3 ALTERNATIVES

This section is equivalent to Section ix, assessment of impacts and identification of alternatives, of the legislative structure. If in doubt, please refer to Table 1.5-1 Environmental Impact Statement Structure on page 1-5.

3.1 Introduction

This section summarises the process undertaken during pre-front-end engineering design (FEED) (design process before FEED) and FEED to evaluate the technically and financially feasible alternatives for the East African Crude Oil Pipeline (EACOP) project while considering potential environmental and social impacts. The alternatives have been broadly categorised as follows:

- project zero alternative
- pipeline routing
- facility siting
- technology
- construction techniques.

3.2 Overview

The project alternatives considered and the decisions taken by the EACOP project during the pre-FEED and FEED phases have led to the validation of the project base case as it is described in Section 2 Project Description. The objective of this section is to document how the project design was optimised to reduce environmental and social impacts while being technically and financially feasible. This is based on assessment of the alternatives for each of the key strategic alternative themes, i.e., the “zero” project alternative and the main alternative areas mentioned in Section 3.1.

While the base case concept for technology was defined during pre-FEED phase, routing and siting alternatives have been analysed progressively in the context of the engineering, environmental, socio-economic and cultural heritage constraints identified during baseline surveys undertaken as part of the environmental and social impact assessment (ESIA) process. It should be noted that there is a requirement to provide flexibility for construction contractors that will develop the most efficient and cost-effective construction techniques while ensuring compliance with project standards. As mentioned in Section 2.1.1, refinements to design may be made during the detailed engineering and pre-construction phases influenced by site-specific conditions.

3.3 Approach to Alternatives Assessment

The environmental impact assessment (EIA) regulations in the host country require an examination of feasible project alternatives and an explanation of the rationale for selecting the proposed project scheme. The specific requirements are detailed below:

In Tanzania, The Environmental Impact Assessment and Audit Regulations 2005 requires for the EIA to:

- identify and analyse alternatives to the proposed project
- provide information on alternative technologies and processes available and reasons for preferring the chosen technologies and processes
- analysis of alternatives including project site, design technologies and reasons for the preferring of the proposed site, design and technologies.

In addition, the International Finance Corporation (IFC) Performance Standards Guidance Note 1: Assessment and Management of Environmental and Social Risks and Impacts (Ref. 4.4), requires:

> "…an examination of technically and financially feasible alternatives to the source of such impacts, and documentation of the rationale for selecting the particular course of action proposed."

The alternatives assessment process is shown in Figure 3.3-1.

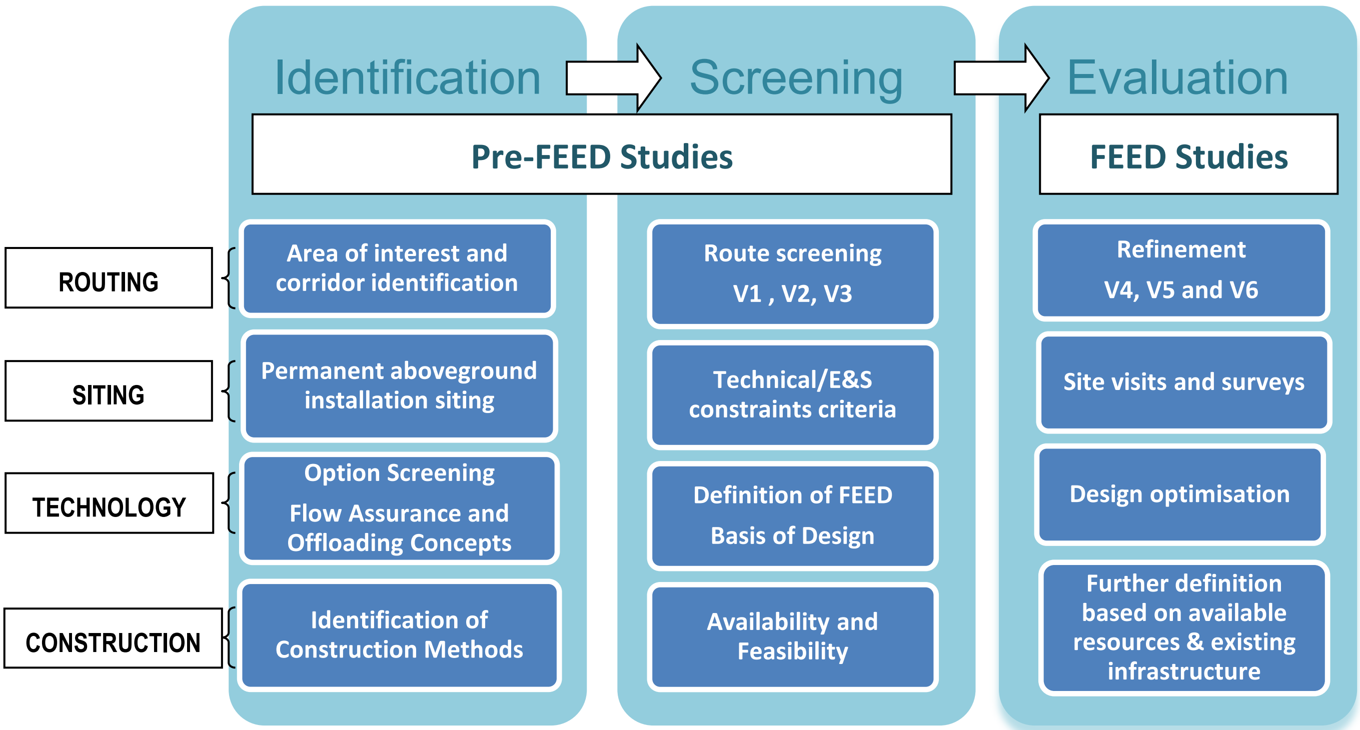


Figure 3.3-1 Alternatives Assessment Process

3.4 Zero Project Alternative

3.4.1 Overview

The "zero project alternative" for the purposes of this alternatives assessment is the situation where the project, i.e., the EACOP System, does not proceed. The development of oil pipelines are large-scale projects. Under the zero project alternative, there would be no environmental or social impacts, on land or in associated waters because no construction nor operation activities would occur. However, the discovery of oil in the Albertine Graben area of Uganda and the opportunity to access global markets provide a new resource revenue stream for Tanzania and employment opportunities for the host countries. A decision not to proceed with the project would result in the absence of revenue from crude oil production, crude oil export sales and associated economic development. Furthermore, benefits for Tanzania and for the district level would not materialise from the opportunities that the project would provide such as employment, skills development, technology transfer and growth in other business sectors such as fabrication, construction and waste management.

As part of the zero project alternative assessment, other modes of crude oil transport were assessed.

3.4.2 Rail

Rail has been considered as a potential mode of crude oil transport from Uganda to international markets. There is an existing narrow-gauge rail link from Uganda to the Mombasa port. This link was constructed in the 1900s as a narrow-gauge rail system. Narrow gauge rail is considered less stable (safety risk) and therefore slower than a standard gauge rail system and transporting the projected peak production of 216 thousand barrels per day (KBPD) would be a significant challenge. The network would require extensive upgrades, risks would be associated with carriage stability and the network capacity would not be enough for the planned transportation rate of approximately 350 tank cars per day of oil. These combined factors resulted in the decision to consider alternative crude oil transport modes.

3.4.3 Road

Road transport via Kenya to the Indian Ocean coast was considered as a potential mode of transporting oil. It was estimated that it would take approximately 14 days for a shipment to travel from Hoima to Mombasa. There are large sections of the existing road infrastructure that are in poor condition in both countries and it would require extensive upgrades over large areas to ensure uninterrupted transportation. To export the projected amount of oil would require 1000 trucks on the road at any given time, which would create a substantial amount of traffic over the lifetime of the project and would result in increased emissions, disturbance and public road safety risks. These combined factors resulted in the decision to consider alternative crude oil transport modes.

3.4.4 Summary

A pipeline provides a well-established, comparatively safe system for the long-term export of oil. In addition, design specifications for pipeline systems are supported by robust international standards. Construction of a pipeline can be completed in a relatively short time. Once operational, pipelines have limited impacts that are localised and can be managed. A buried pipeline system provides the most efficient and dependable method of transport while minimising EIAs during the operational phase. Consequently, the project made the decision to progress the oil transportation project as a buried pipeline (see Section 3.7.2 for information on the consideration of aboveground versus buried pipeline).

3.5 Pipeline Routing

3.5.1 Overview

Several alternative pipeline routes were identified during pre-FEED. The routing process began with the identification of a starting point and a flexible end point which was then followed by numerous screening studies. This work culminated in the selection of eleven 50-km-wide corridor combinations for evaluation. Secondary information was then used to assess the potential corridors using GIS and three main corridor options were selected:

- Kenya North
- Kenya South
- Tanzania.

Using higher-resolution satellite imagery, the corridors were further refined by using several constraints criteria including environmental and social, geohazards, constructability and terrain (river crossings and slopes). Further to consideration of the study of the three identified corridors, the Government of Uganda announced the selected Uganda–Tanzania route on 23 April 2016 as shown in Figure 2.3-1. This section provides an overview of the route alternatives considered.

3.5.2 Pre-Front-End Engineering and Design

3.5.2.1 Initial Pipeline Corridor Options

Routing studies of a crude oil export pipeline from a fixed point at Lake Albert area of Uganda to several terminal options situated at multiple end point locations on the East African coastline were conducted. The resulting area of interest was defined for the preliminary routing and included areas in Uganda, South Sudan, Kenya and Tanzania. The common starting point of all potential routes studies was northeast of Hoima with the end points at Malindi (Kenya), Tanga (Tanzania), Juba (South Sudan), Lokichogio (Kenya) and Lamu (Kenya).

Exclusion criteria were applied to the area of interest, which included slopes over 45°, elevation above 2500 m; lakes, active volcanoes, protected areas, cities and a 1-km buffer around cultural, archaeological and touristic sites. The resulting area of interest and exclusions zones are shown in Figure 3.5-1.

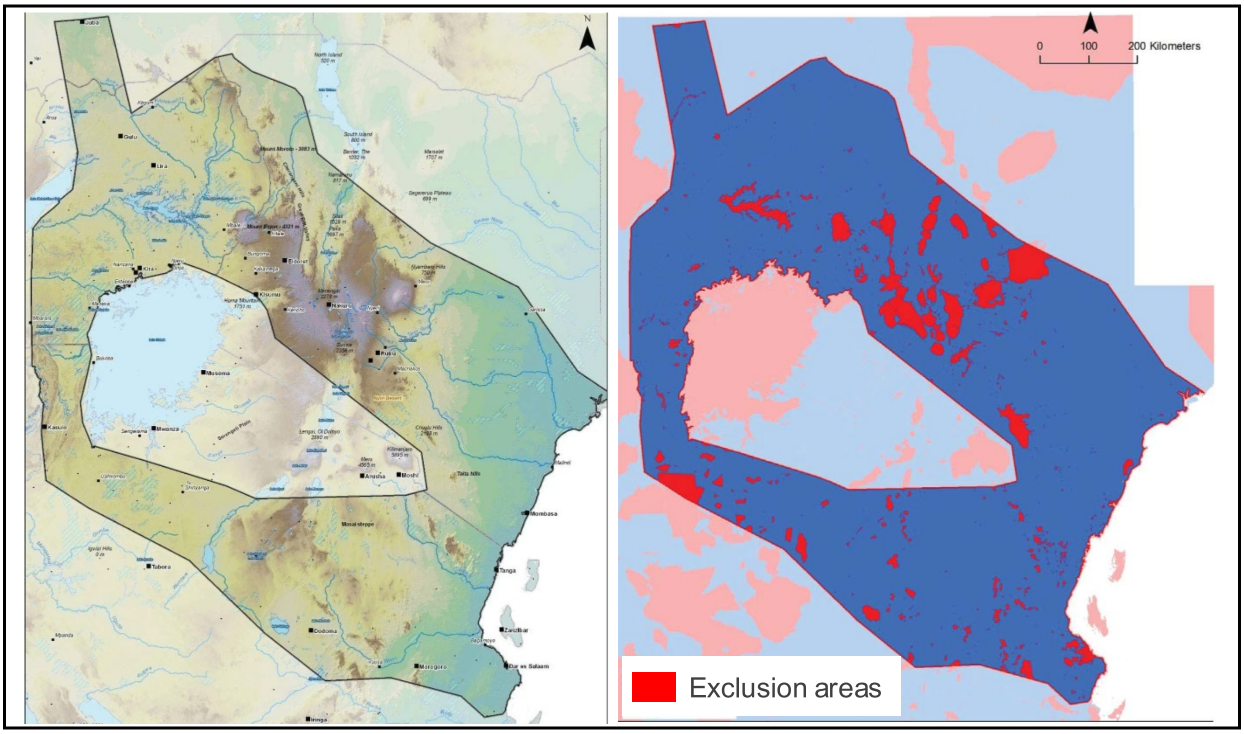


Figure 3.5-1 Routing Area of Interest (left) and Excluded Areas (right)

As a result of the spatial multicriteria analysis, 11 potential 50-km-wide corridor combinations were identified as shown in Figure 3.5-2. Following route optimisation and offloading potential solutions were evaluated using the corridor and siting criteria, Corridors 3 (South Kenya), 6 (Tanzania) and 11 (North Kenya) were selected as the most viable options and were recommended for further study.

