CHAPTER 6

SELECTION OF DESIRABLE ROUTE FOR THE FEASIBILITY STUDY

Chapter 6 Selection of Desirable Route for the Feasibility Study

6.1 Strategies for Development of the Road Network in the Study Area

6.1.1 Future Road Network Configuration in the Study Area

(1) Present and Future Road Network in the Study Area

The trunk roads were reclassified by the MRH based on their functional importance in 1998. The new system reclassified the roads into National, Inter-Regional and Regional Roads, reflecting their national and socio-economic importance and tying in with the present regional and district administrative structures of the country. Beside the trunk road network, there are urban roads managed by the DUR, and feeder roads managed by the DFR both under the MRH.

According to the GHA, the proposed new route of the Eastern Corridor between Asutsuare Jct. and Asikuma Jct. will be classified as a National Road after construction of the new route. Moreover, the international traffic and major logistic corridor functions of the existing N2 between Asutsuare Jct. and Asikuma Jct. via the existing Adomi Bridge will be expected to shift to a proposed new route with a new bridge crossing the Volta River, when the whole section of N2 between Tema and the border with Burkina Faso will be improved.

(2) Proposed Future Road Network Configuration in the Study Area

Figure 6-1 illustrates the present road hierarchy in the Study Area. There are four national roads (N1, N2, N3 and N5), five regional roads (R18, R23, R24 (only a short length), R28 and R95), and various feeder roads. Considering the functional hierarchy of the road network and regional development trend, the north-south axis and the east-axis on both the left and right sides of the Volta River are weak.

In order to accelerate the regional development, particularly agricultural development, the Study Team proposes the future road network configuration in the Study Area as shown in Figure 6-2.

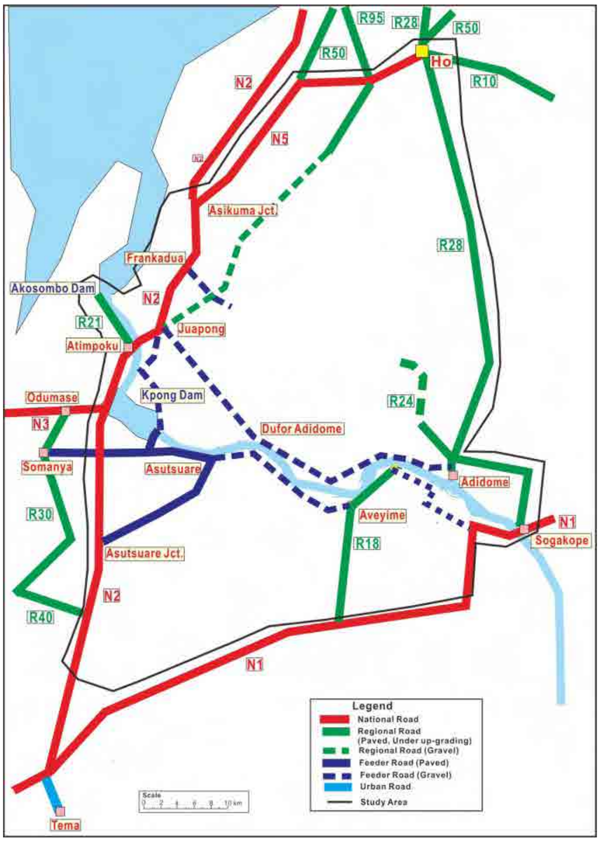
Under this proposed road network configuration, the new proposed route between Asutsuare Jct. and Asikuma Jct. will be classified as a national trunk road with a function as an international corridor between Tema and the border with Burkina Faso, while the road section between Asutsuare and Aveyime will be a part of the inter-regional road connecting N2 and N1 via the green-belt area of Ghana, where major rice production is expected.

6.1.2 Design Standards Applied for the Study Roads and Bridges

(1) Design Speed

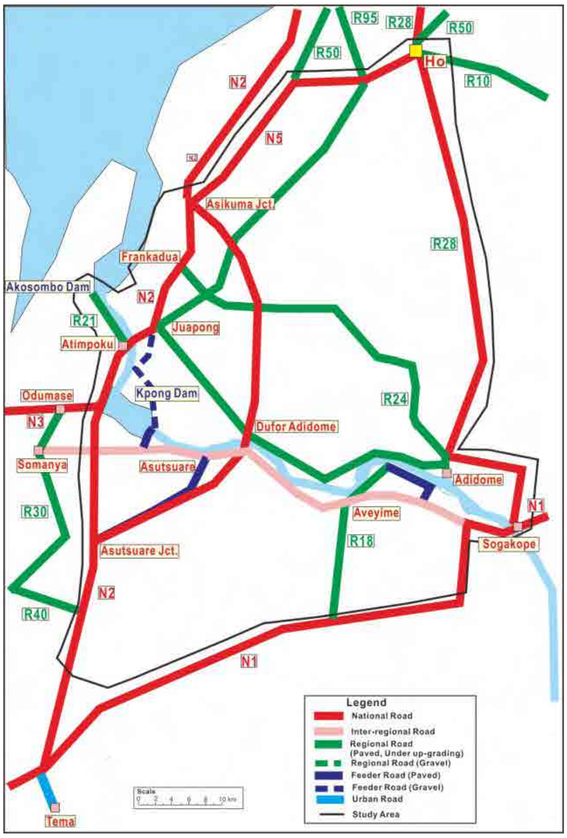
The design speed for the proposed roads are determined by the Road Design Guide of Ghana and the following facts:

- The upgrading works of a part of Lot 2 of N2 between Asikuma Jct. and Have (48 km), just after the section of proposed route (N2) in the Study, has already started with GoG fund. The design speed for the section between Asikuma and the 37 km point from Asikuma Jct. is 100 km/h because of flat terrain.



Source: Study Team

Figure 6-1 Present Road Hierarchy in the Study Area



Source: Study Team

Figure 6-2 Proposed Road Network Configuration in the Study Area

To consider uniformity of the design speed on the same type of terrain, design speed for the new road section between Asutsuare Jct. and Asikuma Jct. is proposed 100 km/h based on the Road Design Guide of Ghana.

Table 6-1 Design Speed for National Road

Road Type	Classification	Design Speed (km/h)	Absolute Values (km/h)
National	Flat	100	80
	Hilly	80	60
	Mountainous	60	40

Source: Road Design Guide in Ghana

(2) Design Radius

In order to accommodate international logistics freight vehicles, mainly large trailers, to secure traffic safety, and to harmonise with the natural and topographical conditions, the radius of curves is designed to be gentle. Although the minimum design radius is 700 m for the design speed of 100 km/h, it is desirable to use a radius of more than 2,000 m or at least 1,400 m corresponding to two or three times the minimum design standard.

(3) Typical Cross Section

a) Lane Width

The main traffic function of the proposed road is to create a national trunk road network to link economic and administrative centres as well as ensure efficient international logistic flows.

A lane width of 3.65 m defined in the Road Design Guide of GHA is proposed for the following reasons:

- A lane width of 3.65 m is adopted for the section between Asikuma Jct. and Have on N2 currently being upgraded.
- A lane width of 3.65 m is also adopted for ongoing national road projects such as the N8 upgrading project.
- According to AASHTO Geometric Design of Highways and Streets (2004), the lane width of roads classified as national highways is recommended as 3.65 m (12 feet).

Thus, a lane width of 3.65 m is proposed for the road sections between Asutsuare Jct. and Asikuma Jct., and Asutsuare and Aveyime according to the Road Design Manual of Ghana.

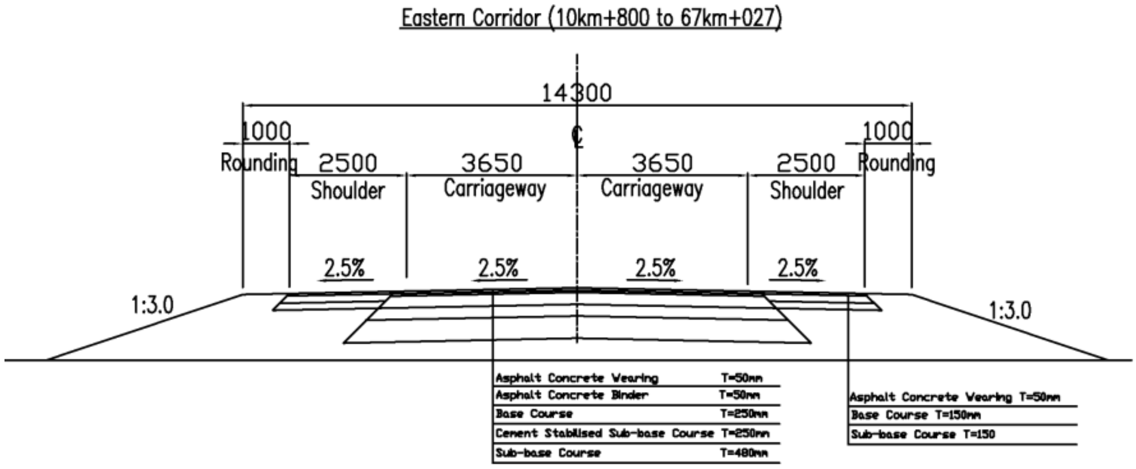
b) Shoulder Width

The main function of shoulders on national roads is not only to provide space for stopping vehicles, including broken-down vehicles, but also walking space for pedestrians. A shoulder width of 2.50 m defined in the Road Design Guide of GHA is proposed for the following reasons:

- A shoulder width of 2.50 m is adopted for the section between Asikuma Jct. and have on N2 currently being upgraded.
- A shoulder width of 2.00 m is adopted for the ongoing national trunk road project (N8 upgrading project). In this case, even though a consultant proposed 2.50 m to follow the Road Design Guide of GHA, the existing shoulder width was 2.00 m following the previous guide, and the GHA finally decided to adopt 2.00 m to comply with the existing shoulder width.
- According to the AASHTO standard, heavily travelled, high-speed highways and highways carrying large numbers of trucks should have usable shoulders of at least 3.0 m (10 feet).
- The Japanese standard, defines, a shoulder width of 2.50 m, and 3.25 m is preferable for national expressways.

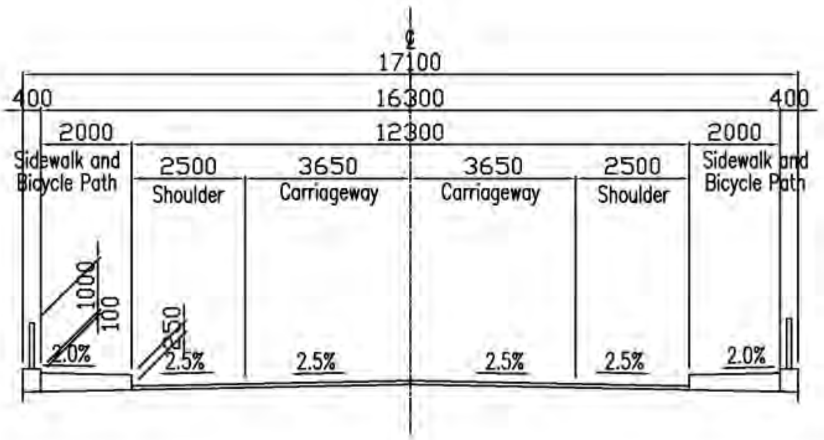
Thus, a shoulder width of 2.50 m is proposed for the road section between Asutsuare Jct. and Asikuma Jct., while a shoulder width of 2.00 m is proposed for the Asutsuare and Aveyime road which will be changed to an inter-regional road after the completion of upgrading works.

Figures 6-3 and 6-4 show typical cross-sections used for the preliminary design of ordinary road sections and bridges, including new bridge across the Volta River, on the Eastern Corridor. Figures 6-5 and 6-6 show typical cross-sections used for the preliminary design of ordinary road sections and roads in townships along the Asutsuare – Aveyime road. Mount-up sidewalks on both sides of the carriageway are proposed in order to secure the safety of both pedestrians and bicycles for bridges and in township areas. The Study Team proposed several alternative cross sections at the Working Group Meetings (WGM) with GHA officials, and both sides agreed to adopt the cross-sections shown in these figures.



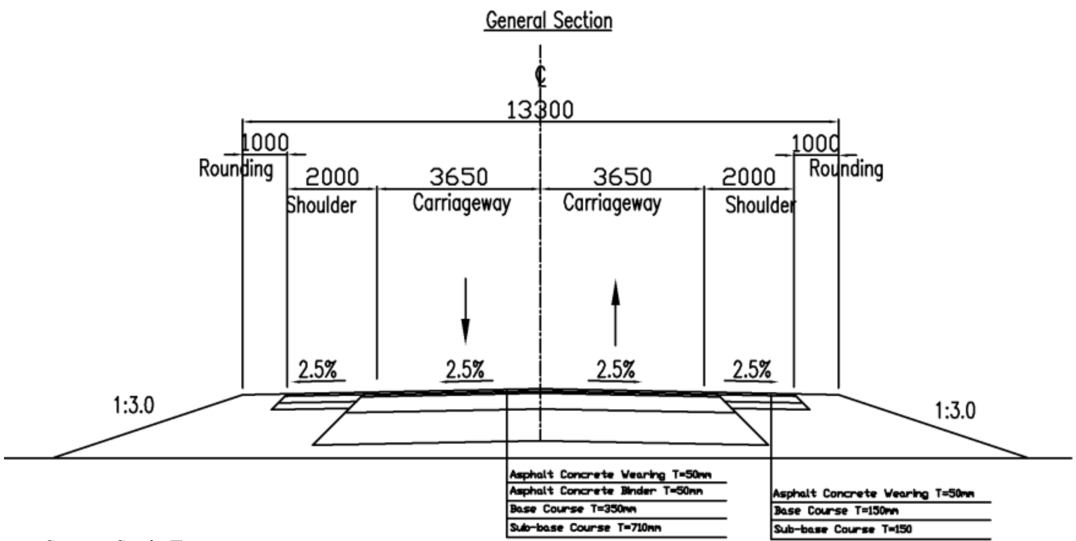
Source: Study Team

Figure 6-3 Typical Cross-section between Asutsuare Jct. and Asikuma Jct.



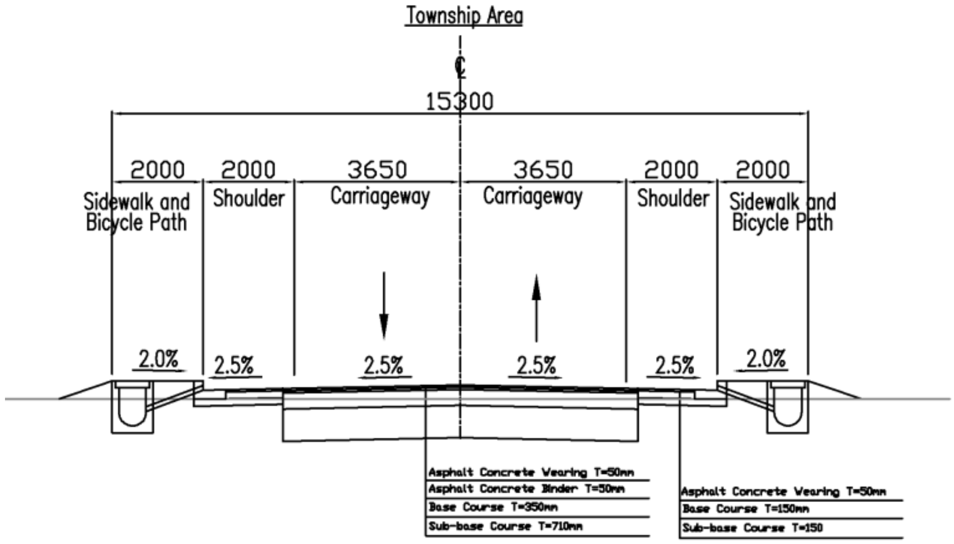
Source: Study Team

Figure 6-4 Typical Cross-section of Bridges



Source: Study Team

Figure 6-5 Typical Cross-section for Ordinary Section of Asutsuare–Aveyime Road



Source: Study Team

Figure 6-6 Typical Cross-section in Township Area of Asutsuare–Aveyime Road

(4) Right of Way

According to the GHA, the Right of Way (ROW) for trunk roads and inter-regional roads must be 90 m wide (45 m from the centreline on both sides) and 60 m wide (30 m from the centreline on both sides), respectively. Thus, 90 m ROW is applied for the new road section between Asutsuare Jct. and Asikuma Jct. on the Eastern Corridor, while 60 m ROW is applied for the Asutsuare–Aveyime road.

