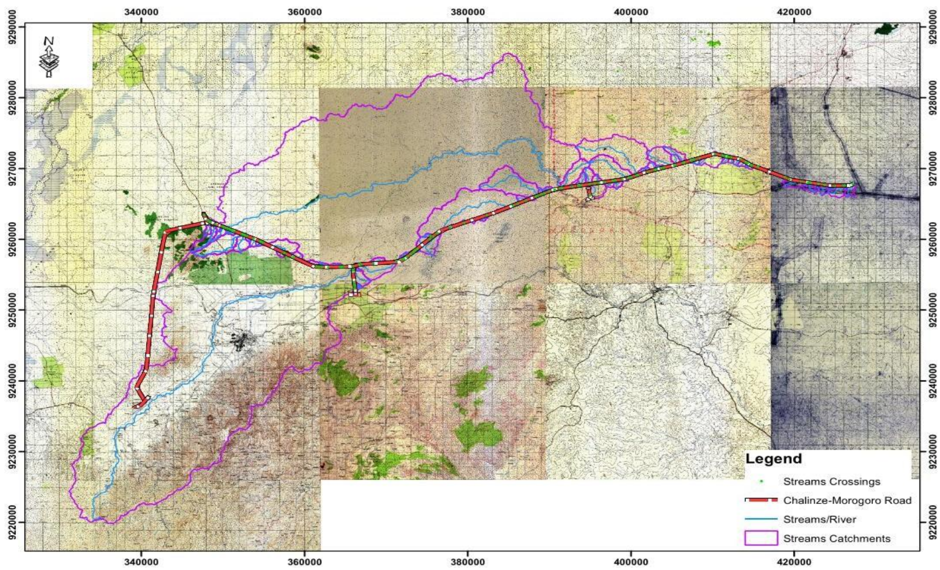
- **Delineation Using DEM and ArcGIS Software**

  The Digital Elevation Model (DEM)/Digital Terrain Model (DTM) of the project was purchasedand or retrieved from the Consultant's GIS database.

DEM processing in ArcGIS involved extracting tiles covering the project road (same extent asselected sheets of topographical maps) and re-projecting the data sets to UTM coordinatesystem (Arc 1960 UTM 37S datum). Other processes included:

- Creating contours from the DEM map (Digital Elevation Model) of the Project Road
- Scanning and geo-referencing paper topographical maps
- Overlaying contoured DEM (Digital Elevation Model) and the geo-referenced topographicalmaps to establish fit between the two data sets.
- Digitizing the Chalinze - Morogoro expressway and superimposing to both topographicalmap and the DEM (Digital Elevation Model).
- Generating a drainage network of the project road. This process involved filling sinks in theDEM (Digital Elevation Model), creating a Flow direction and Flow accumulation rasters anddefining the minimum (threshold) drainage area.
- Comparing the generated drainage network and the river network (available within theconsultant GIS database) in order to confirm/verify reliability of the DEM (Digital ElevationModel).
- Identify all the drains crossing the road and delineate their catchments, considering theintersection between the channel of interest and the project road as the catchment outlet.
- Calculating the areas for delineated catchments and length of the longest channels andcompared them with those calculated from paper topographical maps, prior to using thederived parameters into appropriate models for discharge estimation.
- Estimating all other required topographical parameters (slope, elevation at start/ exit ofchannels/rivers).

*<Figure 3-17: Delineated catchments overlaid on Topographical >*



- **Checking and comparing results from Topographic sheets and DEM/ArcGIS**

  Areas of the sub catchments and other many characteristics obtained from ArcGIS delineationwere then compared and confirmed for accuracy with the few selected catchmentcharacteristics delineated and measured using a digital Planimeter (PLACOM 90).

  The assessment for accuracy indicated that the delineation lines from the two methodsshowed a perfect fit, and from this result the sub catchment were confirmed to be trulyrepresentative of the situation and hence used for extraction of various parameters requiredfor discharge estimation.

&**Flood estimation methods/model**

Understanding the size of the catchment is one of the important factors in hydrological analysis.Catchment size is used as a decisive factor on which of hydrological flood model should be usedto estimate the design discharge of a given catchment.

&**Appropriate hydrological Model for estimation of Discharge**

Several numbers of models (hydrological models) can be used to analyze discharge from un-gauged channels and the flood flow frequencies from gauged channels. However, theapplicability of these models under different environmental conditions would depend on variousfactors.

The decisive factor of which type of hydrological flood model to be adopted in estimation ofdesign/peak discharge at a streams/rivers location on project road has beencatchment/watershed size. Some catchments of the rivers/streams crossing the project roadwere less than 1km2 while most of catchment's areas were between 1km2 and 200km2 and fewgreater than 200 km2. Such variations of catchment sizes suggested that more than onehydrological model have to be used in determining the design floods/discharges of rivers/streamcrossings. In response to the different sizes of catchment areas measured, four methods wereapplied to determine the design floods/discharges of rivers/stream crossing.

The models which were used in hydrological analysis of the study road (proposed Chalinze-Morogoro expressway standard toll road) crossings include:

- Rational method: This type of flood model used to estimate flow for the streams with anarea less than 1km2 (appendix 4 Hydrological survey and analysis report)
- The TRRL East African Flood Model (TRRL-EAFM) which can estimate peak flows forcatchments having areas between 1km2 and 200km2.(Appendix 4 of Hydrological surveyand analysis report)
- Statistical Analysis (Soil Conservation Service [SCS] Method): The technique which providedthe empirical equation for the study area can be used to estimate discharges generated byun-gauged catchments of area greater than 200 km2.
- The Gumbel/Extreme Value distribution (Type I): The technique utilized in establishing theRegional Flood Frequency Factors and the Flood frequency of return period up to 100 yearsat the bridge crossings.

&**Estimation of Design Flood/Peak Discharge for Drainage Structures**

Primary concern in estimating peak design floods that cross a project road rest on the accuracyof these estimates because they determine the sizes of the drainage structures to be constructedand therefore the associated costs.

The design floods were established by selecting the appropriate combination of rainfall andrunoff characteristics that can reasonably be expected to occur. This was calculated inconsideration of a selected design return period. The design criterions were usually themaximum flow carried by the drainage structure with no flooding at all during the design return period.

### 3.8.8 Flood Level estimation

The flood level refers to the maximum possible level which the storm water can raise on theground at a specific location. At the project road the flood levels were established by the use ofprofile which was developed from the DEM (Digital Elevation Model). The DEM gives enoughInformation on the shape of the ground and terrain itself, therefore, it was a good benchmark onthe estimation of the flood level in the flood plains area and swamps to control flood problem onthe project road. A physical observation on big trees and other features were considered as thefinal confirmation of the results of flood level estimated from DEM.

### 3.8.9 Analysis of Results and Recommended Return Period

The return periods recommended is 100 years for bridges, 50 years for box culverts and 25years for pipe culverts and other drainage structures. A justification for this choice is asexplained bellow having considered the following facts: -

The reliable method of estimating the design discharge would be to consider theactualobservations at the site (TRL ORN 9). However, due to paucity of the relevant and requireddata, one would need to use statistical probability and/or other applicable methods to arriveat the design flood for a given return period keeping in mind that: -

- The longer the return period the higher will be the discharge. Taking the economicpoint of view, one cannot play too safe as the cost of the structure to be builtwillincrease with an increased design flood discharge;
- The chances of occurrence and non-occurrence of such flood return periods of 25,50and 100 years return period are already extra ordinary flood for such type of structuressince any flood e.g. 1000 years flood could occur in the 25, 50 or 100 years period overwhich records are available;
- Normally, it is the widely used practice (experience, economic point of view and “sound” engineering practice) to design for a frequency of once in 50 years for minor bridgeswith the total spans of less than 60m and for 100 years for all major bridges (total length > 60m) while 25- and 50-year floods are considered adequate for pipe and box culvertsrespectively.

Having considered the rationale for return period considered above, it is hereby consideredboth safe and cost-effective design for such return periods to be used for such type ofstructures. It is further brought out that, the nature of the problems defining the flood returnperiod is such that there can be no guarantee that in case a bridge is designed for an estimated1000-year return period, for example, the design discharge would not be exceeded in the firstyear of the structure’s life time (“Hydraulic Factors in Bridge Design” by R.V. Farraday, G.Maunsell & Partners, F.G. Charlton, Hydraulic Research Station Ltd, Oxfordshire, U.K, 1983).It is, therefore, a normal practice to adopt such return periods as explained above.

### 3.8.10. Preliminary Hydraulic Design

The purpose of the hydraulic design is to ensure structures are of sufficient size that naturalflooding is not worsened and ensure that the structures can withstand the design flood andremain traversable.

&**Design of Culverts**

The design flood/peak discharges estimated from the TRRL East African Flood Model, RationalMethods and Empirical Method (Soil Conservation Services [SCS] method) have been used tosize efficient hydraulic structures that will safely pass the runoff (storm water) across the road.

Based on the estimated design flood/peak discharges, drainage structures have been proposedas summarized and presented on tables below.

*<Table 3-51: Summary of proposed cross culverts on Chalinze - Morogoro (Lot 2) project road >*

| Structure | Cross pipe culverts | | Access pipe culverts | |
|---|---|---|---|---|
| | Diameter (mm) | Number | Diameter (mm) | Number |
| Concrete pipeculverts | 900mmØ | 149 | 900mmØ | - |
| | 1200mmØ | 63 | 1200mmØ | - |
| | **Total Numbers** | **212** | | - |

*<Table 3-52: Summary of proposed cross box culverts on entire Chalinze – Morogoro (Lot 2) project road>*

| S/No. | Box culvert type/category | No. Single cell | No. double cells | No. Triple cells | No. Tetra cells | TOTAL NUMBER |
|---|---|---|---|---|---|---|
| 1 | 2,000x1,000 | 1 | | | | 1 |
| 2 | 2,000x2,000 | 5 | | | | 5 |

| S/No. | Box culvert type/category | No. Single cell | No. double cells | No. Triple cells | No. Tetra cells | TOTAL NUMBER |
|---|---|---|---|---|---|---|
| 3 | 3,000x2,000 | 3 | 1 | 1 | - | 5 |
| 4 | 4,000x2,000 | 2 | 3 | | | 5 |
| 5 | 4,000x3,000 | 1 | 2 | | | 3 |
| 6 | 5,000x2,000 | | | | 1 | 1 |
| 7 | 5,000x2,500 | | 2 | | | 2 |
| 8 | 5,000x3,000 | 3 | 3 | 4 | | 10 |
| 9 | 5,000x4,000 | | 1 | 1 | | 2 |
| TOTAL NUMBER | | **15** | **12** | **6** | **1** | **34** |
| Legend: All dimensions in this table are in millimeters | | | | | | |

*<Table 3-53: Summary of proposed bridges on Chalinze – Morogoro (Lot 2) project road >*

| S/No. | Bridge type/category | Chainage | Span Length (m) | Depth (m) | No. of Spans | Total length (m) | Name/place |
|---|---|---|---|---|---|---|---|
| 1 | PSC-Beam | 116+335 | 15.00 | 6.0 | 4 | 60.0 | Ngerengere at Bwawani |
| 2 | PSC-Beam | 144+602 | 15.00 | 6.0 | 3 | 45.0 | Ngerengere at Kingolwira |
| **TOTAL NUMBER** | | | | | | | **2** |
| Legend: All dimensions in this table are in meters except Chainage which is in Kilometers | | | | | | | |

### 3.8.12. Conclusion and Recommendations

#### General

The catchment characteristics extracted from the topographic maps and the DEM providedasignificant basis for the hydrological and hydraulic analysis of the project road under study. Also,the applied flood models have been used in accordance to conditions and assumptions whichproduce accurate results.

The hydro-meteorological information available in the study area is short. However, it has beenused carefully to derive the required design inputs.

There are two rainfall stations along the project road. These are located at Chalinze andMorogoro rainfall stations. Other used rainfall station such as Mtibwa rainfall station was out ofproject road (Lot 2) but their influence reflected to the project area in terms of rainfall andtemperatures. All rainfall stations have been considered to be representative over the study area.

Three hydrological models/methods have been used during the course of this study to arrive atthe hydrological and hydraulic design of the drainage structures which were designed. All theapplied models were computerized. The models include:

i. The Rational Method (RM) which was used to estimate peak flows for all the catchments withareas of less than 1km$^2$, or where the drainage flow distance is less than 1 km
ii. The TRRL East African Flood Model (TRRL-EAFM) which was used to estimate peak flows for allthe catchment with areas from 1km$^2$ to 200km$^2$.
iii. Soil Conservation Services (SCS-CN) Method which was used to estimate peak flows for all thecatchments with areas beyond 200km$^2$

## 3.9 TRAFFIC SURVEYS

### 3.9.1 General

To ensure compliance with the terms of reference (TOR), various traffic studies, includingVolumetric Traffic Counts, Speed Delay Surveys, Origin and Destination Surveys, and AnimalCrossing Surveys, were conducted along the study road. These studies were aimed atestablishing current traffic patterns and volumes, which would serve as a basis for futuretraffic projections. The data collected from these surveys will be critical input for the roadupgrading project throughout its design life.

Furthermore, surveys were conducted to identify potential locations and numbers of cattlecrossings along the existing A7 Highway between Kibaha and Morogoro. Understandingpedestrian and animal travel patterns is essential in determining the optimal crossing pointsfor the proposed alignment.

The traffic surveys for LOT1 were conducted from December 11th-12th and December 18th-19th, 2022, while the surveys for LOT2 were conducted from December 14th-20th, 2022. Insummary the following surveys were conducted on the project road

- Classified Traffic Counts (Intersections)
- Classified Traffic Counts (Mid-Blocks)
- Origin Destination and Selected Preference
- Speed Delay surveys
- Pedestrian and Animal crossing surveys

The surveys were planned and executed by a team of enumerators and supervisors who werespecifically trained for this task under the guidance of traffic engineers. The enumerators andsupervisors underwent training to ensure that they possessed the necessary skills andexpertise to carry out the surveys accurately and efficiently.

### 3.9.2 Selection of Count Stations

In order to analyze the current traffic flow patterns on the project road, traffic surveys wereconducted at selected counting stations. Key factors that were taken into considerationduring the selection of traffic counting points included:

- Availability of public shelter to ensure convenience in case of adverse weatherconditions during the field traffic survey period such as high temperatures and rainyconditions.
- Secure location, especially for night counts, to ensure the safety of enumerators.
- Proximity to public accommodation to enable proper timing of the start and end ofcounts.
- Minimal effects of local motorized and non-motorized traffic to enable enumerators toconcentrate during the collection of traffic data.

*<Table 3-54: Traffic Survey Count Stations >*

| Traffic Survey Type | Survey Point |
|---|---|
| Classified Traffic Counts | Mlandizi, Chalinze, Morogoro |
| Classified Traffic Counts (Mid-Blocks) | Kibamba, Lake oil, Mbwawa, Ruvu bridge, Nail oil, Mdaula, Kitungwa, Singasinga |
| SP&OD surveys | Kibaha, Mlandizi, Chalinze, Morogoro |
| Speed Delay surveys | Mbezi to Kipera |
| Pedestrian & Animal crossing surveys | Lake oil, Mdaula, Singasinga |

### 3.9.3 Traffic Survey Methodology

The traffic survey work involved a series of activities, from the planning phase to the data entry and processing phase, as detailed below:

- Planning field surveys: select locations and determine procedures
- Field checking: verify locations, determine team sizing and conduct pilot surveys
- Field survey: hiring and training survey personnel, arrange transport, manage stipendpayments, and ensuring quality control of survey outputs
- Data entry: cleaning, processing of collected data.

**Planning field surveys**

The Traffic Engineer first analyzed traffic trends and scenarios during desk study using GoogleEarth Aerial Images and field visits.

Survey points were then verified on-site with minor adjustments made to optimize data capturegoals.

Pedestrian and animal crossing surveys began on December 18, 2022, after extensive deskworkand scheduling interviews with stakeholders.

&**Field checking**

A team comprising of assistant traffic engineers and supervisors visited survey sites on December9, 2022. The team confirmed locations to position Traffic Enumerators, determined the numberof Enumerators required at each station based on assessed traffic patterns, and obtained generalinformation about food, accommodation, and security for Enumerators. Introductions were alsomade between supervisors and local ward executives.

&**Field traffic surveys**

- **Hiring and training**

The following were key requirements to recruitment and training process

- field surveys -> training place + fields locations, transport
- personnel enlistment
- previous Enumerators
- preferentially university students, but not necessarily
- must be clearly informed of the salary and conditions, before anything else

- it is a temporary job
- they will be dismissed at the smallest suspicious of “cheating”
- they will work on a daily basis (this allows for one’s dismissal, whenever necessary).

To ensure accurate results, a thorough training program was conducted for the selectedenumerators tasked with data collection and interviewing transportation users. The numberof enumerators trained was always higher than the number required to work. Training wasscheduled and conducted two days prior to the actual survey.

During training, more attention was given to the process of gathering information than toexplaining the procedures themselves, as the procedures would be experienced in practice.

*<Figure 3-23: Practical training on field>*

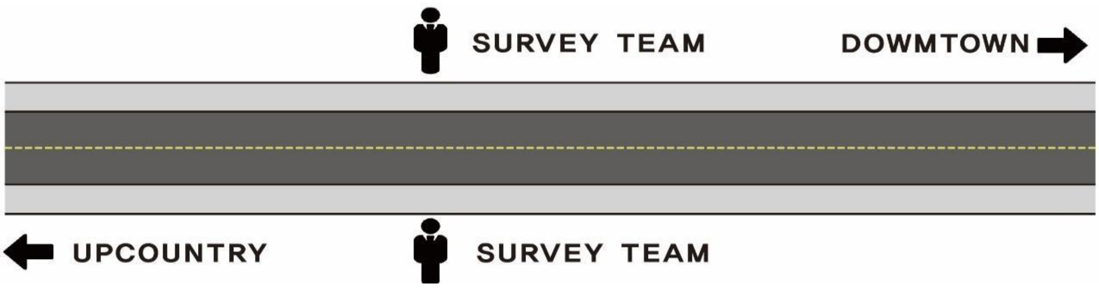
### 3.9.4 Traffic Surveys

**Classified counts (Midblock)**

Manual classified traffic counts of LOT1, also known as classified counts (Midblock), were carriedout for 24 hours on December 11-12 and 18-19, 2022. Traffic counts of LOT2 were carried out forseven days from December 14-20, 2022, with five days for 16 hours and two days for 24 hours(five counts on weekdays and two on weekends). The surveys of LOT2 were carried out for 24hours on one weekday and one weekend and 16 hours for the remaining five days. These surveysof LOT1 were carried out at five counting stations located at Kibamba, Lake oil, Mbwawa,Ruvubridge, and Nail oil. Surveys of LOT2 were carried out at three counting stations located at Mdaula,Kitungwa, and Sangasanga.

Each count station had a team of 3-4 enumerators and 1 supervisor working an 8-hour shift. Oneenumerator was stationed on each side of the road, taking details of the vehicles heading downtown and upcountry. On dual carriageways, 2 enumerators were assigned to each lane tominimize the chances of missing vehicles.

*<Figure 3-24: Typical arrangement for Midblock survey>*




The supervisor oversaw the enumerators, ensuring the forms were properly filled and remindingthem to change every 15 minutes. The supervisor also acted as a backup enumerator in caseanenumerator had an emergency.

The enumerators were responsible for counting the total number of vehicles, according tocategories such as cars, trucks, buses, vans, and motorcycles, that passed a survey point ineachdirection at a 15 minutes interval.