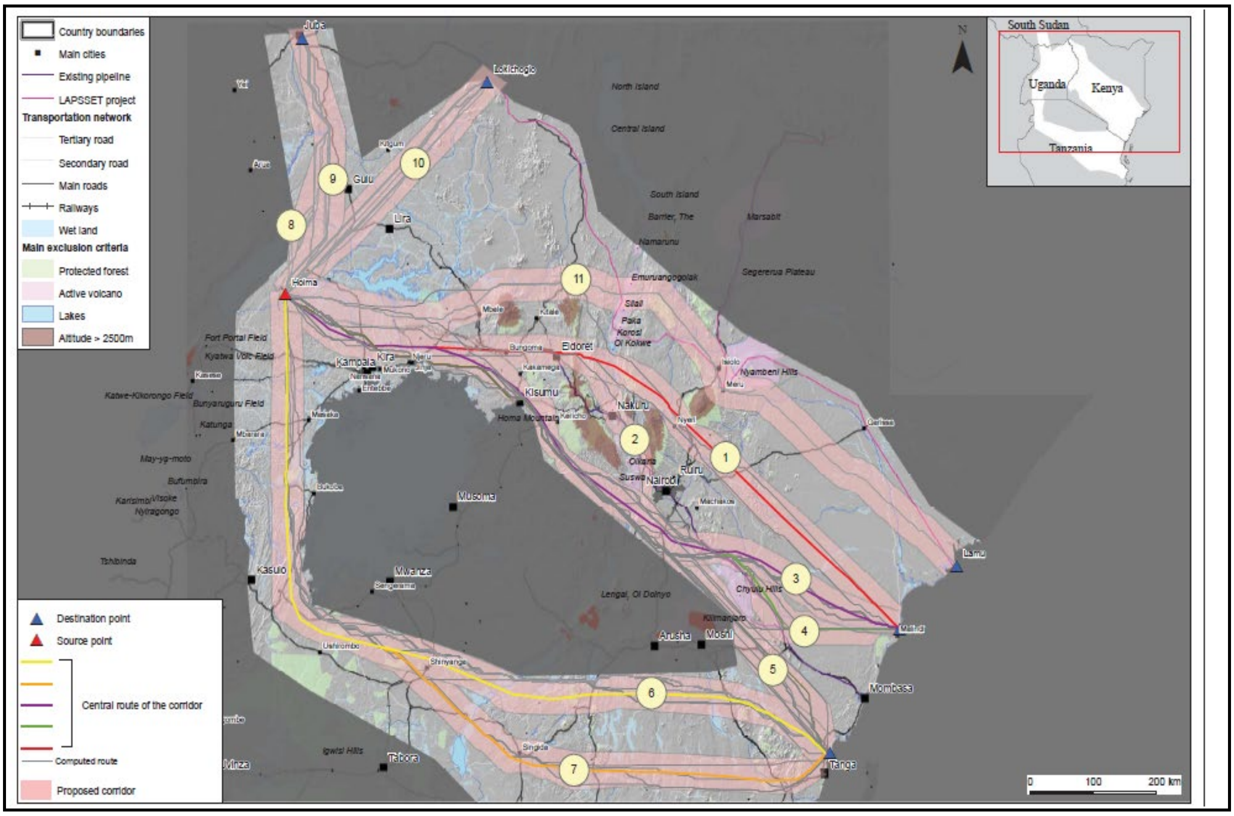


Figure 3.5-2 Pipeline Corridors

3.5.2.2 Corridor Options Screening

Corridors 3 (South Kenya), 6 (Tanzania) and 11 (North Kenya) were screened by applying biological, geological, physical and socio-economic criteria and using a range of secondary data. The screening assessment considered physical factors including topography, climate, hydrology and hydrogeology, geology and geohazards and soils.

The screening assessment identified some disadvantages of Kenya routing alternatives:

- North Kenya (Corridor 11) was routed through the northern portion of Kenya where there is a lack of existing transport and communications infrastructure, vast wetlands north of Lake Kyoga, proximity to active volcanoes and large areas of flash flooding (scour risks) potential.
- South Kenya (Corridor 3) would utilise the existing refined product pipeline corridor from Mombasa to Eldoret. The corridor would then pass through a highly populated region of Uganda along the north side of highway A104 into Uganda and then traversing northwest and south of Lake Kyoga toward Kabaale. The corridor does pass through densely populated areas and where encroachment within the corridor has occurred both in Mombasa and near Eldoret. The use of this corridor would lead to more extensive impacts on local population.

Feasibility studies highlighted the potential benefits of pipeline corridor options in Tanzania, which involves routing the Uganda section of the pipeline east of Lake Victoria in a southerly direction. After further investigation of Corridor 6, it was identified that the corridor was near two national parks, and therefore it was abandoned for the lengthier Corridor 7. In particular, Corridor 7 (as shown in Figure 3.5-2) to:

- be closer to existing infrastructure (roads, railway)
- reduce the number of river crossings
- provide a more suitable elevation profile for pipeline hydraulic design
- locate the export terminal facilities in sheltered waters along the Tanzania coast.

In early 2015, the project concluded that Corridor 6 was not viable owing to difficult mountainous terrain, remote areas, nationally protected biodiversity areas and touristic areas within Tanzania. Although the Uganda section of the EACOP pipeline for corridors 6 and 7 is the same, the southern Tanzania option (Corridor 7) was selected as the base case from Kabaale in Uganda (the pipeline's eventual starting point at kilometre point [KP] 0) to Tanga, Tanzania, and was subsequently used to develop route version V1.

The V1 route avoids most environmentally sensitive zones, i.e., protected land such as forest reserves, wildlife reserves and national parks. An environmental and social screening study was then conducted that confirmed constraints along the route were considered less substantial than the other routing options. For example, the South Kenya route crossing the Tsavo National Park and both Kenyan routes crossing the Nile River.

While there are some constraints (several rivers, Forest Reserves, cultivated areas and the presence of archaeological and heritage sites) near the pipeline route, most of the route traverses areas with low or negligible sensitivity.

The screening study also concluded that the pipeline constructability risks are substantially less because of the proximity of most of the route to existing transportation infrastructure. By avoidance of the technically challenging and environmentally sensitive areas, and year-round export available at Tanga, the pipeline operability is likely to be high, resulting in secure, dependable flows of crude oil through the lifetime of the pipeline.

3.5.2.3 Route Refinement

Figure 3.5-3 shows the selection process undertaken from pre-FEED versions V1, V2 and V3 through the FEED phase versions V4 to V6. With the inputs from detailed mapping, multidisciplinary studies and site visits, the pipeline corridor width was incrementally narrowed down from several kilometres through to 2000 m (V3) to 100 m (V4 and V5) and finally to a 30-m right-of-way (RoW) (V6) with a centreline.

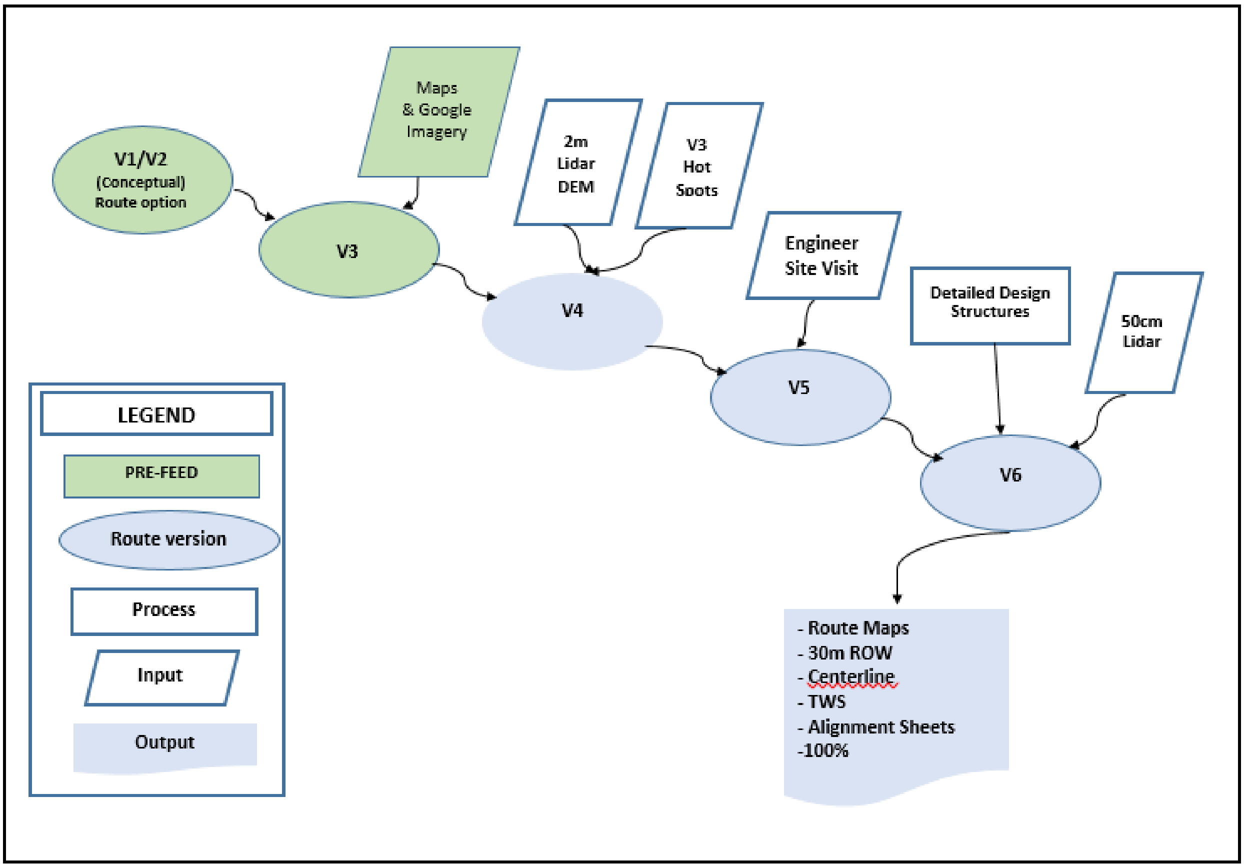


Figure 3.5-3 Route Refinement Process

The main routing criteria used to assess potential routes are shown in Table 3.5-1.

Table 3.5-1 Route Refinement Criteria

Technical Criteria	Environmental Criteria	Socio-economic and Cultural Heritage Criteria
Route length Lateral slope (>10° No Go unless very short distance/ single instance) Front slope (>20° No Go unless very short distance/single instance) Number of cold bends and tie-ins due to terrain undulations Shallow bedrock (granite, gneiss – No Go) Wetlands (permanent and seasonal) River/stream crossing Road/track or rail crossing Fault crossing Other types of crossings	Internationally protected areas (Ramsar sites, UNESCO World Heritage Sites) (No Go) Nationally protected areas (national park, wildlife reserve, wildlife sanctuary, forest reserve, community wildlife management area, high biodiversity wilderness area) Waterbodies (lake, reservoir) (No Go) Internationally designated protected areas (IUCN Cat Ia, Ib and II) Internationally and nationally designated protected areas (IUCN III, IV, V and VI)	Industrial areas (mines, factories, power plants) (No Go) Social and community infrastructure (including places of worship) RoW of existing or planned linear facilities Transport infrastructure Settlements (urban area, town, village) Structures within 50 m of corridor centreline Trees and timber forest Cash crop (e.g., tea, coffee plantation, sisal, sugar cane, banana)

Table 3.5-1 Route Refinement Criteria

Technical Criteria	Environmental Criteria	Socio-economic and Cultural Heritage Criteria
Flooding hazard Landslide hazard Karsts, tunnels and mines (settlement hazard) Seismic zone with liquefaction risk (No Go) Earthquake zone Geological features Infill land and waste disposal sites, including those contaminated by disease, radioactivity or chemicals	Critical habitats[1] Natural habitats[2] Other notable biodiversity areas	Water points, sources and wells Cultural heritage sites Tourism facilities and sites

Application of the criteria highlighted key routing constraints. These include routing around extensive shallow bedrock, passages between protected areas and through hilly terrain. For the sections of the pipeline route external to these constraints, further optimisation was implemented with the aim to balance pipeline length and proximity to existing roads and the length of new access roads required. The route that best met the criteria was selected as the base case and was identified as version V2.

3.5.2.4 Pre-Front-End Engineering and Design Route Optimisation (V2 to V3)

The V2 route was revised to V3 route during pre-FEED as a result of multidisciplinary workshops including engineering, environmental and social input. The focus and effort to optimise the route was intended to improve the side and front slopes, avoid nationally protected areas, reduce impacts to perennial rivers and wetlands, and, where possible, reduce the overall length. Improvement of the side and front slopes along the route is important for several reasons:

- During construction, the rate of elevation change (i.e., front slope) can increase the pipeline’s cost and create challenges for accessibility to the RoW.
- Elevation difference is important, as it affects system hydraulics.
- Side slopes require side cuts and fills necessary for construction equipment to safely manoeuvre and install the pipeline. During operation, the RoW will tend to retain water, which can destabilise the ground supporting the pipeline.

[1] Critical habitats are areas with high biodiversity value, including (i) habitat of significant importance to Critically Endangered and/or Endangered species; (ii) habitat of significant importance to endemic and/or restricted-range species; (iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; (iv) highly threatened and/or unique ecosystems; and/or (v) areas associated with key evolutionary processes (IFC PS6 2012).

[2] Natural habitats are defined as areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area’s primary ecological functions and species composition (IFC PS6 2012).

Route optimisation also identified pinch points where routing options are restricted, as shown in Figure 3.5-4.