6.2 Road Alignment Study

6.2.1 Basic Concept of the Preliminary Design of Road Alignment

(1) Road Classification and Functions

The trunk roads were reclassified based on their functional importance in 1998. The new system reclassified the roads into National, Inter-Regional and Regional Roads, reflecting their national and socio-economic importance and tying in with the present regional and district administrative structures of the country.

According to the GHA, the proposed route of the Eastern Corridor between Asutsuare Jct. and Asikuma Junction will be classified as a National Road after completion of this route. Moreover, the international traffic and major logistics functions of the existing National Road N2 between Asutsuare Jct. and Asikuma Jct. including the Adomi Bridge will be shifted to the proposed route with a new bridge over the Volta River.

(2) Major Policy for Road Alignment Alternatives

a) Number of Lanes

According to the GHA's Project Profile for Upgrading of Asutsuare Jct. – Asutsuare – Frankadua Road in the Greater Accra and Volta Regions of Ghana, the road will be upgraded to a 2-lane single carriageway with asphalt concrete (flexible pavement) surface. The Study Team has confirmed the required number of lanes for the proposed road based on the future traffic demand forecast with the target year of 2036.

b) Considerations to Determine Road Alignment

The major considerations when determining alternative road alignments were as follows:

- To minimise the resettlement of homes and other commercial buildings
- To avoid passing through paddy fields or irrigation schemes in view of the importance of rice cultivation, particularly on the southern side of the Volta River which is defined as the Southern Greenbelt of Ghana with large potential for agricultural activities
- To minimise the effects on existing, on-going and planned agricultural development schemes.
- To set the road alignment perpendicular to the Volta River and to select a location where the river is narrow to reduce bridge construction costs.
- To minimise the number of crossings of rivers, watercourses and irrigation canals in view of road conservation and maintenance works. Even if culverts need to be installed at appropriate locations, water flows may change in the future due to the flat terrain in the Study Area.
- To clearly identify locations of possible deposits of black cotton soil, where either soil replacement or soil stabilisation works will be required.
- To consider a gentle longitudinal profile where alternative routes run alongside the mountains near Asutsuare township. If alternative routes have a longitudinal gradient of 4% for more than 700 m, an additional lane (climbing lane) would be considered in order to secure the smooth flow of traffic without being affected by slow-moving heavy vehicles.

6.2.2 Road Alignment Study between Asutsuare Jct. and the Volta River

(1) Possible Alternative Routes

The Study Team prepared five possible alternative routes between Asutsuare Jct. and the Volta River, as shown in Figure 6-7, in the southern part of the Study Area (S-1, S-2, S-3, S-4 and S-5), which was presented at the First Working Group Meeting (WGM) held on 18th April, 2012 for the first screening of alternative routes.

(2) Comparison of Possible Alternative Routes

Results of the initial comparison of possible alternative routes by the Study Team are summarised in Table 6-2.

(3) Discussions in the WGM

Comments from GHA officials at the WGM are summarised in Table 6-3.

(4) Screening of Alternative Road Alignments

Based on the results of discussions in the WGM, alternative road alignments S-1, S-2, S-3 and S-4 were selected for the further study. Alternative road alignment S-5 was not selected because it could encroach on the area where Golden Exotic Ltd. plans to expand its banana estate.

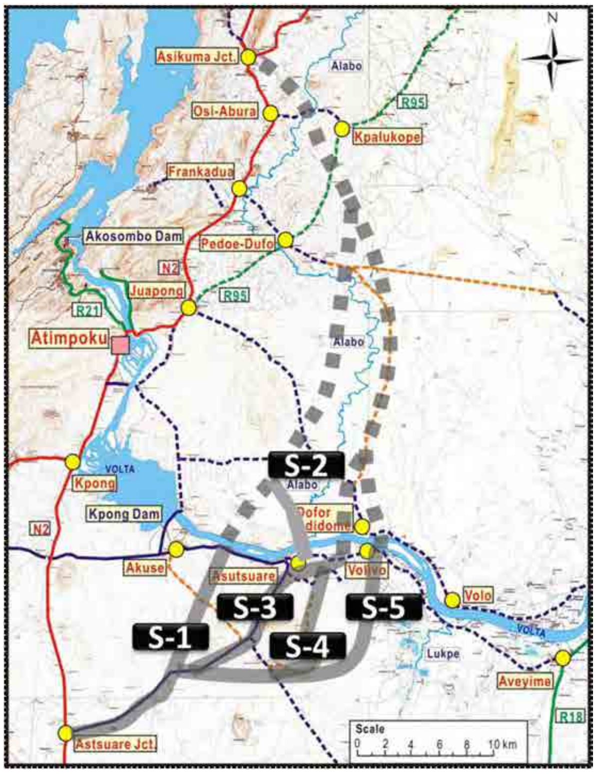
S-1: Route passing between Asutsuare and Akuse, turning toward the eastern direction after crossing the Volta River at bridge location B-1

S-2: Route following the existing road alignment and then crossing the Volta River close to Asutsuare (at bridge location B-2)

S-3: Route following the existing road alignment, changing direction towards Volivo and then crossing the Volta River close to Volivo (at bridge location B-3)

S-4: Route passing on the eastern side of Osuyongwa Mountain, turning toward the eastern direction, and crossing the Volta River on the western side of Volivo township (at bridge location B-3)

S-5: Route passing behind Osuyongwa Mountain and banana estate, shifting toward the western direction, and then crossing the Volta River (at bridge location B-4)



Source: Study Team

Figure 6-7 Possible Alternative Routes between Asutsuare Jct. and Volta River

Table 6-2 Comparison of Possible Alternative Routes between Asutsuare Jct. and the Volta River

	ITEM	Alt. S-1	Alt. S-2	Alt. S-3	Alt. S-4	Alt. S-5
1	Alignment	Gentle (+)	R=700m	R=700m	R=700m	Gentle (+)
2	Travel time saving	Highest (++)	High (+)	Low	Low	Low
3	Bridge construction	Long span bridge	Long span bridge	Long span bridge	Long span bridge	Medium span bridges (+)
3	Contribution to regional development	Medium	Medium	Medium	Medium	Medium
4	Number of resettlements	Few houses (+)	Some houses	Few houses (+)	Few houses (+)	Few houses (+)
5	Disturbance of agricultural activities	Paddy fields and tilapia cultivation	Paddy fields, irrigation scheme	Some paddy fields (+)	Some paddy fields (+)	Some paddy fields (+)
6	Road length requiring investment	19km (+)	23km	29km	30km	32km
	Total Score	High (+++++)	Low (+)	Low (++)	Low (++)	Medium (+++)

Source: Study Team

Table 6-3 Major Comments from GHA

Field	Major Comments from GHA
Agriculture Activities	▪ New trunk road could boost rice productivity, but has to cross some existing canals. ▪ Alternatives should avoid green belt including banana estate on the southern side of the Volta River, in accordance with government agricultural policy. ▪ There are concerns about loss of agricultural land due to the concentration of population along the new trunk road. ▪ Irrigation scheme on the northern side of the Volta River by MiDA will encourage rice exports.
Aquaculture Activities	▪ There are concerns about the impact on tilapia cultivation and decrease of farmers' incomes.
Communities	▪ There are problems about how to access safely the new trunk road with Asutsuare and Akuse.
Road Function	▪ The new trunk road should avoid communities because of its importance for linking agricultural land with Tema Port. ▪ The new trunk road should secure high-speed travelling, avoiding existing communities.
Road Construction	▪ Soil conditions should be investigated.

Source: Study Team

6.2.3 Study of Alternative Bridge Location over the Volta River

(1) Study of Bridge Location

In parallel with the selection of alternative road alignments, the Study Team selected four possible alternative locations for a new bridge over the Volta River. The Study Team considered the following aspects mainly from the results of site investigations, available topographical maps and aerial photos:

- Narrower river width section
- River configuration (to avoid sections with tributaries, curved reaches, and transition points of river bed gradient) and hydrological conditions
- Possible length and configuration of access roads to bridge
- Geological conditions on the river bank and surrounding areas
- Land use and use of river (pumping station, live box for tilapia cultivation, etc.)

(2) Screening of Bridge Locations by the Working Group Meeting

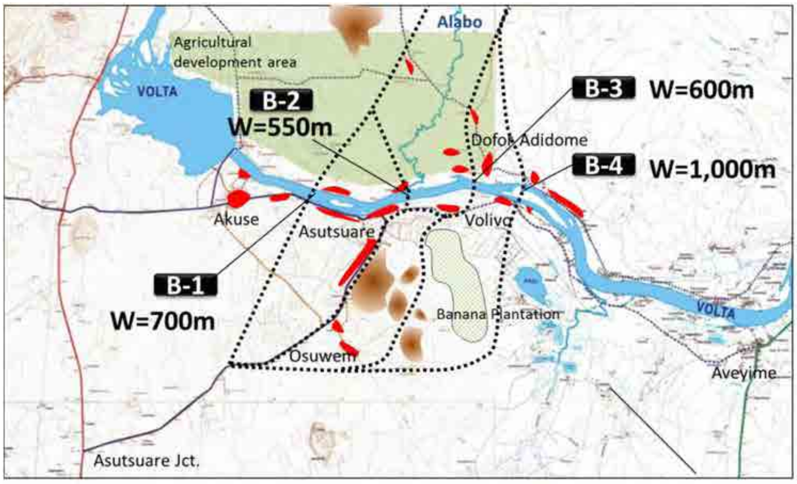
The Study Team considered four possible locations of a bridge over the Volta River between Akuse and Volivo (B-1, B-2, B-3 and B-4) as shown in Figure 6-8. Selection of alternative road alignments mentioned in Section 6.2.2 was fully coordinated with the selection of possible locations of a bridge. Then, the Study Team presented the possible bridge location at the First Working Group Meeting (WGM) for the first screening of locations.

Based on the results of discussions in the WGM, locations B-1, B-2 and B-3 were selected for further study, while B-4 was not selected because alternative road alignment S-5, which connect to B-4, was dropped.

6.2.4 Road Alignment Study between the Volta River and Asikuma Jct.

(1) Possible Alternative Routes

The Study Team prepared three possible alternative routes between the Volta River and Asikuma Jct. on the National Road N2 as shown in Figure 6-9, in the northern part of the Study Area (N-1,N-2, and N-3), and presented them in the First Working Group Meeting for the first screening of alternative routes.



Source: Study Team

Figure 6-8 Possible Alternative Bridge Locations

N-1: Route connects the Volta River and Juapong on N2 with a length of 24 km, mostly follows the alignment of the existing feeder road between Juapong and Dufor Adidome, then follows the existing N2 to Asikuma Jct. with a length of 21km.

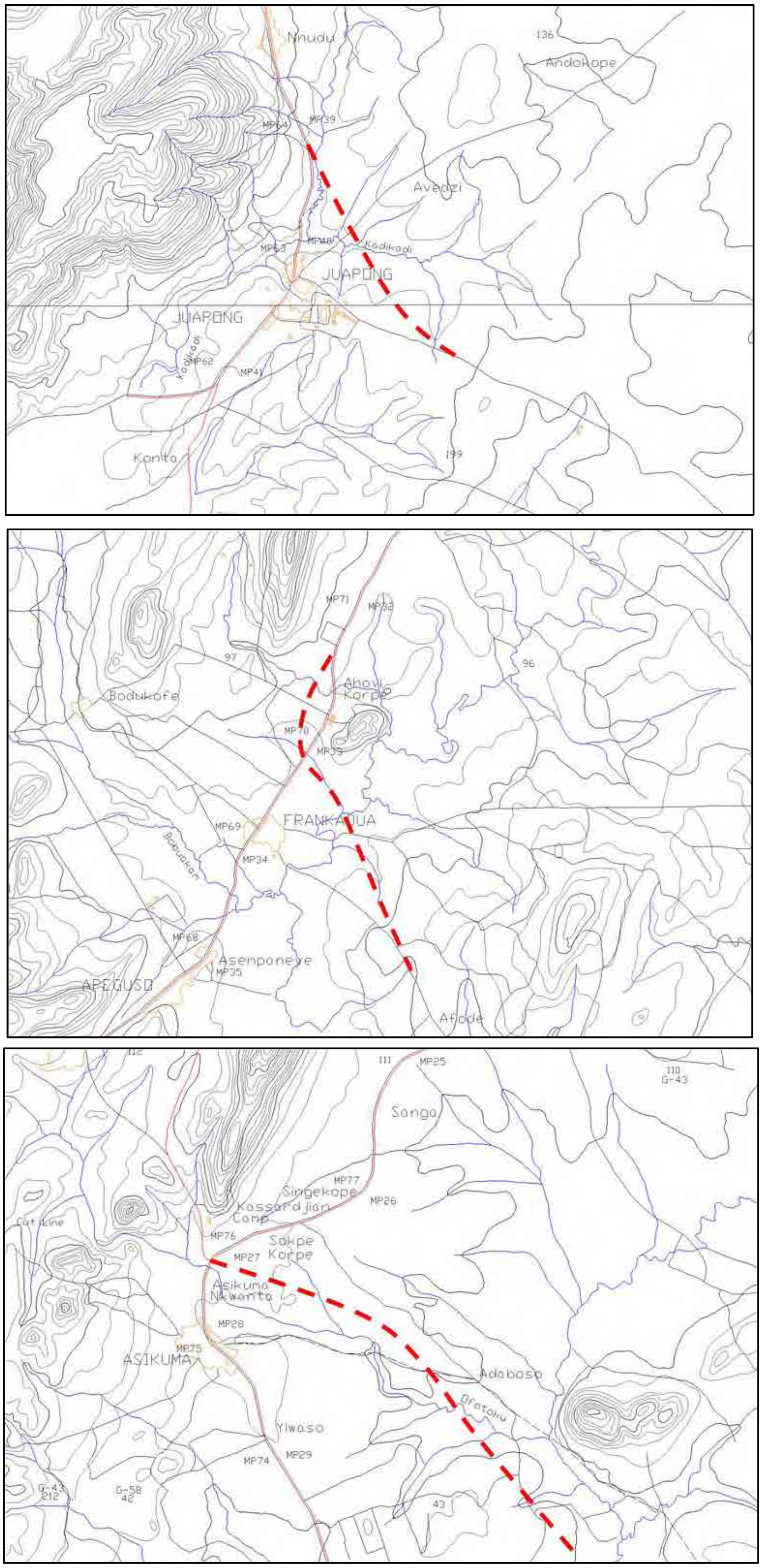
N-2: Route connects the Volta River and Frankadua on N2 with a length of 32 km of mostly new road, then follows the existing N2 to Asikuma Jct. with a length of 11km.

N-3: Route directly connects the Volta River and Asikuma Jct. with a length of 40 km of mostly new road.

Source: Study Team

Figure 6-9 Possible Alternative Routes between the Volta River and Asikuma Jct.