### Origin destination and selected preference surveys

The OD survey collected vehicle particulars, commodity OD particulars, and vehicle utilizationand route information. The survey was conducted at four stations, including Kibaha, Mlandizi,Chalinze, and Morogoro. The survey in Kibaha took place on December 11, 2022, while thesurveys in Mlandizi and Chalinze occurred on December 18, 2022. The survey in Morogoro lastedfor three days from December 18 to December 20, 2022.

*<Figure 3-25: SP&OD survey locations>*


Each survey point was composed of two police officers and one survey team, where each surveyteam had one supervisor and six enumerators.

The police officer was responsible for stopping oncoming vehicles when informed bythesupervisor that the team was ready. Once the vehicle was stopped, the police officer andthesupervisor would brief the driver on the survey’s purpose and request their cooperation.

The Supervisor was responsible for organizing and assigning enumerators to conductinterviews, ensuring the interviews were carried out in a timely manner. (i.e. no longer than2 minutes), and checking the completed forms to ensure that every enumerator filled themout properly. The supervisor also prepared enumerators for conducting interviews with drivers of the next vehicle.

&Speed delay surveys

- **General**

The purposes of travel speed survey are to identify the congested section, or congestedsegment, as well as the reasons for traffic congestion. The results of the survey would serveas indicators of the current traffic conditions on the existing road.

Before commencing the assignment, check points were established between the beginningpoint (Mbezi) and the end point(Kipera), at points where traffic congestion was anticipated.These points served as reference points from which the travel speeds could be establishedbetween road segments.

- **Survey team**

The speed delay survey teams consisted of two teams, each comprising a driver, a surveyor,and a timekeeper. The driver was responsible for safe driving, while the surveyor foundcheckpoints, recorded distances, and travel times. A GPS device was placed on the dashboardto receive signals from satellites during the drive.

Initially, we planned to engage only two people (the driver and the recorder), but we found itdifficult for one person to operate the GPS, stopwatch, and enter data into the field formsimultaneously. Therefore, we decided to have three people per survey car as a necessaryarrangement.

- **Survey method**

The Survey work flow is as follows:

*<Table 3-55: Work flow>*

| Stage | Work to do |
|---|---|
| Ready to start | Power on the GPS and wait until GPS receives signal |
| Start | Begin driving.<br>Surveyor records starting time on the survey sheet |
| Check point 1 | Surveyor records passing time at the check point on the survey sheet. |
| Stop | When the car stops, the surveyor start to calculate time using a stopwatch. |
| Start move again | If stopping time is greater than 15 second, surveyor records stopping timeon the survey sheet and resets the stopwatch.<br>If stopping time is less than 15 second, surveyor resets the stopwatch (noneed to record).<br>Surveyor should find the cause of the stops and record it on the survey sheet. |
| Check point X | Surveyor records passing time at the check point. |
| End | Surveyor records end time on the survey sheet and powers off the GPS. |

Field Surveys of LOT1 were conducted on December 11th, 12th, 18th, and 19th, 2022 usingpassenger cars.

Field Surveys of LOT2 were conducted on December 18th and 19th, 2022.

The surveys were conducted during both the AM and PM peak times and lasted for four days.The values in the table below represent the sum of LOT1 and LOT2.

*<Table 3-56: Speed delay survey>*

| Day | Number of Vehicles | Number of Trips |
|---|---|---|
| 11-12-2022 | 4 | 12 |
| 12-12-2022 | 6 | 12 |
| 18-12-2022 | 12 | 24 |
| 19-12-2022 | 11 | 22 |

After the completion of the field survey, the supervisor collected the GPS used along the routeand delivered it to the consultant's office for data downloading. Data clerks then entered therecorded data from the survey sheet into the prepared MS-Excel datasheets.

- **Turning movement surveys**

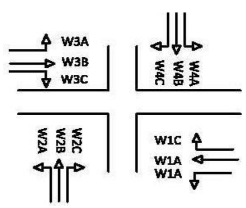
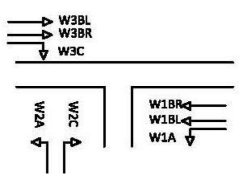
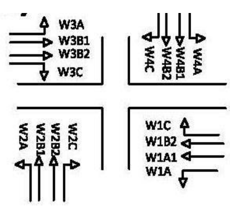
Turning movement surveys were conducted for LOT1 and LOT2 to estimate peak hour trafficfor the design of major and minor intersections. The surveys aimed to provide detailed trafficmovement information at intersections by measuring the volume of vehicles that enter andexit from each direction and possible combination.

LOT1 surveys were carried out for 24 hours on 2 consecutive days at 2 counting stationsinMlandizi and Chalinze from 18th to 19th December 2022.

LOT2 surveys were conducted for 7 consecutive days at a counting station in Morogoro from14th to 20th December 2022. Five counts were done for 16 hours on weekdays, two countswere done for 24 hours (one on a weekday and one on a weekend). The remaining 5 dayswere surveyed for 16 hours.

The counting procedure is exactly the same as the classified counts (Mid-block) while theclassification of vehicles was simpler, including only Cars, Buses, Light Trucks, and Heavy Trucks. A survey team for a three-leg intersection had 6 surveyors and 1 supervisor, while a normalfour-leg intersection had 12 surveyors and 1 supervisor.

*<Figure 3-26: Intersection study>*

| 4 leg intersection | 3 leg intersection | 4 leg intersection dualcarriageway | Index |
|---|---|---|---|
|  |  |  | At each Intersectionthe movements weredescribed as follows<br>A – Left Turn<br>B – Straight<br>C – Right Turn |

&**Data entry**

Specially formatted Microsoft Excel sheets were used to assist the input the survey data fromthe survey forms while performing a number of checks to ensure data conformed to thedefined relationship and stored checking procedures in the databank system.

Immediately after the data was delivered to SCL, data entry clerks checked and arranged thesurvey forms before entering the data into the computer database.

&**Pedestrian and animal crossing survey**

For the pedestrian and animal crossing survey, the methodology involved several activities.

- Deskwork to identify key stakeholders
- Obtaining animal census data from government agencies and institutions
- Conducting interviews with livestock and ranch officials in Kibaha and Chalinze districtsin the Coast region, and Morogoro district in the Morogoro region
- Drive through from Kibaha to Kipera to confirm cattle crossing points and also interviewing cattle keepers along the TANZAM Highway

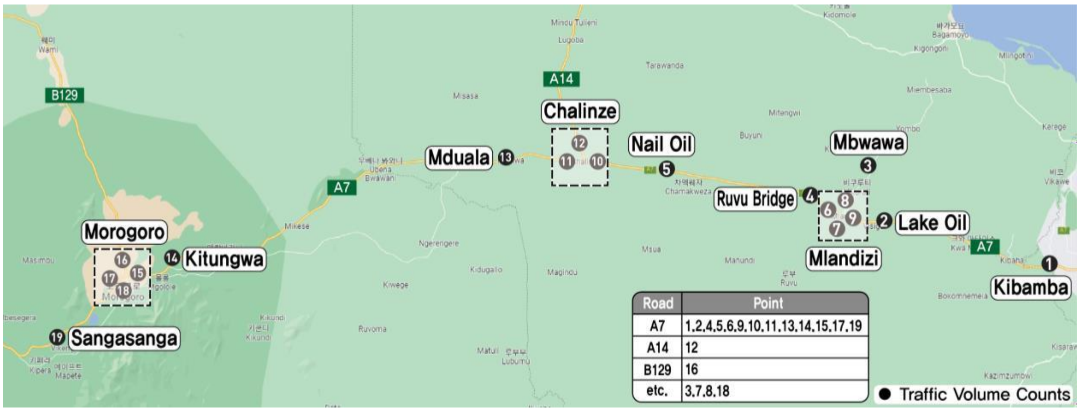
### 3.9.5 Traffic Survey Analysis

&**Traffic volume counts**

The traffic volume count results are as follows:

- The characteristics of the A7 road are similar to the project road (Kibaha to Morogoroexpressway).
- Therefore, it was necessary to select the points corresponding to the A7 road from among the traffic survey points.
- The result of the selection is shown in the following figure.
- Point 1(Kibaha) has the highest traffic volume of 19,198 vehicles per day.
- Point 15(Morogoro) has the second highest traffic volume with 19,057 vehicles/day.
- Point 19(Sangasanga) has the lowest traffic volume with 5,353 vehicles/day.

*<Figure 3-27: Traffic Volume Counts Survey Points>*

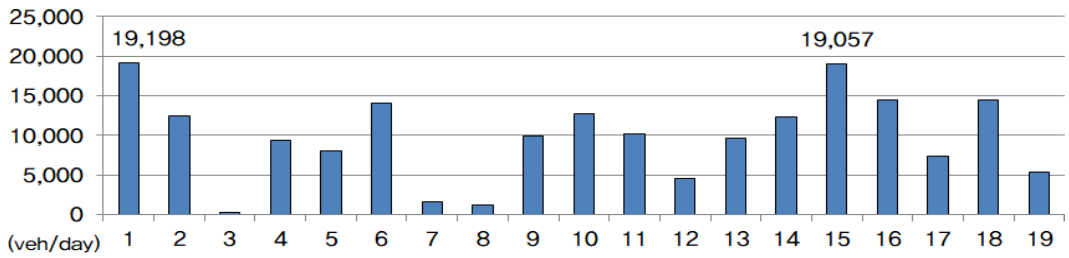


<Table 3-57: Traffic Volume Counts by Survey Points>

| Point | Traffic Volume(veh /day) | Point | Traffic Volume(veh /day) | Point | Traffic Volume(veh /day) |
|---|---|---|---|---|---|
| 1 | 19,198 | 8 | 1,261 | 15 | 19,057 |
| 2 | 12,501 | 9 | 9,897 | 16 | 14,457 |
| 3 | 266 | 10 | 12,685 | 17 | 7,416 |
| 4 | 9,363 | 11 | 10,184 | 18 | 14,457 |
| 5 | 7,975 | 12 | 4,523 | 19 | 5,353 |
| 6 | 14,074 | 13 | 9,697 | - | - |
| 7 | 1,635 | 14 | 12,352 | - | - |

(Note : The traffic volume is applied by ADT)

<Figure 3-28: Traffic Volume Counts by Survey Points>

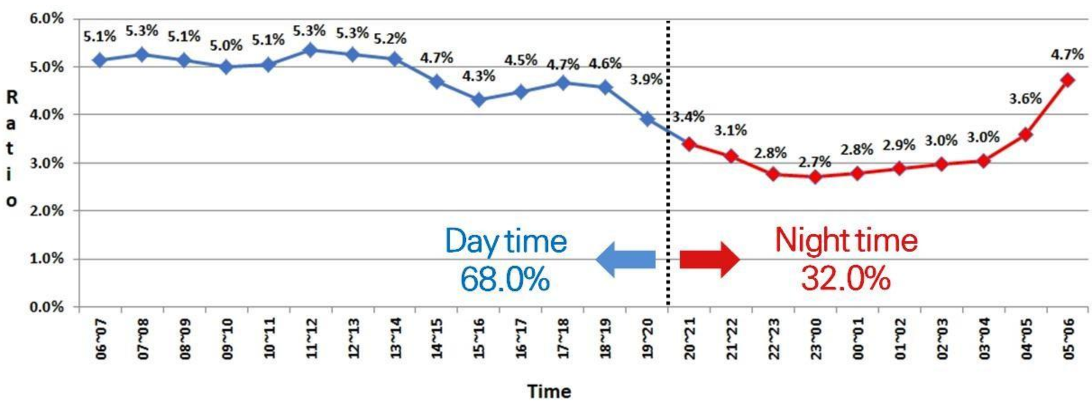



&**Traffic volume by time**

The traffic volume is the sum of traffic volume of the survey points corresponding to the A7road.

- The analysis showed that the traffic volume remained relatively stable between 5.0%and 5.3% from 06:00 to 14:00., with no distinct ratio for peak hour
- During nighttime hours, the traffic volume between 2.7% and 4.7%.
- The share of day time and night time traffic was found to be 68.0% and 32.0%,respectively.

<Figure 3-29: Traffic Volume By Time>



&**Traffic volume by vehicle type**

The values of table below are the sum of traffic volume of the survey points corresponding tothe A7 road.

- The ratio of passenger cars is 37.9%, while that of buses is 17.7%.
- In terms of goods vehicles, the ratios of light trucks, medium trucks, heavy trucks, andtrailer trucks are 3.1%, 5.5%, 7.1%, and 28.7%, respectively.

*<Table 3-58: Traffic Volume by vehicle type>*

| Classicfication | Car | Bus | Goods vehicle | | | | Sum |
|---|---|---|---|---|---|---|---|
| | | | Light truck | Medium truck | Heavy truck | Trailer | |
| Traffic volume (veh/day) | 54,402 | 25,418 | 4,412 | 7,936 | 10,149 | 41,199 | 143,516 |
| Ratio | 37.9(%) | 17.7(%) | 3.1(%) | 5.5(%) | 7.1(%) | 28.7(%) | 100.0(%) |

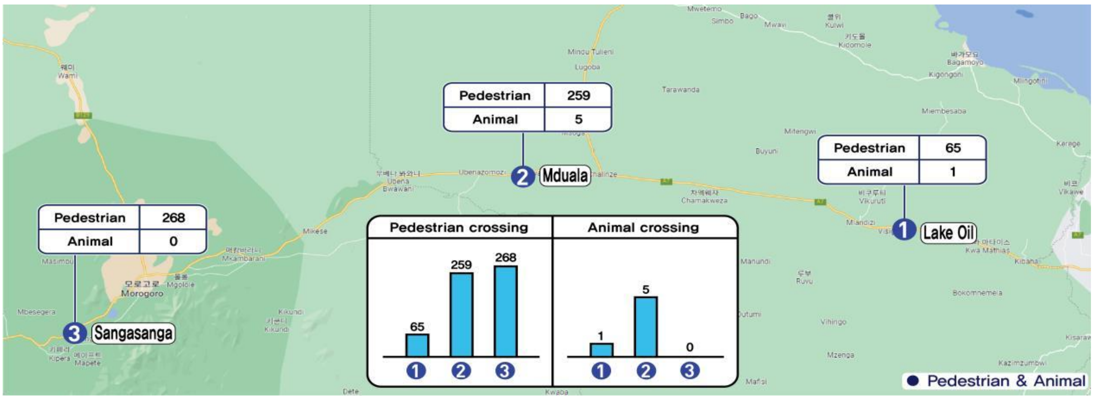
*(Note : The traffic volume is applied by ADT)*

&**Pedestrian and animal crossing surveys**

The results of pedestrian and animal crossing are as follows:

- The number of pedestrians crossing at every survey point is not large, with less than300 people/day, and there were very few animals observed during the survey.
- Sangasanga has the largest number of pedestrians with 268, but no animals were observed.

*<Figure 3-30: Pedestrian and animal crossing surveys points>*




*<Table 3-59: Amount of pedestrian and animal crossing>*

| Classicfication | Pedestrian crossing (person/day) | Animal crossing (animal/day) |
|---|---|---|
| Lake Oil | 65 | 1 |
| Mduala | 259 | 5 |
| Sangasanga | 268 | 0 |

&Speed delay surveys

The result of speed delay surveys are as follows:

- The closer to Dar es Salaam, the lower the driving speed is and the same for Morogoro.
- The Mbezi-Kibaha section has the lowest driving speed, which ranges from 15.3km/hto 26.1km/h.

*<Figure 3-31: Speed delay surveys point and results>*


*<Table 3-60: Speed delay surveys results>*

| Classification | | | | | Speed (km/h) | | | |
|---|---|---|---|---|---|---|---|---|
| Section | Length | Direction | Time | Attempt | 11-12-2022 | 12-12-2022 | 18-12-2022 | 19-12-2022 |
| A | 16.1km | Mbezi → Kibaha | AM PEAK | 1st | 16.9 | 15.3 | - | - |
| | | | | 2nd | 26.1 | 21.0 | - | - |
| | | | PM PEAK | 1st | 23.0 | 18.9 | - | - |
| | | | | 2nd | 17.9 | 24.2 | - | - |
| | | Kibaha → Mbezi | AM PEAK | 1st | 22.0 | 17.9 | - | - |
| | | | | 2nd | 25.4 | 16.9 | - | - |
| | | | PM PEAK | 1st | 22.5 | 18.9 | - | - |
| | | | | 2nd | 22.5 | 22.5 | - | - |
| B | 28.5km | Kibaha → Mlandizi | AM PEAK | 1st | 26.3 | 34.2 | - | - |
| | | | | 2nd | 30.5 | 24.4 | - | - |
| | | | PM PEAK | 1st | - | - | 22.8 | 23.8 |
| | | | | 2nd | - | - | 31.1 | - |
| | | Mlandizi → Kibaha | AM PEAK | 1st | - | - | 19.4 | 22.8 |
| | | | | 2nd | - | - | 28.0 | - |
| | | | PM PEAK | 1st | 27.6 | 31.7 | - | - |
| | | | | 2nd | 31.1 | 27.1 | - | - |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C | 44.2km | Mlandizi → Chalinze | AM PEAK | 1st | - | - | 37.9 | 33.6 |
| | | | | 2nd | - | - | 40.2 | 56.4 |
| | | | PM PEAK | 1st | - | - | 51.0 | 36.8 |
| | | | | 2nd | - | - | 39.6 | 39.6 |
| | | Chalinze → Mlandizi | AM PEAK | 1st | - | - | 27.6 | 41.4 |
| | | | | 2nd | - | - | 26.5 | 39.6 |
| | | | PM PEAK | 1st | - | - | 44.2 | 25.0 |
| | | | | 2nd | - | - | 44.2 | 44.2 |
| D | 83.3km | Chalinze → Morogoro | AM PEAK | 1st | - | - | 30.1 | 34.2 |
| | | | | 2nd | - | - | 30.7 | 43.5 |
| | | | PM PEAK | 1st | - | - | 40.0 | 45.4 |
| | | | | 2nd | - | - | 41.0 | 41.7 |
| | | Morogoro → Chalinze | AM PEAK | 1st | - | - | 31.2 | 43.5 |
| | | | | 2nd | - | - | 29.8 | 44.2 |
| | | | PM PEAK | 1st | - | - | 36.0 | 29.6 |
| | | | | 2nd | - | - | 51.5 | 45.4 |
| E | 23.6km | Morogoro → Kipera | AM PEAK | 1st | - | - | 15.7 | 15.7 |
| | | | | 2nd | - | - | 26.7 | 19.1 |
| | | | PM PEAK | 1st | - | - | - | - |
| | | | | 2nd | - | - | - | - |
| | | Kipera → Morogoro | AM PEAK | 1st | - | - | - | - |
| | | | | 2nd | - | - | - | - |
| | | | PM PEAK | 1st | - | - | 24.8 | 29.5 |
| | | | | 2nd | - | - | 24.8 | 20.8 |

## 3.11 Summary of Baseline Design

### 3.11.1 Design Standards

The design basis should be established as guidelines for the implementation of theengineering design, and must at least include the selection of design speed, final alignmentalternative, typical cross section standards, and final pavement construction option anddrainage rehabilitation principles.

The same design standards approved in Lot-1 were applied to this project and details are asfollows.