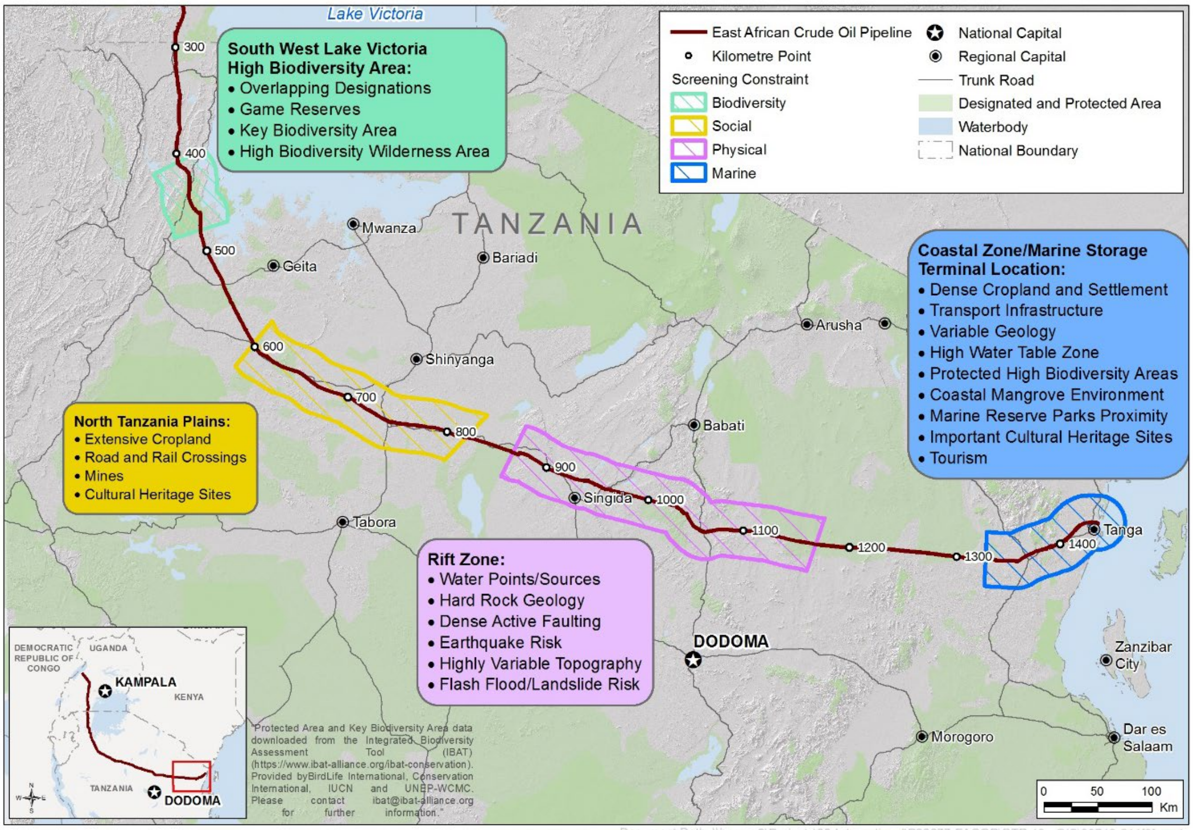


Figure 3.5-4 Pre-Front-End Engineering and Design EACOP Tanzania Corridor Summary Constraint Zones

3.5.3 Front-End Engineering and Design

3.5.3.1 (V4 and V5) Routing Refinements

Version V3 provided a 2000-m-wide corridor to guide the LIDAR[3] survey from Kabaale, Uganda to the marine storage terminal (MST) at Tanga, Tanzania.

The LIDAR survey data produced a digital elevation model (DEM). The DEM was used, along with other routing tools to select and refine the route. This included using satellite imagery to identify dwellings and other structures to aid routing. Reroutes to reduce the number of dwellings and other structures were made from KP641 to KP649 and KP1051 to KP1057. The product of this work was route version V4. In total, V4 reduced the number of dwellings and other structures within 50 m of the pipeline centre-line by more than a third.

[3] Light Detection and Ranging (LIDAR) is a remote sensing method that uses pulsed laser to measure ranges (variable distances) to the Earth, generating precise, three-dimensional information about the shape of the Earth and its surface characteristics (https://oceanservice.noaa.gov/facts/lidar.html).

The V4 corridor was then mapped with a 100-m-wide corridor, suitable for technical verification during engineering site visits to Uganda and Tanzania.

Data collected and ground truthing performed during an engineering site visit (April 2017) by a multidisciplinary team including environmental and social specialists was used to establish a centreline within the 100-m-wide corridor and to advance the V4 route to V5. Route V5 was then used:

- to produce route maps with a 100-m-wide corridor and a centreline
- as a basis for engineering, i.e., procurement of essential materials and long lead items, such as pipe, heat tracing, valves and hot bends
- to prepare the EACOP Tanzania Scoping Report.

The following environmental and social constraints were applied during FEED to refine the pipeline corridor through route versions V4 to V5:

- avoid:
  - physical resettlement of local population to the greatest extent possible
  - creation of access roads to otherwise inaccessible areas
  - cultural heritage and archaeological sites to the greatest extent possible
- reduce:
  - economic resettlement, disruption to livelihood of local population
  - combustion, metal vapour emissions
  - project footprint (including RoW, aboveground installation [AGI], work sites, access roads)
  - land take; habitat and agricultural land lost
  - project disturbances (such as noise, light, vibration, dust)
  - groundwater abstraction/discharge
  - restoration of habitats and hydrogeological regimes after construction.

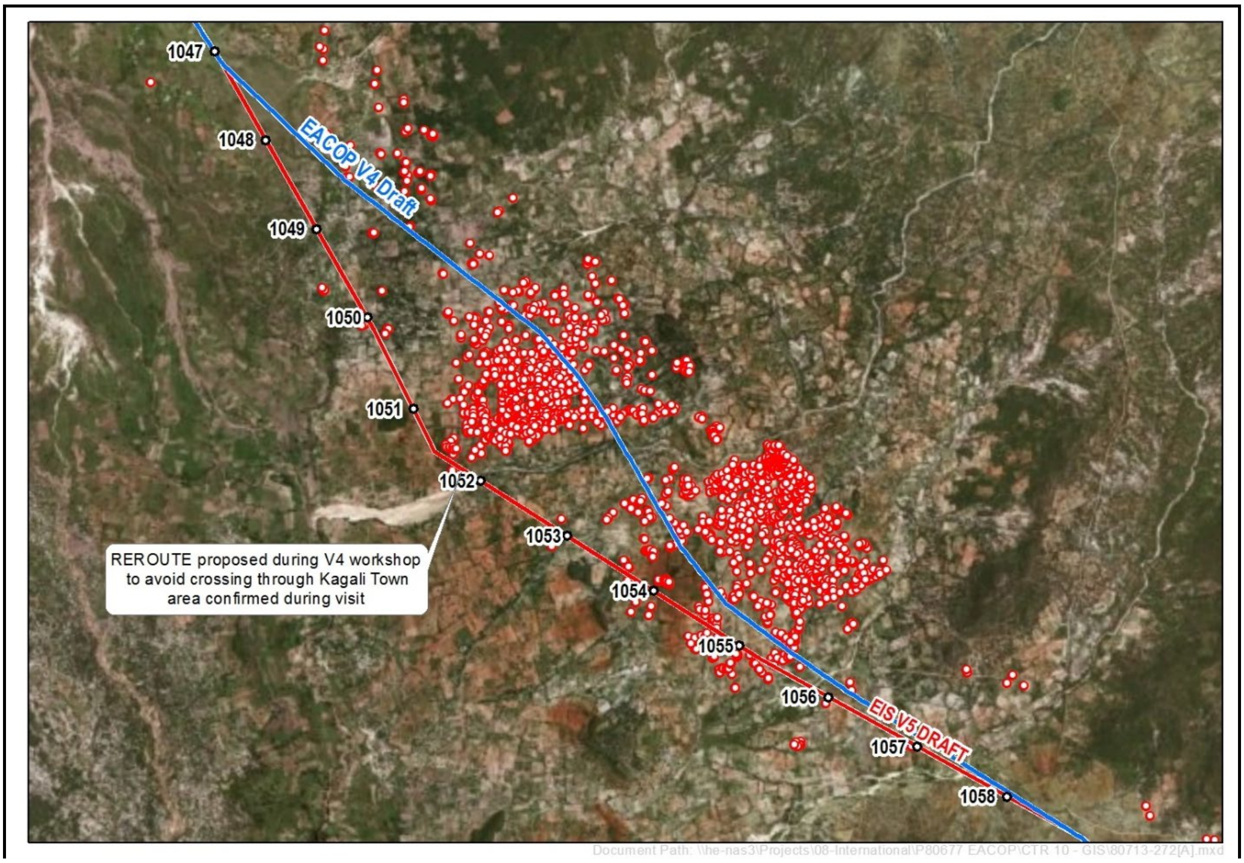
Consistent application of this criteria has been of paramount importance while narrowing the study corridor from 2000 m down to the 100-m-wide corridor with pipeline centreline (V5) and the 30-m-wide RoW (V6), see Section 3.5.2.3.

Route version V5 was used to support the ESIA scoping report, risk assessment, site-specific geotechnical and geophysical surveys, and in development of the main scope of work for detailed engineering.

Examples of route improvements for EACOP Tanzania from V4 to V5 are shown in Figure 3.5-5 and include:

- minor route adjustment to allow for Kagera river horizontal directional drilling (HDD) workspace and avoid newly built service station
- improved crossings of slopes and scarps, waterbodies, avoid structures, avoid crossing Swaga Swaga Game Reserve and the Korogwe Fuel Forest Reserve
- minor route adjustment to the west from KP466 to KP483 to avoid dwellings and other structures
- route realignment to the north to avoid a densely populated area between KP611 and KP618.5
- route realignment to the north between KP1047 and KP1058.5 to avoid Kigali town area

- minor route realignment from KP1091.5 to KP1114 to avoid dwellings and other structures, straighten the route and reduce the number of pipe bends required
- minor route realignment from KP1210 to KP1270 to avoid clusters of dwellings and other structures and also shorten the pipeline route
- route realignment to allow for HDD crossing of Sigi river
- end point of the route was aligned with the updated MST layout.



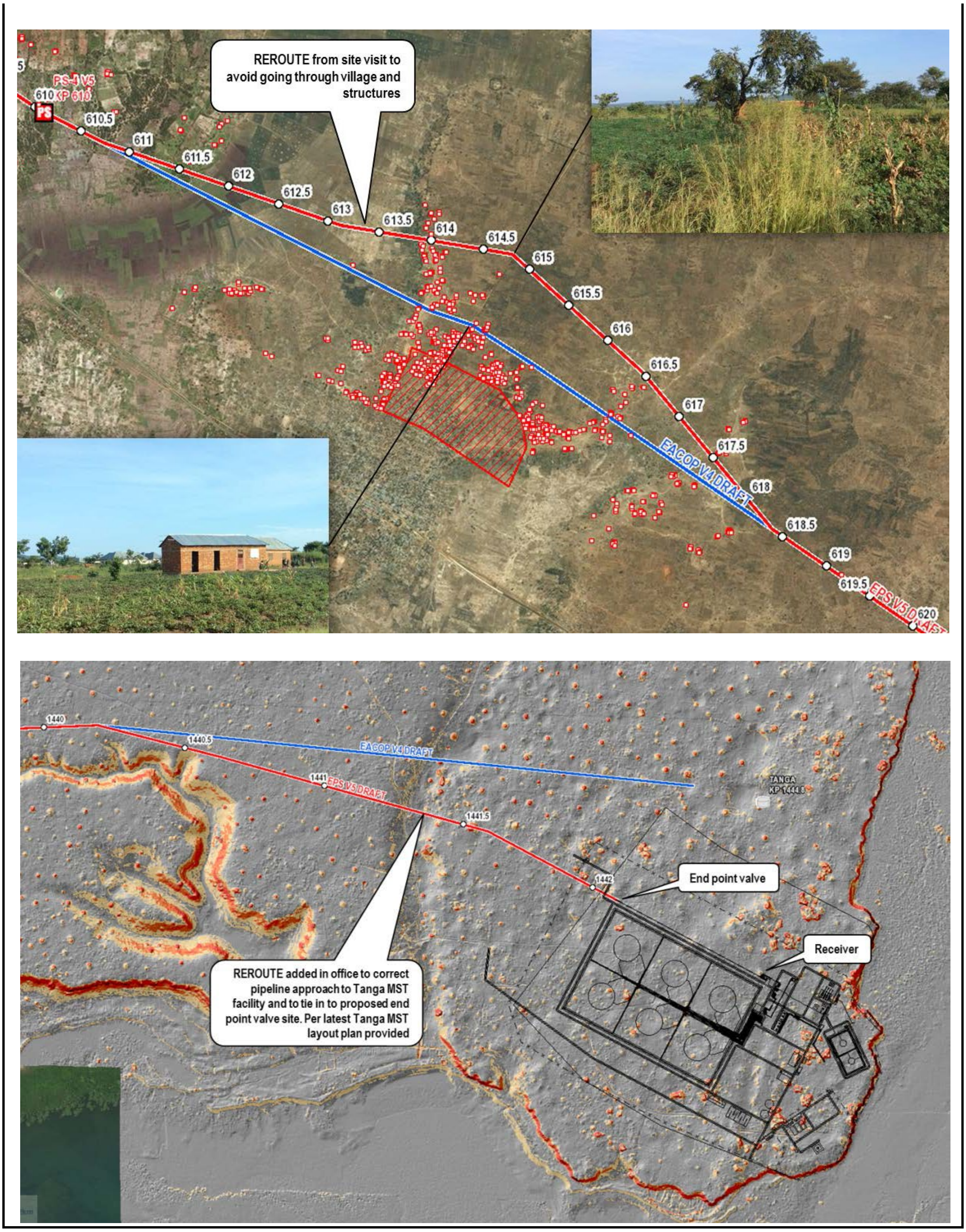


Figure 3.5-5 Tanzania EACOP Route Improvements V4 to V5

NOTE: MST layout has since been optimised – see Section 2 for final MST layout description.