The urban areas of Juapong, Frankadua and Asikuma townships have been expanding along existing roads and it is almost impossible to connect the proposed new road at the existing intersection with N2 without many resettlements. Furthermore, it is necessary to give priority to the intersection approach alignment for the proposed new road when designing the intersection with N2, as the new road will become an international transport corridor. Therefore, the Study Team studied possible concept of the intersection of the proposed road with N2 for alternative roads N-1, N-2 and N-3 at Juapong, Frankadua and Asikuma Jct., respectively, to minimise resettlement as well as to improve the approach alignment for the proposed road, as shown in Figure 6-10.



Source: Study Team

Figure 6-10 Concept of Intersection at Juapong, Frankadua and Asikuma

(2) Comparison of Possible Alternative Routes

The results of initial comparison of possible alternative routes by the Study Team are summarised in Table 6-4.

Table 6-4 Comparison of Possible Alternative Routes between the Volta River and Asikuma Jct.

	Item	Alt. N-1.	Alt. N-2	Alt. N-3
1	Travel time saving (Dufor Adidome – Asikuma Jct.)	Low	Medium	High (+)
2	Solve problems of existing N2	Not expected	Partially expected (+)	Fully expected (++)
3	Contribute to regional development (agriculture)	Low	Partially expected (+)	Fully expected (++)
4	Number of resettlements	Few houses (+)	Few houses (+)	Few houses, one hotel
5	Disturbance of agricultural activities	Some areas near Juapong	Some areas near Frankadua	Very limited (+)
6	Road length for construction	24 km (+)	32 km	40 km
	Total Score	**Low** (++)	**Medium** (+++)	**High** (++++++)

Source: Study Team

(3) Discussions in the WGM

Since both Alt. N-1 and N-2 will require upgrading of the existing N2, which passes through several townships, and this upgrading scheme is not covered by the Study, every participant of the WGM agreed to screen out Alt.N-1 and N-2.

In addition, the GHA requested the Study Team to consider a fly over at Asikuma Jct. if future traffic demand will exceed the capacity of the at-grade intersection.

(4) Screened Road Alignment

Based on the results of discussions in the WGM, an alternative road alignment N-3 was selected for further study.

6.2.5 Further Studies for Selected Alternatives

(1) Alternative Route Alignments

The Study Team conducted the detailed site investigations for the alternative alignments S-1, S-2, S-3 and S-4 in the south and N-1 in the north after the WGM. As a result, the Study Team identified an additional alternative alignment which passes beside Osuyongwa Mountain, follows the Alt. S-4 alignment, and joins Alt. S-2 to cross the Volta River near Asutsuare (at bridge location B-2) in order to minimise negative impacts on paddy fields by crossing them by Alt. S-4, and securing smoother horizontal alignment. Therefore, there are five alternative routes for further study: Alt. 1, Alt. 2, Alt. 4 and Alt. 5, as summarised in Table 6-5 and Figure 6-11.

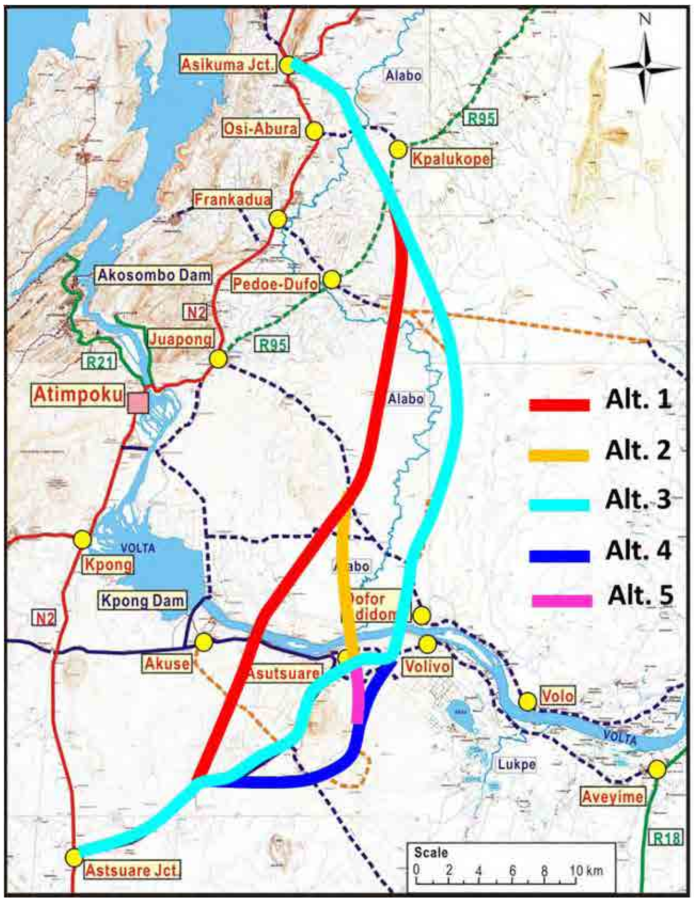
(2) Horizontal Alignment of Alternative Routes

a) Common Section

- The road alignments in the south up-to about 9 km from Asutsuare Jct. is the same for all alternatives because they follows the existing feeder road. The curve radius of this section is 1,500 m to 5,000 m.

Table 6-5 Summary of Alternatives for Further Study

Alternative	Description
Alt. 1	Route passing between Asutsuare and Akuse, crossing the Volta River, turning toward the northeast, crossing the Alabo River once, turning north, crossing the Alabo River a second time, and connecting Asikuma Jct.
Alt. 2	Route following the existing Asutsuare Jct. – Asutsuare Road alignment and then crossing the Volta River on the eastern side of Asutsuare, going north and joining Alt. 1.
Alt. 3	Route following the existing Asutsuare Jct. – Asutsuare Road alignment, going toward the eastern direction., crossing the Volta River on the western side of Volivo township, turning north on the eastern side of the Alabo River, and joining Alt. 1 after crossing under the high-voltage transmission line.
Alt. 4	Route passing on the eastern side of Osuyongwa Mountain, turning toward the eastern direction, and joining Alt. 3.
Alt. 5	Route following Alt. 4 until near the banana estate, and directly joining Alt. 2.



Source: Study Team

Figure 6-11 Alternative Route Alignments between Asutsuare Jct. and Asikuma Jct.

- A common section of road alignments for all alternatives in the north starts from adjacent to the high-voltage cable near Kpomkpo, goes north-west, crosses R95 near Dongbe and the Alabo River on western side of Amasiayakope, and reaches Asikuma Jct.

b) Alternative 1 (Alt. 1)

- The road alignment of Alt. 1 intersects at the common section, goes north, crosses the Lomen River and existing Somanya – Asutsuare road between Akuse and Asutsuare adjacent to the Volta River, and reaches the alternative bridge location B-1 of the new Volta River Bridge.

- After crossing the Volta River, the proposed road crosses two small rivers (Gblo River and Nyifla River), goes north-west, crosses the existing feeder road Juapong – Adidome and the Alabo River, and joins the common section in the north mentioned above.

c) Alternative 2 (Alt. 2)

- The road alignment of Alt. 2 mainly follows the existing feeder road Asutsuare Jct. – Asutsuare up to 21 km point from Asutsuare Jct. near Asutsuare township, crosses the existing feeder road Asutsuare – Aveyime, and reaches the alternative bridge location B-2 near the pumping station.
- After crossing the Volta River, the proposed road crosses the centre of the agricultural development scheme carried out by PE-AVIV company, and join Alt. 1.

d) Alternative 3 (Alt. 3)

- The road alignment of Alt. 3 intersects from Alt. 2 near Asutsuare, runs along the existing feeder road Asutsuare – Aveyime, and reaches the alternative bridge location B-3 near Volivo township.
- After crossing the Volta River, the proposed road runs north on the eastern side of the Alabo River, and joins the common section in the north.

e) Alternative 4 (Alt. 4)

- The road alignment of Alt. 4 intersects Asutsuare Jct. – Asutsuare road at the 11 km point from Asutsuare Jct., runs east until near Asuwem township and changes direction to the north to cross the hilly area on the east of Osuyongwa Mountain, passes the western side of the Golden Exotics banana estate, changes direction to the east to minimise its impact on paddy fields, and joins Alt. 3.

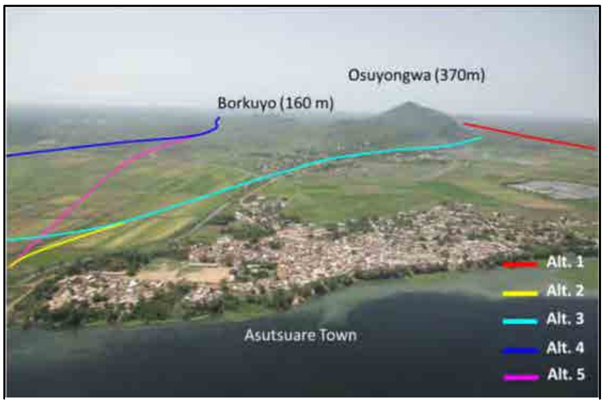
f) Alternative 5 (Alt. 5)

- The road alignment of Alt. 5 follows the alignment of Alt. 4 up to the eastern side of the Golden Exotics banana estate and from the intersection with Alt. 4, goes north to join Alt. 2.

(3) Planned Horizontal Curve

The planned horizontal curve of each alternative alignment is as follows.

- Alt. 1: Very gentle continuous curves of 2,000 m to 3,000 m in radius
- Alt. 2: Single curves of 1,000 m in radius
- Alt. 3: Gentle continuous curves of 1,500 m to 1,000 m in radius
- Alt. 4: Very gentle continuous curves of 1,800 m to 2,000 m in radius
- Alt. 5: Same as Alt. 4



Source: Study Team

Figure 6-12 Alternative Alignment near Asutsuare

(4) Longitudinal Profile

There is basically no problem of longitudinal profile because the Study Area is mostly on flat terrain. However, there is an exception where Alt. 4 and Alt. 5 pass on the eastern side of Osuyongwa Mountain. The slope gradient at this section is between 2% and 3.2% (for a 500 m section). Regarding this hilly section, however, the Study Team considers that it is not necessary to construct an additional lane (climbing lane), because the gradient can be reduced to less than 3% by civil works.

(5) Crossing Roads

a) Section between Asutsuare Jct. and the Volta River

- Alt. 1 crosses the existing Somanya – Asutsuare road adjacent to the Volta River.
- Alt. 2, Alt. 3, Alt. 4 and Alt. 5 cross the existing feeder road Asutsuare – Aveyime, however, this road is planned to be upgraded to an inter-regional road and an improvement plan will be prepared in the Study.

b) Section between the Volta River and Asikuma Jct.

- Alt. 1, Alt. 2, and Alt. 5 cross the existing feeder road Juapong – Adidome on the western side of the Alabo River.
- Alt. 3 and Alt. 4 cross the existing feeder road Juapong – Adidome on the eastern side of the Alabo River.
- The common section of the proposed road crosses R95 between Dangbe village and Kpalukope township,
- The common section of the proposed road is the existing feeder road Osi-Abura – Kpakukope on the western side of Amasiayakope township.

(6) Crossing Rivers other than the Volta River

a) Section between Asutsuare Jct. and the Volta River

- Other than the Volta River and an irrigation canal of the KIS, only Alt. 1 crosses the Romen River.

b) Section between the Volta River and Asikuma Jct.

- Alt. 1 crosses the Gblo River, Nyifla River, Honi River and Alabo River before joining the common section of the proposed route.
- Alt. 2 and Alt. 5 cross the Honi River and Alabo River after joining Alt. 1.
- Alt. 3 and Alt. 4 do not cross a river other than small streams before joining the common section.
- The common section crosses the Alabo River on the western side of Amasiayakope township.

(7) Soil Condition

a) Soil Testing

From the initial site survey, the Study Team found that there is a high possibility of black cotton soil[21] deposit based on the FAO Soil Classification Map of the Study Area shown in Figure 2-15.

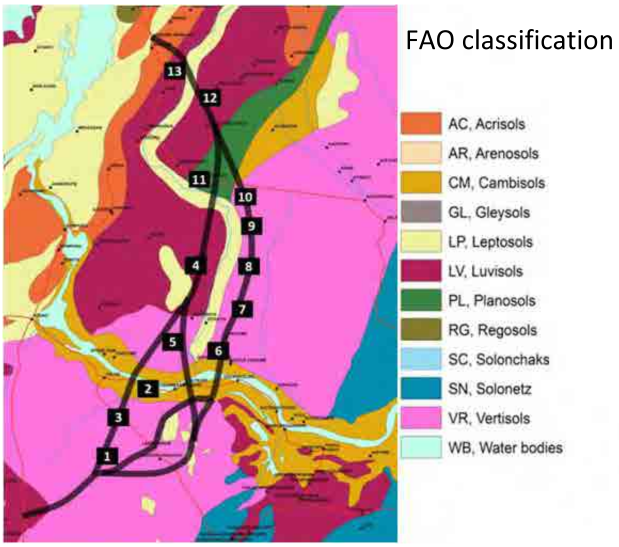
In order to identify possible areas of black cotton soil deposit along the proposed alternative road alignments, the Study Team conducted a soil investigation focusing on black cotton soil deposits in May 2012, with cooperation from the Material Division of the GHA by collecting samples and laboratory tests.

The results of the soil investigation are shown in Table 6-6 and Figures 6-13 and 6-14.

Table 6-6 Soil Conditions between Asutsuare Jct. and Asikuma Jct.

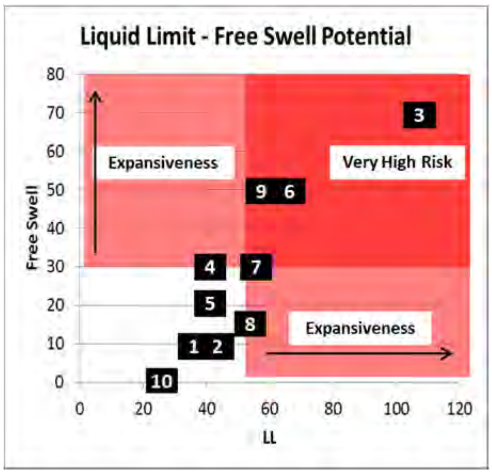
Sample	Atterberg Test			Natural Moisture	Free Swell Potential
Soil samples (Thickness of black soil)	LL %	PL %	PI %	%	%
PIT 1 (0.6 m)	40	20	20	10.81	10.0
PIT 2 (over 1.0 m)	43	23	20	8.67	10.0
PIT 3 (over 1.0 m)	109	38	71	34.77	70.0
PIT 4 (0.6m)	42	22	20	10.14	30.0
PIT 5 (0.8m)	41	20	21	10.04	20.0
PIT 6 (0.8m)	64	22	42	26.3	50.0
PIT 7 (0.65m)	57	31	26	14.7	30.0
PIT 8 (over 1m)	53	25	28	20.9	15.0
PIT 9 (over 1m)	61	25	36	14.6	50.0
PIT 10 (0.4m)	27	16	11	13.6	-
PIT 11	Gravel				
PIT 12	Gravel				
PIT 13	Gravel				

Source: GHA, Material Division



Source: Soil Research Institute

Figure 6-13 Location of Soil Investigation Testing Pits



Source: Study Team

Figure 6-14 Relation of Liquid Limit and Free Swell Potential for Soil Samples

As shown in The soil sample from PIT 3 showed the highest values of the Liquid Limited (LL-109%), Plasticity Index (PI-71%) and Free Swell Potential (70%). This means that there is

[21] Characteristics of black cotton soil is described in 2.4.4 (2) in this report.

the highest risk of extensive black cotton soil in the area around PIT 3. Other than PIT 3, LL values exceeding 50% were found for samples from PITs 6, 7, 8 and 9, while Free Swell Potential values of more than 30% were found for samples from PITs 6, 7 and 9. These results also means a higher risk of extensive black cotton soils in these areas as well.

b) Countermeasures

There are several countermeasures for the black cotton layer, such as replacing the black cotton layer or using lime-stone stabilisation, in order to stabilise the subgrade and prevent shrinking and swelling of black cotton soil, etc. This Study proposes replacement of the black cotton layer because the lime stone stabilisation method would be more expensive in Ghana.