*<Table 3-82: Applied Design Criteria>*

| Description | Design Criteria | Nationality | Apply |
|---|---|---|---|
| | • Road Geometry Design Manual (MoWT1), 2011) | Tanzania | ◎ |
| | • Code of Practice for Geometric Design of Trunk Roads(Draft) (SATCC2), 1998) | South Africa | reference |
| | • Korea Expressway Corporation Standard (Interchange, Toll plaza and Rest Area) | Korea | ◎ |

| | | | |
|---|---|---|---|
| Geometric/Traffic | • A Guide to Traffic signing by MOID 2009 | Tanzania | ◎ |
| | • HCM 7th Edition (Traffic Analysis) | USA | ◎ |
| | • KHCM2013 | Korea | reference |
| Pavement | • Pavement and Materials Design Manual (MoWT, 1999) | Tanzania | ◎ |
| | • Pavement Design Manual, Volume II Rigid Pavements 2013 | Ethiopia | ◎ |
| | • AASHTO Standard for Pavement | USA | reference |
| Structure | • British Standards BS 5400 | U.K | ◎ |
| | • BS EN Code for Structural Design : BS EN 1991, BS EN 1992, BS EN 1998 | U.K | ◎ |
| Hydrology /Hydraulics | • TRRL3) East African Flood Model | U.K | ◎ |
| Ancillary | • The Guide to Traffic Signing (MOID4), 2009) | Tanzania | ◎ |
| Specification | • Standard Specifications for Road Works (MoWT, 2000) | Tanzania | ◎ |
| Surveying | • Land Survey and Mapping StandardsofTanzania(Land Surveying Regulations CAP 390)<br>• Field Testing Manual 2003 | Tanzania | ◎ |
| Testing Procedure | • Laboratory testing manual, 2000, Ministry of Works, Tanzania | Tanzania | ◎ |

*1) MOWT : Ministry of Works and Transport*
*2) SATCC : Southern Africa Transport and Communications Commission*
*3) TRRL: Transport and Road Research Laboratory*
*4) MOID : Ministry of Infrastructure Development*

### 3.11.1.1 Geometric Design Standard

As shown in the Table above, the 'Road Geometry Design Manual (MoWT, 2011)' was appliedas a geometry design standard according to the RFP. And in case that if the 'Road Geometry Design Manual (MoWT, 2011)' is deemed insufficient, the Korea Expressway CorporationStandard, which is currently used in Korea, was applied and was mainly reflectedininterchanges, toll plazas, and rest areas. In this case, South African design standards were alsoreferred to, and efforts were made to select standards suitable for local conditions.

As for the traffic analysis, to determine the number of lanes for the mainline as well as ramps,HCM 7$^{TH}$(USA) and KHCM 2013(Korea) since there are no particular manual for theexpressway in Tanzania.

The road class and design speed, which are the key to the geometric design of the road, wasdetermined as follows.

▌ Road Classification

The classification of the roads based on the two fundamental transportation functions are thekey elements of the access control plans and the decisions on the design criteria. The projectroad is intended to form a gateway to the Central, Northern and Southern road corridors ofTanzania, which provide access to neighboring countries of Kenya, Uganda, Rwanda, Burundi,Zaire, Zambia and Malawi. Therefore, it should be classified as the highest grade, and also,based on the estimated AADT of the target year is more than 8,000 vehicle per day, thereforethe Project is classified as a design class A (DC 1.)

The relationship between Road Design Class and Functional Class as shown in RGDM (MoWT,2011) are as follows;

*<Table 3-83: Linkage between Road Design Class and Functional Class>*

| Road DesignClass | AADT in Designyear | Functional Class | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| DC 1 | > 8000 | | | | | |
| DC 2 | 4000 – 8000 | | | | | |
| DC 3 | 1000 – 4000 | | | | | |
| DC 4 | 400 – 1000 | M | | | | |
| DC 5 | 200 – 400 | | M | | | |
| DC 6 | 20 – 200 | | | | | |
| DC 7 | 20 – 50 | | | | | |
| DC 8 | < 20 | | | | | |

## Design Speed

The design speed is one of the fundamental elements in determining the criteria for the roadgeometric design. Also, when establishing road alignment, it directly affects the decisions onthe limits of alignment elements, as well as the comfort of the drivers on the road. Therefore,when determining the design speed, the topology of the terrain, the traffic volume, and thefunctional class of the road should be contemplated sufficiently.

Also, in order to ensure successful connections with the existing road network, the designspeed at the connecting roads should also be considered.

The following is the design speed by the road design class as suggested in RGDM (Mow), 2011.

*<Table 3-84: Design speed for Various Road Design Classes>*

| Design Class | Carriageway width(m) | Recommended design speed(km/h) | | | Minimum design speed(km/h) | | |
|---|---|---|---|---|---|---|---|
| | | Flat torolling | Rolling tohilly | Mountainous | Flat torolling | Rolling tohilly | Mountainous |
| DC 1 | 2×7.0 | 120 | 90 | 70 | 120 | 90 | 70 |
| DC 2 | 7.5 | 110 | 80 | 70 | 100 | 80 | 60 |
| DC 3 | 7.0 | 110 | 80 | 70 | 100 | 80 | 60 |
| DC 4 | 6.5 | 100 | 80 | 60 | 80 | 70 | 50 |
| DC 5 | 6.5 | 80 | 70 | 50 | 70 | 50 | 40 |
| DC 6 | 6.0 | 80 | 70 | 50 | 70 | 50 | 40 |

### 3.11.1.2 Structural Design Standard

The design Structural standards for bridge structures, box culverts, pipe culverts andlongitudinal drainage structures shall be according to British Standards (British Codes ofPractices), EURO codes, American Standards, Tanzania Standards and in some areas SouthAfrican Standards as stated below: -

## British Codes and Standards

BS 5400 -2000: British Code of Practice for Design and Construction of Steel, Concrete andComposite Bridges and Specifications for Loads, Materials and Workmanship. The Codecomprises the following Parts and Sections:

- Targeting specific parts of design and construction as follows: -
  - BS 5400 – Part 1: General statement
  - BS 5400 – Part 2: Specification for loads
  - BS 5400 – Part 3: Code of practice for design of steel bridges
  - BS 5400 – Part 4: Code of practice for design of concrete bridges
  - BS 5400 – Part 5: Code of practice for design of composite bridges
  - BS 5400 – Part 6: Specification for materials and workmanship, steel;
  - BS 5400 – Part 7: Specification for materials and workmanship, concrete, reinforcementand pre-stressing tendons.
  - BS 5400 – Part 8: Recommendations for materials and workmanship, concrete, reinforcement and pre-stressing tendons.
  - BS 5400 – Part 9: Code of practice for bearings
  - BS 5400 – Part 10: Code of Practice for Fatigue
  - BD 37/01: Code of Practice for Bridge loading - HA and HB loading for normal vehicle otherthan abnormal vehicle.
  - BS 8110 –1997: Structural use of concrete
  - BD 31: Design of Buried Box Culverts

    (Design the in-situ concrete culvert shown below to carry HA and HB Loading is adopted for analysis of the box culvert based on the class of the road being designed. For expressway HB45 (45 Units) shall be adopted)
  - BS 1377, 1990: Methods of Testing for Soils for Civil Engineering Purposes
  - BS8004: Code of Practice for Foundation
  - BS 4449: Hot rolled steel bars
  - BS 4461: Cold worked steel bars
  - BS 4482: Hard drawn mild steel wire
  - BS 4483: Steel fabric reinforcement
  - BS 4466: Bar schedule dimensions; cutting and bending. Reinforcement
  - BS 5930: Code of practice for site investigation
  - BS 5975:Code of practice temporary works procedures and the permissible stress designof falsework
  - BS 8002: Code of practice for earth retaining structures for
  - BS 5950-1:2000: Structural use of Steel in Buildings. Code of practice for design — Rolledand welded sections
- Euro Codes and Standards
  - BS EN 1997 (EUROCODE 7) - Geotechnical design

- BS EN 1998 (EUROCODE 8) - Design of the structures for earth quake resistance
- EUROCODE 7): Code of Practice for Foundation
- EUROCODE 8: Design of structures for earthquake resistance
- BS EN 1536P: Execution of special geotechnical works – Bored piles
- BS EN 1992: Eurocode 2: Design of concrete structures
- BS EN 1993: Eurocode 3: Design of steel structures
- Eurocode 7: Geotechnical design – Part 1: General Geotechnical design, Part 2: Ground investigation and testing (incorporating corrigendum 2010)

- Material
  SpecificationsConcr
  ete

- C15/20 - Blinding Concrete
- C40/20 - Bridge Deck Slab and Concrete Beams
- C40/20 - Pears, Abutment and Pile cap
- C40/20 – Bridge Pre-stressed Beams
- C40/20 – Foundation- Cast In-situ Concrete Bored Piles
- C40/20 – Foundation- Precast Concrete Bored
- C30/20 – Concrete Box Culverts
- C30/20 – Concrete Pipe Culverts
- C25/20 – Concrete for Longitudinal Open Drains

Steel Reinforcement

- High Yield Strength Bars G50
- Steel Fabric Reinforcement to BS4483

Pre-Stressing Strands

- High Tensile Strands : Common Size: 12.7mm 15.24mm, 7.94mm-28.6mm
- Standard :GB/T5224,ASTM416,BS5896,JIS G3536,UNE 36094,KS D,AS/NZS4672

Structure And Size:1×7wires - 9.5/11.1/12.7/15.2/15.7/17.8/21.6 mm

- Good performance characteristic:
- high tensile strength and elongation;

low relaxation value; - small stress losing; excellent durable anti-fatigue performanceSteel Structural Works

- BS 5950-1:2000 : Code of practice for design — Rolled and welded sections

Guard Rails

- Highway Galvanized Guardrail to AASHTO M180-08, EN1317-2, W beam, U-Post, Bolts andNuts, Metal Reflectors to

Gabions Walls and Mattresses

- The design of gravity retaining walls - gabion earth retaining walls complying to Eurocode 7Clause 9 and Clause 4 and Clause 5 of BS8002:20153.4.3 Pavement Standards
- Pavement will be designed following guidelines presented in following manuals developedby Tanzanian Ministry of Works
  - Pavement and Materials Design Manual, 1999

- Interim guideline for Design of Hot-Mix Asphalt, 2018
- Field Testing Manual, 2003
- Laboratory Testing Manual, 2000
- Other manuals/guidelines found to be relevant, i.e., BS, AASHTO, Road Note, etc3.

### 3.11.1.3 Geotechnical Design Standard

- Codes of Practice adopted:
  - BS EN 1997-1: 2004 – Code of Practice for Eurocode 7: Geotechnical design
- Design requirement
  - **Design situation**

Short term and long-term consideration

- applied load cases and load combination, general stability of the ground carrying
- the structure, soil material or rock supporting the structure, condition of the rock
- fracture, faults, weathering, cavities. Environment including erosion, scour,
- effect of chemical corrosion.

- Durability

Durability of the structure with respect to environmental condition to

- be assessed in order to provide protection for material used such as concrete
- sulphate resistance cement, protection of steel reinforcement from corrosion.

- Pile Foundation

The section apply to end bearing piles, friction piles, tension plies and transversely loaded piles.

The section incorporates the following standards: -

- EN 1536: 1999 for bored piles
- EN 12063: 2020 for sheet piles
- EN 12699:2000 for displacement piles
- EN 14199: Execution of special geotechnical works- Micropiles

- Limit State is to be considered for :- Loss of overall stability,

Bearing resistance failure of the pile foundation, uplift or insufficient tensile resistance of the pile, structural failure of the pile due in compression, tension, bending or shear, combinedfailure of the ground and in the pile foundation,

Excessive settlement, excessive heave, excessive lateral movement. These are some ofimportant items to be considered

- Design consideration

Single pile design and pile group design

- Pile load test
  - Static load test
  - Dynamic load test

Both load test should be considered to obtain reliable information of pile design

- Estimation of axial load capacity of Bored Piles

The ultimate axial capacity (Qult) of bored pile is determined as follows:- for compression anduplift loading, respectively:

- Qu = Qs + Qt
- where: Qu = total ultimate axial capacity of the foundation
- Qs = ultimate skin friction capacity
- Qt = ultimate end bearing or base tip

capacityFor Bored Piles in Cohesive and non-

cohesive soils:-

- Ultimate Load Carrying of the pile (Pult) = Shaft Friction (Ps) + End Bearing (Pb)
- Allowable working load of the pile = Pult / FS, Factor of safety (FS) of 3 is considered

### 3.11.2 Geometric Design

### 3.11.2.1 Main Road

Geometric design was carried out in compliance with the Road Geometric Design Manual(RDGM) published by Ministry of Works and Transport, Tanzania. In addition, the Standard ofKorea Expressway Corporation was also referred to the detailed specification for expresswaydesign such as intersections, toll plazas and rest areas which are not specified in Tanzaniandesign standard.

*<Table 3-85: Applied Road Geometric Criteria for the Main Road>*

| Description | | Unit | RGDM (MoWT,2011) | RSFS (MLTM,2009) | AASHTO (2004) |
|---|---|---|---|---|---|
| Type of the road | | | Trunk Road (Class A) | Expressway | Expressway |
| Road Class | | | DC 1 | - | - |
| Region | | | Flat ground | Flat ground | Flat ground |
| Design Speed | | km/h | 120 | 120 | 120 |
| Min. Curve Radius | | m | 780 (760) | 710 | 756 |
| Min. Curvaturel ength | 5° or above | m | - | 140 | - |
| | 5° or less | m | - | 700/Θ | - |
| Max. vertical Gradient | | % | 3 | 3 | 3 |
| Min. Vertical | Crest | m/% | 201 | 120 | 95 |
| | Seg | m/% | 74 | 55 | 63 |
| Description | | Unit | RGDM (MoWT,2011) | RSFS (MLTM,2009) | AASHTO (2004) |
| Curve Change ratio | | | | | |
| Min. Vertical Curve Length | | m | - | 100 | - |
| Stopping Sight Distance | | m | 285 | 215 | 250 |
| Passing Sight Distance | | m | 792 | - | - |
| Lane width | | m | 3.50 | 3.25 ~ 3.50 | 3.3 ~ 3.6 |
| Median Width | | m | 9.0 ~ 12.0 | 3.0 | 1.2 ~ 30 |
| Min.Shoulder | Right | m | 2.5 | 2.0 ~ 3.0 | 0.6 ~ 3.6 |
| | Left | m | 0.9 | 0.75 ~ 1.00 | 0.6 ~ 3.6 |
| Application | | | ◎ | | |

** RSFS : Regulations for structure & Facility standard of the road (MLTM, 2009, Korea)*

### 3.11.2.2 Interchanges

The design speed of interchange is a critical factor of its size and geometric standards.Thedesign speed of a ramp should be related to the design speed of the through and intersectingroads, and should preferably not be less than the through road. Ramp speed can, however,gradually be reduced to half of the through road under restricted circumstances.

▮ Proposed design speed for ramps

Proposed design speeds are appropriate and now using in the Korea for toll interchanges and,proposed speeds for interchanges' ramps have been judged efficiently in the aspect of costseffective and environmental aspect by reducing size of interchanges. Following table ispresented for ramp design speed.

*<Table 3-86: Proposed design speed for ramps>*

| Classification | Ramp(km/h) | Remarks |
|---|---|---|
| Tollgate | 30 | Interchanges and Main road |
| Loop Ramp | 40 | Trumpet Type |
| Diamond Ramp | 40 | Diamond Type |
| Semi-directional Ramp | 50 | Trumpet Type |
| Directional Ramp | 80 | Direction Type |

▮ Minimum curve Radii

Based on the recommended design speed of 30km/hr, 40km/hr, 50km/hr and 80km/hrespectively the following minimum radii have been adopted

*<Table 3-87: Minimum radii for design of roads for most common design speeds>*

| Design Speed(km/h) | Minimum Radii of Curves (m) | | |
|---|---|---|---|
| | Desirable | Absolute(Calculated) | |
| | | $E_{max}$ =0.08 | $E_{max}$ =0.06 |
| 30 | 50 | 28 | 31 |
| 40 | 75 | 50 | 55 |
| 50 | 100 | 82 | 90 |

| Design Speed(km/h) | Minimum Radii of Curves (m) | | |
|---|---|---|---|
| | Desirable | Absolute(Calculated) | |
| | | $E_{max}$ =0.08 | $E_{max}$ =0.06 |
| 80 | 300 | 229 | 252 |

The maximum rate of super elevation for paved road shall be 0.08(8%) for flat, rolling andhilly terrain and 0.06(6%) for mountainous terrain. Project area is laid on flat area but, rampson the interchanges should access between expressway and existing road by a gradeseparated intersection form with a short distance and curve for securement of efficiency ofcosts effectiveness. To ensure of stability of driving about centrifugal force on the small radiusin this circumstance, it is appropriate to adopt 8% of super elevation.

▮ Vertical alignment

Project road traverses flat areas but, ramps of interchanges are showing differently from thecommon roads. Their terminals of both sides of ramps should connect between two roadscrossing by type of grade-separated intersection. Characteristics of ramp require a highergradient than the main route and make them to be identified as rolling and hilly terrain,although it is laid on a flat area.

Vertical gradient is therefore an extremely important criterion that greatly affects both theserviceability performance and cost of the road. These performance considerations haveformed the basic limiting criteria for gradients used in the design and are shown in table below.

*<Table 3-88: Maximum Grades(%)>*

| Terrain | Design Speed (km/h) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| Flat | | | 5 | 5 | 4 | 3.5 | 3 | 3 | 3 |
| Rolling | 8 | 7 | 6 | 6 | 5 | 4.5 | | | |
| Hilly/ Mountainous | 10 | 9 | 8 | 7 | 7 | | | | |

Application of minimum rate of curvature(K-values) for vertical curves are presented at thebelow table.

*<Table 3-89: Minimum rate of curvature (K-Values) for Vertical curves>*

| Design Speed(km /h) | K-Values to Safety Stopping sight distances(m / % of g) | | K-Values to SafetyStopping sight distances |
|---|---|---|---|
| | Crest | Sag | |
| 30 | 3 | 4 | 31 |
| 40 | 5 | 8 | 55 |
| 50 | 10 | 12 | 90 |
| 80 | 49 | 32 | 310 |

For implementation of the project, Consultant has considered economical point of view tocomplete it successfully, but consideration of safety has been ensured basically. Proposeddesign criteria of vertical alignment are following RDGM.

### Deceleration and acceleration lanes

The length of the auxiliary lane depends on the difference in speed between the ramp andthe main expressway, and the longitudinal gradient at the merge point at the mainexpressway is also considered.

Below table is described in RGDM, 2011

*<Table 3-90: Length of Deceleration Lanes (m)>*

| Design speed(km /h) | Ramp control speed(km/h) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | LT(m) | 0 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 80 | 75 | 125 | 115 | 75 | 55 | 30 | | | |
| 90 | 85 | 115 | 150 | 110 | 85 | 60 | 30 | | |
| 100 | 91 | 190 | 185 | 145 | 125 | 100 | 70 | 35 | |
| 110 | 101 | 235 | 225 | 185 | 165 | 140 | 110 | 75 | 40 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 120 | 107 | 280 | 270 | 230 | 210 | 180 | 155 | 120 | 85 |
| 130 | 111 | 325 | 320 | 275 | 225 | 230 | 200 | 170 | 135 |

*<Table 3-91: Length of Acceleration Lanes (m)>*

| Design speed(km/h) | Ramp control speed(km/h) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | LT(m) | 0 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 80 | 54 | 350 | 265 | 215 | 155 | 80 | | | |
| 90 | 64 | 450 | 360 | 310 | 250 | 175 | 95 | | |
| 100 | 70 | 550 | 460 | 415 | 350 | 280 | 200 | 105 | |
| 110 | 80 | 670 | 580 | 530 | 470 | 395 | 315 | 220 | |
| 120 | 86 | 790 | 700 | 655 | 595 | 525 | 440 | 350 | |
| 130 | 90 | 930 | 840 | 797 | 730 | 660 | 580 | 485 | |

70m of tapers have been presented for project by calculation of rate 1:15 with width 4m oframp. The result of 1:15 is 60m of length but, consultant considered 120km/h of expresswayto give drivers more smooth movement.

### 3.11.2.3 Typical Cross section of Expressway

▌Main Road

The determination of the number of lanes is based on traffic analysis and demand forecasting.During the previous DSM-Chalinze feasibility study (2017), the TA presented several scenariosthrough traffic analysis based on data collection of socio-economic indicators and future plansof the project area. And the appropriate number of lanes was determined through technicaland financial optimization of the project feasibility, traffic capacity, and service level oftheproject.