Reroute that was proposed after evaluating the Kelema River crossing during the site visit as shown in Figure 3.5-6.

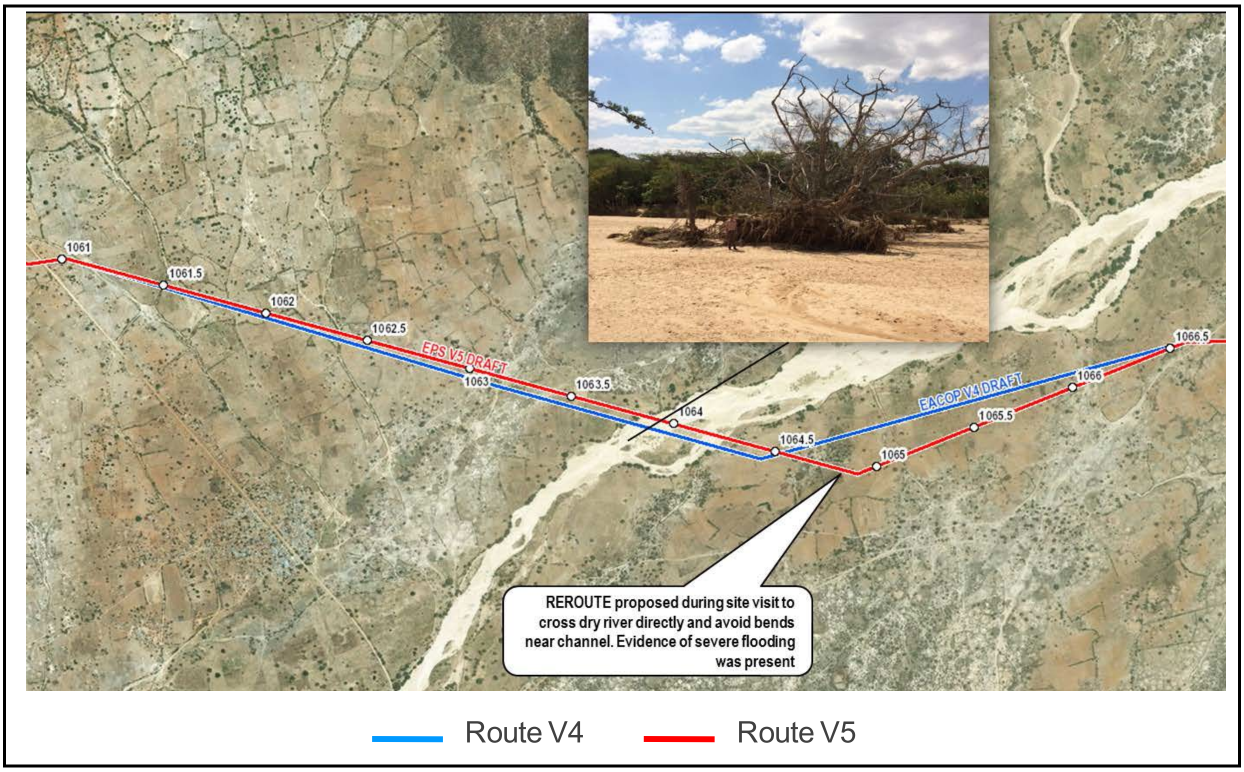


Figure 3.5-6 Route Adjustment at Kelema River

3.5.3.2 V5 to V6 Routing Refinements

All refinements from V5 to V6 were minor, with most pertaining to constructability considerations and avoidance of dwellings and other structures, ecologically sensitive areas and watercourses. Updates in route version V6 also included:

- location and size of AGIs
- locations of the main line block valves, most of them aligned with intermediate electrical substations
- locations of construction camps and pipe yards.

3.5.3.3 V6 Base Case Route

The base case route of the 30-m RoW is shown in Figure 2.3-1. In total, between route version V3 and V6 over 1100 dwellings were avoided. However, as investigations are ongoing at the time of writing this ESIA, e.g., geophysical and geotechnical surveys, small-scale adjustments may still be made.

3.6 Facility Siting

3.6.1 Overview

This section describes the main alternatives assessed for the number, location, layout and footprint of the following facilities:

- AGIs
- construction facilities

- MSTs.

The functional requirements of the surface facilities have been the main driver for the identification, screening and final location selection.

The selection of appropriate sites for the pumping station (PS) and pressure reduction station (PRS) was determined during pre-FEED by pipeline hydraulic studies. Additional imagery and site visits were used to establish locations during FEED. Siting of the heat trace substations is ongoing and will be refined based on further electrical studies, whereas the block valve locations have been defined based on detailed technological risk analysis.

The functional requirements vary for each type of facility and are described in this section. The selection process has also considered relevant safety, environmental and social constraints.

3.6.2 Aboveground Installations

The main driver for the type, number and location of the AGIs has been the technical specifications. In particular, the PS and PRS locations have been selected based on pipeline hydraulic requirements (design pressure and maximum operating pressures). However, additional criteria have been considered:

- thermal design requirements
- safety and environmental risk factors
- site physical conditions (topography, accessibility, proximity to existing infrastructure)
- environmental and social constraints.

3.6.2.1 Pumping Stations

During pre-FEED, three hydraulic design scenarios were considered. The requirement to maintain the hydraulic profile was the main influencing factor in determining the number and location of the PSs (see Figure 3.6-1).

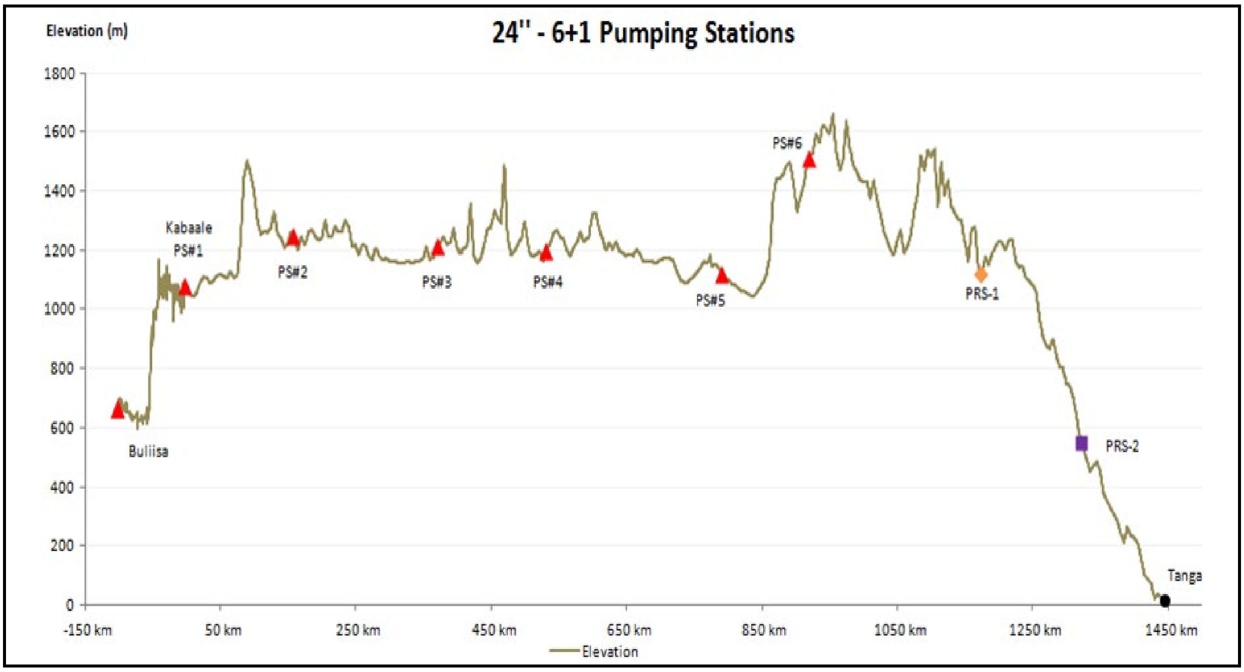


Figure 3.6-1 Pressure Profile and PS Locations

The PS locations have been identified by the points on the pipeline where at maximum flow, the pressure in the pipeline falls to approximately 6 barg; regard was also taken of topographical profile so as not to locate the PS in a deep dip.

Table 3.6-1 summarises the design alternatives considered for the pipeline. Case 2 was assessed to reduce design pressure and Case 3 was assessed to reduce the number of PSs.

Table 3.6-1 Pipeline Design Cases During Pre-Front-End Engineering and Design

Design Case	Scenario	Key Drivers
Case 1 Base Case	24 in. 6 PSs	Confirmed base case for FEED
Case 2 – Design Pressure Reduction Case	26 in. 6 PSs	Reduce design pressure to continue with Class 600 piping
Case 3 – Pumping Station Reduction Case	24 in. 5 PSs	Reduce number of PSs

The studies concluded that Case 1 should be maintained as the base case for FEED.

Preliminary locations based on hydraulic modelling are shown in Table 3.6-2. The actual location of the PSs has been amended iteratively concurrently with pipeline route refinement. In addition, a site visit was undertaken in May 2017 to validate the proposed locations of the AGIs based on the following:

- accessibility and distance to infrastructure (suitable access roads)

- geotechnical information (expected ground conditions, presence of escarpments, wetlands, flood potential, seismic data)
- societal impact (population displacement and land use).

Table 3.6-2 summarises the initial locations of PSs during pre-FEED and site visit findings and iterations undertaken with the routing team.

Table 3.6-2 Preliminary and Final Pump Station Locations

	PS3	PS4	PS5	PS6
KP (Concept Study, Route V1)	415	612	825	905
Results of Site Visit, May 2017	Access considerations steep switchbacks moved to KP405.4	Access is poor but high and well drained	Move location east 1 km to higher ground	Move by 200 m as in a low area.
KP (Final Route V6)	405.4	610	825	931

3.6.2.2 Pressure Reduction Stations

Along the pipeline route, up to KP1100, the elevation is relatively consistent and there are no specific low points where nominal design pressure would be exceeded. However, after KP1110, over the western-most 400 km the elevation decreases from the high point of 1500 m to 10 m at the MST. Without active pressure regulation, pressure in the pipeline will increase as the elevation drops. Studies undertaken during pre-FEED identified the concept of increasing the wall thickness as the pipeline descends to counteract the gravity-induced increase in fluid pressure. This option has higher cost and design complexities associated with fully rated pipeline system. Consequently, the EACOP project team opted for active pressure management with PRSs and high integrity valves on the descending section of the pipeline.

Similar to the PS site selection, locations for the PRS were refined alongside the route optimisation process with proposed locations being reviewed during the site visit in 2017. The finalised locations of PRS are: PRS1 at KP1171.5 and PRS2 at KP1330. These are described in Section 2.3.3.3.

3.6.2.3 Electric Substations

As described in Section 2.3.3.4, the electric substations house transformers required for power transmission through the high-voltage cable and step-down transformers to provide the required voltage for the electric heat tracing (EHT) system. The rationale for siting of electric substations is based on the overall number of substations required by the trace heating system, i.e., maximum cable length of 30 km and therefore the maximum distance between power supplies required would be 60 km.

During FEED, the siting of the electric substations was reviewed and, where possible, combined with the AGIs and block valves. The number of substation combinations with AGIs and block valves, and the standalone substations, are shown in Table 3.6-3.

Table 3.6-3 Electric Substation Siting – Combined and Standalone

Facility	EACOP Tanzania
Standalone electric substations	3
Substations combined with PS, PRS and MST	7
Substations combined with block valves	11
Total	21

3.6.3 Block Valves

The primary function of block valves is to isolate sections of the pipeline and the number and location of block valves is based on ASME B31.4 (434.15), which requires that block and isolating valves will be installed to:

- limit hazard and damage from accidental discharge
- facilitate maintenance of the piping system.

The number and location of valves has also been informed by risk assessment based on safety and environmental risk considerations. Preferred locations include:

- upstream side of major river crossings and public water supply reservoirs
- at other locations appropriate for the terrain features
- at remotely controlled pipeline facilities to isolate segments of the pipeline
- on the inlet and outlet of pump stations whereby the pump station can be isolated from the pipeline
- on lines entering or leaving tank farms or terminals at convenient locations
- in industrial, commercial, and residential areas where construction activities pose a risk of external damage to the pipeline.

Based on these preferences, block valves were sited at:

- every PS, PRS, meter station and the MST
- long continuously ascending or descending elevation profile
- on each side of wetlands and major water crossings (> 30 m wide)
- at each river or stream < 30 m wide, where downstream impacts from a pipeline leak could impact populations, reservoirs, waterways and/or sensitive areas.

Further evaluation and optimisation of block valve locations was undertaken when the list of electric substations required for the pipeline heat tracing system became available during FEED. Additional work was then performed to combine the locations for block valves and electric substations as much as possible to optimise facilities' footprint and access requirements.

The results of the optimisation process of block valve placement for EACOP Tanzania pipeline are as follows:

- elimination of 11 block valves
- addition of another 2 block valves

- combining of 11 block valves with electric substations
- total of 60 block valves in the RoW.

3.6.4 Construction Facilities

The following construction facilities are to be established:

- main camp and pipe yards (MCPYs)
- coating facility (CF) and camp.