6.2.6 Bridge and Drainage Structure Study

This section describes bridge and drainage structural study other than for the Volta River.

(1) Structure Type to Cross Rivers and Irrigation Canal

Construction of a bridge is proposed for a location where the alternative route cross the following rivers. While the Study Team proposes that drainage structures over small streams (less than 30 m of width) and an irrigation canal are planned to be concrete culverts (either box culver or pipe culvert).

- Alt. 1: Lomen River (100 m), Gblo River (30 m), Alabo River (55 m)
- Alt. 2: Lomen River (50 m), Alabo River (55 m)
- Alt. 3: Lomen River (50 m)
- Alt. 5: Alabo River (55 m)
- Common section in the north: Alabo River (50m)

(2) Bridge Type

a) Selection of Superstructure Type

With reference to Table 6-7, a continuous T-girder bridge is selected for the following reasons:

- Continuous structures, which are more resistant to earthquakes, are mainly compared.
- Concrete bridges are maintenance-free and economical.
- These types of bridges are commonly used in Ghana.
- As PC continuous composite girder bridge is unfavourable in terms of ease of construction and quality control compared with a PC continuous T-girder bridge, and offers no advantage.

b) Selection of Substructure Type

Table 6-8 compares the applicable bridge substructure type and standard bridge height. Since a substructure height of about 10 m is required for every bridge according to site investigations, the Study Team proposes the reverse T-style abutment for all bridges. In the case of bridge piers, the Study Team proposes column piers for every bridge in order to minimise negative impacts on the river flow and better workability.

Table 6-7 Comparison of Superstructure Types and Standard Spans of Bridge

	Superstructure Type	Standard Span (50 m / 100 m / 150 m; 30m)	Possibility of Curves: Main Structure	Possibility of Curves: Bridge Deck	Girder height Span ratio
Steel bridge	Simple composite plate girder		○	○	1/18
	Simple plate girder		○	○	1/17
	Continuous plate girder		○	○	1/18
	Simple box girder		○	○	1/22
	Continuous box girder		○	○	1/23
	Simple truss		×	○	1/ 9
	Continuous truss		×	○	1/10
	Reverse Langer girder		×	○	1/6,5
	Reverse Lohse girder		×	○	1/6,5
	Arch		×	○	1/6,5
PC bridge	Pretensioned girder		×	○	1/15
	Hollow slab		○	○	1/22
	Simple T girder		×	○	1/17,5
	Simple composite girder		×	○	1/15
	Continuous T girder, composite girder		×	○	1/15
	Continuous composite girder		×	○	1/16
	Simple box girder		○	○	1/20
	Continuous box girder (cantilever method)		○	○	1/18
	Continuous box girder (Push-out or support method)		○	○	1/18
	π shaped rigid frame ridge		×	○	1/32
RC bridge	Hollow slab		○	○	1/20
	Continuous spandrel-filled arch		○	○	1/ 2

Source: Study Team

In view of consider the results of previous studies as well as geological conditions in the Study Area, the Study Team proposes to adopt direct foundations for the foundation type, because of the shallow supporting layer as well as lower construction cost.

However, the details of the substructure of bridge(s) on the selected alternative route will be studied in more detail based on geotechnical investigations at the bridge site(s).

(3) Proposed Structure Types and Bridge Lengths for each Alternative Route

Table 6-9 summarises the proposed structure types and bridge lengths of bridges on each alternative route.

Table 6-8 Comparison of Substructure Types and Applicable Heights of Bridges

Bridge part	Substructure type	Applicable height (m) 10 20 30	Characteristics
Abutment	1. Gravity type		With shallow support ground, the gravity type is suitable for direct foundations.
	2. Reverse T-style		Used in many bridges. Suitable for direct foundations and pile foundations.
	3. Buttressed type		Suitable for tall abutments. Few materials are used for this type, but the lead time is long.
	4. Box type		Designed for tall abutments. The lead time is somewhat long.
Pier	1. Column type		Low piers. Suitable for stringent intersection conditions and installation in a river.
	2. Rigid frame type		Relatively tall piers. Suitable for wide bridges, but their installation in a river may hinder water flow during flooding.
	3. Pile bent type		The most cost efficient, but not suitable for bridges with high horizontal force. Their installation in a river may hinder water flow during flooding.
	4. Elliptical type		Tall bridge piers. Suitable for bridges with high external force.

Source: Study Team

Table 6-9 Proposed Structure Types and Bridge Lengths for Alternative Routes

Item		Alabo River (1)	Alabo River (2)	Lomen River	Gblo River
Superstructure type		PC continuous T girder bridge	PC continuous T girder bridge	PC continuous T girder bridge	PC simple T girder bridge
Substructure type		T-style abutment, Column type pier	T-style abutment, Column type pier	T-style abutment, Column type pier	T-style abutment
Foundation type		Direct foundation	Direct foundation	Direct foundation	Direct foundation
Bridge Length	Alt.1	55m	50m	100m	30m
	Alt.2	55m	50m	50m	----
	Alt.3	----	50m	----	----
	Alt.4	----	50m	----	----
	Alt.5	55m	50m	----	----

Source: Study Team

6.3 Study of Bridge across the Volta River

6.3.1 Study of Bridge Location

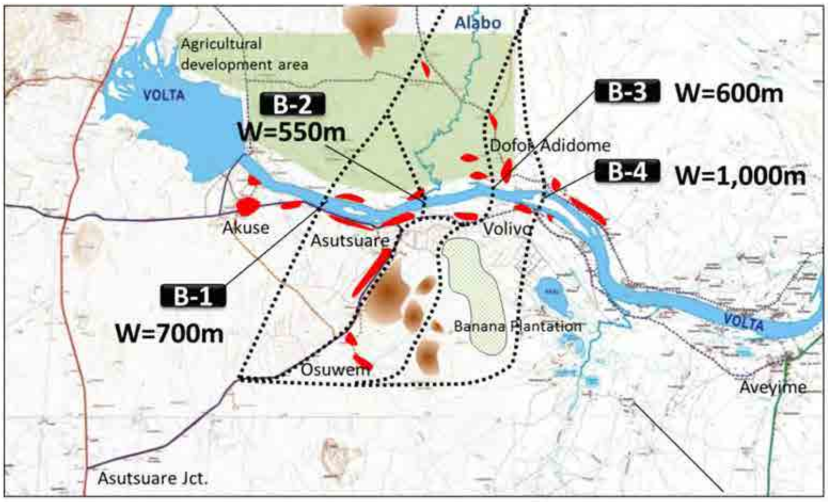
Recommended bridge locations are decided based on the alignments of new road, which are selected through many control points. The exact location is selected where the river is narrower to reduce the construction cost. The decision on the location also depends on other factors such as:

- The river configuration (to avoid sections with tributaries, curved reaches, and points of changing gradient) and hydrological conditions

- Length and configuration of access road
- Geological conditions at the river and surrounding areas
- The state of usage of the river and surrounding areas (to consider temporary uses for construction)

6.3.2 First Screening of Bridge Locations by the WGM

The Study Team presented the following four possible bridge locations for the Volta River between Akuse and Volivo (B-1, B-2, B-3 and B-4) together with the alternative alignments to the Working Group Meeting. Based on the results of discussions in the WGM, alternative bridge locations B-1, B-2 and B-3 were selected for further studies.



Source: Study Team

Figure 6-15 Alternative Possible Bridge Locations

6.3.3 Study of Bridge Type for the Selected Bridge Location

(1) Bridge Length

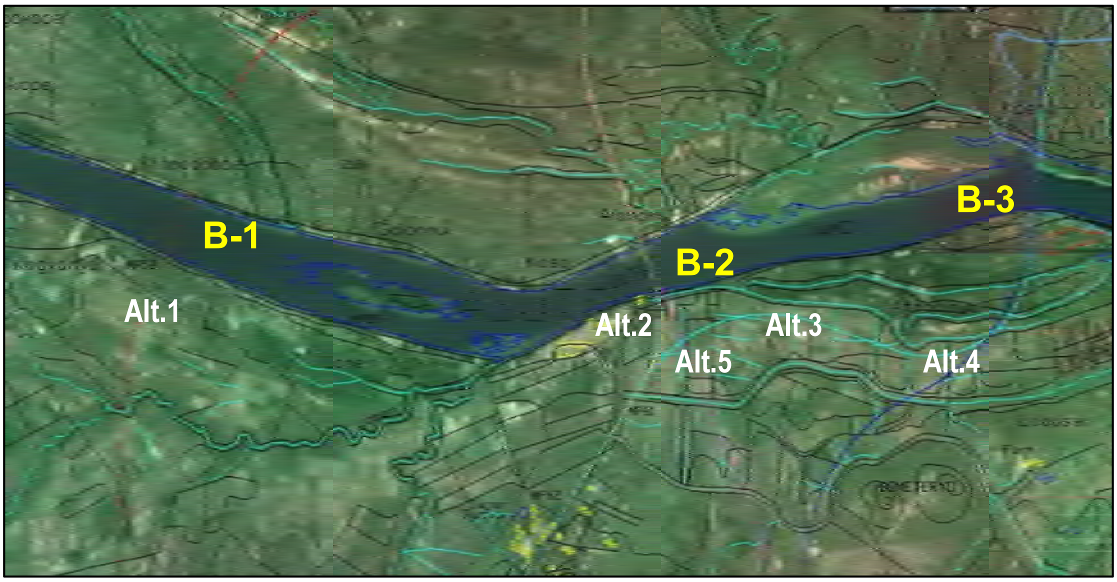
The Study Team conducted detailed site surveys for the selected alternative bridge locations B-1, B-2 and B-3 (see Figure 6-15), mainly considering minimisation of resettlement of houses and shops.

- Bridge length at B-1 for Alt. 1: 620 m
- Bridge length at B-2 for Alt. 2 and Alt. 5: 530 m
- Bridge length at B-3 for Alt. 3 and 4: 580 m

(2) Topographical and Geological Conditions

The bathymetric survey and geotechnical investigation revealed the following natural conditions at the proposed locations of alternative bridge sites.

- The Volta River, with a maximum riverbed depth of 6–8 m.
- The Volta River has a uniform current which is controlled by the Kpong Dam and the velocity is approximately 0.6 m/s.
- The river water is not saline.



Source: Study Team

Figure 6-16   Locations of Selected Alternative Bridges

- The support layer is very near to the river bed, with a minimum depth of 3–6 m from the river bed.
- The support layer is a very hard rock layer with an N-value of more than 300.

(3) Seismic Load

a) Seismic Resistance Design Standard

The Study Team used the Japanese standard when considering the seismic design of the new bridge for the Volta River because Japan has experienced several big earthquakes and structures have been upgraded to withstand the seismic forces. The Japanese standard considers two types earthquakes. One is the probable earthquake during the service life of the structure and is called the "Level I" earthquake. The other is a rare but very big earthquake called the "level II" earthquake. Each earthquake level requires performance (see Table 6-10). Therefore, the Japanese standard is designed to give bridges seismic resistance against either weak or strong earthquakes.

Table 6-10   Design Seismic Resistance and Required Performance

Earthquake Type	Required Performance
Level I earthquake	After an earthquake, bridge structures will not be broken.
Level II earthquake	After an earthquake, damage will be limited to allow a part and functions of the bridge to be quickly restored.

Source: Study Team

b) Level I Earthquake

The maximum response acceleration is estimated by considering past earthquakes in and around the Study Area, formula for distance damping and difference between response acceleration and ground level acceleration. The design return period is 75 years as the probable earthquake during the service life of structures. The size of earthquake in this period is estimated by using the revised epicentre distance (see Table 6-11).

Table 6-11 Past Earthquakes and Level I Maximum Response Acceleration

Year	Magnitude	Epicentre Distance (km)	Historic Return Period (year)		Revise Epicentre Distance (km)	Ground Level Acceleration (gal)	Max Response Acceleration (gal)
1636	5.7	290.0	----	----	----	----	----
1862	6.5	99.4	(2012-1862)/2=	75	121.7	55.2	108
1872	4.9	98.9	(2012-1862)/4=	37.5	85.6	34.7	68
1906	5.0	101.0	(2012-1862)/4=	37.5	87.5	35.8	70
1939	6.4	114.0	(2012-1862)/2=	75	139.6	45.9	90
Design maximum response acceleration = 110 gal							

Source: Study Team

- Revise epicentre distance = epicentre distance × (historical return period)$^{0.5}$ / (design return period)$^{0.5}$
- Ground level acceleration = $987.4\times10^{0.216}M\times(\Delta+30)^{-1.218}$

  M: Magnitude   Δ: Epicentre distance
- Max response acceleration = (ratio between response acceleration and ground level acceleration in Japanese standard = 200/102.24) × ground level acceleration

c) Level II Earthquake

The bridge site is located near an active fault which experienced a big earthquakes in 1862 and 1939, and the Study Team expects an earthquake to occur at the active fault. The expected magnitude of that earthquake is considered to be 6.5, the same as the earthquake in 1862. The epicentre distance is expected to be 10 km in the worst situation. (see Table 6-12 and Figure 6-17)

Table 6-12 Expected Level II Earthquake

Magnitude	6.5
Epicentre distance (km)	10.0
Ground level acceleration (gal)	280.0
max response acceleration (gal)	712.5
Design maximum response acceleration = 720 gal	

Source: Study Team

Source: Study Team

Figure 6-17 Expected Level II Earthquake and Active Fault

- Ground level acceleration = $987.4\times10^{0.216}M\times(\Delta+30)^{-1.218}$

  M: Magnitude Δ: Epicentre distance

- Max response acceleration = (ratio between response acceleration and ground level acceleration in Japanese standard = 2000/786) × ground level acceleration

6.3.4 Preliminary Study of the Bridge across the Volta River

(1) First-Step Comparison of Superstructures

a) Selection of Alternatives Superstructure Types for the First-Step Comparison

With reference to Table 6-13, possible combinations of bridge types and span allocations for this bridge, were selected and seven alternatives steel bridges and six alternative PC bridges were chosen for the comparison, mainly considering the following points:

- A simple girder type was not selected for the comparison, because this type of bridge could fall off a pier and has less seismic resistance.
- Steel Langar girder, steel Lohse girder and steel arch types were not selected because they are suitable for only short-span bridges.
- The pretensioned girder type was not selected because there is no girder manufacturing workshop in Ghana.
- A PC π shaped rigid frame bridge was not selected, because this type is basically used for flyover bridges and there is no example of its use for a river bridge.
- PC Hollow slab, RC Hollow slab and RC continuous spandrel-filled arch types were not selected because their applicable span length was too short for this bridge.
- The steel continuous box girder type was not selected because the production and transportation of the steel girder are expensive, advanced technology and equipment are required for erection of girders, and there is no merit compared with the truss girder type for the same bridge span.
- The PC continuous composite girder type was not selected, because it is unfavourable in terms of ease of construction and quality control compared with the PC T-girder type.
- The PC continuous box girder (push-out or support method) is less economical for a 40 m span length compared with the PC T-girder type and almost the same economical level for a 60 m span length compared with the PC T-girder type using the cantilever method. This type, however, would become one of the longest girder lengths if applied in this bridge. Thus, this type was not selected because of difficulty of construction, because advanced technology would be required for construction with the push-out method.
- b) Selection of Alternatives Superstructure Types for the Second Step Comparison
- For the 13 alternative superstructure types for the first-step comparison, a second-step comparison was made, considering the effects on the river flow, landscape aesthetic value, ease of maintenance and construction cost, as shown in Table 6-14. Based on this comparison, the following three alternative superstructure types were selected for the following reasons:

Table 6-13 Comparison of Superstructure Types and Standard Spans of Bridge

	Superstructure Type	Standard Span (50 m / 100 m / 150 m)	Evaluation	Judgment
Steel bridge	Simple composite plate girder		Not applicable	No
Steel bridge	Simple plate girder		Less seismic resistance	No
Steel bridge	Continuous plate girder		Applicable	Yes
Steel bridge	Simple box girder		Less seismic resistance	No
Steel bridge	Continuous box girder		Less economical than truss	No
Steel bridge	Simple truss		Less seismic resistance	Yes
Steel bridge	Continuous truss		Applicable	Yes
Steel bridge	Reverse Langer girder		Not applicable	No
Steel bridge	Reverse Lohse girder		Not applicable	No
Steel bridge	Arch		Not applicable	No
Steel bridge	Continuous cable-stayed bridge		Applicable	Yes
PC bridge	Pretensioned girder		Not applicable	No
PC bridge	Hollow slab		Applicable span is too short	No
PC bridge	Simple T girder		Less seismic resistance	No
PC bridge	Simple composite girder		Less seismic resistance	No
PC bridge	Continuous T girder,		Applicable	Yes
PC bridge	Continuous composite girder		Less economical than T-girder	No
PC bridge	Simple box girder		Less seismic resistance	No
PC bridge	Continuous box girder (cantilever method)		Applicable	Yes
PC bridge	Continuous box girder (Push-out or support method)		Less economical than T-girder	No
PC bridge	π shaped rigid frame bridge		Not applicable	No
PC bridge	Continuous extradosed bridge		Applicable	Yes
RC bridge	Hollow slab		Applicable span is too short	No
RC bridge	Continuous spandrel-filled arch		Applicable span is too short	No

Source: Study Team

Alternative 1: Steel-3 – Continuous cable-stayed bridge (Span: 117.5 + 265.0 + 117.5)

Alternative 2: PC-2 – Continuous box girder bridge (Span: 70 + 3@120 ; 70)

Alternative 3: PC-3 – Continuous extradosed bridge (Span: 95 + 2@155 + 95)

- Even though the Steel-1 Continuous plate girder type is relatively cheaper with a span of 60 m, it is difficult to construct due to many construction works in the river and it offers no better landscape aesthetic value. Thus, this type was excluded from the second-step comparison.