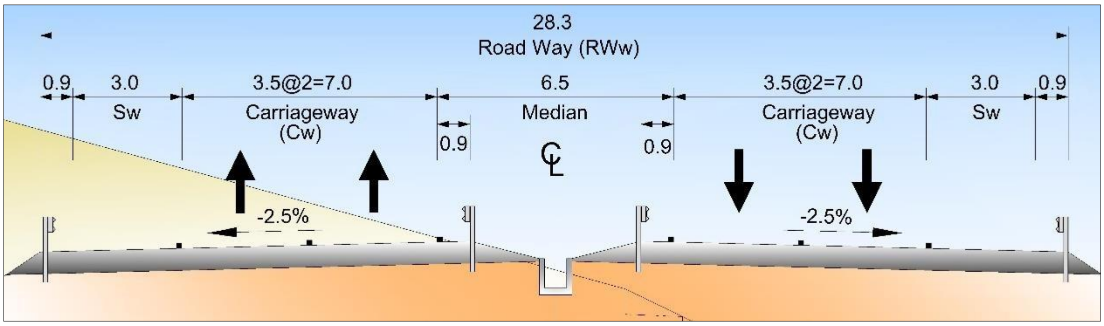
In this feasibility study, many factors that affect traffic demand forecasting have changedcompared to the previous ones. Therefore, TA re-performed overall tasks related to trafficdemand forecasting, including traffic surveys, and came to the conclusion that the applicationof 4-lane for the entire section was the most appropriate from a technical and financial point of view. More details on traffic demand forecasting are included in Section 3.8 and 3.9.

The application of typical cross-sectional configuration values were determined based on the'Road Geometric Design Manual (RDGM)' published by the Ministry of Works, and optimizedas follows by reflecting TA's experience.

*<Table 3-92: Applicate value for cross-section (main road)>*

| Description | | Unit | RGDM (MoW,2011) | Applicate Value |
|---|---|---|---|---|
| Lane width | | m | 3.50 | 3.50 |
| Median Width | | m | 9.00 ~ 12.00 | 6.50 |
| Min. Shoulder | Left | m | 2.50 | 3.00 |
| | Right | m | 0.90 | 0.90 |
| Outer Shoulder | | m | 0.90 | 0.90 |

*<Figure 3-39: Typical Cross Section (Main road)>*




## Ramps of Interchanges.

The number of lanes for ramps at interchanges was also calculated by traffic demandforecasting for each interchange, and two types of ramps were applied to Lot 1.

- 2-lane 2 direction (Dual carriageway)
- 1-lane 1 direction (Single carriageway)

The application of typical cross-sectional configuration values were determined based on the'Road Geometric Design Manual (RDGM)' and the contents not included in the RGDM referredto the Korea Expressway Corporation Standard.

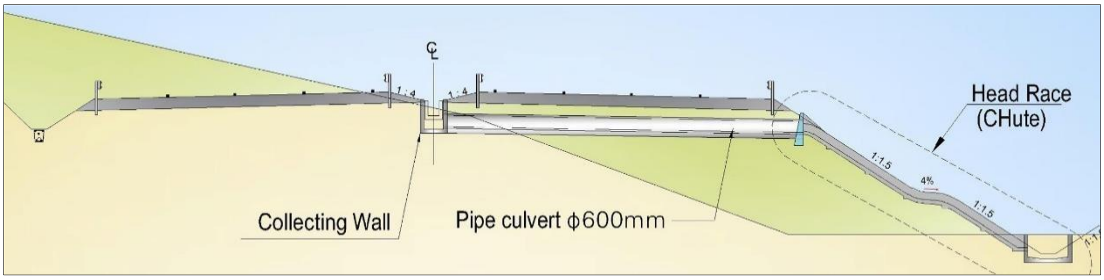
*<Table 3-93: Applicate value for cross-section (ramp)>*

| Description | | Unit | RGDM(MoWT,2011) | Applicate Value | |
|---|---|---|---|---|---|
| | | | | 2-lane 2 direction | 1-lane 1 direction |
| Lane width | | m | 4.00 | 4.00 | 4.00 |
| Median Width | | m | N/A | 2.50 | N/A |
| Min.Shoulder | Left | m | 2.00 | 2.00 | 2.00 |
| | Right | m | 2.00 | 0.50 | 2.00 |
| Outer Shoulder | | m | 0.90 | 0.90 | 0.90 |

## Drainage for Median

Typical cross section with V-shape of median is proposed for the main route, this type of median should be considered discharge of where the low points in median will be gatheredstorm water. Accordingly, collecting wall to concentrate water at one point, pipe culverts todischarge water and head race (chute) to prevent from scouring on the slope presented fortaking care of median discharge as shown below figure.

*<Figure 3-40: Drainage for Median>*




### 3.11.3 Route Identification

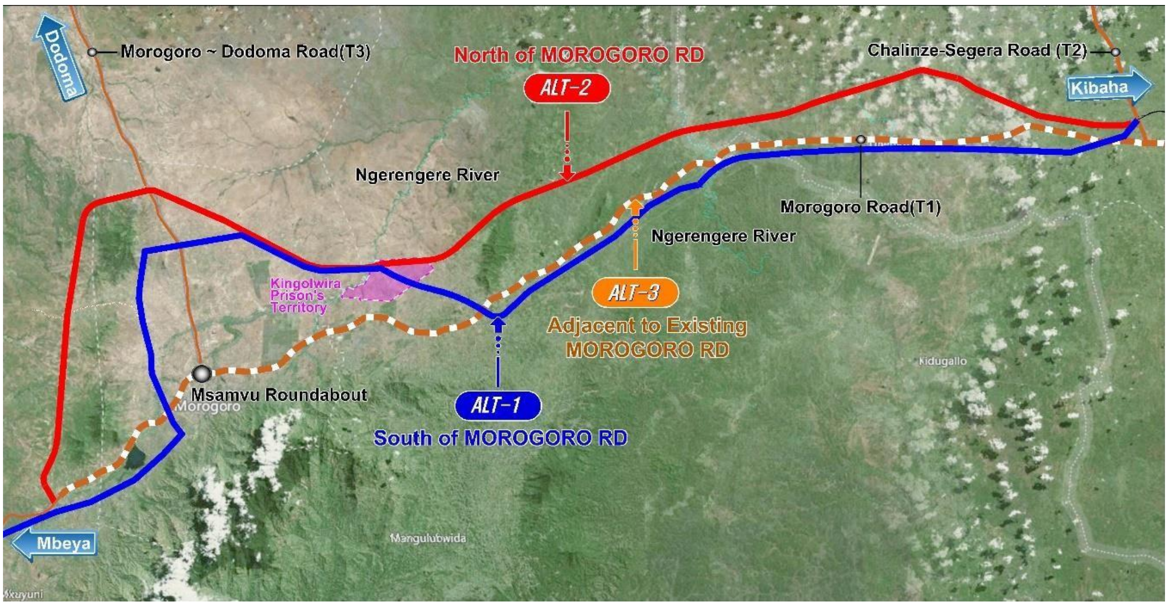
#### 3.11.3.1 Alternative Routes

In 2022, TECU developed three (3) route corridor alternatives for further studies between Chalinze and Morogoro as follows:

- Alternative 1: South of Existing Morogoro Road
- Alternative 2: North of Existing Morogoro Road
- Alternative 3: Adjacent to Morogoro Road

TECU conducted a compliance examination of the alternative routes and concluded that thenorthern bypass alternative of the existing Morogoro road (Alternative 2) was the mostsuitable route after conducting a thorough and multi-criteria comparative analysis. Theselection process for each section is outlined below.

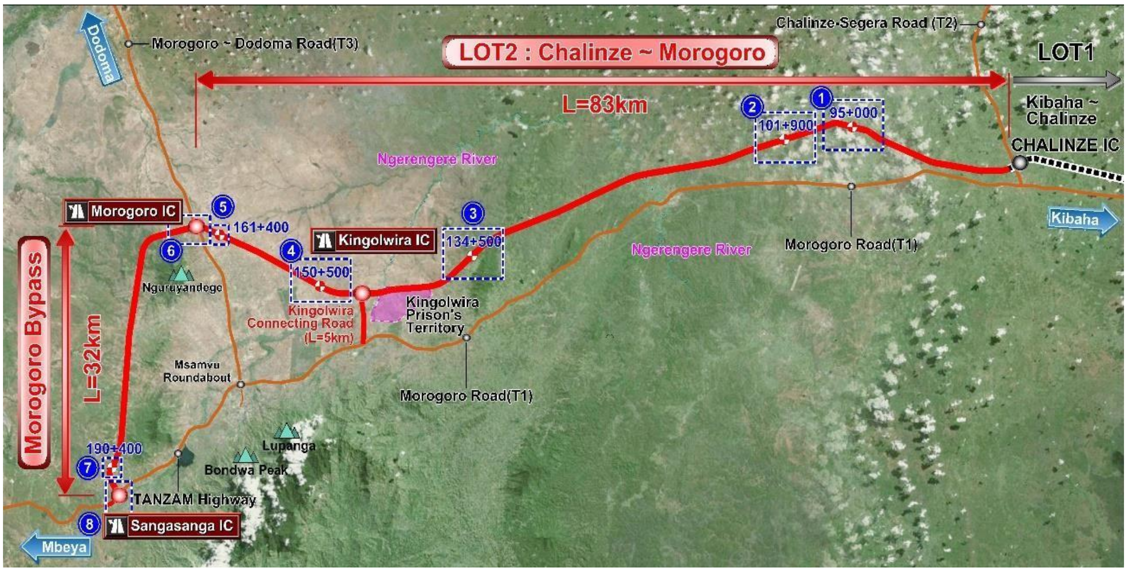
*<Figure 3-41: Proposed alternatives of alignments from Chalinze to Morogoro (LOT 2)>*



### 3.11.3.2 Selection and Adjustment of Preferred Route

After conducting the review on the 3 alternatives and deciding the preferred alignment whichis Alt-2 (North of Morogoro rd), the TA has identified 8 sections that require adjustment andupdating, as illustrated in the Figure below. While the majority of the adjustments are madeto optimize construction costs and there are not anticipated to have a significant impact onthe road's function or user’s convenience.

*<Figure 3-42: Status of Realignment of Pre-Feasibility Study by TECU (LOT 2)>*

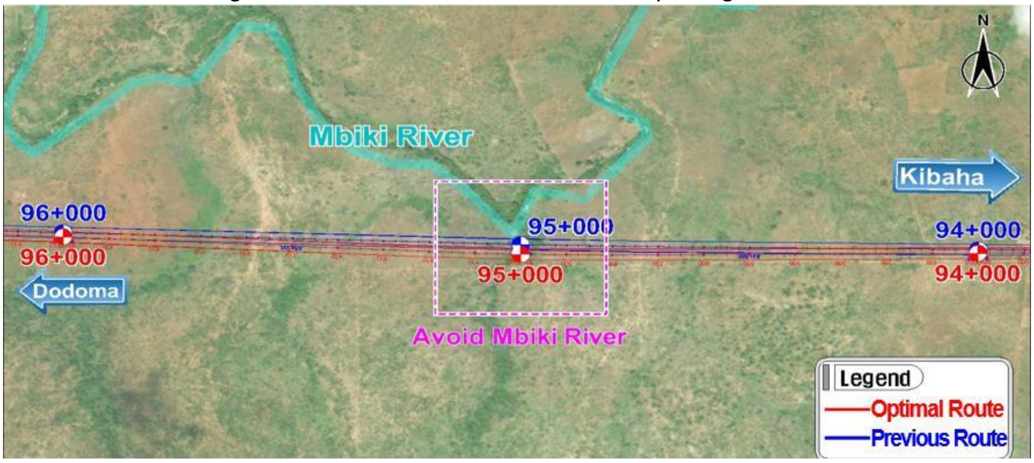



**Section 1: Preserve Mbiki River (Sta. 95+000)**

As this section runs very close to the Mbiki River, special attention was given to ensurethatthere would be no negative impact on the river or waterway. To achieve this, the routealignment was adjusted by shifting it towards the south, thereby avoiding any modification ofthe river or waterway.

This was done to ensure that the road construction would not interfere with the natural flow ofthe river and waterway, and to preserve their ecological balance. The modifications madeinthis section were aimed at minimizing the impact of the road construction on the surroundingenvironment, while also ensuring the safety and convenience of those who use the road.

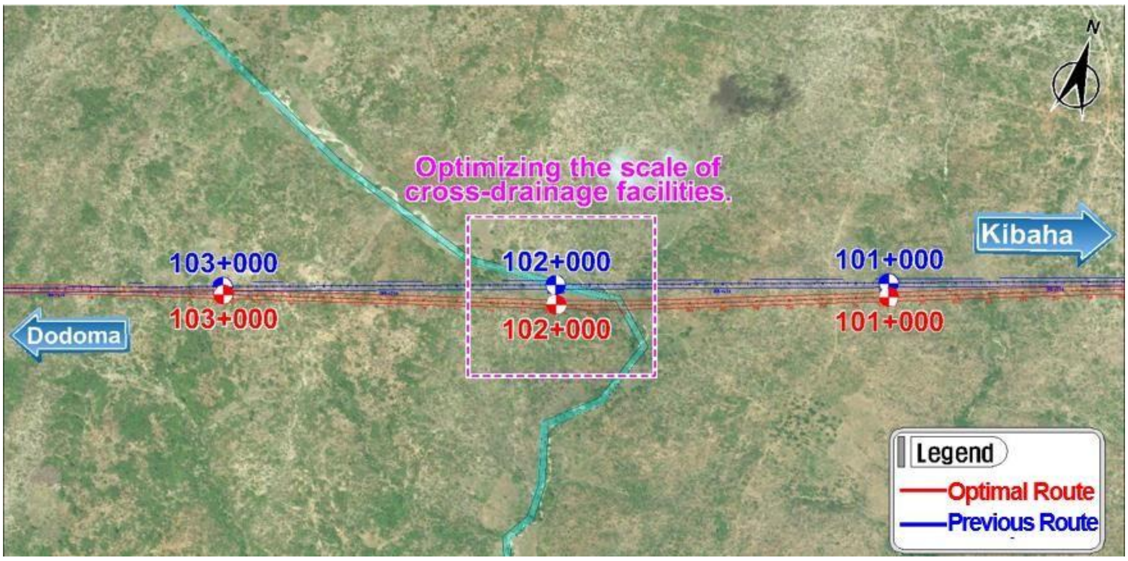
*<Figure 3-43: Section 1: Mbiki River near passage section>*



**Section 2: Optimizing the River Crossing (Sta.101+900)**

The proposed route crosses a seasonal river at STA.101+900 (Ubenazomozi area). However, thealignment of TECU implies the possibility of enlarging the drainage structure and altering thewaterway, as it crosses the river at a shallow angle. In light of this, TA has proposed an alternateroute that minimizing drainage structures and maintains the natural flow of the river.Thisproposed route involves a slight adjustment towards the south and crossing the stream atasclose to a perpendicular angle as possible.

*<Figure 3-44: Section 2: Stream passage section>*




**Section 3: Stream Near Passage Section (Sta.133+900 – 135+300)**

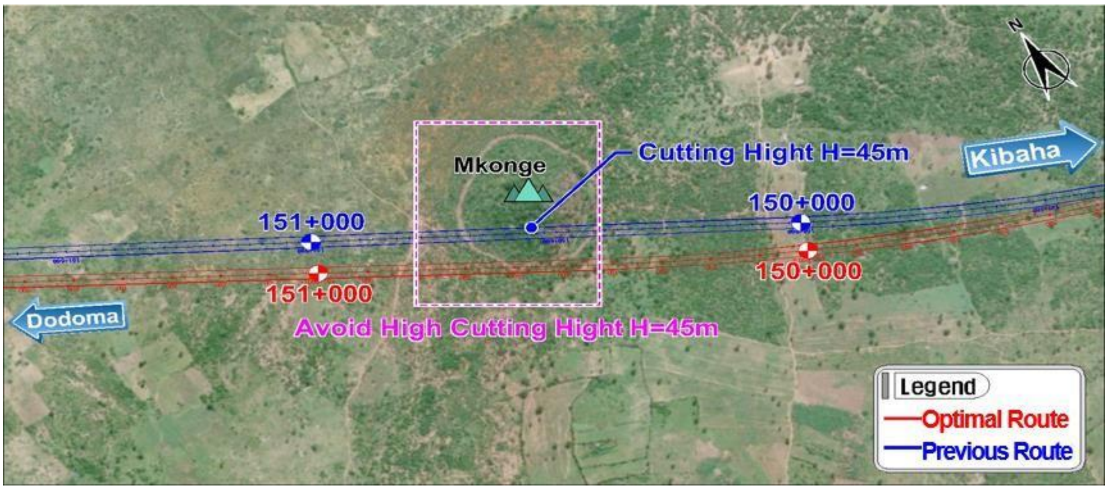
The TECU’s proposed route in this section runs parallel and close to the waterway. Whiletheroad's effective width does not encroach on the waterway, considering the embankment'sheight (approximately 4.0m), the waterway may still impact by the embankment. Therefore, TAhas adjusted the proposed route to the south, to preserve the natural flow of the waterway andminimize the impact of the embankment by the water, in order to ensure the road's stability.

*<Figure 3-45: Section 3: Stream near passage section>*

### Section 4: Hilly Area (Mt. Mkonge, 598m) (Sta.150+550)

TECU's proposed route intersects Mkonge Mountain directly at STA.150+550, requiringasignificant cut section of approximately 45m. This raised concerns regarding bothenvironmental impact and slope stability. As a solution, TA has adjusted the route to the southto avoid the impact of Mount Mkonge, reduced the maximum cutting height to 5.0m tominimize environmental damage, and addressed concerns about slope stability.

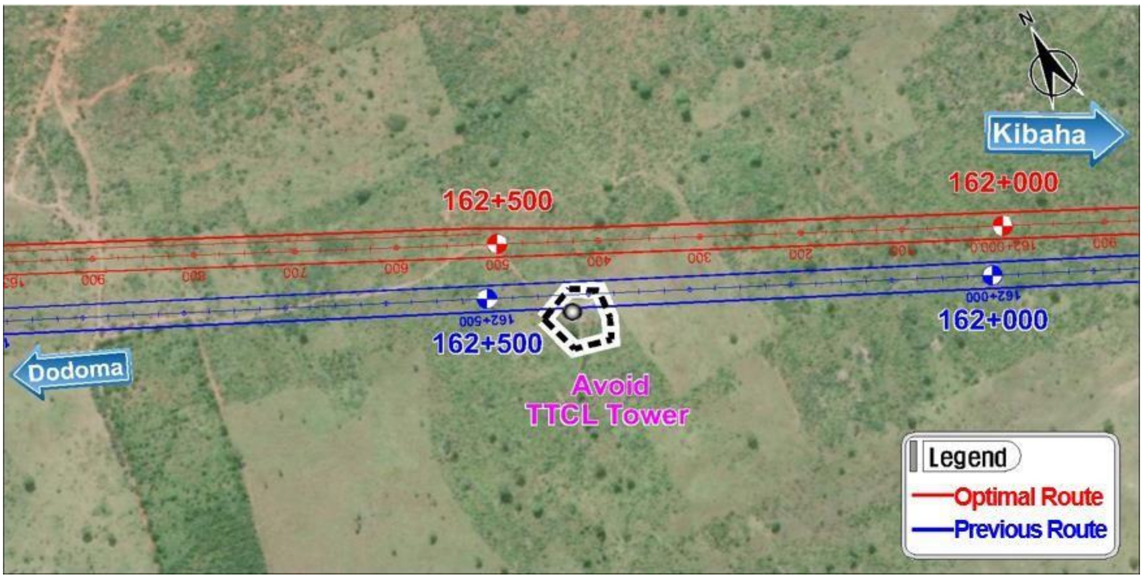
*<Figure 3-46: Section 4: Low mountain passage section>*




### Section 5: Tanzania Telecommunication Co.(TTCL) Tower Passage Section (Sta.162+400)

In this section of the route, TECU's proposed alignment conflicted with the existing TTCLcommunication tower. As a crucial facility, relocating the TTCL tower could cause temporarycommunication failures and potentially increase construction costs. Given that there issufficient available space nearby to avoid this conflict, TA has proposed a route that bypassesthe TTCL towers to the north.