The construction facilities site selection process has taken into consideration the requirement to:

- minimise land acquisition
- reduce distance from existing road networks
- avoid populated and protected areas
- take cognisance of the terrain type and topography suitability
- water availability.

In September 2016, a construction site overview was undertaken to assess locations proposed for the V3 route. The locations were subject to preliminary assessment based on the criteria in Table 3.6-4.

Table 3.6-4 Construction Facility Location Selection Criteria

Technical	Environmental	Social
Facilitate access to RoW for the MCPY Facilitate access for pipes from main roads and rail for CF Availability of water Availability and capability of local contractors to undertake the required scopes	Limit footprint and impact by minimising requirements for temporary roads Avoid nationally protected site and internationally recognised sites of conservation interest and critical habitats, Topography Terrain type (avoiding wet areas) Potential geohazards (such as flood zones, faults)	Avoiding resettlements and/or limiting extent of resettlement Clear of villages and schools Social and community infrastructure (including places of worship) Settlements (urban area, town, village) Cash crop (e.g., tea, coffee plantation, sisal, sugar cane, banana) Water points, sources and wells Cultural heritage sites Tourism facilities and sites Avoid the clearance of trees, existing crops and bush in dry areas (where crops would be easier to restore) Clear of military facilities Coating facility to be close to existing towns to provide local employment opportunities and reduce camp size

The three criteria for construction facility location as shown above were applied with the relevant criteria used for the pipeline route selection as shown in Table 3.5-1.

Each of the sites were then subject to further construction facilities assessment work derived from available baseline information which identified further constraints and with the main objective to confirm site selection. Further iteration will be undertaken to ensure that the footprint and orientation of construction facilities is fully optimised.

3.6.4.1 Main Camp and Pipe Yards

Each of the MCPY sites identified have been evaluated and the optimum locations selected and as shown in Figure 2.3-12. During the construction site overview, for each of the MCPY locations three options were identified:

- V3 route suggestion identified in early FEED
- Alternate 1
- Alternate 2.

An example of the site selection process for EACOP Tanzania is provided for MCPY5. Figure 3.6-2 shows the original site identified by the selection process undertaken by FEED in July 2016 and the alternate sites identified following subsequent social and environmental constraints and constructability studies. Figure 3.6-3 and Figure 3.6-4 show Alternate 1 and 2 sites respectively for MCPY5. The following observations were recorded during the siting of MCPY5:

- Moving west and northeast of two roads; site is now Alternate 1.
- Alternate 1: sugar cane field, flat ground. Road will need upgrade.
- Alternate 1 is on slightly higher ground.
- Alternate 2 was selected after a review of satellite imagery.
- None of the sites appear to require relocation of people.

Following this review, Alternate 2 at KP was selected as the optimum site.

The construction facilities assessment work undertaken during FEED confirmed that the alternative sites reviewed both on desktop and during site visit indicated the most suitable site with good access was at site KP325.5 and was chosen as the base case for MCPY5. The chosen site for MCPY5 is shown in Figure 3.6-5.

Figure 3.6-2 Original Site Selected for Main Camp and Pipe Yard 5 at KP325.5

Figure 3.6-3 Alternate 1 Site for Main Camp and Pipe Yard 5 at KP325

Figure 3.6-4 Alternate 2 Site for Main Camp and Pipe Yard 5 at KP326

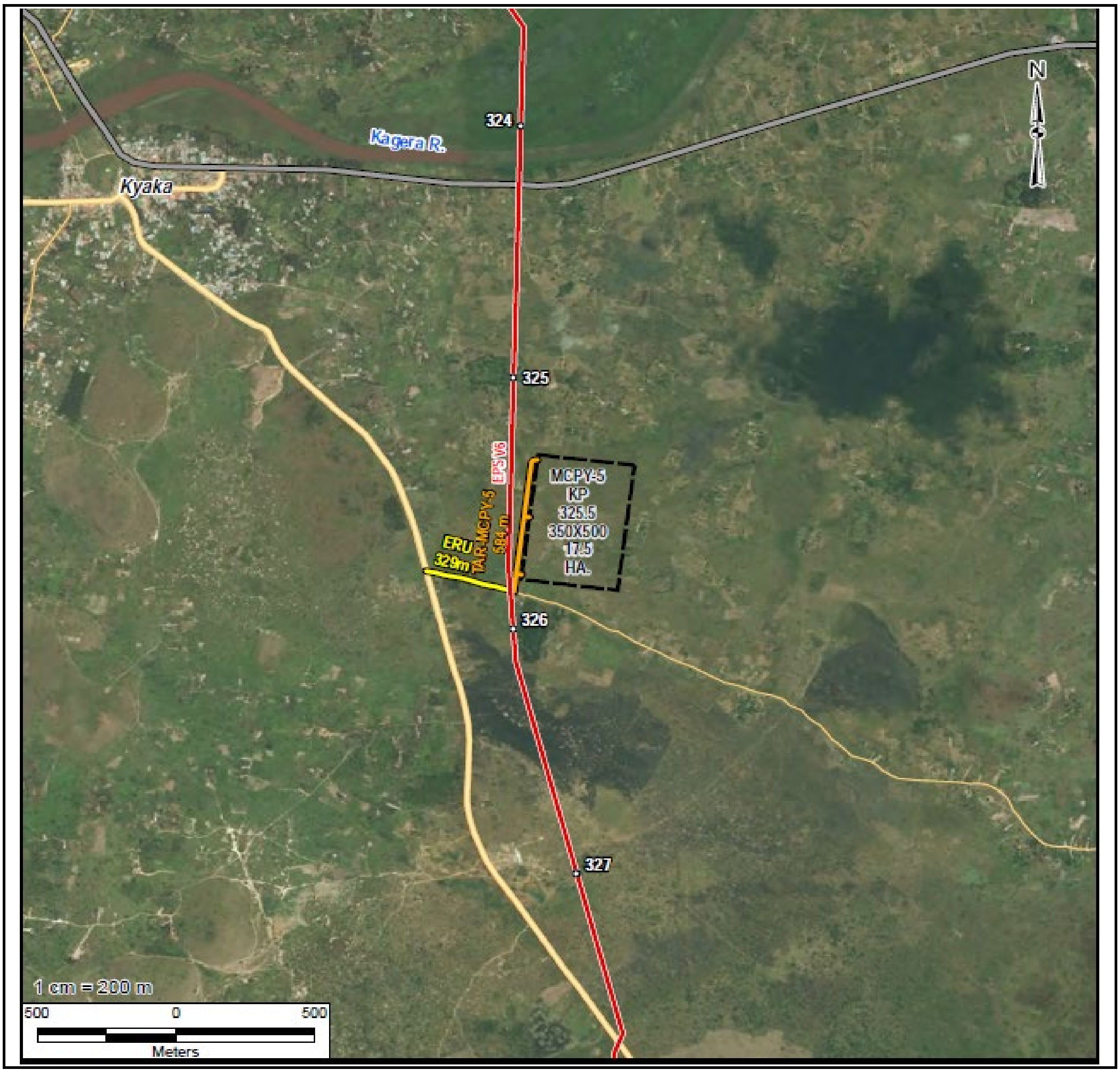


Figure 3.6-5 MCPY Final Site for Main Camp and Pipe Yard 5 at KP325.5

3.6.4.2 Coating Facility and Camp

Three site options were assessed for the CF during the construction sites overview. Figure 3.6-6 shows the original site undertaken by FEED in July 2016 and the alternate sites identified following subsequent constructability studies. The following observations were recorded during the assessment:

- The ground truthing visits did not include the V3 identified site at KP701.
- A KP702 location was visited which is referred to as Alternate 1.
- Social and environmental data identified the need to fine tune the site to avoid flood risk.
- Alternate 2 is away from the RoW but close to the railway.
- The land requirements are assumed sufficient for three production lines and to store all the pipe, before distribution.

During the FEED construction facilities assessment work, the proposed location at KP701 was assessed thoroughly. It was found to be on a flat site with mixed scrubland with small to mid-scale agricultural plots and sparse trees, and directly off an existing well maintained murram road. The site is also close to the 1-m gauge serviceable railway. The review determined that the site has good access to the RoW as well as the road and nearby rail infrastructure, is centrally located for the project and was selected as the optimised location, as shown in Figure 3.6-7.

The principal criteria for siting the CF is the requirement for transportation of pipe to and from the facility. Pipe will be transported to the CF via truck or in combination with rail, when practicable once imported into the country. Discussions are ongoing with the rail authorities to maximise the use of rail. Rail will be used in preference to road transport when this is feasible. In this case, the selected location (close to the rail yard) is considered a major factor to reduce the amount of vehicle traffic associated with pipe transportation in and from the area and will also provide local employment opportunities.

Figure 3.6-6 Original Coating Facility Location KP701, Alternate 1 Coating Facility Location KP702 and Alternate 2 Coating Facility KP701

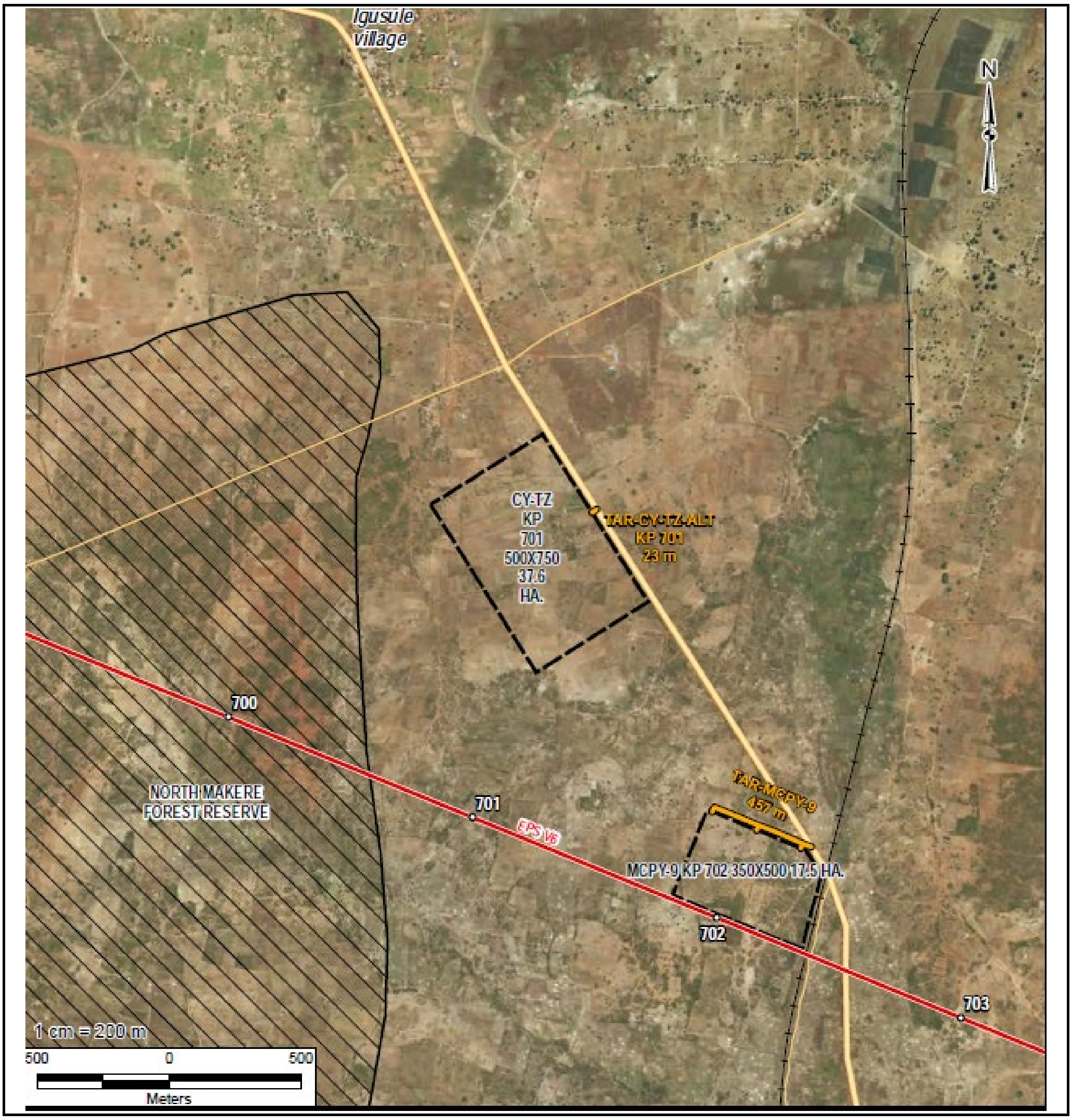


Figure 3.6-7 Chosen Coating Facility at KP701

3.6.5 Marine Storage Terminal

Numerous studies were conducted during the early stages of pre-FEED to identify, screen and evaluate suitable locations for the MST using the initial site selection criteria as shown in Table 3.6-5. The criteria were developed for a potential coastal export facility in consideration of several main (including marine) access, environmental and social constraints and terminal constructability. The key drivers for the site selection were:

- vessel requirements, i.e., Suezmax and Aframax
- options for the load-out facility are described in Volume 2, Section 3.4.