- The Steel-2 continuous truss bridge was excluded from the second-step comparison, because it is relatively expensive and offers no particular merit.
- The Steel-3 continuous cable-stayed bridge was selected for the second-step comparison, because of its better landscape aesthetic value and comparatively low construction cost. Regarding 3 spans or 4 spans, the 3 span type is superior in terms of landscape aesthetic value with a monumental and landmark shape for the surrounding area due to the main tower which is more than 50 m in height: this was selected for the second-step comparison, because this advantage is judged to be more superior than the 3% higher construction cost of the 4-span alternative.
- The PC-1 connected T-girder bridge was not selected because it would have large effects on the river, its landscape aesthetic value is low and construction cost is higher.
- The PC-2 continuous box girder bridge is a better alternative, because its construction cost is the lowest. The 5-span type was selected for the second-step comparison, because it is easier to construct with relatively few construction works in the river.
- The PC-3 continuous extradosed bridge with 4 spans was selected for the second-step comparison because of its relatively high landscape aesthetic value with the striking landscape features of the cable structure.

(2) First Step Comparison of Substructure

a) Selection of Abutment Type

- The economical reverse T-style abutment was selected in the first-step comparison, and the height of abutment was determined as 12 m, which is the marginal height of a reverse T-shape abutment, in order to reduce the bridge length. The economical direct foundation was selected for the foundation type, as a sandy gravel layer with an N-value of more than 50 exists at the bottom of the planned footings (the height of abutment and foundation type are revised in the second-step comparison).

b) Selection of Pier Type

- The column type elliptical pier was selected as the pier type, in order to minimise the obstruction of river flow, as most of the piers will be constructed in the river. The economical direct foundation was adopted for the foundation, because a hard rock layer was found at a shallow level.

Table 6-14 Comparison of Structural Type of the Bridge over the Volta River (First-Step)

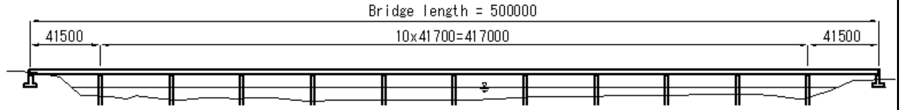
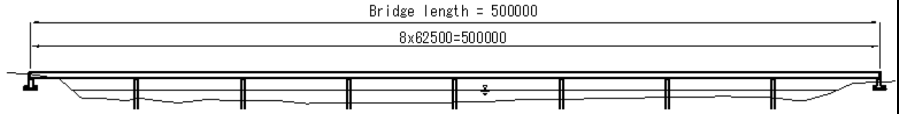
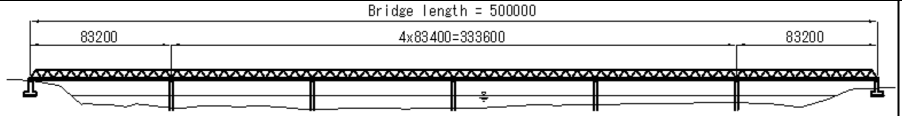
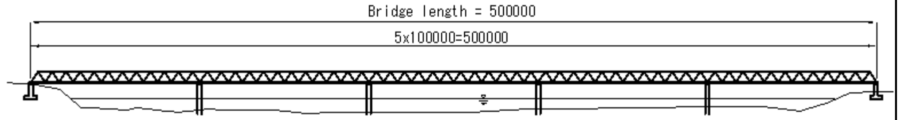
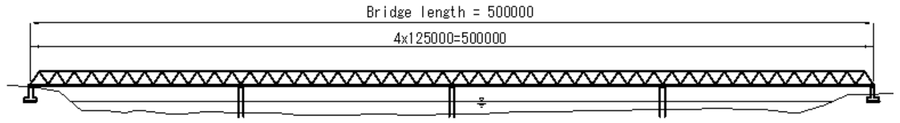
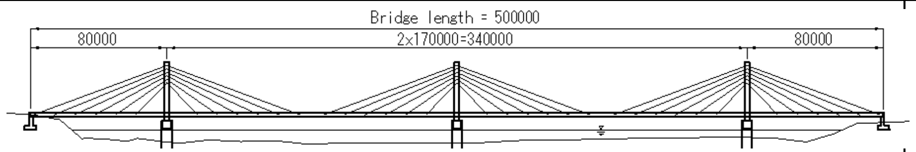
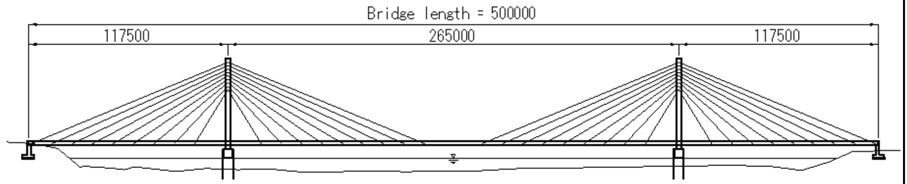
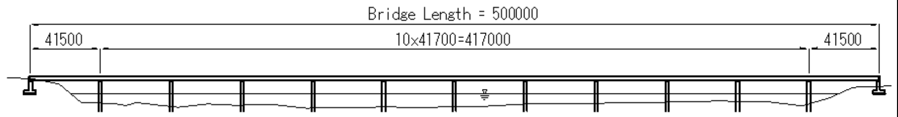
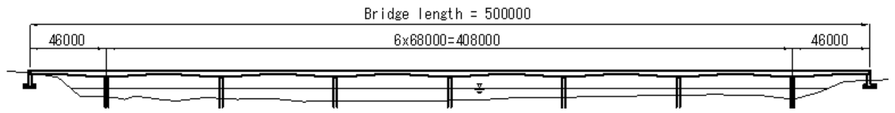
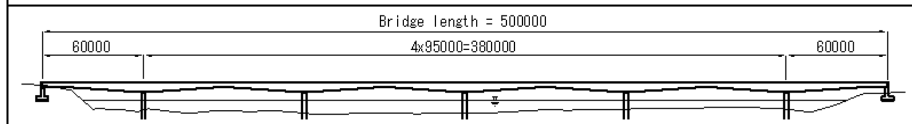
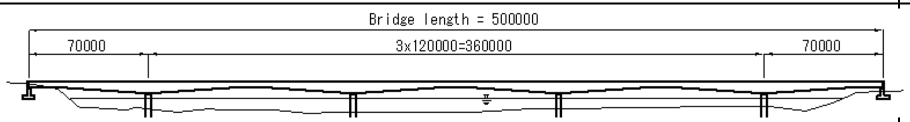
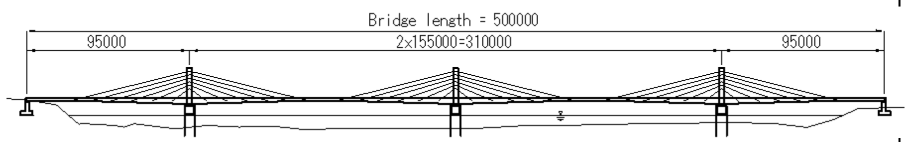
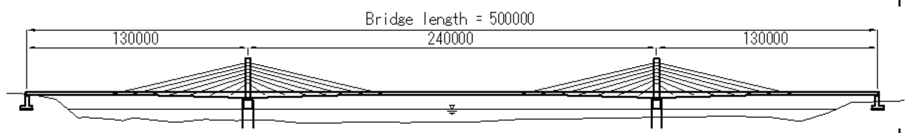
Structure Type	Structural Image	Span Allocation	Structural Features	Obstacle ratio in river section at work	Land Scape Aesthetic Value	Maintenance	Comparison of Construction Cost	Judgment
Steel -1 Continuous Plate Girder Bridge			No major problem (Good)	Too many [approx. 24%] (Fair)	Less aesthetic (Fair)	No major maintenance is required using weathering steel (Good)	1.22 (Bad)	
			No major problem (Good)	Too many [approx.16%] (Fair)	Less aesthetic (Fair)	No major maintenance is required using weathering steel (Good)	1.04 (Good)	
Steel -2 Truss Bridge			No major problem (Good)	Too many [approx.16%] (Fair)	Monumental but complicated (Fair)	No major maintenance is required using weathering steel Less durability with RC-slab (Fair)	1.02 (Very Good)	
			No major problem (Good)	Too many [approx.11%] (Fair)	Monumental but complicated (Fair)	No major maintenance is required using weathering steel Less durability with RC-slab (Fair)	1.06 (Good)	
			No major problem (Good)	Relatively few [approx.8%] (Good)	Monumental but complicated (Fair)	No major maintenance is required using weathering steel Less durability with RC-slab (Fair)	1.20 (Bad)	
Steel -3 Cable-Stayed Bridge			No major problem (Good)	Relatively few [approx.8%] (Good)	Monumental (Good)	No major maintenance is required using weathering steel (Good)	1.03 (Very Good)	
			No major problem (Good)	Fewest [approx.6%] (Very Good)	Highly monumental (Very Good)	No major maintenance is required using weathering steel (Good)	1.06 (Good)	**Very Good**
PC -1 Connected T Girder Bridge			No major problem (Good)	Too many [approx.24%] (Fair)	Less aesthetic (Fair)	No major maintenance is required (Good)	1.20 (Fair)	
PC -2 Continuous Box Girder Bridge			No major problem (Good)	Too many [approx.16%] (Fair)	Rhythmical (Good)	No major maintenance is required (Good)	1.13 (Fair)	
			No major problem (Good)	Too many [approx.16%] (Fair)	Rhythmical (Good)	No major maintenance is required (Good)	1.03 (Very Good)	
			No major problem (Good)	Relatively few [approx.11%] (Good)	Rhythmical (Good)	No major maintenance is required (Good)	1.00 (Very Good)	**Very Good**
PC -3 Extradosed Bridge			No major problem (Good)	Relatively few [approx.8%] (Good)	Monumental (Good)	No major maintenance is required (Good)	1.04 (Good)	**Very Good**
			Bearing support is too big (Fair)	Fewest [approx.6%] (Very Good)	It gives a high monumental impression. (Good)	No major maintenance is required (Good)	1.29 (Bad)	

Table 6-15 Comparison of Substructure Types and Applicable Heights of Bridges

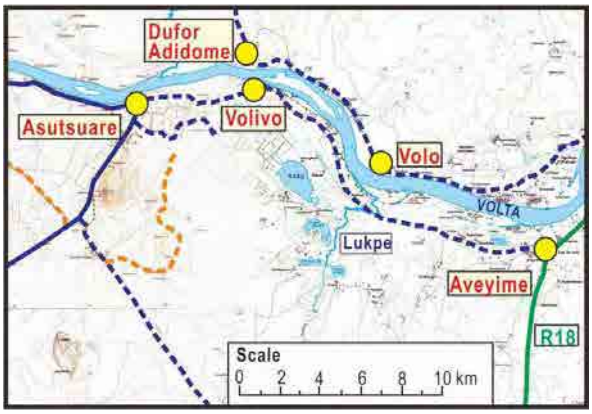
Bridge part	Substructure type	Applicable height (m) 10 20 30	Characteristics
Abutment	1. Gravity type		With shallow support ground, the gravity type is suitable for direct foundations.
	2. Reverse T-style		Used in many bridges. Suitable for direct foundations and pile foundations.
	3. Buttressed type		Suitable for tall abutments. Few materials are used for this type, but the lead time is long.
	4. Box type		Designed for tall abutments. The lead time is somewhat long.
Pier	1. Column type		Low piers. Suitable for stringent intersection conditions and installation in a river.
	2. Rigid frame type		Relatively tall piers. Suitable for wide bridges, but their installation in a river may hinder water flow during flooding.
	3. Pile bent type		The most cost efficient, but not suitable for bridges with high horizontal force. Their installation in a river may hinder water flow during flooding.
	4. Elliptical type		Tall bridge piers. Suitable for bridges with high external force.

Source: Study Team

6.4 Road Alignment Study between Asutsuare and Aveyime

(1) Road Category

According to the GHA, the category of feeder road section between Asutsuare and Aveyime will be changed in part to an inter-regional road connecting Somanya and N1 via Akuse, Asutuare, and Aveyime after the improvement is completed. The existing feeder between Asutsuare and Aveyime is a gravel road about 6.0 m wide for 25 km. This road passes through the centres of Asutsuare, Volivo and Aveyime townships.



Source: Study Team

Figure 6-18 Location of Asutsuare and Aveyime Road

(2) Proposed Horizontal Road Alignment

Since the classification of this road will become an inter-regional road, the Study Team proposes that the horizontal alignment of this road section should basically follow the existing road alignment, except at sections on the east of Asutsuare township, where the existing road crosses two irrigation canals: in Volivo township, where the present alignment will not satisfy the minimum curve radius: and in Aveyime township, where some houses are encroaching on the road and there is a T-shape intersection adjacent to the Aveyime roundabout.

The preliminary design of this road section will be carried out in the next stage of the Study, when topographical maps will be created based on topographical surveys.

(3) Proposed Longitudinal Profile

Since the topography along this road is totally flat on the Accra Plain along the Volta River, there are no problems of longitudinal profile for the proposed improvement.

(4) Crossing Road

There is no classified cross road other than minor gravel feeder roads.