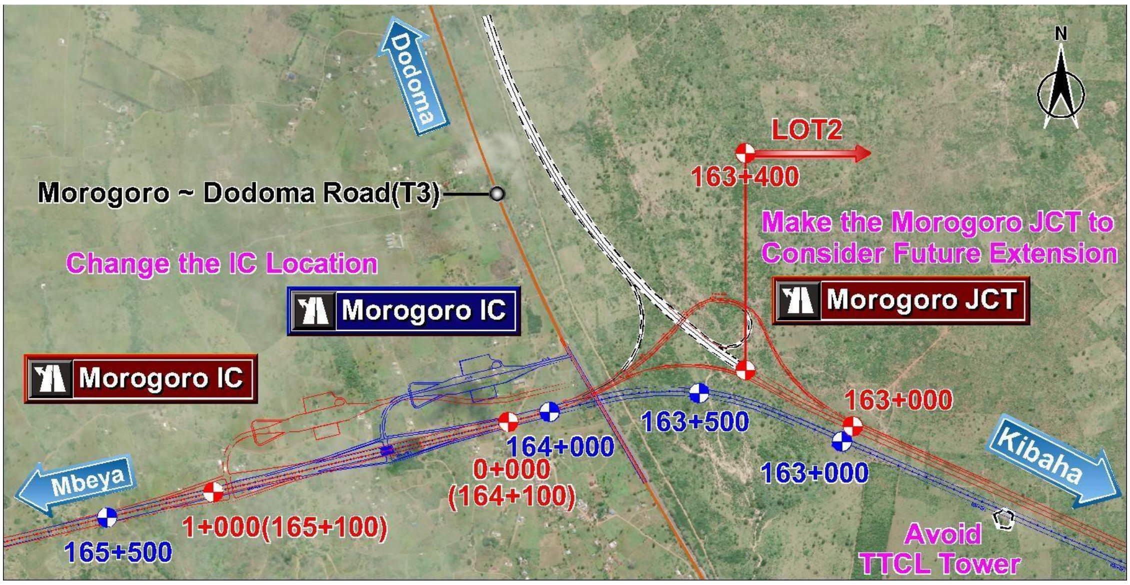
*<Figure 3-47: Section 5: TTCL Tower passage section>*



### Section 6: Morogoro IC Passage Section (Sta.163+000 – 165+500)

This section is the Morogoro Interchange passage, and considering that this road will be partof a corridor connecting to Dodoma in the future, the Morogoro Bypass road was adjusted byadding a junction to connect to the route that will enable the connection to Dodoma.Therefore, in this project, only the connection necessary for the Morogoro Bypass is plannedthrough the Morogoro junction, and the connection necessary for the route to Dodomawillbe implemented by the relevant concessionaire at a later stage.

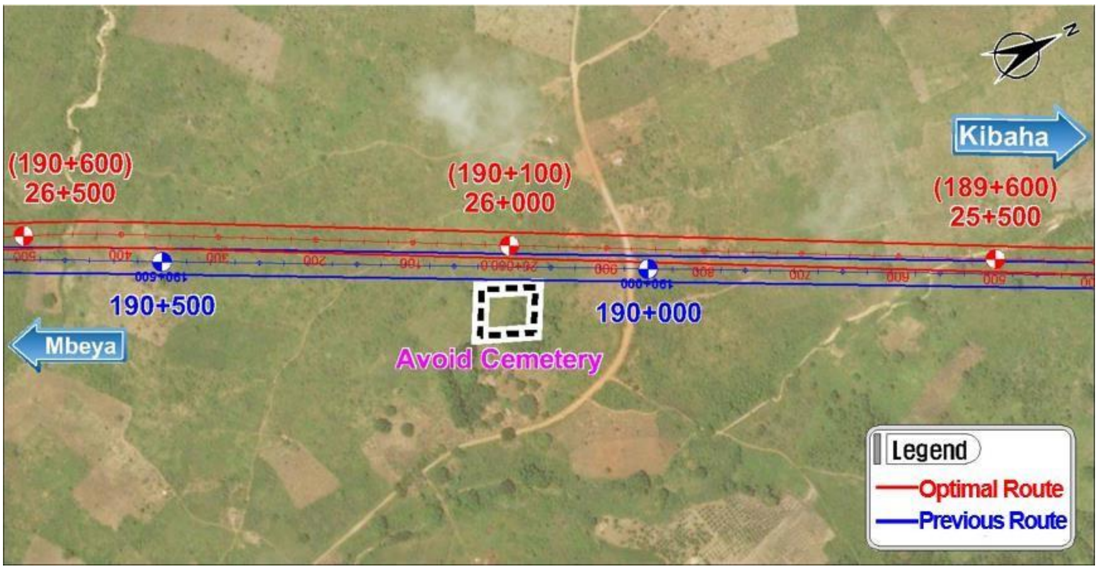
*<Figure 3-48: Section 6: Morogoro IC passage section>*




### Section 7: Cemetery Passage Section (Sta.190+140)

This section of the road passes in close proximity to the cemetery, which would be affectedby the construction. To minimize social impact, the route alignment was adjusted to bypassthe cemetery.

*<Figure 3-49: Section 7: Cemetery passage section>*



**Section 8: End Point (Sta.193+293)**

This section of the project is the endpoint of the task, where the Sangasanga Interchangeconnects to the Morogoro Road (T1). However, the Sangasanga Interchange is encroachingupon a nearby cemetery, causing social impact concerns. Additionally, a future route corridorconnecting to Mbeya is anticipated, so the route alignment was adjusted to bypass thecemetery and accommodate the future route connection at the Sangasanga Interchange.Therefore, in this project, only the connection to the Dodoma direction is planned for theSangasanga Interchange, and the necessary connections for future Mbeya route connectionswill be implemented by the relevant concessionaire.

*<Figure 3-50(a): Section 7: Cemetery passage section>*


Preferred Route Alignment

The below shows the preferred route alignment after adjusting the TECU's proposed route inconsideration of functional, environmental, and economic aspects.

*<Figure 3-50(b): Recommended Route Alignment (LOT 2)>*

### 3.10.3.2 Final Route for PPP Arrangement

After selecting the preferred route alignment, further discussion was made between theTAand the Client in the Interim report stage.

This is due to the fact that this project is under a public-private partnership (PPP) and it'scrucial to consider the financial aspect as well. Based on the traffic demand forecastingconducted by the TA, it was projected that the future traffic volume on the Morogoro bypasssection (Morogoro IC ~ Sangasanga IC) is notably lower than other sections within Lot-2. Thisdisparity could render the entire Project financially unaffordable.

In light of this evaluation, the TA recommended the exclusion of the Morogoro bypass sectionof 29km as the PPP arrangement. This recommendation was made with the intention ofensuring the overall affordability of the Project. Subsequently, the Client approved thisrecommendation, thus finalizing the decision.

The below shows the final route alignment under PPP arrangement.

*<Figure 3-51: Final Route Alignment under PPP (LOT 2)>*


### 3.11.4 Pavement Design

The pavement recommendations were developed following guidelines and tables set upinPMDM, while Ethiopian Design Manual for rigid pavements with traffic loading greaterthan50 million E80 were used.

**Traffic**

Traffic data were collected for each major section including traffic mix and composition. Fromthe data, it was observed that commercial vehicles represent significant percentages in thetraffic mix. Traffic projections used in this report was adopted from the economic study andanalysis for medium growth scenario.

Projected traffic volumes for buses and commercial vehicles extracted from economicanalysis report for various road sections and are summarised in the Table below.

*<Table 3-94: Projected traffic volume per day in year 2031 for both directions>*

| Road section | Buses | MGV | HGV | VHGV |
|---|---|---|---|---|
| Morogoro – Kingolwira | 2,710 | 316 | 651 | 2,405 |
| Kingolwira – Bwawani | 2,922 | 445 | 920 | 1,683 |
| Bwawani – Chalinze | 1,583 | 412 | 853 | 1,437 |

### Design Traffic

Traffic loading was obtained from analysis of traffic count data and a comprehensive forecastof traffic growth to provide specific pavement design inputs required in the detailed design.

Cumulative traffic was estimated based projected traffic volume over 20 and 30 years.Estimations were for the medium growth taken from the economic forecast and analysis.

### Vehicle Equivalency Factor

The Vehicle Equivalency Factor (VEF) represents the number of Equivalent Standard Axles of8160-kg (E80) per heavy vehicle. The estimated Vehicle Equivalency (VEFs) were obtainedfrom analysis of traffic cargo at Vigwaza weigh bridge. Adopted VEF from heaviest lane areshown in Table below.

Vehicle equivalency factor (VEF) were computed from weights measured at temporary weighstation placed near Kibaha town.

*<Table 3-95: VEF for each vehicle category>*

| Traffic direction | MGV | HGV | VHGV | Buses |
|---|---|---|---|---|
| Chalinze | 1.64 | 2.51 | 5.40 | 1.15 |
| Dar es Salaam | 2.36 | 2.48 | 3.71 | 1.68 |

### Traffic Load Class

Traffic forecasts for the 20-year design period at medium growth rate (around 5% fromeconomic analysis) indicated that project traffic loading exceeded 50 million E80 which is thehighest value provided for pavement layers in PMDM pavement design catalogue. Traffic loadclass for the identified road sections is shown in the Table below.

*<Table 3-96: TLC for road section for E80 for 20-year design period>*

| Road Section | Cumulative E80 | Traffic Load Class |
|---|---|---|
| Morogoro – Kingolwira | 92,510,853 | NA (>TLC50) |
| Kingolwira – Bwawani | 92,078,601 | NA |
| Bwawani – Chalinze | 75,671,952 | NA |

The loading level requires consideration of rigid pavement. Therefore, the Pavement DesignManual, Volume II Rigid Pavements of 2013 published by the Ethiopian Roads Authority wasselected for the design of pavement layers. It is however recommended that for an economicreturn, rigid pavements should be designed for at least 30 years life.

*<Table 3-97: Cumulative traffic loading (E80) for 30-year design period>*

| Road Section | 30-year |
|---|---|
| Morogoro – Kingolwira | 127,518,410 |
| Kingolwira – Bwawani | 129,467,634 |
| Bwawani – Chalinze | 107,579,827 |

### Climate

Figure 2.1 of the PMDM shows that the Project area falls within a Moderate rainfall areatherefore the climatic zone for pavement design for this project is taken as being in moderateclimatic condition.

### Subgrade Strength

The minimum subgrade strength (CBR) required for pavement construction is 15%. Sectionswith subgrade strength lower than required needs to be brought up to subgrade strength ofCBR 15% by constructing one or more layers of improved subgrade.

Analysis of subgrade strength for each section have indicated needs for improvements forsome sections. Table below shows the layer thicknesses required for each connecting road.

*<Table 3-98: Requirements for caping layer>*

| Section | Length (km) | CBR range | Caping layer, mm | Remark |
|---|---|---|---|---|
| 79+000 to 85+500 | 6.5 | 2 | 400 | Replace material |
| 85+500 to 92+500 | 7.0 | 13 | 200 | |
| 92+500 to 104+500 | 12 | 5 | 250 | |
| 104+500 to 123+500 | 19 | 7 | 250 | |
| 123+500 to 142+500 | 19 | 5 | 250 | |
| 142+500 to 156+500 | 14 | 10 | 200 | |
| 156+500 to 162+000 | 5.5 | 1 | 400 | Replace material |

Isolated areas within the identified sections with CBR strength less than 3 should be replacedand capping layer of 400mm placed.

### Rigid Pavement

Cumulative E80 for heavily loaded lane of 130million. Due to high percentage of VHGV, itisrecommended to use rigid pavement, which can withstand more stresses and act as bridge toweaker subgrade soils.

PMDM does not provide design of rigid pavement structures. For this reason, pavementdesign manual developed by Ethiopian Authority was selected and used for design of rigidpavement.

- Jointed Unreinforced Concrete Pavement (JUCP)

Plain concrete surface of 40MPa was considered as preliminary design. Following Figure 6.1(a)of the manual (ERA) for pavement with tied shoulders.

Pavement Slab

Pavement of 310mm thick of 40MPa is required, joints spaced at 5m should be introduced tolimit development of cracks and dowels 32mm thick spaced at 300mm should be used.

Joints

Section 6.4.1 of ERA provides that maximum transverse joint spacing for JUCP pavements is 4metres for slab thicknesses up to 230mm and 5 metres for slab thicknesses greater than230mm.

Joints are introduced to reduce stresses development. Stresses comes from warping orthermal expansion and contractions caused by varying temperature at the surface andbottom of the concrete slab. Also, joints are introduced to facilitate constructionwhenconcreting is stopped. For the slab thickness of 270mm.

**Contraction joints:** spaced at 5m. Dowel bars shall be 25mm in diameter, 400mm long spacedat 300mm centres.

**Expansion joints:** Dowels of 32mm diameter, 600mm long placed at spacing of 300mm centreto centre.

**Warping joints:** not expected but if required should be connected with tie bars of 12mmdiameter, 1000mm long spaced at 300mm.

**Longitudinal joint:** paced at the middle of the carriageway, separating the lanes. Tie bars of12mm diameter, 1000mm long spaced at 600mm centres. Tie bars should be placed at themid-depth of the slab. Load transfer from panels is through aggregate interlock. Tie barsprevents opening of cracks

- Jointed Reinforced Concrete Pavement (JRCP) with tied shoulders

Subgrade design CBR was established to be 5%. Since it is less than 15%, then capping layer isrequired and subbase layer is required whenever the subgrade material does not comply withthe requirements for a subbase (CBR is less than 30%).

For subgrade (class S3) with CBR of 5%, a 250mm capping layer and 150mm subbase layer isrecommended. However, in order to provide good support for concrete pavement, a subbaseof 150mm of UCS strength of 1MPa and capping layer consisting of 350mm having minimumCBR of 15%.

Subbase

For good performance of the rigid pavement the sub-base material should be very resistantto erosion. To ensure this it should, ideally, be stabilised with cement or lime (with unconfinedcompressive strength in the range 0.75 – 1.5 MPa).

Pavement Slab

From Figure 6.3(c) of ERA, concrete pavement thickness of 270mm with longitudinalreinforcements 600mm$^2$/m is required for JRCP with tied shoulders. Transversereinforcements of 12mm diameter spaced at 600mm should also be provided.

Joints

Section 6.4.1 of ERA provides that maximum contraction joint spacing for JRCP is a standarddistance of 25 metres. Expansion joints are required at junctions with other pavement typesand with structures. The need of expansion joints elsewhere can be avoided by casting theconcrete slab at the hottest period of the year. However, if required, expansion joints shouldreplace every third contraction joint.

Joints should be introduced to a panel by either sawing or placing a crack inducer at thebottom of the slab.

Contraction (transverse) joints are spaced at 25m. Since the thickness of concrete slab isgreater than 240mm, the dowel bars shall be 32mm in diameter at 300mm spacing, 400mmlong.

Expansion joints to be spaced at minimum every third contraction joint i.e., 75m. For theconcrete slab of 310mm thickness, the dowel bars shall be 32mm in diameter at 300mmspacing, 600mm long.

Longitudinal joints placed in the middle of the carriageway. Tie bars shall be 12mmindiameter at 600mm spacing, 1000mm long.

- Continuous Reinforced Concrete Pavement (CRCP)

CRCP pavement can better withstand severe stresses induced by differential movements. Fortraffic volume of 130 million E80, following slab thickness is recommended.

### Pavement Slab

Figure 6.5 of ERA. With concrete strength of 40MPA, a concrete pavement thickness of230mm is required for a tied shoulder.

Longitudinal reinforcements of 1200mm$^2$/m should be provided i.e., reinforcement of 16mmdiameter spaced at 150mm centres. To prevent opening of longitudinal cracks which mayform, transverse reinforcements of 12mm diameters spaced at 600mm centres should beprovided.

### Selection of Pavement Type

Selections is based on the merits and demerits of each pavement type compared to another,including relative costs and construction challenges. Level of experience and machinesrequired during construction and maintenance.

- JUCP is suitable for all levels of traffic and whenever the risk of subgrade movementislow.
- JRCP is suitable for all levels of traffic and is used when the risk of settlements ofthesubgrade cannot be neglected.
- CRCP is considered for high levels of traffic (>30 million E80) and where low cost ofmaintenance is paramount. They are suitable where risk of settlement of subgradeishigh.
- Less maintenance is required if there are fewer joints.
- CRCP provides the best riding quality but it requires an experienced contractor toconstruct and is expensive than other two types.

Considering pavement alternatives presented above, it is recommended to adopt JUCP. Thistype of pavement ensures minimum cracks by provision of reinforcements

*<Table 3-99: Summary of pavement layers>*

| Layer type | JUCP | | JRCP | |
|---|---|---|---|---|
| | Layerthickness | Description of materials | Layerthickness | Description of materials |
| Wearingcourse | 310mm | Concrete of 40MPa | 270mm | Concrete of 40MPa withreinforcement 600mm2/m |
| Subbase | 150mm | Stabilised soilofminimum 1MPa (class C1) | 150mm | Stabilised soil of minimum1MPa (class C1) |

| Layer type | JUCP | | JRCP | |
|---|---|---|---|---|
| | Layerthickness | Description of materials | Layerthickness | Description of materials |
| Capping layer | 250mm | granular materials withminimum CBR of 15 | 250mm | granular materials withminimum CBR of 15 |

Recommended Pavement Layers and Thicknesses

For a 30-year design period with cumulative traffic load of 130 million E80 along Chalinze–Morogoro road section, it is recommended to use JUCP with concrete strength of 40MPa.

Concrete Slab310mm, 40MPa

Subbase150mm, UCS 1MPa

Capping layer250mm min. CBR 15

Subgrade CBR = 5%

### 3.11.5 Structural Design

#### Preliminary Design of Bridge Structures

Geometry

Preliminary design of bridge structures consists of reinforced concrete (RC) T-Beam Bridge,Pre-stressed concrete Bridges, with Bulb T-Beam, Super T-Beam, and Box Girder Beamsections that covers long spans in skew and curved alignments. Typical cross sections forbridge superstructures, covering both four (4) lanes and six (6) lanes is presented.

Loads and Loading Combinations

Similar loads applied in this section were also considered, with additional of other loads asdescribed in Table below.

*<Table 3-113: Superstructure lane live loading >*

| Load case | Foot walk live load (kN/m2) | Lane 1 | Lane 2 | Lane 3 | Foot walk live load (kN/m2) |
|---|---|---|---|---|---|
| 1 | 5k | Full HA | Full HA | 1/3 HA | 5k |
| 2 | 5k | HB 37.5 | Full HA | 1/3 HA | 5k |
| 3 | 0 | HB 37.5 | | | 0 |
| 4 | 0 | HB 37.5 | | | 0 |

*(Note:k is defined in BS5400, Part 2, 1978, clause 7.1.1)*

The loading combinations and partial factor of safety for different loading group consideredfor the bridge design is given in Tables below.