Table 3.6-5 Pre-Front-End Engineering and Design Marine Storage Terminal Siting Criteria

Marine	Terminal Requirements	Environment and Social
Marine access and egress Available water depth Navigational hazards Metocean and shelter Manoeuvring sea room Other marine traffic Availability of marine resources Security Constructability (offshore) Type of seabed Length of offshore pipeline	Electricity Road network Existing trestles and marine infrastructure Potential to construct a new utility trestle Water Suitable terrain for location of terminal Access for the inlet and export pipelines to and from the MST Length of onshore (export) pipeline Constructability (onshore)	Ecology and habitats Land quality, drainage, seabed sediment and seawater quality Visual setting, archaeology and cultural artefacts Atmospheric and noise emissions Social and health infrastructure Economy and employment Livelihood and fisheries Tourism, access and recreation Accidental events Proximity to populated areas

The selection procedure was undertaken in three phases:

- selection of a screening list (50 sites)
- refinement to a long list (34 sites)
- additional refinements resulting in a short list and candidate sites (4).

The coasts of Kenya and Tanzania were screened using admiralty charts and 50 potential sites were identified for further evaluation. Each site was then further screened using professional experience and basic parameters to determine suitability for the long list review. The screening process produced 34 sites that were then evaluated using the environmental, social and constructability criteria.

The study concluded that the exposed nature of the Kenyan coast provided very few locations with natural shelter and no natural locations with enough water depth (without significant dredging) for a marine trestle and loading platform for Suezmax tankers. Based on the consistency of the prevailing offshore metocean conditions, it was concluded there would likely be substantial downtime for a single-point mooring solution thus impacting the required storage capacity required for the MST.

As a result of the initial screening study, four sites (three sites suitable for subsea load out options and one marine trestle with loading platform) all in Tanzania were selected for further study.

Following the completion of the screening studies at pre-FEED, the MST location options were revisited owing to the introduction of the south Tanzania pipeline routing option which dictated the requirement to locate the terminal in the Tanga region. As a result, locations on the Chongoleani peninsula, approximately 6 km northeast of the seaport of Tanga were also evaluated. The area has existing port infrastructure and harbour infrastructure (cranes, warehouses and workshops) to facilitate project activities as required.

Table 3.6-6 presents the specific environmental and social criteria used during the evaluation of the Tanga MST locations. The options were narrowed to two potential locations (Location A and Location B as shown in Figure 3.6-8). Location A was preferred owing to:

- greater distance from the settlement of Chongoleani and cultural sites (a Sharif tomb and a sacred baobab tree)
- lower risk of impacts on groundwater compared with Location B, assuming best construction and operation practices are implemented.

Table 3.6-6 Environmental and Social Criteria for Tanga Marine Storage Locations

Environmental Criteria	Social Criteria
Proximity to sensitive habitats (protected areas mangrove forests, corals, other areas of biodiversity value,) Land take on or near physical environment features: local drainage, fluvial systems, coastal zone Impacts on air quality and noise emissions Potential for impacts on groundwater and surface water quality and quantity from the wastewater treatment plant Sensitivity of the environment to an oil spill and other potentially polluting releases	Extent of potential physical and economic displacement of people (permanent and temporary) Extent of other potential impacts on land take: potential loss of, or access to, natural resources; fragmentation of communities Potential for positive and adverse impacts on local economy and employment Potential for impacts on social services Impacts on community health, safety and well being Potential for impacts on archaeology, heritage and cultural setting Potential for impacts on visual aesthetics Potential for impacts on tourism and recreation

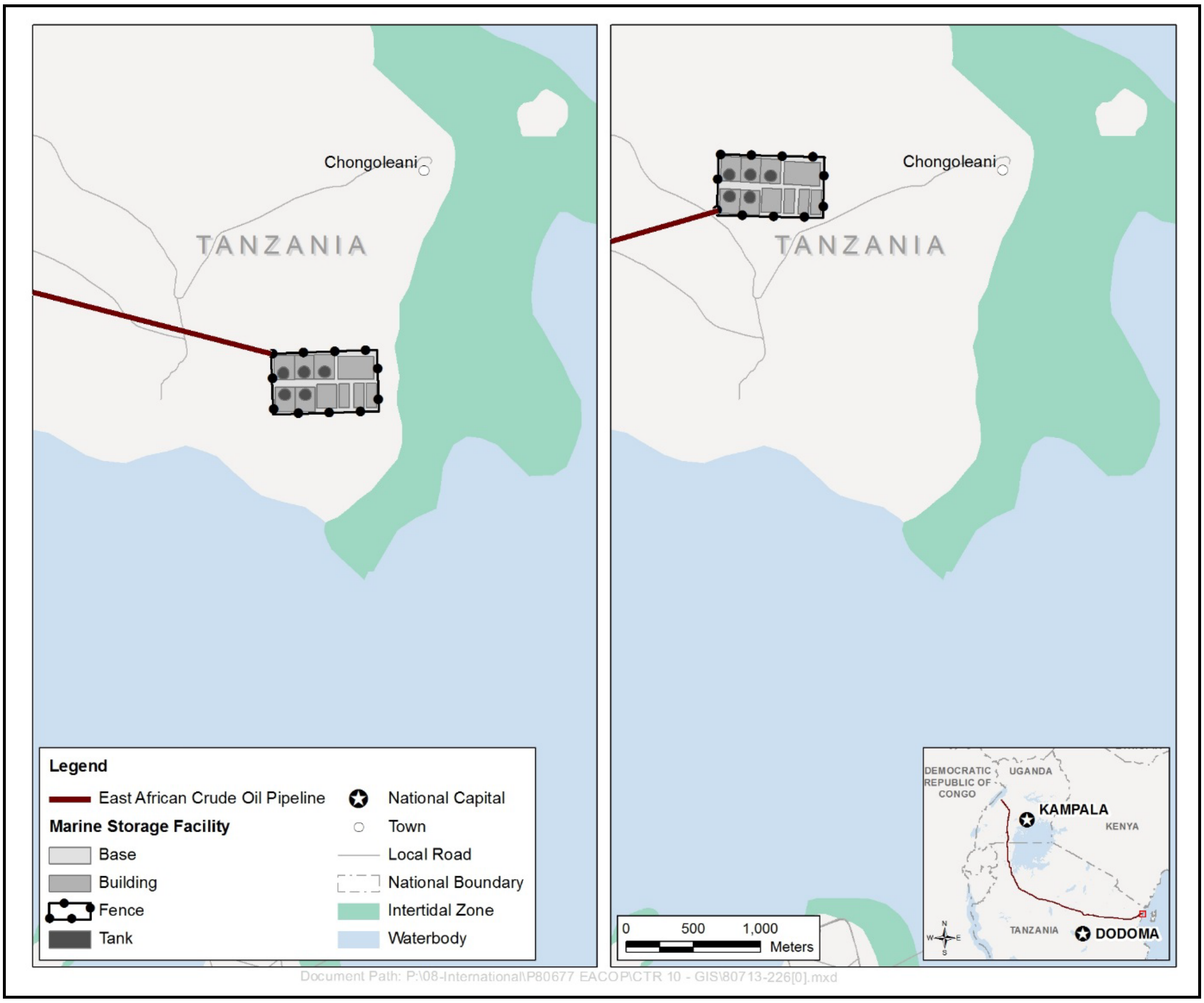


Figure 3.6-8 Potential Marine Storage Terminal Locations A (Left) and B (Right)

During FEED, further evaluations based on geotechnical and bathymetric data required some adjustments in the orientation of the MST at Location A as illustrated in Figure 3.6-9. Subsequently, Location A was chosen as the base case for the MST.

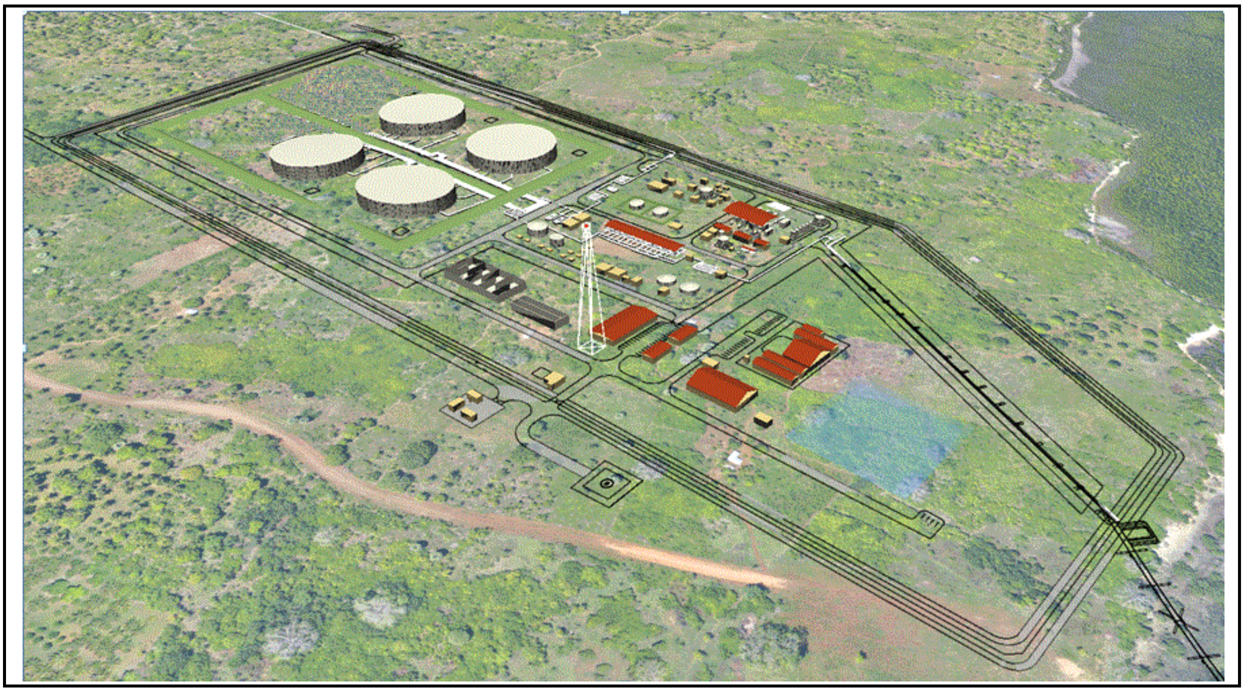


Figure 3.6-9 Final Orientation of Marine Storage Terminal

3.7 Technology

3.7.1 Overview

This section describes the main design alternatives to the project base case as described within Section 2.3. The pre-FEED phase focused on the screening and option evaluation of the main technology alternatives while FEED has concentrated on further refinement. The process has focused on the following elements of the design:

- pipeline (diameter and wall thickness)
- pumps
- power generation
- insulation
- heating
- storage.

The challenges associated with flow assurance as well as the requirement to select the most suitable option for storage and loading have been the main considerations throughout pre-FEED and FEED with respect to technology selection. Several design alternatives have been subject to screening and evaluation as described in the following sections.

3.7.2 Pipeline

A partially aboveground pipeline alternative was considered during early pre-FEED but was discounted for numerous reasons including concerns associated with security and safety, risk of interference by third parties, permanent land take, visual impacts and impacts to large wildlife movement. Furthermore, pipeline design codes that would later be adopted by the EACOP project require pipelines to be buried. Therefore, the concept selected for study at pre-FEED was a trenched and buried pipeline.

Two strategies were considered to enhance oil flow required by the oil characteristics:

- a cold transport option requiring the partial removal of paraffinic components ensuring that gelling of the oil is prevented. This requires some oil processing and is extremely expensive. Consequently, this alternative was screened out.
- a hot transport option aimed at maintaining the fluid temperature above 50°C with the use of thermal insulation and a combination of heating options. Hot transport was selected as the base case for further study.

Various studies considered the alternative pipeline options and recommended the most suitable and practical means to be taken forward for study during FEED. The key consideration at that stage was the hydraulic design concept, namely:

- Case 1 (Base Case): 24 in. – six PSs
- Case 2 (Design Pressure Reduction): 26 in. – six PSs
- Case 3 (PS Reduction): 24–26–24 in. – five PSs

The main conclusions from the pre-FEED studies were that Case 1 (24 in. with 6 PSs) should be taken forward, as it is the most balanced option in terms of meeting technical and economic criteria. Case 1 is also considered to be the most suitable case for phasing of bulk heaters, as no heating is required at commissioning, ramp up and production plateau.

3.7.3 Pumps

3.7.3.1 Type

The pump technology selection has been determined by the characteristics of the Albertine Graben fluid (viscous with no GVF[4]), which means that volumetric pump types are not viable. Therefore, centrifugal pumps are considered the most suitable design for the fluid type because they are proven technology, robust and cost effective.

3.7.3.2 Number and Configuration

During pre-FEED, the number of PSs was optimised from seven to six. The effect of removing a PS was studied to evaluate the impact on the maximum design pressure. It was decided to eliminate one PS from the design and relocate PS3 and PS4 to compensate for the eliminated PS.

The crude oil pump configuration was optimised during FEED from four with an operating capacity of 33% per pump (3+1) to three with an operating capacity of 50% per pump (2+1). This was possible through a review of the pump sizes required for the standard pumping requirements for PS1 to PS5 and for the higher

[4] Gas volume fraction

MOP requirements at PS6. The study concluded that the 3 × 50% configuration requires a smaller overall footprint owing to the removal of one pump.

3.7.4 Power Generation

3.7.4.1 Type

The power generation facilities are described in Section 2.3.3.2 and their primary function is to:

- provide power for pumps
- energise the EHT.

During pre-FEED, several alternative technologies to provide the necessary power requirements of the project pipeline system were assessed, including:

- self-sufficient power generation using crude from the EACOP:
  - crude oil powered engines
  - crude oil powered engines with additives (pour point depressant injection or blending with gas oil)
  - steam and organic Rankine (ORC) cycle turbines
  - crude oil treatment via local or semi-centralised topping unit
  - crude oil treatment via centralised topping unit and multiproduct transport via an additional pipeline
- import of energy:
  - gas oil
  - self-generated electricity from centralised power stations
  - grid electricity
  - gas
  - solar (partial).