(5) Crossing Rivers and Streams

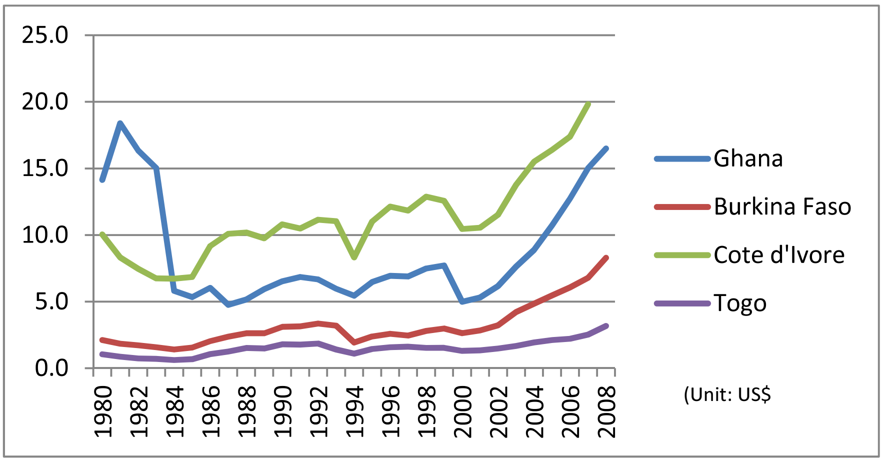
There is only one river, the Lupe River, which is located around 15 km from Asutsuare and there is one double box-culvert at present. Since the Norboyita Dam is planned on the upper reaches of the Lupe River, the water discharge volume and current velocity are expected to be controlled by this dam.

6.5 Rough Cost Estimation

6.5.1 Study of Unit Construction Cost

(1) Inflation in Ghana

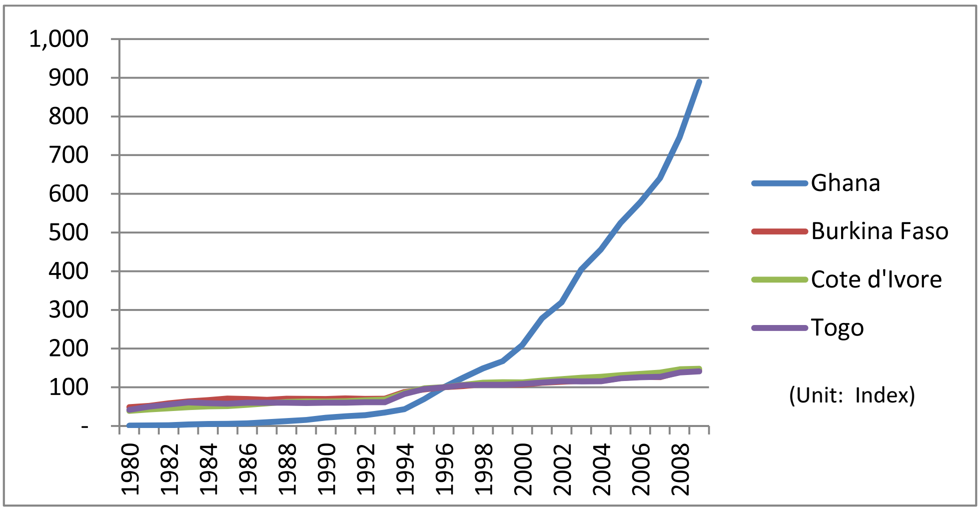
Figure 6-19 indicates the trend of nominal GDP of Ghana and its three neighbouring countries from 1980 to 2008.



Source: Study Team based on World Economic Outlook Database, IMF

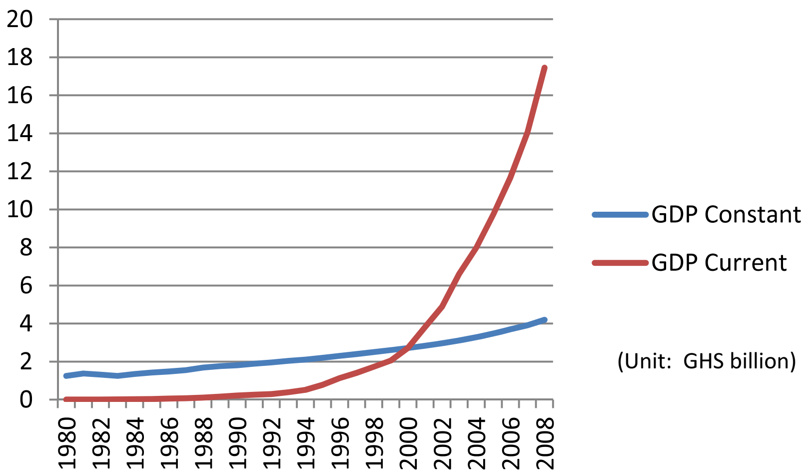
Figure 6-19 Trend of Nominal GDP of Ghana and Surrounding Countries

Prices have risen more steeply in Ghana than in neighbouring countries as shown in Figure 6-20. Although the rise has recently eased (to less than 10%), the difference among these countries remains large. Thus, the real GDP is not high, as indicated in Figure 6-21.



Source: Study Team based on World Economic Outlook Database, IMF

Figure 6-20 Inflation Index (Base Year: 1996)



Source: Study Team based on World Economic Outlook Database, IMF

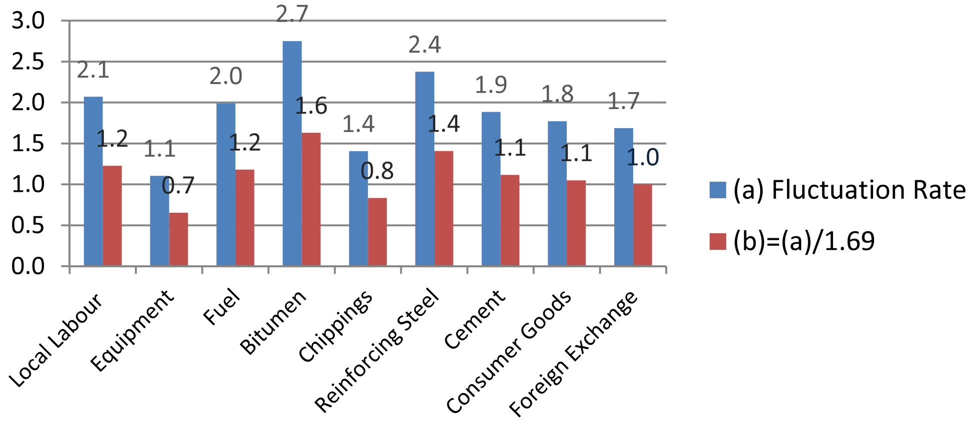
Figure 6-21 Trend Chang of Real GDP of Ghana

(2) Construction Unit Price

The GHA's Quantity Surveying Department conducts an annual survey of construction prices through the market in order to update unit prices. The GHA is submits its findings to the MRH to be reflected in monthly cost indices for the adjustment of contract prices.

Indices up to the end of 2011 were available on the MRH's web-site. The blue bar in Figure 6-22 shows the ratio of the indices in October 2011 to those in January 2007. The rise in prices during this period is approximately estimated to be 1.67 based on the World Economic Outlook Database (IMF). The brown bars (marked (b) in the figure) express the proportion of the number on the blue bar divided by 1.69 (fluctuation of foreign exchange rate). Many indices rose by more than the foreign exchange index.

In this report, the construction cost is estimated based on interviews, the previous JICA study report, and the Eastern Corridor project report, taking into consideration of the rise in prices.



Source: Study Team

Figure 6-22 Fluctuation Rate of Cost Indices Comparison of Oct. 2011 to Jan. 2007

Ghana's unit prices for works are higher than those of other countries in sub-Saharan Africa. The Study Team interviewed various persons about the reasons, and although there were no quantitative answers, suspected reasons including the following:

- Rising prices of fuel and labour wage
- High general cost for engineers in contact value owing to lack of sufficient number of qualified engineers
- High mobilisation cost for imports because of lack of reliable equipment and materials

(3) Estimation of Unit Prices

a) Rise in Prices

When using an actual construction cost for the estimation, the cost should be converted to present value by using the inflation index table shown in Table 6-16.

Table 6-16 Inflation Index

Item	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Inflation, average consumer prices	1.00	1.10	1.22	1.42	1.69	1.88	2.04	2.17	2.28	2.39	2.51

Note: Estimates Start After 2009
Source: World Economic Outlook Database, IMF

b) Estimation in SMTDP

SMTDP illustrates financial plan for four years for development works, as shown in Table 6-17.

Table 6-17 Unit Price for Road Development Works in SMTDP

(Unit: US$ million)

Work Item	Unit	2010	2011	2012	2013
Major rehabilitation	km	467,000	584,000	1,235,000	1,235,000
Reconstruction	km	683,000	828,000	572,000	572,000
Construction	km	860,000	800,000	756,000	756,000
Interchanges	m	44,100	n.a.	n.a.	n.a.
Bridges	m	0.050	0.050	0.050	0.050

Source: Study Team based on SMTDP, 2010-2013, MRH

c) Road Construction Cost

1) Construction

Table 6-18 shows the construction unit price for each surface type under the GHA. The revised unit price is that converted to the value as of 2012 using the inflation index shown in Table 6-16. The construction unit price shown in Table 6-17 is less than the paved road construction cost in Table 6-18, and is assumed to be the average price for all surface types.

Table 6-18 Unit Price for Road Construction

(Unit: US$ million)

Work Item	Unit	Unit Price		Revised Unit Price	
		Source 1	Source 2	Source 1	Source 2
		as of 2005	as of 2008-2009	as of 2012	as of 2012
Gravel construction	km	200,000	359,500	434,000	502,000
Paved construction with A/C	km	500,000	1,250,000	1,090,000	1,740,000
Paved construction DBST	km	300,000	785,000	651,000	1,095,000

Source-1: Statistical and Analytical Report (2000-2009), October 2011, MRH, MoT, and GSS
Source-2: Eastern Corridor Programme Preparatory Survey, 2010, JICA

The construction cost for the Eastern Corridor (N2) is estimated by the GHA for each lot as shown in Table 6-19. The section of the Study (Asutsuare Jct. – Asikuma Jct.) is part of Lot 1, but a 2-lane road is planned in this section, and so Lot 1's unit price should not be used without modification.

Table 6-19 Construction Cost of N2

Section		Length (km)	Cost (US$ million)	Cost/Length (US$ million)	Remarks
Lot 1	Tema Jct. – Asikuma Jct.	91.0	145	1.70	Including 6- lane section (20 km) and 4-lane section (5 km)
Lot 2	Asikuma Jct. – Pose Cement	147.2	230	1.56	2 lanes (undecided)
Lot 3	Pose Cement – Nkwata	78.2	77	0.98	2 lanes upgrade to BST from gravel
Lot 4	Nkwata – Damanko	70.0	120	1.71	2 lanes upgrade to BST from gravel
Lot 5	Damanko – Yendi	86.0	165	1.92	2 lanes upgrade to BST from gravel
Lot 6	Yendi – Nakpanduri	123.2	245	1.99	2 lanes (undecided)
Lot 7	Nakpanduri – Kukungugu	100.0	200	2.00	2 lanes (undecided)

Note: Cost of lot is after reduction of cost of flyover, interchange and Adomi Bridge.
Source: Eastern Corridor Programme Preparatory Survey, 2010, JICA

2) Upgrade and Reconstruction

Table 6-20 shows unit prices for upgrade and reconstruction. These works are frequently implemented, and the data are considered to be valid for actual activities. However, if large-scale embankment works are required to raise the road level on a sag section, these data are not suitable, as some drainage structures have inadequate capacity and need to be replaced. The reconstruction including elevation of sag section and replacement of drainages is estimated referring to the N8 Rehabilitation Plan[22] (US$1.25 million/km, as of 2008).

According to the GHA, road reconstruction/construction project (75 km of asphalt concrete pavement for 2-lanes road) between Kumasi and Techiman on the Central Corridor was completed in 2011 founded by EU, and the total contracted amount was EUR 47.29 million (US$ 946,000/km).

[22] N8 Rehabilitation Plan Basic Survey Report, Dec 2008, JICA

Table 6-20 Unit Price of Upgrade and Reconstruction

(Unit: US$/km)

Work Item	Year	GHA	DFR
Upgrading to bituminous surface treatment	2012	217,300	220,000
Asphalt overlay	2012	281,800	-
Reconstruction	2012	572,000	350,000

Source: GHA, DFR

3) Replacement of Black Cotton Soil

Black cotton soil is thought to be distributed in the Study Area. This black cotton soil is not suitable for road sub-bases because its volume is greatly affected by water, thus damaging the road surface. If the road must be aligned over black cotton soil, the soil will need to be replaced by a suitable material. The cost of replacement is estimated based on the GHA's works rate with the material price accounting for the majority. In the second stage of the Study, the plan for procuring material will be carefully examined.

Table 6-21 Unit Price of Replacing Black Cotton Soil[23]

(Unit: GHS)

Work Item	Unit	Quantity	Unit Cost	Cost
Excavate unsuitable material	m^3	1.0	7.81	7.81
Filling and compact material from borrow pits (sand)	m^3	1.0	24.73	24.73
Total				32.54

Note: Referring to the unit price of the material for spot maintenance in DFR.

Source: Survey Team

4) Summary

The unit price used for estimation in the first stage of the Study is summarised in Table 6-22.

i) Construction

Comparing the prices of N2 Lot2 and prices of A/C paved road in Table 6-18, the construction price is between US$0.76 million and US$1.80 million/km (2012 price). The project site is easily accessible from Accra and Tema, and there are some quarry sites nearby. Thus, the construction unit price is estimated to be US$1.4 million/km considering lower haulage and availability of cheaper aggregates.

ii) Upgrade and Reconstruction

The unit price for reconstruction of ordinary road section is estimated to be US$572,000/km (GHA's unit price 2012). There is a possibility to raise unit price in case of relatively larger scale works than the above mentioned reconstruction of ordinary road sections, referring to unit price of the Kumasi and Techiman road project.

iii) Replacement of Black Cotton Soil

As shown in Table 6-22, the cost is estimated to be US$17/$m^3$[24].

[23] Works rate includes profit and margin, but does not include the cost of General Item and Contingency.

[24] Exchange rate: GHS 1 = US$0.535 as of 1st May 2012.

Table 6-22 Calculation of Unit Price for Estimation

Item	Unit	Unit Price (US$)	Inflation rate	Revised Unit Price (US$)	Adoption (US$)
1. Construction cost	km	-	-	-	1,400,000
SMTDP 2012		756,000	1.00	756,000	
GHA's unit price 2005		500,000	2.17	1,090,000	
GHA's unit price 2008-09		1,250,000	1.40	1,740,000	
N2 report 2010		1,560,000	1.15	1,800,000	
2. Upgrade/reconstruction	km	-	-	-	572,000
GHA's unit price 2012		572,000	1.00	572,000	
Kumasi-Techiman Project 2011		1,002,000	1.06	1,060,000	
3. Black cotton soil replacement	m^3	-	-	-	17

Source: Survey Team

d) Bridge Construction

1) Bridge across Volta River

The bridge across the Volta River is unique in Ghana because of its long length (over 600 m) and span (over 60 m), and useful local information is not available. There seems to be no contractor in Ghana with the capability to construct such a bridge, or a factory for making the superstructure.

The Study Team estimated the construction cost to choose among alternatives considering estimations in Japan and the cost of other bridges with type in Ghana during the first stage of the Study, and will survey and estimate detailed costs for the selected option in the second stage of the Study.

2) Other Bridges

The GHA does not define unit prices for bridge works. GHA personnel calculate the cost for estimating each bridge works. Table 6-23 indicates the contract value of the GHA's ongoing bridge works. The package consisting of three bridges is assumed to include high haulage owing to the site in the Upper Western Region.