*<Table 3-114: Factors for load combination 1>*

| LOAD CASE | SLS | ULS |
|---|---|---|
| Dead load | 1.000 | 1.320 |
| Superimposed dead load | 1.200 | 1.925 |
| Live load on foot walks and parapets | 1.000 | 1.650 |
| HA live load alone | 1.200 | 1.650 |
| HA with HB or HB alone | 1.100 | 1.430 |

*<Table 3-115: Load combination 3 for bridge bearings design>*

| LOAD DESCRIPTION | FACTOR (SLS) | FACTOR (ULS) |
|---|---|---|
| Dead load (concrete) | 1.000 | 1.320 |
| Superimposed dead load | 1.200 | 1.925 |
| HA live load alone | 1.000 | 1.375 |
| HA with HB or HB alone | 1.000 | 1.210 |

| LOAD DESCRIPTION | FACTOR (SLS) | FACTOR (ULS) |
|---|---|---|
| Effect of temperature difference | 0.800 | 1.10 |
| Live load on foot walks and parapets | 1.000 | 1.375 |

*<Table 3-116: Load combination 4 for sub-structure bridge design >*

| LOAD DESCRIPTION | FACTOR (SLS) | FACTOR (ULS) |
|---|---|---|
| Dead load | 1.000 | 1.32 |
| Superimposed dead load | 1.200 | 1.925 |
| Longitudinal HA and associated primary liveload | 1.000 | 1.375 |
| Longitudinal HB and associated primary liveload | 1.000 | 1.210 |
| Accidental skidding load and associatedprimary live load | 1.000 | 1.375 |
| Live load on foot walks and parapets | 1.000 | 1.375 |
| Earth pressure: retained fill and/or live loadsurcharge | 1.000 | 1.650 |

### Structural Analysis for Bridges

The longitudinal beams and/or girders for the bridge structures were analyzed and designedas a constant depth for either continuous and/or simply supported. For convectionalreinforced concrete T-beams bridges, a monolithic assumption was used where the slab wasacting as compression flange for sagging moments. Thus, the slab was analyzed and designedas spanning across longitudinal beams and having cantilevered ends at deck edges.

The transverse diaphragms, i.e. cross beam, were provided and analyzed to enhance lateraland torsion restraint to longitudinal beams. For pre-stressed concrete girder beams,acomposite assumption was used where slab was analyzed and designed differently asspanning across longitudinal beams and having cantilevered ends at deck edges. In both cases,the grillage analysis was performed for the superstructure, including abutments and piersusing Midas Civil software. However, it should be noted that foundations, i.e. shallow andpiles, were preliminarily designed based on experience and assumed geotechnical data.

General arrangement of the bridge deck structure, spacing of bridge deck beams has beenarranged by considering the road carriage way width and its features such as parapet walls,shoulder widths and medium width. For proposed expressway the width is 28.3m comprising

11.8m in each direction with overlapping median of 6.5m.

Deck slab and beams are arranged for carriage way width of 11.8m and 12m respectively fornormal overpass bridges and Ngerengere river bridge respectively. The carriage way consistsof two lanes 3.5m each, with 3m shoulders at the outer side. Edge strip and parapet of 0.9mat each side of carriage way.

- Super Structure

Three types of bridge deck structure have been adopted, namely: Reinforced Concrete T-Beams for 20m span bridges, Post Tension Concrete T-Beams, for 40m span bridges, and Post Tension Concrete Supper Closed Flange T-Beams. The deck slab is of reinforced concrete slabis adopted.

### 3.11.5.2 Schedule of Structures

- Drainage box culverts

Total number of 68 drainage box culverts for drainage has been planned for project and, thelists are presented in the table below.

*<Table 3-117: Schedule of Box culverts for River>*

| Classification | Cells | Length | Number | Location |
|---|---|---|---|---|
| 2x1 | 1 | 40 | 1 | 151+350 |
| Sub total | | **40** | **1** | **Sub Total = 40m** |
| 2x2 | 1 | 40 | 5 | 149+000, 149+575, 153+500, 158+800, 161+400 |
| Sub total | | **200** | **5** | **Sub Total = 200m** |
| 3x2 | 1 | 40 | 3 | 83+140, 101+800, 153+340 |
| Sub total | | **120** | **3** | **Sub Total = 120m** |
| 3x2 | 2 | 40 | 1 | 112+708 |
| Sub total | | **40** | **1** | **Sub Total = 40m** |
| 3x2 | 3 | 40 | 1 | 163+460 |
| | | **40** | **1** | **Sub Total = 40m** |
| 4x2 | 1 | 40 | 2 | 82+425, 86+780, |
| Sub total | | **80** | **2** | **Sub Total = 80m** |
| 4x2 | 2 | 40 | 3 | 100+750, 161+560,<br>3+400 (Ramp-A on Kingolwira IC) |
| Sub total | | **120** | **3** | **Sub Total = 120m** |
| 4x3 | 1 | 40 | 1 | 92+525 |
| Sub total | | **40** | **1** | **Sub Total =4 0m** |
| 4x3 | 2 | 40 | 2 | 93+300, 94+660 |
| Sub total | | **80** | **2** | **Sub Total = 80m** |

| | | | | |
|---|---|---|---|---|
| 5x2 | 4 | 40 | 1 | 113+760 |
| Sub total | | **40** | **2** | **Sub Total = 40m** |
| 5x2.5 | 2 | 40 | 2 | 80+116, 84+180 |
| Sub total | | **80** | **2** | **Sub Total = 80m** |
| **5x3** | **1** | 40 | 3 | 85+300, 94+900, 159+200 |
| Sub total | | **120** | **3** | **Sub Total = 120m** |
| 5x3 | 2 | 40 | 3 | 95+755, 101+900<br>0+340 (Ramp-A on Bwawani IC) |
| Sub total | | **120** | **2** | **Sub Total = 120m** |
| 5x3 | 3 | 40 | 4 | 105+225, 119+260, 134+000, 135+880 |
| Sub total | | 160 | **4** | **Sub Total = 160m** |
| **Classification** | **Cells** | **Length** | **Number** | **Location** |
| 5x4 | 2 | 40 | 1 | 107+450 |
| Sub total | | **40** | **1** | **Sub Total = 40m** |
| 5x4 | 3 | 40 | 1 | 106+690 |
| Sub total | | **40** | **1** | **Sub Total = 40m** |
| **Total** | | | **34** | **TOTAL LENGTH = 1,360m** |

## Passage box culverts (Vehicular Box Culverts)

Passage box culverts with size 4.5m x 4.5m have been planned for minor roads such as accessroad, village road etc. crossing the alignment to secure economical validity.

*<Table 3-118: Schedules of Proposed Passage (Vehicular) Box Culverts >*

| Classification | Cells | Length | Number | Location |
|---|---|---|---|---|
| 4.5x4.5 | 1 | 20 | 6 | 1+575 Ramp-A on Bwawani IC<br>0+545, 2+750,3+875 Ramp-A on Kingolwira IC<br>0+850, 0+925 Ramp-A on Morogoro IC |
| Sub total | | | 6 | **Sub total Length =120 m** |
| 4.5x4.5 | 1 | 40 | 33 | 79+800, 80+335, 83+900, 86+000, 88+825, 90+650, 92+600, 96+665, 97+150, 113+960, 117+120, 118+025, 119+100, 128+900, 130+010, 130+790, 133+980, 136+337, 137+650, 139+150, 141+992, 143+622, 144+875, 146+225, 150+010, 153+558, 155+250, 157+500, 157+995, 158+610, 160+396, 160+725, 163+800 |
| | | 45 | 1 | 127+925 |
| | | 50 | 2 | 110+775, 140+800 |
| 4.5x4.5 | 2 | 40 | **1** | 86+700 |
| Sub total | | | **37** | **Sub total Length =1,505 m** |
| Total | | | **43** | **Total Length =1,625 m** |

### Bridges

Total of 13 Bridges consisting of 1 bridge Expressway over Msolwa road, 5nos flyover bridges,3 IC bridges ramps, 4 bridges across the rivers are planned for project design, the list for totallength of bridges is shown in the table below.

*<Table 3-119: Schedules of Proposed Passage Bridges >*

| Classification | Number | Length (m) | Remarks |
|---|---|---|---|
| Bridges for Road | 9 | 515 | Main route, Interchanges, over bridges |
| Bridges for rivers and valley | 4 | 300 | Rivers and valley |
| Grand Total | **13** | **815** | |

List of bridges for roads is presented in the table blow.

*<Table 3-120: Schedules of bridge for roads>*

| Classification | Length (m) | Number | Locations | |
|---|---|---|---|---|
| 4 lanes of main Route | 30 | 1 | K 86+928.5 - Msolwa Bridge | |
| Sub Total | | **1** | **Sub Total Length** | **30** |
| Flyover | 45 | 1 | 93+875 – Mdaula Bridge | |
| | 50 | 1 | 99+700 – Ubenazomzi Bridge | |
| | 60 | 1 | 133+275 – Mikese Bridge | |
| | 80 | 2 | 105+550 -Mwadu Bridge, 121+800 -Maseyu Bridge | |
| Sub Total | | **5** | **Sub Total Length** | **315** |
| InterchangesBridge | 40 | 1 | 112+900 – Bwawani Ramp Bridge (Bwawani IC) | |
| | 80 | 1 | 144+271.70-Kingolwira Ramp Bridge(Kingowira IC)<br>Total 2 lane, 16.3m width for both Directions | |
| | 50 | 1 | 162+700 – Morogoro Ramp Bridge (Morogoro IC)Total 2 lane, 16.3m width for both Directions | |
| Sub Total | | **3** | **Sub Total Length** | **170** |
| Total | | **9** | **515** | |

List of bridges for rivers is presented in the table below.

*<Table 3-121: Schedules of bridges for rivers & valley>*

| Classification | Length (m) | Number | Locations | Total Length (m) |
|---|---|---|---|---|
| 4 lanes of mainRoute | 100 | 1 | 116+335 Ngerengere Bridge-2 | 100 |
| | 100 | 1 | 144+602.50 Ngerengere Bridge-4 | 100 |
| | 40 | 1 | 116+140 Ngerengere Bridge-1 | 40 |
| | 60 | 1 | 122+510 Ngerengere Bridge-3 | 60 |
| Sub Total | | **4** | **Sub Total Length** | **300** |

▮ Minimum head rooms for the structures crossing the roads.

There are total 36nos of box culverts with single cell and 1no of box culvert with doublecellall sized 4.5m x 4.5m along the main expressway to allow for local roads crossing theexpressway at grade. Likewise there 6nos of single cell sized 4.5mx4.5m crossing theexpressway at the interchanges. The structures are provided for vehicles to cross the the proposed expressway at grade. This makes the total 0f 43nos of all vehicle box culvertscrossing the main expressway and the interchanges.

For the main existing roads crossing project road which are expected to have high trafficvolume and large size cars, 13nos of bridges with minimum head room 5.5m have beendesigned for project road.

### 3.10.5.6 Conclusion

In summary total thirteen (13nos) of bridges have been proposed along the expresswaycomprising of 4nos of water ways bridges and 9nos of passage bridges over the roads. Thereare 43nos of vehicular box culverts, 34nos of waterway box culverts, Total 43nos of boxculverts and 9nos of bridges have been proposed for vehicles to cross the proposedexpressway and existing roads. There are 4nos of waterway bridges proposed for the crossingmajor rivers. Total 34nos of waterway box culverts have been proposed for streams crossingthe expressway.

Tanzania RGDM regulate minimum head room 5.5m for road, but generally minor road in thecountryside and villages are not expected high traffic volume and lager size cars such as cargocar and big size container cars.

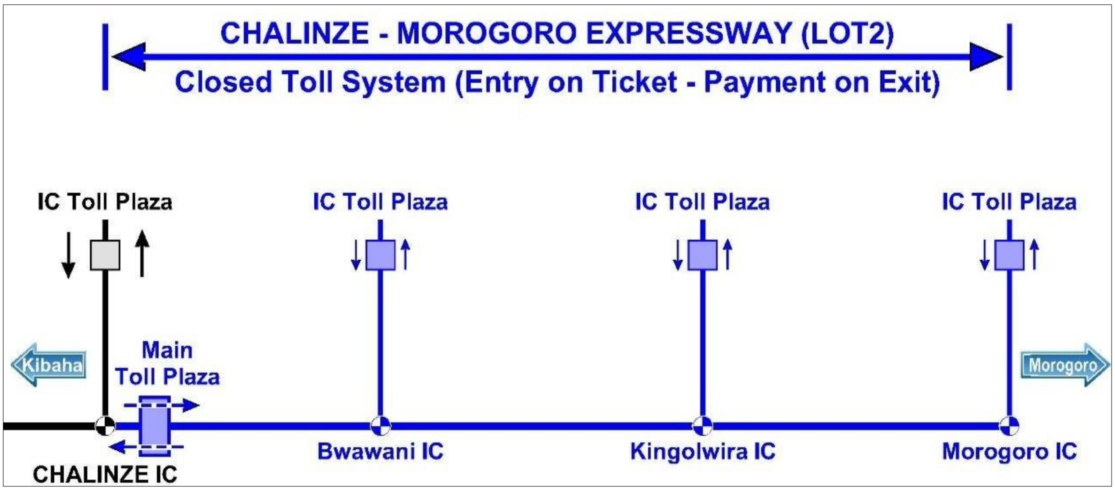
### 3.11.6 Toll Plaza Design

▌ Locations of Toll Plaza

Toll Plaza is a facility to collect fee for operation. Toll road usually adopt closed type collectingfee system. (Drivers receive ticket in the entering toll and pay the fee in the exit toll)

In lot-2, one (1) main plaza and three (3) interchange toll plazas are planned.

*<Figure 3-57: Location of Toll Plaza>*




Tollgate is purposed to control vehicle entering and exiting of expressway to collect fees andto operate maintenance of the expressway. Weight bridges laying on the entrance tollgatewill check whether the goods vehicle exceeds of regulated weight.

&Calculation for required lanes of Tollgates

Required lanes of toll plaza based on the traffic analysis are shown in the table blow.

*<Table 3-122: Required lanes of tollgates >*

| | Entrance | | Exit | | Total Lanes |
|---|---|---|---|---|---|
| | Normal | Weight Br. | Normal | widen | |
| Main toll plaza | 1 | 2 | 3 | 3 | 9 |
| Bwawani IC | 1 | 1 | 1 | 2 | 5 |
| Kingolwira IC | 1 | 1 | 2 | 2 | 6 |
| Morogoro IC | 1 | 1 | 3 | 2 | 7 |

&The area of office site and Layout of Toll Plaza

The area of office site generally varies with number of lanes. Also it is affected by interchangeor size of toll-barrier, condition of terrain and others (bus stop etc). The table below showsthat appropriate area for the size of Toll Plaza.

*<Table 3-123: Required lanes of tollgates >*

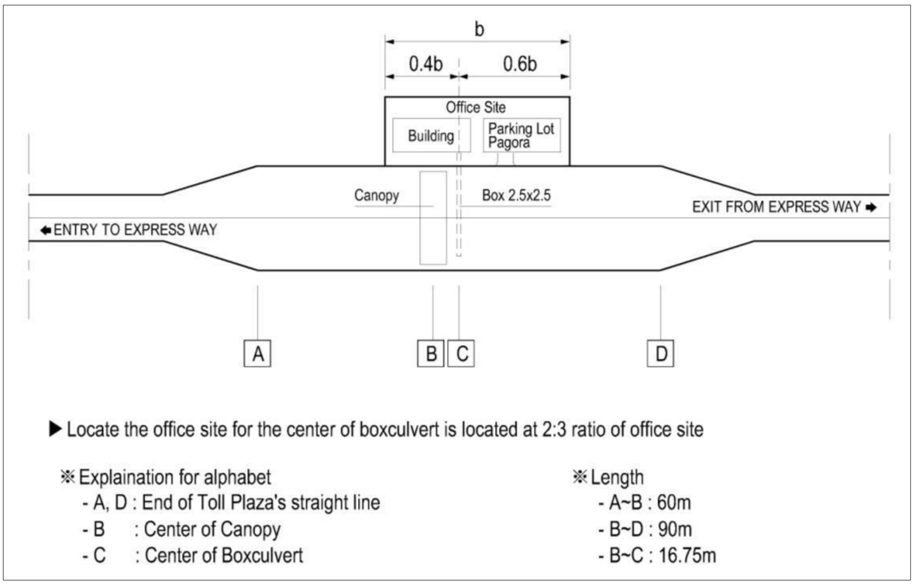
| Type | Number of Lane | Site Size of (B x H, m) | Area of Office Site(m²) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Total | Office | Parking | Landscape | Others |
| Small | <10 | 40x80 | 3,300 | 600 | 700 | 1,200 | 800 |
| Medium | <20 | 45x90 | 4,300 | 700 | 1,100 | 1,600 | 900 |
| Large | <30 | 45x120 | 5,600 | 800 | 1,400 | 2,100 | 1,300 |

**Reference from the Expressway Design Manual of KEC (Korea Expressway Corporation)*

- Parking area: 80% of the office staff's number.
- Landscaping area: 40% of the site size
- It's not included in this area for warehouse of facilities and emergency

stationIt is shown below for typical layout of Toll Plaza

*<Figure 3-58: Typical layout of Toll Plaza >*



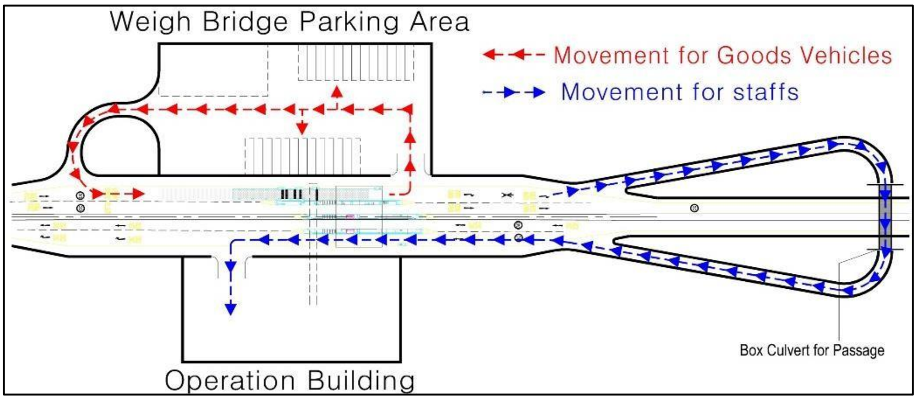

U-turn lane that can be used passage for staffs who are working in the operation building andcan provide turning movement to the car in the emergency has been planned on the tollplazas.

*<Figure 3-59: Reference image of Toll Plaza >*


&Parking and warehouse area for weigh bridges

A weigh bridge system in the Tanzania is supposed to provide parking area in order to loadand unload freight and to provide warehouse in order to store freights. The cargo trucks that exceeded regulated weight could go into this parking area and store freight exceeded, andthe cargo trucks should return at the entry point to recheck the weight. Below figure showsweight bridge site, truck movement and U-turn lane on the toll plaza.