Table 3.7-1 summarises each alternative.

Table 3.7-1 Power Generation Alternatives

Alternative	Technical and Economic Considerations	Environmental Considerations	Pre-FEED Conclusions
Crude engines	The energy supply under control of EACOP	No separate fuel transport or substantial infrastructure Greenhouse gases (GHG) and air emissions	Preferred as base case because of availability of crude and no requirement for additional transport infrastructure
Crude engine with additives or blending	Wax and pour point require treatment or limit engine options	Additional logistical impacts associated with transport and storage of additives Crude additives may improve burning efficiency and emissions	Not preferred, increased complexity associated with crude treatment (use of pour point depressor [PPD] not sufficient) and transportation requirements for additives

Table 3.7-1 Power Generation Alternatives

Alternative	Technical and Economic Considerations	Environmental Considerations	Pre-FEED Conclusions
Steam or ORC turbine	Low Capex Higher Opex than gas or electricity	Less NO_x than engines Increased crude consumption Water sourcing and treatment Boiler blow down discharge	Not preferred, uncertainty of water sourcing and additional treatment required for boiler blow down discharge
Local treatment of crude (semi-centralised topping)	Simplicity	Flare required – increased footprint, visual impact, emissions Gas oil engine burns cleaner and options are greater Semi-centralised variant requires transport	Not preferred, complexity of operation (flare required)
Centralised topping and transport by pipeline	The energy supply under control of EACOP	Gas oil engine burns cleaner and options are greater Centralisation rationalises footprint (flare can be shared with CPF), but a lot of storage is required there	Not preferred, increased complexity (additional storage required at CPF)
Gas oil	Screening study indicates PPD injection would not be able to sufficiently lower the crude pour point	Increased transport and storage required, with variety of associated risks and impacts Gas oil burns cleaner and engine options are greater	Not preferred, increased transportation requirements (environmental and social impacts)
Self-generated electricity	Gas oil requires additional Opex	Lower air pollutant and GHG emissions New overhead transmission lines required for AC (visual impact, construction impacts) or buried cable in additional trench within EACOP RoW for direct current Additional storage at MST and Tilenga CPF	Not preferred, limited infrastructure and uncertainties in availability and reliability of electricity
Grid electricity	The energy supply remains within the project's control	Low GHG emissions Transmission infrastructure similar to self-generated electricity	Not preferred, limited infrastructure and uncertainties in availability and reliability of electricity

Table 3.7-1 Power Generation Alternatives

Alternative	Technical and Economic Considerations	Environmental Considerations	Pre-FEED Conclusions
Gas	Possible synergy with bulk heaters	Gas burns cleaner and more efficiently Additional pipeline required along entire length	Not preferred, third-party interface and uncertainties of availability of supply. High Capex associated with additional pipeline
Solar	Additional Capex and Opex	Cleaner, renewable energy Land take	Not preferred, flow rate fluctuations and additional land take required for solar infrastructure

The overall conclusions are:

- Import of fuel alternatives has been discounted owing to the uncertainties over availability of infrastructure and technology as well as the matter of reliability associated with third-party ownership. There would be additional environmental and social impacts associated with increased traffic movements (dust, noise, emissions, increased traffic safety risk).
- The options for transportation of fuel have similarly been discounted based on environmental and social impacts associated with increase traffic, noise, dust and emission impacts. An estimated additional 8–20 tanker movements per day would be required to transport fuel to the AGIs.

Based on these conclusions, it is considered that crude oil engines utilising crude from the pipeline is the most efficient, self-sufficient and technically feasible option.

3.7.4.2 Configuration

The pre-FEED for power generation studies confirmed that PS2 to PS6 would be self-contained with individual crude oil fired power generation units. For EACOP Tanzania, owing to the higher loading at PS6, three power generation units were selected. An optimisation study was undertaken during FEED, which reviewed the potential to eliminate power generation at PS4 and PS6 with centralisation at PS3 and PS5. The key changes between pre-FEED and FEED are:

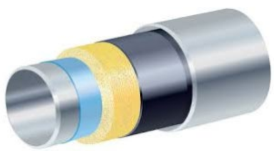
- four generators at PS3 instead of three
- five generators at PS5 instead of three
- PS3 will supply PS3, PS4 and associated intermediate electrical substations
- PS5 will supply PS5, PS6, PRS1 and associated intermediate electrical substations
- MST will supply PRS2, MST and associated intermediate electrical substations.

3.7.5 Thermal Insulation

The pre-FEED assessed insulated and uninsulated pipeline options. The steady state analysis concluded that heat losses with the uninsulated case would require 35 separate crude fired heating stations resulting in high crude consumption, larger project footprint, larger environmental impact and operational costs. Conversely, by applying thermal insulation on the pipeline, the heating requirements could be optimised with power for heating being provided from six stations with lower crude consumption, lower project footprint, less requirement for facilities, higher initial cost, but more economical over the lifetime of the project.

Several existing pipe thermal insulation alternatives were screened in terms of thermal efficiency, availability and constructability as summarised in Table 3.7-2. The decision was taken to incorporate polyurethane foam (PUF) as the base, as it offers the highest thermal efficiency with lowest Capex.

Table 3.7-2 Insulation Alternatives

Insulation Type	Characteristics		Conclusion
PUF	Lower thermal conductivity New coating plant required with high productivity Two methods possible for foam application: spray or moulding Excess foam material above heat tube or raceway is to be removed with spray process PE jacket added over foam to provide mechanical protection Many references of pipeline in service		Accepted as base case
Glass	Higher thermal conductivity makes it less efficient Conventional pipeline construction including bends Field applied in long lengths with glue or resin and external membrane High manpower requirement making it not suitable for long pipelines Very limited references essentially for piping in plants Pre-cut grooves fit over pipe or channel / heat tape		Not selected for main line because of lower thermal efficiency and lack of references – possible use at field cold bends (approx. 4000 pipe joints, i.e., 70 km) Under evaluation vs cold bending of high density PUF application
Pipe in Pipe (PIP)	High linear weight making it suitable for wetlands Water ingress risk very low owing to welded construction Field bends possible with care External steel sleeve implies additional welding and coating		Not selected because of higher Capex

3.7.6 Heating

The temperature management principles of the pipeline are:

- maintain operating temperature above 50°C at all times during export conditions (normal, transient and degraded modes)
- ease commissioning and ramp-up phases by maintaining fluid temperature above 50°C
- under no flow condition, i.e., preservation, temperature will be maintained by the EHT above 50°C
- allow a cold restart from minimum ambient temperature up to 50°C.
- no bulk heating (BH) will be required during production plateau, providing the fluid export temperature from Tilenga Project CPF is exported at 80°C
- after plateau and throughout production decline, BH may be introduced to support EHT in maintaining the crude oil temperature above 50°C in flowing conditions to provide a more energy efficient solution overall for the low flow cases. EHT will still be required for cold restart.

Three heating configurations were considered to maintain the oil temperature above 50°C:

- Case 1 – EHT only case
- Case 2 – BH only
- Case 3 – EHT + BH (mixed heating architecture).

EHT is considered the optimal design case during commissioning, ramp up and production plateau for flowing conditions as it provides numerous operational advantages by providing:

- active heating to maintain fluid temperature continuously in all export modes
- preservation management to maintain temperature above 50°C during no flow condition
- the only method of heating the pipeline in the event of cold restart.

For Case 1, although EHT is less efficient than BH in terms of crude consumption, the implementation of EHT is mandatory from a flow assurance perspective. A screening exercise was undertaken during pre-FEED to assess operating the pipeline with EHT only throughout field life. Although the study concluded that EHT can provide the heat required throughout field life, the use of combined BH and EHT is considered more efficient during operations to compensate crude oil temperature during the latter stages of production with low flow cases.

Case 2 includes localised heating at each station with a discharge temperature such that the fluid arrival temperature at the next station is maintained above the minimum (50°C). This type of heating has large heat losses in comparison to EHT as shown in Figure 3.7-1. It is estimated that up to 13 BH stations would be required along the pipeline route. The study concluded that the flow assurance requirement for EHT was deemed the most critical factor and this option was discounted.

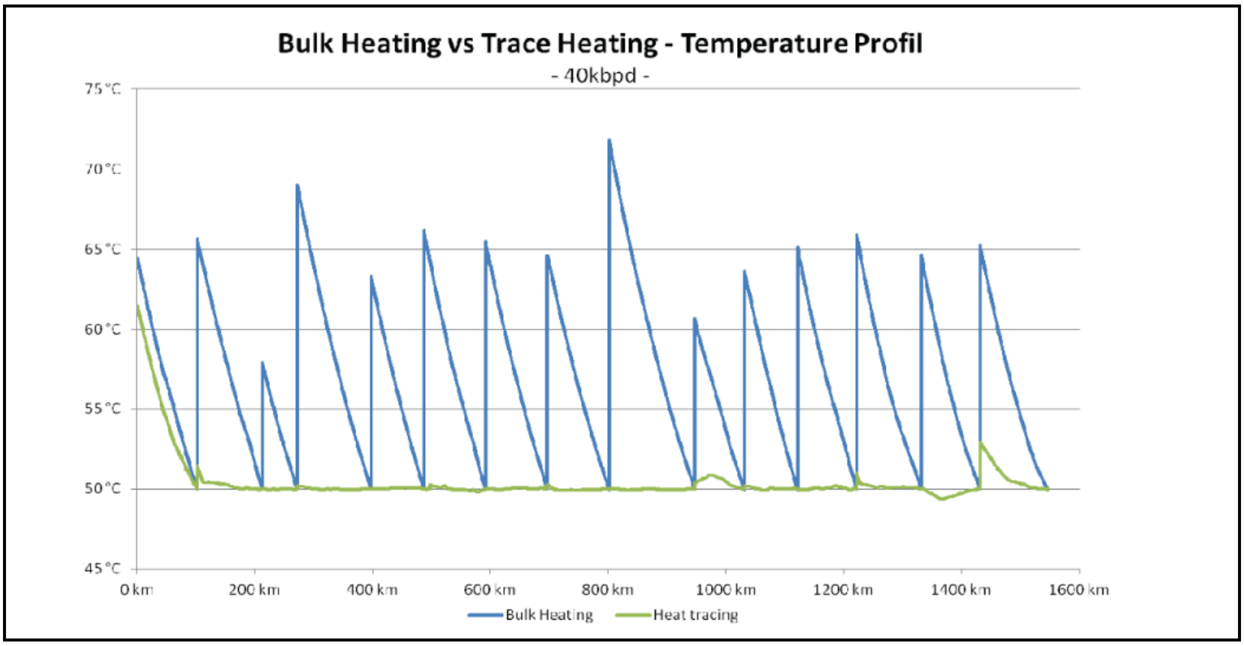


Figure 3.7-1 Bulk Heating vs Electric Heat Trace Heat Loss

Case 3 (combination of EHT and BH) was assessed to address the heat losses as production comes off plateau. It shows that that the use of BH is required to maintain crude oil temperatures above 50°C minimum, 80°C maximum and EHT to maintain temperatures above 50°C in no flow conditions. Although BH has larger heat losses than EHT, there is less overall crude consumption and it is therefore favoured (both environmentally and economically) as the primary source of heat after production plateau.

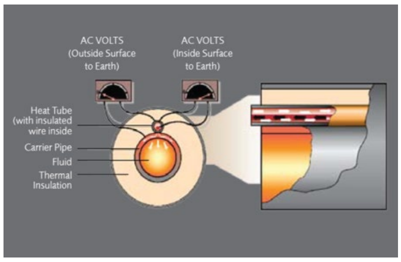
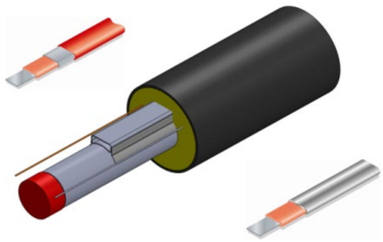
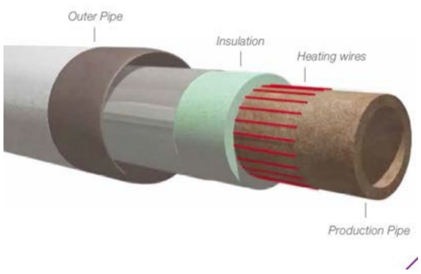
The overall conclusions from the study were:

- EHT only to be adopted as the base case design for commissioning, ramp-up and plateau
- BH may provide additional heating inputs used in combination with EHT after production plateau
- EHT will provide active heating throughout field life for maintaining temperature above 50°C in combination with BH and ensuring temperature above 50°C in no flow conditions and allowing cold restart.

3.7.6.1 Electrical Heat Tracing System Types

Several EHT alternatives were screened during pre-FEED as both primary and secondary sources of heat input. Aspects of the screening study are shown in Table 3.7-3. The three systems reviewed were skin effect heat tracing, long line heat tracing (LLHT) and pipe in pipe (PIP).