Table 6-23 Contract Value of Ongoing Bridge Projects

Bridge	Type	Span		Length	Width	Contract		Unit Price
		No	Maximum Length (m)	(m)	(m)	Date	Amount (GHS)	(US$/m²)*
Aboabo-Box Culvert (E/R)	RC	3	6.0	18.0				
Birim Bridge (E/R)	RC	2	21.9	43.7	11.5			
Asuboni Bridge (E/R)	RC	1	21.0	21.0	11.5			
Ochi Bridge (E/R)	RC	1	21.0	21.0	11.5	May 10, 2012	9,416,944	5,504
Kalagmua Bridge (UW/R)	RC	1	18.0	18.0	11.5			
Sissili Bridge (UW/R)	RC	1	36.0	36.0	11.5			
Nanpene Bridge (BA/R)	RC	1	17.5	17.5	11.5	May 10, 2012	7,887,527	6,686

Note: * - GHS1=US$0.697

Source: Study Team

JICA's previous survey reports[25] indicate bridge unit prices as shown in Table 6-24. The estimation for the Praso Bridge does not include the cost owed by the GoG.

[25] N8 Rehabilitation Plan Basic Survey Report, Dec 2008 and Eastern Corridor Programme Preparatory Survey, 2010

Table 6-24 Estimation for Bridge Works in JICA's Reports

Bridge	Type	Span		Length	Width	Estimation		Unit Price	Remark
		No.	Length (m)	(m)	(m)	Month/ year	Total (US$)	(US$/m²)	
Praso Bridge	PC	3	48.0	98.0	12.0	May 2008	3,723,256	3,166	Under construction
New Abay Bridge (Ethiopia)	PC	3	145.0	303.0	10.2	June 2005	21,564,413	6,984	Japanese Grant Aid

Source: Study Team

3) Summary

Table 6-25 shows the estimation of unit prices as of 2012 for bridge works considering inflation as described above.

Table 6-25 Estimation of Unit Price for Bridge Works

Item	Year	Unit	Unit Price (US$)	Inflation	Revised Unit Price (US$)	Remark
SMTDP estimation	2011	m^2	4,300	1.06	4,600	assumed width: 11.5 m
4 Bridges package	2010	m^2	5,500	1.15	6,300	
Praso Bridge	2008	m^2	3,166	1.53	4,800	

Source: Study Team

The unit price for general bridge works is estimated at US$4,000/$m^2$ by the following reasons:

- This project site is not far from Accra and Tema, and thus the haulage is assumed to be lower than the average.
- Most of unit price for bridge works is constituted to imported material or imported equipment. Thus, unit price for bridge works is not sensitive to inflation.
- SMTDP estimation and 4 Bridges package may include other costs.

The unit price for the bridge over the Volta River is estimated at US$7,000/$m^2$ for the following reasons.

- Unit price for the bridge over the Volta River is estimated with reference to the Abay Bridge in Ethiopia, which is one of long span bridges constructed in Africa by Japanese Grant Aid Programme.
- Unit price of Abay Bridge works is not affected by inflation, because the bridge was constructed by Japanese Grant Aid and most of bridge materials and equipment were imported.

6.5.2 Rough Cost Estimation of Each Alternative

The estimation for each alternative is calculated based on unit prices described in Section 6.5.1. Table 6-26 summarises the results of the estimation.

Table 6-26 Rough Cost Estimation of Each Alternative

Item	Unit Cost		Alt. 1		Alt. 2		Alt. 3		Alt. 4		Alt. 5	
			Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Construction	1,400,000	US$/km	50.2	70.3	40.4	56.6	43.5	60.9	54.2	75.9	53.7	75.2
Upgrading	572,000	US$/km	9.0	5.4	21.0	12.6	21.0	12.6	11.0	6.6	11.0	6.6
Black cotton soil Replacement	17	US$/$m^3$	103,000	1.8	92,000	1.6	235,000	4.0	330,000	5.6	112,000	1.9
Volta Bridge	7,000	US$/$m^2$	8,742	61.2	7,473	52.3	8,178	57.2	8,178	57.2	7,473	52.3
Other Bridges	4,000	US$/$m^2$	2,424	9.7	1,376	5.5	655	2.6	655	2.6	1,376	5.5
Total		US$ million		148.4		128.6		137.3		147.9		141.5

Source: Survey Team

6.6 Process of Selecting the Desirable Route

After the first screening of alternative route alignments for a part of the Eastern Corridor between Asutsuare Jct. and Asikuma Jct., the Study Team carried out the preliminary studies, including a detailed site investigation, data collection related to regional development, and a baseline survey for environmental and social considerations.

6.7 Evaluation Criteria

6.7.1 Environmental and Social Considerations

The Study Team carried out a baseline survey of environmental and social considerations, and evaluate each alternative route.

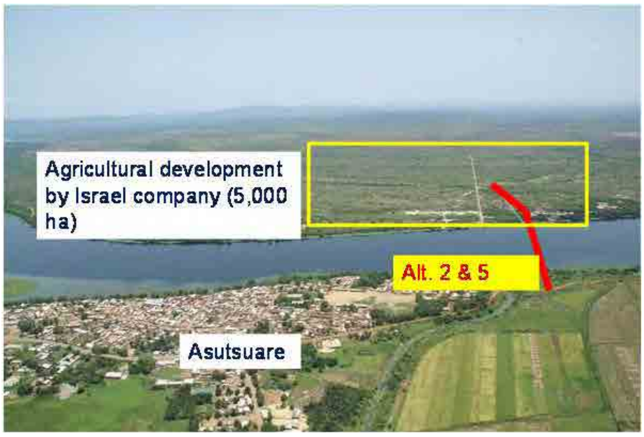
- Alternatives were evaluated based on the environmental impact of the following parameters: physical environments, land and land use, impacts of natural resources on people, traffic conditions and infrastructure, as well as negative and positive impacts on society.
- The Study Team then evaluated weather each alternative is 'recommended' in terms of environmental and social considerations.

6.7.2 Impact on Regional Development

Impacts on regional development are considered to be as follows:

(1) Impact on Agricultural Land

As described in Chapter 2, the southern part of the Volta River is a part of the Southern Green Belt, where cultivation of food crops, particularly rice, is very important for the national economy as well as food security. It is therefore desirable to minimise the effects on existing agricultural land



Source: Study Team

Figure 6-23 Alternatives Routes and Agricultural Development Scheme

when planning alternative road alignments, as an ROW width of 90 m is required.(2) Impact on Agricultural Development Scheme. An Israeli company has already started an agricultural development scheme of 5,000 ha on the left bank of the Volta River on the opposite side of Asutsuare. As the proposed alignment of Alt. 2 and 5 pass through the centre of this development scheme, the road would disturb the scheme, as shown in Figure 6-23.

(3) Development of Arable Land

As described in Section 2.4.4, there are Vertisols, which are suitable soils for cultivation, over much of the Study Area leading to large-scale development in both the north-eastern part of the Volta River. On the contrary, as shown in Figure 6-24, the area on the eastern side of the Alabo River (about 25,000 ha) has not been developed, mainly due to lack of access roads to this arable land. The construction of a new road through this area would contribute to development of this arable land.

Source: Study Team

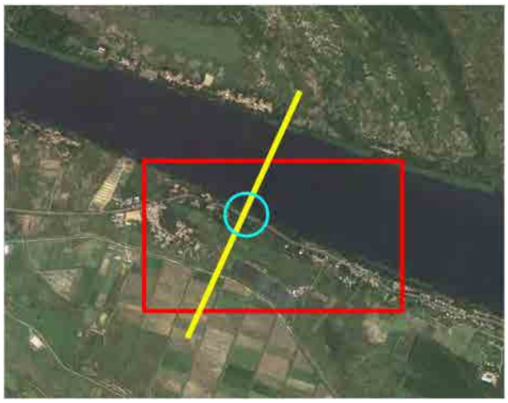
Figure 6-24 Arable Land in the Study Area

6.7.3 Engineering Aspects

The following engineering aspects were considered in the evaluation:

(1) Realignment of Existing Road

In the case of Alt. 1, the proposed location to cross the Volta River on the right bank is very close to the existing feeder road Somanya – Asutsuare (about 50 m) and an abutment of the new bridge would need to be constructed on this road, as shown in Figure 6-25. As a result, this feeder road must be realigned to the southern side where there are no houses.



Source: Study Team

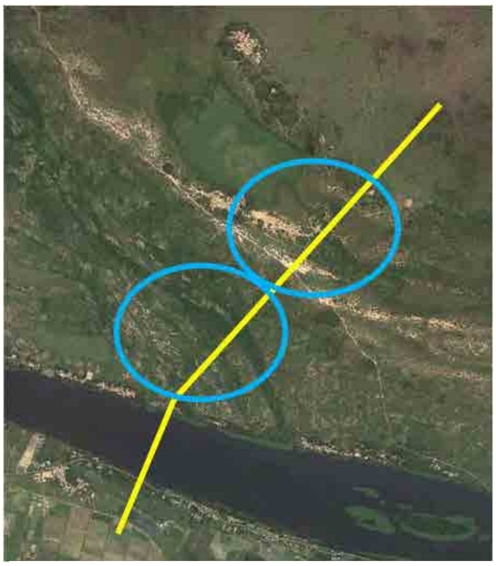
Figure 6-25 Feeder Road Section Necessary to be Realigned

(2) Watercourses

Work during construction and maintenance after completion may be impeded in the low-lying land on the left bank of the Volta River on Alt. 1, where the road may be affected by watercourses in the rainy season. Figure 6-26 shows the locations of possible watercourses.

(3) Minimum Radius and Maximum Longitudinal Gradient

The geometric design elements of the proposed road sections, such as minimum radius and maximum longitudinal gradient, are important factors, since the Eastern Corridor will be an important north-south axis in the eastern part of Ghana will and accommodate domestic and international logistic traffic.



Source: Study Team

Figure 6-26 Possible Watercourses

6.7.4 Economic Aspects

(1) Initial Investment Cost

The economic aspect considered in the evaluation in the Study is the initial investment costs for civil works, which are roughly estimated based on similar projects in Ghana and other African countries.

Economic analyses for the selected alternative route will be carried out in the second phase of the Study.

(2) Number of Bridges

The number of bridges is one factor affecting the construction cost. For the evaluation, rivers requiring a bridge 30 m or longer are counted. Rivers other than the Volta River where a bridge is required are shown in Figure 8-5 and are follows:

1) Alabo River (Bridge 1): 60 m

Alt. 1, Alt. 2, Alt. 3, Alt. 4, Alt. 5

2) Alabo River (Bridge 2): 100 m

Alt. 1, Alt. 2, Alt. 5

3) Gblo River (Bridge 3): 30 m

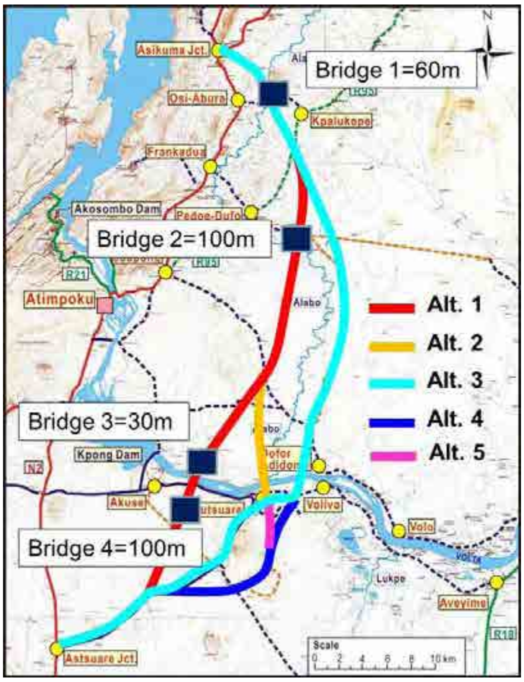
Alt. 1

4) Lomen River (Bridge 4): 100 m

Alt. 1

The total length of bridge(s) on each alternative route is as follows:

- Alt. 1: 290 m
- Alt. 2: 160 m
- Alt. 3: 60m
- Alt. 4: 60m
- Alt. 5: 160 m



Source: Study Team

Figure 6-27 Expected Bridge Location

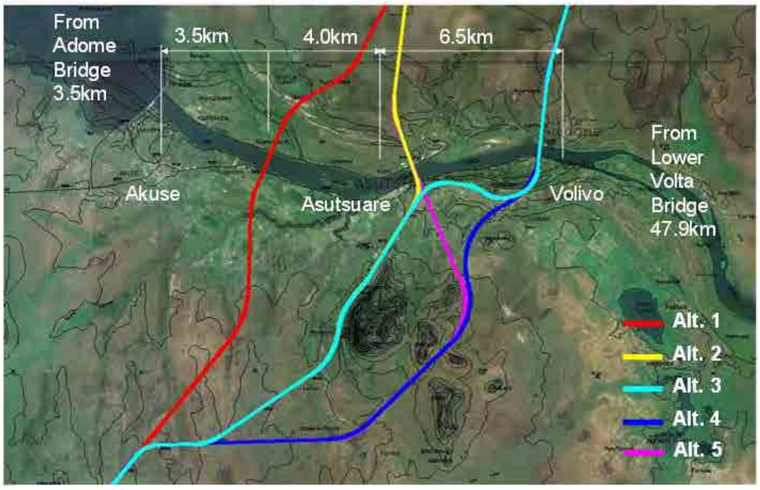
(3) Black Cotton Soil

As described in Section 6.2.5, deposits of black cotton soil will increase the construction cost, since it is unsuitable for the sub-base and must be replaced or stabilised. The expected length and physical characteristics of black cotton soil are considered in the evaluation.

6.7.5 Other Aspects

(1) Distance between Bridges

At present, there are two bridges crossing the Volta River (Adomi Bridge and Lower Volta Bridge) 65.4 km apart, as shown in Figure 6-28. In addition, the VRA allows vehicles to use the maintenance road of the Kpong Hydroelectric Dam. Since both the Adomi Bridge and Lower Volta Bridge are old, rehabilitation will be necessary: such as the scheduled rehabilitation work for Adomi Bridge expected to start in early 2013. If one of the bridges becomes closed for some reason, it is desirable to have another bridge in between to secure shorter transport distance.



Source: Study Team

Figure 6-28 Distance between Bridges and Proposed Bridge Locations

(2) Passing through or by Communities

If the proposed road passes through or by communities, traffic safety measures will be necessary, and the speed limit will be 50 km/h. International trunk roads with many heavy vehicles should to avoid passing through communities for both traffic safety and smooth vehicle flow.

6.8 Evaluation of Alternative Routes

6.8.1 Evaluation of Alternative Routes between Asutsuare Jct. and Asikuma Jct.

(1) Comparison of Alternative Routes based on Environmental and Social Consideration

Tables 6-27 and 6-28 compare the potential environmental and social impact, and Table 6-29 summarises the environmental social impact for each alternative route. Regarding environmental and social considerations, Alt.1, Alt. 4 and Alt. 5 are recommended, while Alt. 2 and Alt. 3 are not recommended because they would pass through the community in Asutsuare township and would have greater negative impact on the lives of people in Asutsuare than the other alternative routes.

Therefore, Alt. 2 and Alt. 3 not considered further.

Table 6-27 Comparison of Potential Impacts (1/2)

Index	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Physical	-7	-9	-9	-8	-8
Land/land use	-8	-8	-9	-9	-8
Natural resources	-4	-1	-1	-4	-4
People	0	-3	-3	0	0
Traffic condition	-2	-6	-6	-1	-1
Infrastructure	0	-1	-1	0	0
Total	**-21**	**-28**	**-31**	**-22**	**-21**

Source: Study Team

Table 6-28 Comparison of Potential Impacts (2/2)

<table>
<tr><th>Index</th><th>Alt. 1</th><th>Alt. 2</th><th>Alt. 3</th><th>Alt. 4</th><th>Alt. 5</th></tr>
<tr><td rowspan="2">Negative impacts on society</td><td colspan="5">3 farm houses near Asutsuare Jct.
A school and a cemetery near Tedeafenui-Volo
One hotel near Asikuma Jct.</td></tr>
<tr><td>No</td><td colspan="2">Some houses and shops at Asutsuare township</td><td>No</td><td>No</td></tr>
<tr><td>Positive impacts on society</td><td colspan="5">Improved access for people, goods and social services</td></tr>
<tr><td>Number of affected people</td><td>Low</td><td>Medium</td><td>Medium</td><td>Low</td><td>Low</td></tr>
</table>

Source: Study Team

Table 6-29 Summary of Environmental and Social Impacts

Index	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Environmental	Low	Medium	High	Low	Low
Social	Low	Medium	Medium	Low	Low
Recommendation	Recommended	Not Recommended	Not Recommended	Recommended	Recommended

Source: Study Team

(2) Comparison of Alternative Routes based on Impacts on Regional Development

Table 6-30 compares alternative routes Alt. 1, Alt. 4 and Alt. 5 in terms of their impacts on regional development.