*<Figure 3-60: Parking area for a weigh bridge and U-turn on the Toll Plaza >*



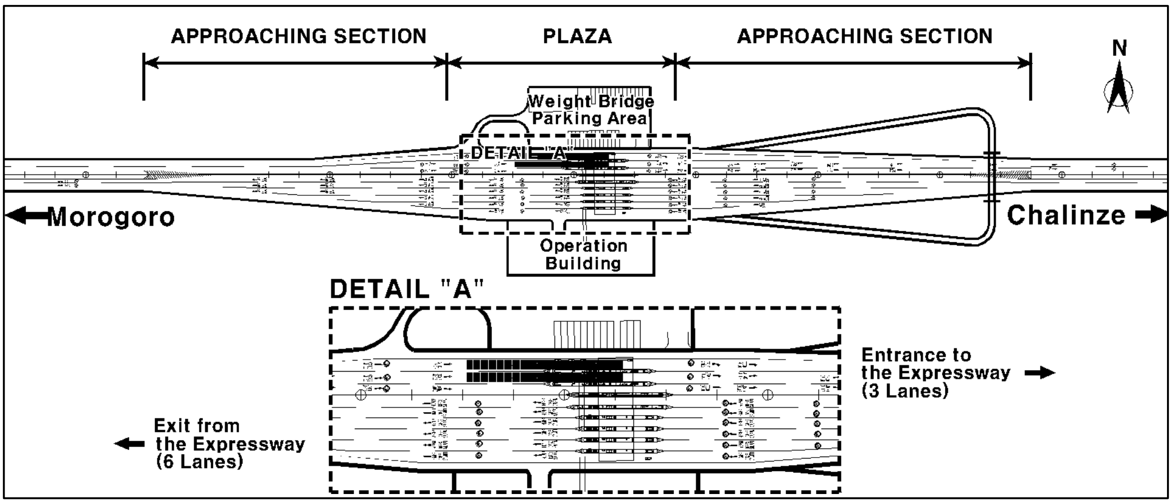

&Parking and warehouse area for weigh bridges

A weigh bridge system in the Tanzania is supposed to provide parking area in order to loadand unload freight and to provide warehouse in order to store freights. The cargo trucks thatexceeded regulated weight could go into this parking area and store freight exceeded, andthe cargo trucks should return at the entry point to recheck the weight. Below figure showsweight bridge site, truck movement and U-turn lane on the toll plaza.

&Design of Main Toll PlazaChalinze Main Toll Plaza

Chalinze main tollgate is comprised of total nine (9) lanes with three (3) lanes for entranceand six (6) lane for exit according to traffic forecasting result. Two (2) weight bridge lane foroverweight cargo control and weigh bridge parking area are planned.

*<Figure 3-61: Layout of Chalinze Main Toll Plaza >*




Interchange Toll Plaza is illustrated in the 3.10.8 Interchange Design below.

### 3.11.7 Rest Area Design

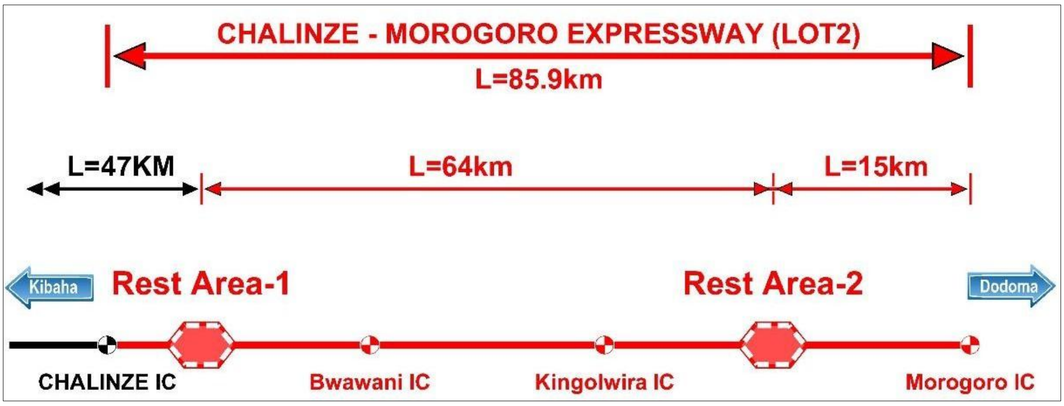
▍Location of Rest Area

The Project Expressway is subject to full access control and can only be entered and exitedthrough interchanges. Due to the nature of expressways, connecting regions and full accesscontrol, drivers have to drive for a long time, which might cause accumulates driver tirednessand physiological need and thus will affect safe driving.

Rest Area is purposed for drivers and passenger to be provided convenience facilities torelease tiredness, tensions and physiological need by long travel, and facilities such as fuelstation, restaurant, shop, garage etc. provide drivers and passenger’s opportunities of rest,services and maintenance of cars.

Two rest areas are planned in lot 2 (Chalinze-Morogoro section) as a Major Rest type.

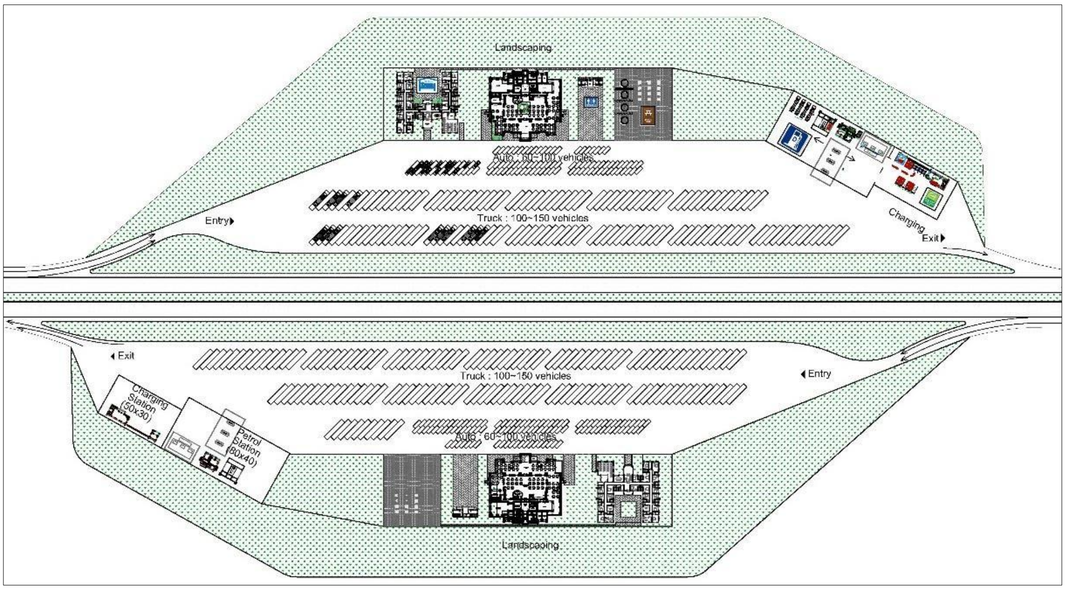
*<Figure 3-62: Location of Rest Area >*




&Layout plan for Rest area

The below figure shows Layout plan for rest area in this project.

*<Figure 3-63: Layout for Rest Area>*



&Facilities plan for Rest area

The facilities are planned for rest area corresponding to the cost estimates as the referenceinformation to bidders.

In this case rest area are developed in large, attractive with spaces, well maintained comfortstation, these places were uses for both indigenous and visitors or travelers what mayinvolving in the rest area, Motel, Public Washrooms. Restaurants, Picnic area and Filling andEV stations

- MOTEL


Motel play a role in the hospitality and travel industry offering a range of important servicesand benefits to both travelers and the local economy here are some key aspects highlightingthe importance of motel

- PUBLIC WASHROOMS

Wash rooms also known as restroom comfort stations or rest areas are of paramountimportance on toll road and highway they serve various crucial purposes for both traveler androad infrastructure here’s why washroom is essential on toll road

- RESTAURANT


Restaurant ion toll road are crucial for providing convenience comfort safety and economicbenefit to travelers. They enhance the overall travel experience and contribute to the successof the toll road infrastructure. Having restaurant or rest stop along toll road can offer severalimportant benefits for travelers and the overall road infrastructure

- PICNIC AREA

Picnic area along toll roads serve several important purposes for travelers andthesurrounding community here are some reasons why picnic areas are important on toll roads

- FILLING including LNG and CNG/EV STATION



**Design of the Filling Station Layout:** The layout accommodates fuel pumps for conventionalfuels, CNG/LNG dispensers, parking spaces, a convenience store, and washroom facilities. Italso includes a vehicle circulation plan to handle the influx of vehicles entering and exiting thestation, with provisions for clear signage, optimized traffic flow patterns, and measures toprevent congestion on the toll road.

**EV Charging Station Functionality:** An electric vehicle (EV) charging station provides electricalpower to charge the batteries of electric vehicles.

### 3.11.8 Interchange Design

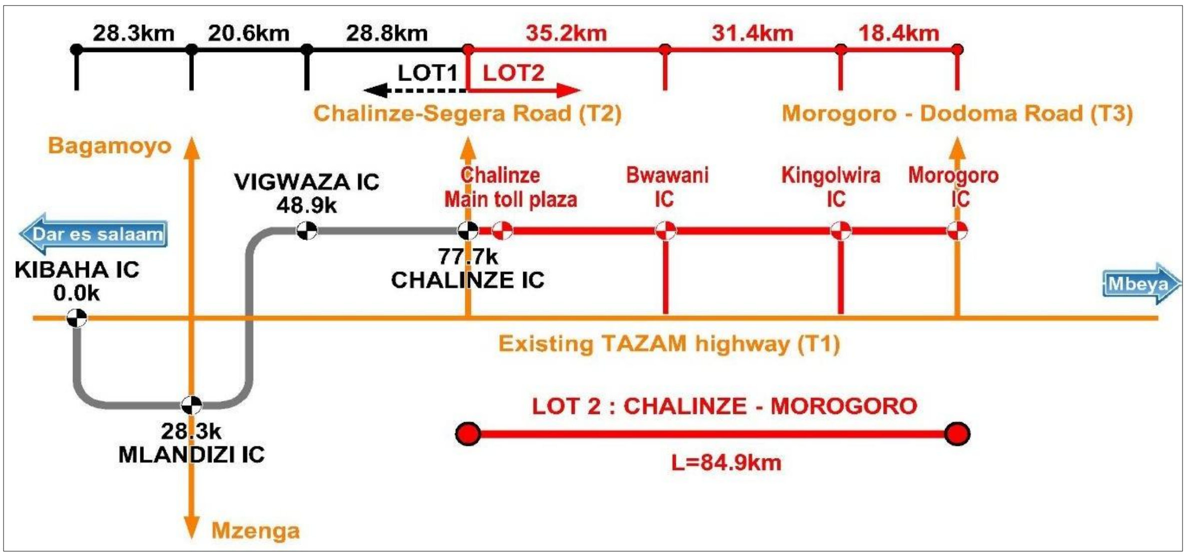
- Location of interchanges

Bwawani interchange is added compared to the Route carried out by the TECU. This makesthe interval between interchanges up to 29.1km.

Furthermore, adding the Bwawani interchange is to increase the traffic volume so the trafficrevenue also is increased.

Below shows the location of interchanges together with its spacing.

*<Figure 3-64: Location of interchanges>*

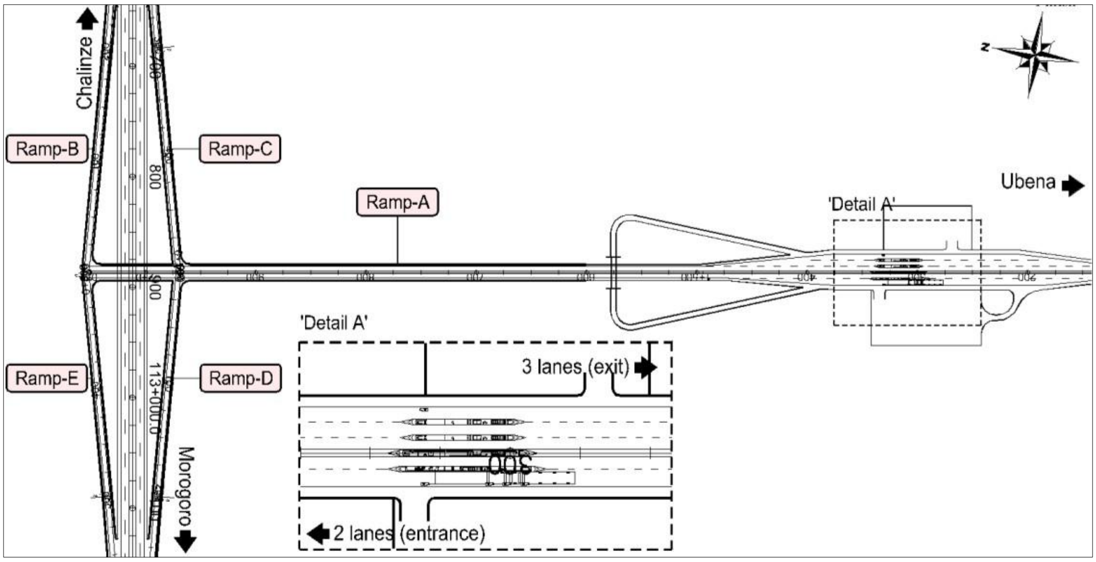


&Interchange Design

The followings indicate the features of the interchanges being connected with the existingroad.

- Bwawani IC

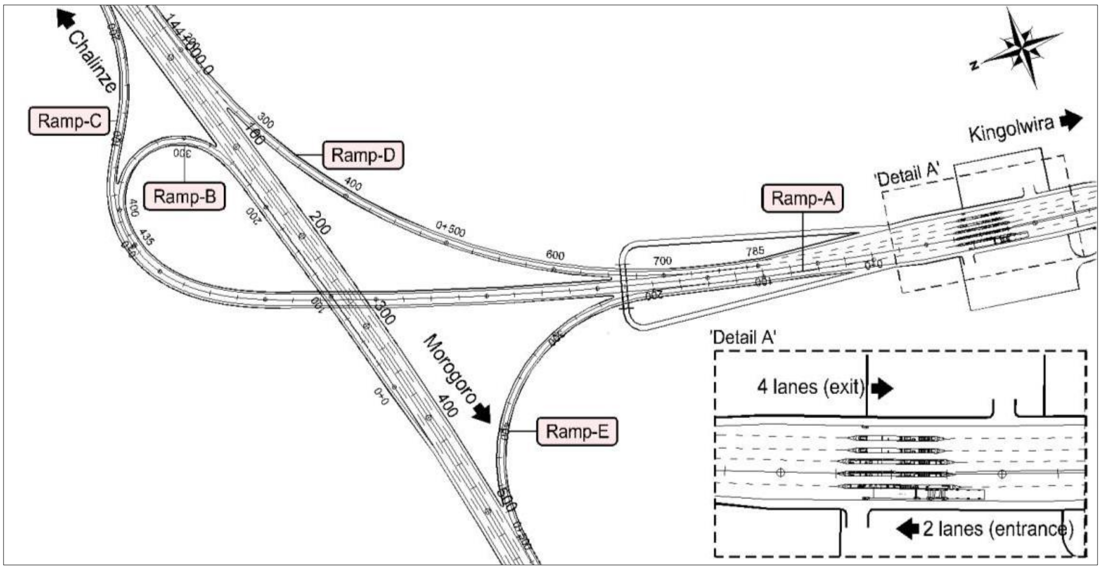
*<Figure 3-65: Features of Bwawani Interchange>*




| Location | • North of Ubena Bwawani (Mainline STA.112+887) |
|---|---|
| Type of IC | • Diamond type interchange |
| Connective Road | • Morogoro road (T1) |
| Length of Link Road (Ramp-A) | • 2.05km |
| No. of Lanes (IC toll plaza) | • Entrance: 2 lanes (Normal: 1, Weight bridge: 1)<br>• Exit: 3 lanes (Normal: 1, Widen: 2) |

- Kingolwira IC

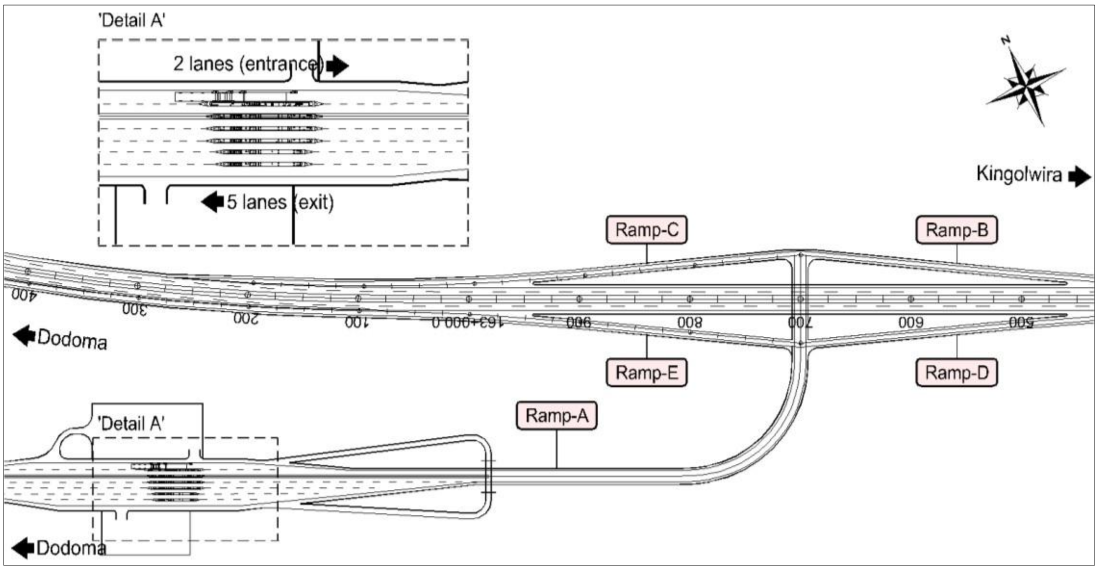
*<Figure 3-66: Features of Kingolwira Interchange>*



| | |
|---|---|
| Location | • Near Kingolwira Prisons (Mainline STA.144+271) |
| Type of IC | • Trumpet type interchange |
| Connective Road | • Morogoro road (T1) |
| Length of Link Road (Ramp-A) | • 3.7km162 700 |
| No. of Lanes (IC toll plaza) | • Entrance: 2 lanes (Normal: 1, Weight bridge: 1)<br>• Exit: 4 lanes (Normal: 1, Widen: 2) |

- Morogoro IC

*<Figure 3-67: Features of Morogoro Interchange>*




| | |
|---|---|
| Location | • Near Morogoro town (Mainline STA.162+700) |
| Type of IC | • Diamond type interchange |
| Connective Road | • Morogoro – Dodoma Road (T3) |
| Length of Link Road (Ramp-A) | • 1.3km |
| No. of Lanes (IC toll plaza) | • Entrance: 2 lanes (Normal: 1, Weight bridge: 1)<br>• Exit: 5 lanes (Normal: 3, Widen: 2) |

## 3.11.9 ROAD FURNITURE DESIGN

### 3.11.9.1 Introduction

Road furniture is auxiliary facilities such as sign boards, traffic light, street light, guardrails,fences, etc. to give drivers information, instructions, and to enhance safety. Although it is notessential to form road, thus facilities help driver's judgement by giving directions of theirdestination and control traffic flow by giving traffic sign and information at the junction.

Supplementary safety facilities such as guardrails, fences, barriers will be able to enhancedriver's safety by protecting erratic flow in the direction to out of road. Safety barrierscanprotect pedestrians walking on foot way by fences as well.

### 3.11.9.2 Road Signs

▌Regulatory Signs

Regulatory signs are used to control the actions of road users in the interests of safety andthe efficient use of road space. Failure to obey regulatory signs is an offence. Classification of regulatory Signs is showed in the below table.

*<Table 3-124: Classification of Regulatory signs>*

| Group | Sample sign | Function | Sign numbers |
|---|---|---|---|
| Control |  | Exercise control over the right of way of traffic | R1 – R6 |
| Command |  | Instruct drivers what to do | R103 - R137 |
| Prohibition |  | Instruct drivers what they must not do | R201 - R245 |
| Reservation |   | Reserve road space for specific vehicletypes | R301 - R360 |

## Warning Sign

Warning signs are used to alert drivers to danger or potential danger ahead. They indicateaneed for extra caution and may require a reduction in speed or other maneuver. Adequatewarning signs can greatly assist road safety. To be most effective however, they should beused sparingly. Do not use warning signs in situations where the problem is obvious, or is sominor that no extra care is necessary. Side road junctions for example are not usually a dangerwhen traffic speeds are low. Classification of warning sign is shown in the below table.