Table 3.7-3 Electrical Heat Tracing Alternatives

System	Characteristics		Conclusions
SEHT	Current flows through centre of insulated wire and returns though heat tube Requires special transformers Welding and coating for tubing increases cost and schedule Coverage 9–12 km maximum with one tube Field proven used for most of trace heating pipelines		Not selected on basis of less coverage over long distances, more cabling required and more electric substations required More power consumption (as one phase out of the three is not used) Higher Capex than LLHT
LLHT	Experience of use on plants and some buried pipelines All three phases used Requires transformers Uses standard pipe Coverage up to 30–50 km		Selected as base case as greater coverage over long distances, less core cable quantities and less electrical substations required (lower overall project footprint)
PIP	Application for short subsea lines with steel pipe encased in large diameter steel pipe Multiple cables (24) provide redundancy Pre-constructed lengths welded and heating cables jointed on site. Includes insulation (needs to be dry)		Not selected because not considered suitable for length of line Will require an extra 1550 km of at least 28-in. steel pipe to serve as external jacket to 24-in. pipe Highest Capex of the three options

3.7.6.2 Bulk Heater Technology

Several BH alternatives were screened during pre-FEED. A summary is shown in Table 3.7-4. The types of heaters considered were direct heating, indirect heating and steam boilers. The indirect method was selected as the most feasible based on experience and technical challenges faced by direct heating and steam boilers.

Table 3.7-4 Bulk Heater Alternatives

System	Characteristics	Conclusions
Direct heating	Crude oil is extracted at 50°C from the pipeline heated and reintroduced at 80°C 6 heating stations	Not selected for pipeline owing to acid corrosion concerns
Bulk heaters (indirect heating)	Fired heaters using heating medium at higher temperature (water or oil) to heat the crude oil 6 heating stations	Selected as base case as proven technology
Steam boilers	Use of steam turbines for crude oil pumping fed by steam generated in steam boilers Boilers less efficient but less NOx Water treatment concerns	Not selected owing to matters associated with water treatment and efficiency

3.7.7 Crude Oil Storage

The layout and components of the MST are described in Section 2.3.4. Alternatives for pumping and power generation have already been described in Sections 3.7.3 and 3.7.4 respectively. This section is on the alternatives for crude oil storage. Several tank designs were considered as described in Table 3.7-5. An external floating roof design was selected as the base case owing to increased structural requirements for the required diameter and capacity of tank.

Table 3.7-5 Crude Oil Storage Alternatives

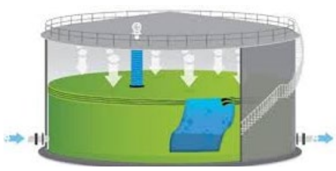
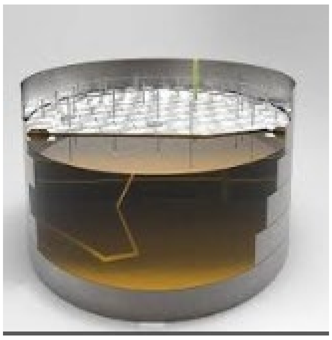
Tank Type	Characteristics		Pre-FEED Conclusion
Fixed roof	Cone- or dome-shaped roof that is permanently affixed to a cylindrical shell Fixed roof tanks generally vent to atmosphere Vapour space leads to higher volatile organic compound (VOC) generation but recovered under normal operations by vapour recover unit (VRU) For the capacity ad dimension required, fixed roof would require larger amount of supporting structure Higher Capex		Not selected due to structural requirements

Table 3.7-5 Crude Oil Storage Alternatives

Tank Type	Characteristics		Pre-FEED Conclusion
External floating roof	Open- topped cylindrical steel shell with a roof that floats on the surface of the stored liquid. The roof rises and falls with the liquid level in the tank. No vapour space There is a rim seal system between the tank shell and roof to reduce rim evaporation. Limit product loss and reduce the emission of VOC Normally (roof not landed), there is little For the capacity and dimension required, external floating roof requires less supporting structure Less Capex		Selected as the base case, as less structural requirements required for diameter and capacity of tanks at MST
Internal floating roof	Guarantee the oil quality under various weather conditions. Limit product loss and reduce the emission of VOC VOC recovered under normal operation by VRU Least Capex		Not selected

In addition to the type of tanks selected, several production availability studies were performed. As part of these studies a review of MST capacity was undertaken to determine the feasibility of operating the MST with four 500,000-bbl storage tanks instead of five (as was the base case at the end of pre-FEED). The study concluded that the operation of the MST with four tanks totalling a working capacity of 2.0 MMBLS is feasible under normal and maximum operation conditions considering the production profile with a relative short plateau of 216 KBPD (from year 3 to year 5), future production from year 10 to 14 with a decline from 89 to 48 KBPD. The removal allows reduction of footprint and reduces the overall inventory of crude at the MST.

3.8 Construction Techniques

3.8.1 Overview

This section describes the various construction techniques considered during pre-FEED and FEED phases. The most critical factors in defining the construction strategy are:

- route optimisation and siting
- logistics strategy (optimisation of road and rail networks)
- weather conditions and seasonal constraints
- biodiversity-related seasonal constraints
- availability and proximity of existing infrastructure for material transport and for siting of facilities
- sequencing of pipeline insulation and coating activities with pipelay
- availability of materials and labour
- trenchability including blasting requirements.

This section identifies the main alternatives reviewed during pre-FEED that have culminated in the definition of the constructions strategy as described in Section 2.4.2.

3.8.2 Strategy and Logistics

A traditional “spread” construction approach is proposed for the EACOP facilities. During FEED, numerous site visits and surveys along the pipeline route made important observations on the approach to construction and concluded that most of the pipeline is on relatively flat or rolling hill areas, which present few construction difficulties. However, several different options for scheduling were considered during an early constructability study during pre-FEED. Two initial options were identified for construction execution:

- 36-month schedule utilising five spreads
- 42-month schedule utilising three spreads.

The study concluded that, owing to constraints on the sizes, length and particularly the type of thermal insulation, efficient coordination of insulation and coating activities with the pipelay schedule are the most critical factors for construction execution. In addition, the study identified the requirement to ensure fully free access to the RoW to prevent delays to mobilisation for construction. The conclusions from the study have been used to develop the base construction strategy and schedule as presented in Section 2.6.

The logistics strategy has been developed during the pre-FEED and FEED phases based on the following principles:

- achieve early enough, but not too early, material delivery (knowledge of all material flows is the key to a smooth transportation plan)
- provide smooth equipment replenishment to avoid unnecessary costs as well as delays

- synchronise material supply with the construction schedule to make reliable estimation of material requirement and locations where the material required
- align the equipment resourcing and transportation plan with fuel supply strategy to limit delay
- estimate the optimum storage capacity to reduce the cost of storage while maintaining reliability of timely material supply to the project
- eliminate or reduce potential unpredicted delays at border crossings, custom clearance and other logistics bottlenecks by making realistic predictions and observing local/country capacity and calendar
- ensure availability of trucks and site transportation and plan for importing or sourcing adequate equipment and vehicles to fulfil the project requirements
- determine the season dependency of the road conditions, availability of transportation vehicles and border crossing times, and prepare for it.

An example of logistics optimisation is the transportation of line pipe. Three options were reviewed as described in Table 3.8-1.

Table 3.8-1 Line Pipe Transportation Options

Transportation Method	Advantages	Disadvantages
Bare pipe, insulated at CF 	More pipes per truck load, reducing number of cross-country trips by approximately a third Lower shipping cost as transported from pipe mill to port of entry Opportunity to utilise local content and optimise schedule by combining insulation application activities with CF Overall the most cost effective when considering all logistical constraints and coating plant costs	Insulation costs may become more expensive owing to requirement for dedicated facility Additional transportation between insulating facility and pipe yard Additional schedule constraint with land access, construction, set up and qualification of insulation facility
Insulated pipe 	Transportation directly to site for lay	Less pipe per truck load increases number of trips by a third Higher shipping costs (transported to insulating facility and then to port of entry)
Bare pipe shipped and insulated at port of entry	Maximum use of local content Lower shipping costs Not as cost effective as coating plant near to mid-way of pipeline route.	Cost and schedule constraints associated with land access, set up and qualification of insulation facility at port of entry Less pipe per truck load increases number of trips by a third

The review concluded that transportation of bare line pipe is the best solution on the basis that more pipes can be transported (thus reducing shipping costs and truck movements) while providing maximum opportunity to utilise local content for the CF. It should be noted that the option of transporting all imported materials via truck or in combination with rail will be subject to further evaluation as the project progresses. Rail will be used in preference to road transport when this is feasible. This option ensures less community disturbance, as well as dust and noise impacts associated with road traffic movements.

3.8.3 Pipeline Construction

3.8.3.1 Construction Techniques

The pipelay sequence is described in Section 2.4.2.2 and is comprised of three main aspects:

- open areas where the spread technique is utilised, i.e., pipe storage, RoW clearing and grading, stringing, bending, welding and trenching
- crossing locations where specialist crews and specific techniques are used, e.g., HDD
- special sections such as restricted working areas, difficult terrain and environmentally and socially sensitive areas.

During pre-FEED, the spread technique was considered the most suitable for onshore pipe lay and therefore no other alternative construction strategies were considered during pre-FEED and FEED.

3.8.3.2 Blasting/Micro-blasting

In rocky sections of the pipeline route, where normal excavation is not possible, blasting may be required to fracture the rock and enable pipeline trench excavation.

Micro-blasting avoids rock projectiles and creates less noise and vibrations but can only be used under certain conditions. Sections suitable for micro-blasting will be identified during construction, based on geology, the proximity to infrastructure and environmentally sensitive features.

3.8.3.3 Crossings

The pipeline route crosses numerous watercourses and wetlands, some of which are permanent, and others are of seasonal nature. In addition, the pipeline will cross existing infrastructure such as roads, buried cables and railways.

Several alternatives exist for the installation of the crossings for roads, railways, streams, rivers and wetlands. Both open cut and trenchless techniques will be considered and the identification of appropriate technique will be based on a systematic assessment of the pipeline route using the following criteria:

- size and nature of the crossing (length, location, terrain, geotechnical constraints)
- nearby environmental and social features
- constructability (access restrictions, size of construction spread required).

The open-cut technique is the preferred option for most small crossings owing to its simplicity and minimal construction footprint. Several trenchless construction alternatives were reviewed, including auger boring, HDD and micro-tunnelling. For tarmac roads and railways, the auger boring technique will be used to prevent service disruptions. While HDD has been selected as the most suitable technique for the two larger river crossings (Kagera and Sigi), other techniques such as direct pipe and micro-tunnelling were discounted during FEED owing to the requirement for a much larger construction footprint and increased capital expenditure.

Table 3.8-2 shows the methodology and rationale for selecting the appropriate crossing techniques. Table 2.4-4 shows the finalised crossing list for EACOP Tanzania.

Table 3.8-2 Crossing Alternatives

Technique	Open Cut	HDD	Micro-tunnel	Auger Boring
Summary	Most efficient and simple technique involving excavation of a trench, pipe is laid and backfilled For flowing watercourses, the crossing site is isolated to prevent construction materials from entering the watercourse	Drilling of a hole, along a pre-determined alignment, by pulling or pushing a drill string and installing "stringing" the pipeline from the opposite side of the crossing back through the drilled hole Used for crossings up to 1.5 km	Circular precast concrete pipe sections being pushed (jacked) through the ground along a predetermined alignment	Well proven technique that requires excavation of pits on either side of the crossing to aid the installation of the pipeline. The depth of the pits depends on the nature of the crossing and the local ground conditions. Used for crossings up to 120 m
Cost	Lowest	Low (comparable with micro-tunnelling)	Highest (expected to be 50% more than HDD)	Low (comparable with HDD)
Logistics	Simplest logistically requiring the least amount of equipment and plant	Logistically challenging requiring mobilisation of drill rig, mud management, and excavators and personnel	Logistically challenging requiring mobilisation of drill rig, mud management, excavators and personnel	Logistically challenging based on required plant, equipment and personnel
Environment	Risk of sedimentation but controlled with proper isolation techniques and avoid seasonal sensitivities	Risk of hydrofracture* Lowest material required and spoil generated Larger construction footprint for spread	Risk of hydrofracture* Highest spoil generated Larger construction footprint for spread	Minimal construction footprint required

NOTES: *The inadvertent seepage of drilling mud onto the ground or into surface waters through fractures in the subsurface. Hydrofracture can occur when using pressurised crossing construction methods such as HDD

3.8.3.4 Water Sourcing

Construction activities requiring water comprise mainly concrete mixing and dust suppression. These activities do not require potable water, although potable water must be available for consumption by construction workers (it is assumed bottled water will be provided).

To reduce water abstraction and discharge, the reuse of treated sewage effluent is a viable alternative for industrial water supply. It has been established that it is economically feasible to truck treated effluent to the zone of pipeline construction activity within a range of approximately 10 km of a camp. Potential sources of surface water abstraction for construction activities were identified using satellite imagery analysis. These are waterbodies, some of which appear to be perennially available and within approximately 10 km of truckable distance of the pipeline route. Potable water to serve the camps will be sourced through a variety of methods including borehole installation and the purchase of water from water districts and water boards. Information on water sources is also included in Section 2.4.1.2 Water Supply Study.

3.8.3.5 Waste Management

Alternative solid waste management solutions are dependent on local, existing recyclers and waste management facilities with capacity to manage project waste.

The EACOP project will follow good international industry practice for waste management and follow the waste management hierarchy (as described in Section 2.4.2.9) of reduce, reuse, recycle/recover. This will be achieved by working with existing recyclers and waste management facilities.

Project waste will be managed as described in Section 2.4.2.9 while pollution prevention measures described in the pollution prevention plan will prevent project solid and liquid waste being a source of pollution to land, water or air.

Project wastewater (e.g., domestic wastewater, vehicle wash) will be treated using onsite water treatment plants at each camp; project wastewater discharges will be compliant with relevant discharge standards included in Appendix F. Domestic wastewater treatment is described in Section 2.3.5.1.