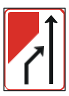
*<Table 3-125: Classification of Warning signs>*

| Group | Sample sign | Description | Sign numbers |
|---|---|---|---|
| Advance Warning Signs |  | Road Layout | W100 Series |
| | | Movement | W200 Series |
| | | Symbol | W300 Series |
| Hazard Marker Signs |  | Curve and object markers etc. | W400 Series |

## Guidance Signs

Guidance signs give road users information on how to find their way to their destination. Theyalso help to reduce delay and keep traffic flowing smoothly and safely through junctions.Guidance signs belong to one of five groups: It is shown in the below table

*<Table 3-126: Groups of Guidance signs >*

| Group | Sample sign | Description | Sign number prefix |
|---|---|---|---|
| Location |   | Place names, river names | GL |
| Direction |   | Direction signs before and atjunctions | GD |
| Tourism |   | Directions to tourist attractions,services and facilities | GF |
| Local Direction |   | Direction signs for minor, localdestinations in urban areas | GDL |
| Diagrammatic |  | Signs warning of a change in roadlayout ahead (e.g. start and finish of climbing lane) | GS |

[1] *Temporary signs will normally have black letters on a yellow background and a black border*

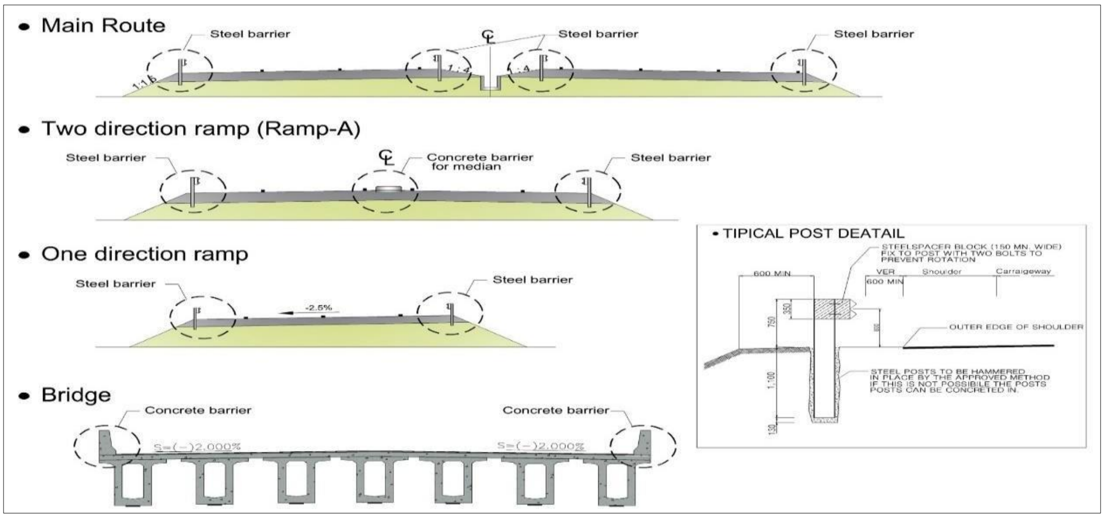
### 3.11.9.3 Safety Barriers

Project road with high design speed of 120km/h is necessary of safety barriers. Safety barrierare installed to redirect errant vehicles with a specified performance level for the project road.

Project road regulated as express way which all entry and exit are controlled by tollgate togive vehicles fast flow to their destination by providing free-flow. Accordingly entry and exitthrough the other points are not allowed and both side of all road including ramps should beinstalled guardrails to prohibit entry and exit of vehicle and people.

There are few type of barriers adopted for project design. Rigid concrete barriers are designedon the two direction ramp and edge of bridge and steel barriers of both side are designed onedirection ramps and main road. Below figure is example of installation.

*<Figure 3-68: Layout of safety barriers>*




### 3.11.10 ITS (Intelligent Transportation System) Design

**Overview**

Intelligent Transportation System(ITS) is an intelligent transportation system that integratesadvanced technologies such as electronics, control and communication in transportation andtransportation facilities to provide traffic information and services.

In this study, the basic facilities for convenience and safety of user and operation of theexpressway were reviewed.

The types and characteristics of each facility are as follows.

- VMS (Variable Message Signs)

A variable message sign(VMS) is an electronic traffic sign often used on roadways to givetravelers information about special events. Such signs warn of traffic congestion, accidents,incidents, roadwork zones, or speed limits on a specific highway segment. They may also askvehicles to take alternative routes, limit travel speed, warn of duration and location of theincidents or just inform of the traffic conditions.

*<Figure 3-69: Operation of VMS example>*


When selecting the installation location of the VMS, traffic conditions, exhibition conditions,systems and other conditions(obstruction, etc) should be considered as follows.

*<Table 3-127: VMS Installation Location Considerations>*

| Classification | Installation Location |
|---|---|
| TrafficConditions | - Upstream of the point where congestion is a problem due to trafficdemand on the peak, on the regular, on the weekends or on holidays<br>- Upstream areas where congestion is expected in the event of anunexpected or frequent occurrence can be bypassed<br>- Upstream of major detourable points where distribution of traffic flowis expected, such as JCT, IC, and major intersections<br>- Upstream of points that require attention to traffic, such as bottlenecksand tunnel entrances, etc<br>- Upstream of the freezing vulnerable management section point |
| RoadConditions | - It is installed in a straight section as much as possible to securethedriver's visibility, and the point where the curve or longitudinal slopeis not severe |

- VDS (Vehicle Detector System)

The Vehicle Detector System (VDS) function collects traffic flow data, such as traffic volume,speed, occupancy and vehicle length, using vehicle flow images to collect traffic flow datasuch as vehicle traffic volume, speed, occupancy and length

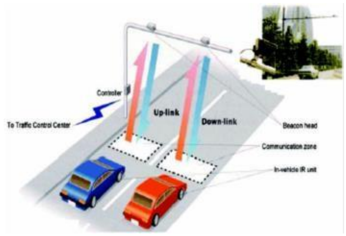
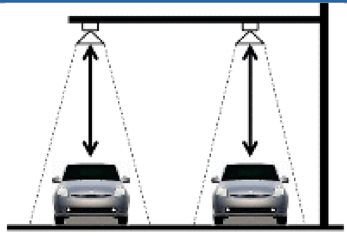
The VDS types include infrared detectors, ultrasonic detectors, loop detectors, etc., and thecharacteristics and strengths and weaknesses of each type are as follows

*<Table 3-128: Features by VDS type>*

| Classification | Characteristics | Strength | Weakness |
|---|---|---|---|
| Infrareddetectors | - Recognize the detectiontarget by emitting light tothe detection targetandthen detecting reflectedand returning light | -No direct obstructionof traffic flow duringinstallation work<br>-Easy to install<br>-low maintenance | -Expertise required forinstallation andmaintenance |

| Classification | Characteristics | Strength | Weakness |
|---|---|---|---|
| Ultrasonic detectors | -Using ultrasonic waves asa detection sensormedium, it is injected intoa vehicle on the road todetect reflected wavesreflected from the vehicle | -The detector can bedistinguished by height<br>-No direct obstructionof traffic flow duringinstallation | -High purchase andinstallation costs<br>-Difficulty detectingvehicles by direction<br>-Not accurate incongested areas |
| Inductive Loopdete ctors | -Most commonlyusedspot detection technology<br>-A method of detectingchanges when a vehiclepasses on the loop byburying it under the road | -Reliability of detectioninformation and lowinstallation cost | -Classification ofvehicle types is difficultand maintenance costsare excessive due toroad damage |

*<Table 3-129: Example of VDS type>*

| Infrared Detectors | Ultrasonic detectors | Inductive loop detectors |
|---|---|---|
|  |  |  |



- CCTV (Closed-Circuit Television)

CCTV(Closed-Circuit Television) is a video information collection system that monitors variousroad traffic conditions, such as congestion and unexpected situations, in real time so thatoperators can establish effective traffic management strategies.

CCTV is a system that can remotely control traffic conditions on major roads when real-timeimages are needed, and can manage or prevent traffic congestion and secondary trafficaccidents by providing on-site support in case of an emergency.

CCTV is used for a variety of purposes on the road

- Traffic condition and monitoring
- Accident detection
- Security function to cooperate with police

- VES (Vehicle Enforcement System)

A traffic enforcement System (also red light camera, road safety camera, road rule camera,photo radar, photo enforcement, speed camera, Gatso, safety camera, bus lane camera, flashfor cash, Safe-T-Cam, depending on use) is a system which may be mounted beside or over aroad or installed in an enforcement vehicle to detect traffic regulation violations, includingspeeding, vehicles going through a red traffic light, unauthorized use of a bus lane, or forrecording vehicles inside a congestion charge area.

&Installation plan of ITS facility

- **Standard of installation**

The installation standards were set as follows according to the characteristics of each facility.

*<Table 3-130: Standard of installation>*

| Classification | Standard of installation |
|---|---|
| VMS (Variable Message Signs) | Installation in start point(Main Toll Plaza) and end point |
| VDS (Vehicle Detector System) | Installation of main line in highway requiring traffic detection/statistics |
| CCTV (Closed-Circuit Television) | Interchanges that require monitoring of surrounding areas due to vehicle entry and exit |
| VES (Vehicle Enforcement System) | Installation in front of the curve point<br>(In case of double curves, installation in front of first curve)<br>Installation of long-distance straight sections |

- Installation of each facility

On the project road, ITS facilities planned 2, 3, 6 and 8 VMS, CCTV, VDS and VES, respectively.The number of installations for each facility is as follows.

*<Table 3-131: Planning of ITS facilities>*

| Classification | | VMS | CCTV | VDS | VES |
|---|---|---|---|---|---|
| Toll Gate | Start Point(Main Toll Plaza) | 1 | - | - | - |
| | End Point | 1 | - | - | - |
| Interchange | Bwawani IC | - | 1 | - | - |
| | Kingolwira IC | - | 1 | - | - |
| | Morogoro IC | - | 1 | - | - |
| Main line ofproject road | Start Point-Bwawani IC | - | - | 2 | 2 |
| | Bwawani IC-Kingolwira IC | - | - | 2 | 4 |
| | Kingolwira IC-Morogoro IC | - | - | 2 | 2 |
| Total | | 2 | 3 | 6 | 8 |

&Installation plan of Toll Collection facility

- **Installation of Toll Collection facility**

In the Expressway Toll Road section under the PPP (Chalinze-Morogoro), after stopping, TollCollection System (TCS) using cash or prepaid cards is applied. The facilities for eachinterchange are as follows and further details on the TCS will be described in 3.12 Operationand Maintenance.

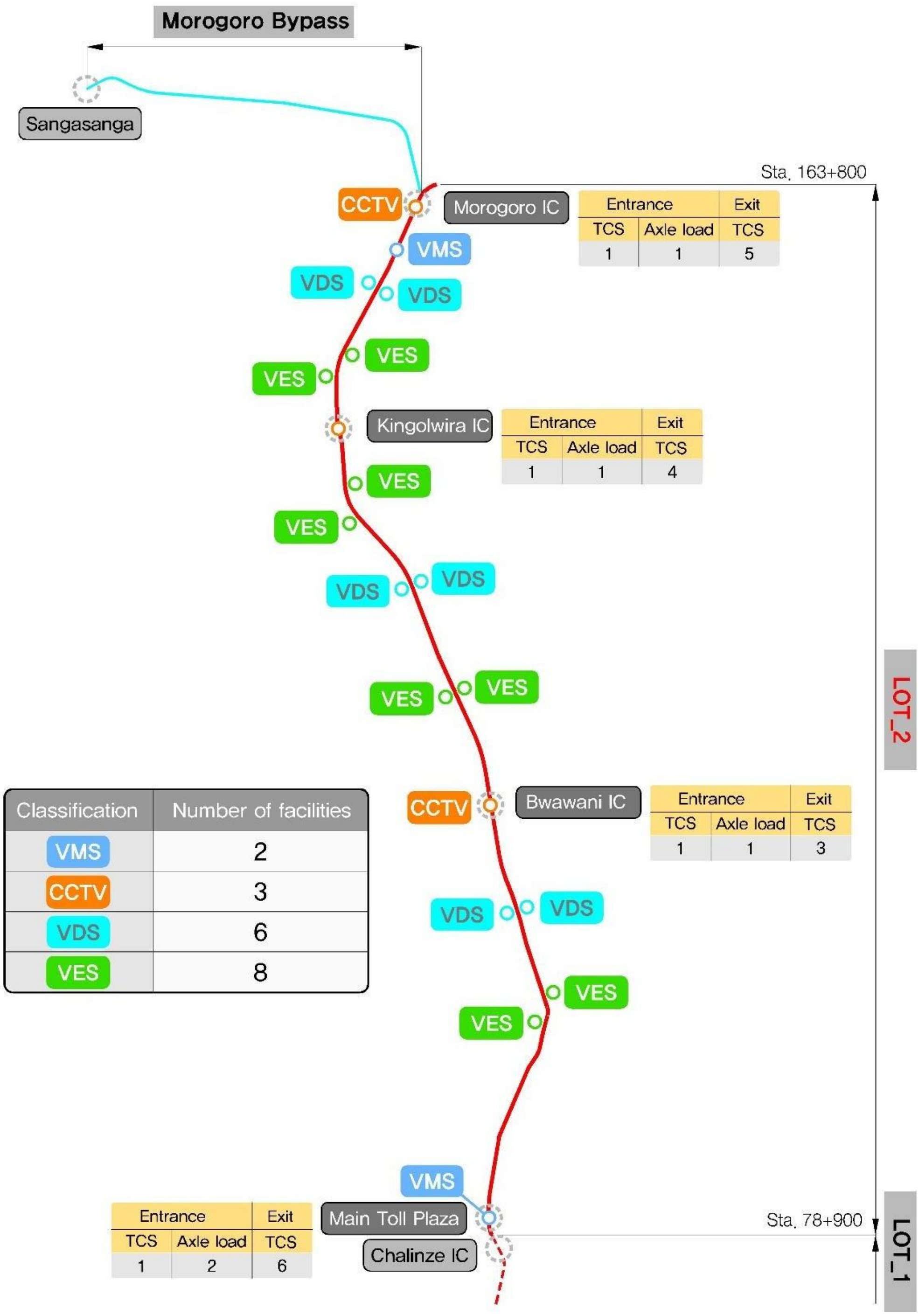
*<Table 3-132: Plan of Toll gate facilities>*

| Classification | Entrance | | | | Exit | | | Total |
|---|---|---|---|---|---|---|---|---|
| | Standard Vehiclela nes | Axle Loadla nes | Widened lanes | Total | Standard Vehiclela nes | Widened lanes | Total | |
| Morogoro IC | 1 | 1 | - | 2 | 3 | 2 | 5 | 7 |
| Kingolwira IC | 1 | 1 | - | 2 | 2 | 2 | 4 | 6 |
| Bwawani IC | 1 | 1 | - | 2 | 1 | 2 | 3 | 5 |
| Main Toll Plaza | 1 | 2 | - | 3 | 3 | 3 | 6 | 9 |

&Plan of ITS and Toll Collection facility

Plan of ITS and Toll collection facility is as follows.

*<Figure 3-70: Plan of ITS and Toll collection facility>*



### 3.11.11 Project Cost

The total project cost for Lot 2: Chalinze–Morogoro section (applied the unit cost in 2023, real terms) is summarized as follows:

CAPEX: USD 376.0 million

OPEX: USD 160.3 million

**Total project cost: USD 536.3 million**

# 4. COMMERCIAL ASSESSMENT SUMMARY

## 4.1 PPP Structure

| | |
|---|---|
| **PPP Model** | DBFOMT (Design, Build, Finance, Operate, Maintain and Transfer) |
| **Payment Mechanism** | Availability Payment (Unitary Payment) from CA (TANROADS) to Private Party (SPV) |
| **Concession Period** | Approx. 30 years (including construction period) |
| **Toll Collection** | Road user tolls will be collected by the Private Party on behalf of TANROADS/GoT, with all toll receipts deposited into a ring-fenced Escrow Account. The toll revenues held in the Escrow Account will be used to pay the Unitary Payment. |
| **Toll System** | Closed Toll System (CTS) — 4 toll stations |

## 4.2 Hand-back Requirements

At the expiry of the concession period, the Private Party shall hand back the project assets to TANROADS in a condition complying with the Handback Requirements specified in Annexure 17 (Schedule 17) of the PPP Agreement. The key handback requirements include pavement residual service life, structural integrity of bridges and drainage, ITS operational status, and software licensing.

Note on pavement residual life: Annexure 17 Appendix A specifies a 40-year residual life at handover. This is physically inconsistent with the 30-year pavement design life and 30-year concession period. A decision has been made to maintain the current wording for both Lot 1 and Lot 2 (for consistency), with the matter to be addressed at RFP stage via Addendum — see Flag F-1.

## 4.3 Inter-Lot Coordination

Lot 2 has a structural dependency on Lot 1 at the Chalinze interface. The key coordination matters are:

- The Chalinze Main Toll Plaza is operated by the Lot 1 SPV. Revenue attributable to Lot 2 road users must be calculated, apportioned, and transferred to the Lot 2 SPV Escrow Account.

- An Inter-Lot Cooperation Agreement (3-party: CA + Lot 1 SPV + Lot 2 SPV) must be executed prior to the Tolling Date of Lot 2. The agreement shall cover inter-Lot operational responsibilities, toll apportionment methodology, daily settlement procedures, data exchange, and dispute resolution.
- Lot 1 Annexure 1 Section 3 already sets out the Lot 1 SPV obligations regarding this coordination. A corresponding mirror provision for Lot 2 is to be drafted in the Lot 2 PPP Agreement — see Flag F-2.

### 4.4 Revenue Sources

- Primary: Road user tolls (Closed Toll System)
- Secondary: Rest area rental revenue (2 rest areas)

Rest area rental revenue is assumed to offset the required Unitary Payment; having the effect of reducing the Unitary Payment paid by TANROADS/GoT.

## 5. ENVIRONMENTAL AND SOCIAL ASSESSMENT SUMMARY

### 5.1 ESIA Status

The project is registered with the National Environment Management Council (NEMC) under registration number EC/EIA/2023/1275. A Preliminary Environmental and Social Impact Assessment (ESIA) has been conducted. The full ESIA, including ESIA Report and Environmental and Social Management Plan (ESMP), will be required prior to commencement of construction works.

### 5.2 Key E&S Risks and Mitigation

- Land acquisition and resettlement (RAP): The alignment traverses populated areas. Resettlement Action Plan (RAP) preparation and land acquisition are CA obligations under the PPP Agreement prior to and during the concession period.
- Biodiversity and sensitive areas: Alignment review has been conducted to avoid ecologically sensitive areas. Non-professional maps in the draft F/S were corrected in the Final F/S.
- Community engagement: Public consultations conducted with relevant institutions and communities. Meeting minutes, attendance lists, and signatures included in the Final F/S as required by PPPSC.
- NEMC EIA process: The Private Party must obtain an EIA Certificate from NEMC prior to commencement of construction. The review period is 60 days following EIS submission.

### 5.3 Critical E&S Issues

The following E&S items remain as critical issues for the procurement phase:

- ESIA must be completed and approved by NEMC before construction commencement.
- RAP must be finalised and land acquisition substantially completed before or concurrent with the Effective Date.

- ESMMP (Environmental and Social Management and Monitoring Plan) to be submitted by the Private Party as part of design documentation.