Table 6-30 Comparison of Alternative Routes by Impacts on Regional Development

Item	Alt. 1	Alt. 4	Alt. 5
Area of affected agricultural land	29 ha	22 ha (6 ha ++)	18 ha +
Disturbance of agricultural development scheme	No ++	No ++	Yes
Contribution to development of arable land without road access	No	High ++	No
Total score	**2 +**	**4 + (6 +)**	**1 +**

Source: Study Team

Alt. 4 shows the highest score. The route alignment of Alt. 5 directly passes through the centre of agricultural development by an Israeli company.

The Study Team interviewed the Israeli company, PE-AVIV, which has already started agricultural development on the left bank of the Volta River, and found that the company is not happy that the proposed alternative route would pass through their premises (almost through the centre of their development area). Internal traffic of agricultural equipment and farmers on their cultivation land would often cross the proposed road. Since the proposed road is a national trunk road also serving as an international corridor, this situation should be avoided in view of operations and traffic safety.

Therefore, the Study Team dropped Alt. 5 from further study.

(3) Comparison of Alternative Routes Alt. 1 and Alt. 4

Table 6-31 compares alternative routes Alt. 1 and Alt. 4 in terms of engineering, economic aspects and other aspects.

Even though the scores of both alternatives are almost the same and Alt. 1 is shorter, Alt. 1 would requires realignment of an existing road and would affected watercourses. Thus, the Study Team dropped Alt. 1 from the candidate routes for the F/S.

Table 6-31 Comparison of Alternative Routes Alt. 1 and Alt. 4

Item	Alt 1	Alt 4
Length of Road	60.0km +	65.8km
Realignment of existing road	Yes	No +
Affected by watercourses	Yes	No +
Minimum Radius (new construction section)	2,000m	1,800m
Maximum longitudinal gradient	Less 2%	3% (2km)
Number of bridges	5	2 +
Length of required soil improvement for Black Cotton Soil	8.4km +	26.9km
Transport redundancy (bridge location)	Not desirable	Desirable +
Construction Cost (US$ million)	148.4	147.9
Total Score	**2 +**	**4 +**

Source: Study Team

(4) Considerations for Further Study

In order to reduce the area of paddy fields in the southern part of the Volta River affected by Alt. 4 (from 22 ha to 6 ha) as well as to improve the horizontal alignment with a continuous curve of 1,800–2,000 m radius, the Study Team will further examine the alignment of Alt. 4.

6.8.2 Upgrading of the Asutsuare – Aveyime Road

The negative impact of upgrading of the Asutsuare - Aveyime road is the necessity of resettling a few houses and temporary shops in Volivo and Aveyime townships. On the other hand, the positive impact for society is improved access for people, goods and social services.

6.9 Results of Evaluation and Proposed Alternative for the Feasibility Study

6.9.1 Road Section between Asutsuare Jct. and Asikuma Jct.

(1) The First Workshop

The first Workshop was held on 18th May 2012, inviting various stakeholders listed below, to discuss the priorities of alternative routes for selecting the highest priority route for carrying out the feasibility study in the second stage of the Study. However, the workshop was unable to select a particular alternative for the feasibility.

List of Participating Organisations

- Ministry of Roads and Highways
- GHA
- Department of Feeder Roads (DFR)
- JICA Ghana Office
- Ministry of Finance and Economic Planning (MoFEP)
- Ministry of Transport (MoTr)
- European Union (EU)
- Millennium Development Authority (MiDA)
- Motor Transport Unit (MTU) of Ghana Police Service
- Regional Coordinating Council, Eastern Region
- National Planning Development Commission (NPDC)
- National Road Safety Commission (NRSC)
- JICA Study Team
- Local consultant (Associated Consultant)

(2) Further Discussions with GHA

Since a particular alternative for the feasibility study could not be selected in the First Workshop, the Study Team and the GHA held further discussions. At the meeting held on 1st June, 2012, the GHA finally agreed to select Alt. 4 for the F/S.

6.9.2 Road Section between Asutsuare and Aveyime

Based on the discussion, the GHA agreed with the idea of the Study Team to mainly follow the present alignment for the improved road section between Asutsuare and Aveyime, but a typical cross section with the inter-regional road should be adopted even in townships.

CHAPTER 7

PRELIMINARY DESIGN FOR CONSTRUCTION OF ROAD BETWEEN ASUTSUARE JCT. AND ASIKUMA JCT.

Chapter 7 Preliminary Design for Construction of Road between Asutsuare Jct. and Asikuma Jct.

7.1 Justification for Construction of Road between Asutsuare Jct. and Asikuma Jct.

In the first phase of the Study, various positive impacts of constructing a new road between Asutsuare Jct. and Asikuma Jct., including a new bridge across the Volta River, were identified: 1) to avoid crossing the existing Adomi Bridge, which has a limited maximum gross weight of freight vehicles, 2) to avoid passing through several congested townships on the existing N2, 3) to attract more investment in agricultural development on the northern side of the Volta River, and 4) to accommodate international freight traffic when the Eastern Corridor (at least up to Yendi) is upgraded, which will attract diversion traffic from the Central Corridor to the Eastern Corridor.

In view of these positive impacts, the Study Team considered that it is worth carrying out the F/S for the construction of a new road between Asutsuare Jct. and Asikuma Jct., including a new bridge across the Volta River.

7.2 Preliminary Design of Road

7.2.1 Horizontal and Vertical Alignment

(1) Design Geometric Standard

The design geometric standard is based on the Road Design Guide of Ghana shown in Table 7-1. The design speed for the proposed Eastern Corridor is 100 km/h as discussed in Chapter 6.

Table 7-1 Design Geometric Standard

Item		Value
Design speed (km/h)		100
Minimum curve radius (m)	Desirable	700
	Absolute	370
Radius not requiring transition (m)		910
Minimum curve length (m)	IA > = 7	170
	IA = 2	600
Minimum transition length (m)		56
Curve radius where super elevation is unnecessary (m)		5,000
Standard gradient (%)		3
Maximum length for gradient (m)	4%	700
	5%	500
	6%	400
K value		64

Source: Road Design Guide of Ghana

(2) Crossing Rivers, Watercourses and Canals to be Considered

a) List of Crossing Rivers, Watercourses and Canals to be Considered

There are several crossing rivers, watercourses and canals to be considered for the preliminary design of the road section between Asutsuare Jct. and Asikuma Jct. listed in Table 7-2.

Table 7-2 Cross Rivers, Watercourses and Canals between Asutsuare Jct. and Asikuma Jct.

Station		Watercourses	Existing Facilities	Remarks
1	No.00 + 660	Watercourse	None	Upgrading
2	No.01 + 710	Watercourse	None	Upgrading
3	No.07 + 100	Branch of Romen River	Box B2.0 H1.2 @3	Upgrading
4	No.08 + 000	Branch of Romen River	Box B1.4 H0.9 @3	Upgrading
5	No.10 + 410	Branch of Romen River	Box B2.5 H1.0 @1	Upgrading
6	No.12 + 780	Branch of Romen River	None	New Alignment
7	No.15 + 340	Branch of Romen River	None	New Alignment
8	No.15 + 700	Branch of Romen River	None	New Alignment
9	No.23 + 265	Canal (to banana estates)	B17.0 H2.6 (Masonry)	Bridge (planned)
10	No.23 + 305	APGIP Main Canal (Planned)	W = 15.0 including maintenance road	Bridge (planned)
11	No.24 + 320	Canal (Southern Low Level Canal)	B8.0 H1.1	New Alignment
12	No.25 + 210	Lupu River (Main Drain)	B16.0 H0.9	New Alignment
13	No.26 + 700	New Crossing Drainage	None	New Alignment
14	No.28 + 425	Volta River	None	Bridge (planned)
15	No.33 + 000	Branch of Alabo River	None	New Alignment
16	No.45 + 890	Branch of Alabo River	None	New Alignment
17	No.47 + 800	Branch of Alabo River (Ayedetsi River)	None	New Alignment
18	No.49 + 540	Branch of Alabo River (Adove River)	None	New Alignment
19	No.50 + 157	Branch of Alabo River (Adove River)	None	New Alignment
20	No.54 + 910	Branch of Alabo River (Avegbeve River)	None	New Alignment
21	No.60 + 500	Branch of Alabo River	None	New Alignment
22	No.60 + 985	Alabo River	None	Bridge (planned)
23	No.62 + 000	Branch of Alabo River	None	New Alignment
24	No.62 + 770	Branch of Alabo River (Ofotoku River)	None	New Alignment
25	No.65 + 510	Branch of Alabo River (Ofotoku River)	None	New Alignment

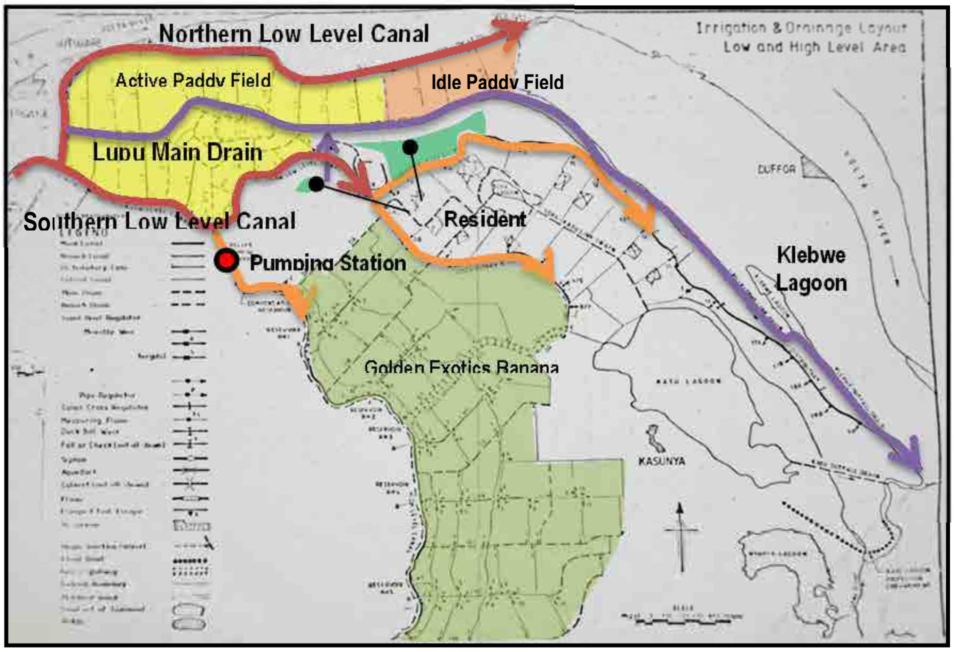
Source: Study Team

b) Bridges

- Facilities over the two main rivers, the Volta River and the Alabo River, are needed to construct bridges, and facilities over the canal to banana estates (No. 23 km+265) and the APGIP main canal (No. 23 km+305) are needed to construct a bridge of 51.7 m in length, according to the Preliminary Design of Bridges.
- The above bridge (No. 23 km+259.9 – No. 23 km+311.6) includes the KIP road to banana estates (No. 23 km+290), which has a vertical clearance of 5.0 m from the existing road surface (GH = 18.0).

c) Irrigation and Drainage System of KIP (Section between 23 km+265 and 26 km+700)

- There are two irrigation canals, the Northern Low Level Canal and the Southern Low Level Canal, flowing from west to east in the area of section B of the KIP. These canals provide adequate irrigation water to the paddy fields in the KIP, and then the water goes into the Lupe Main Drain which runs through the centre of the KIP (Figure 7-1).
- Irrigation water for the banana plantations is provided by the pumping station, which takes water from the branched Southern Low Level Canal.

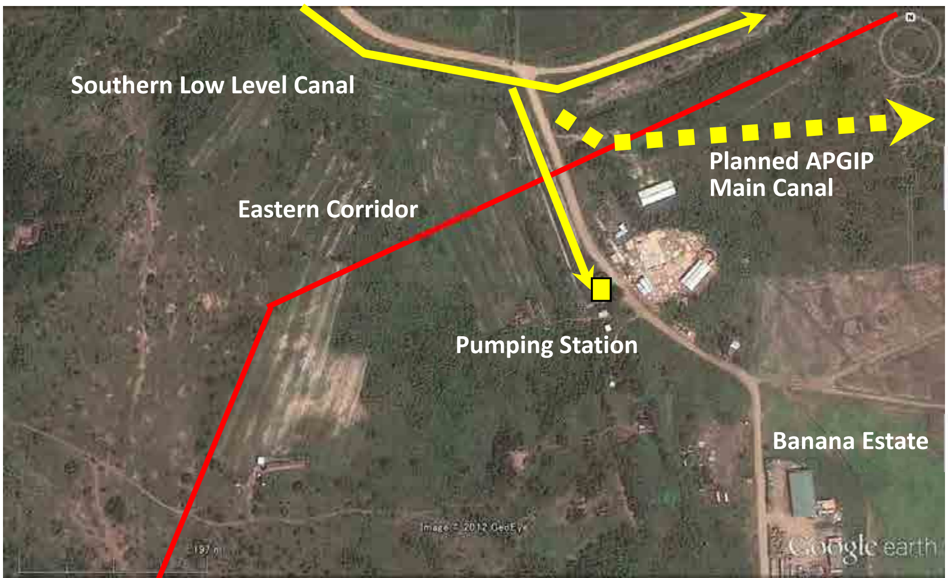


Source: GIDA

Figure 7-1 Irrigation and Drainage System of KIP (Section B)

d) Planned APGIP Main Canal (23 km+305)

- The KIP is a component of the APGIP, which is a comprehensive wide irrigation scheme.
- According to information about the future of the APGIP, there are plans to construct a Main Canal running through the APGIP. Although there is no specific plan for this Main Canal including its alignment and size, the proposed horizontal and vertical alignment of the Eastern Corridor should consider how the Main Canal will be established in the future.
- Therefore, the Study Team assumed the location of the planned APGIP Main Canal based on the future view of APGIP as shown in Figure 7-2, and also assumed a width of 15 m for the planned canal and its maintenance roads.



Source: Study Team

Figure 7-2 Estimated Location of Planned KIP Main Canal

(3) Crossing Roads to be Considered

a) List of Crossing Roads to be Considered

Crossing roads to be considered for the preliminary design of the road section between Asutsuare Jct. and Asikuma Jct. are listed in Table 7-3.

Table 7-3 Crossing Roads between Asutsuare Jct. and Asikuma Jct.

Station		Road	Existing Facilities	Remarks
1	No.00 + 000	National Road - 2 (N2)	Intersection (A/C)	Upgrading
2	No.11 + 050	Feeder Road	W = 8.0 (Gravel)	New Alignment
3	No.16 + 970	Feeder Road	W = 6.0 (Gravel)	New Alignment
4	No.23 + 290	KIP Road (to Banana Estates)	W = 8.0 (Gravel)	New Alignment
5	No.24 + 210	KIP Road	W = 7.0 (Gravel)	New Alignment
6	No.25 + 270	KIP Road	W = 6.0 (Gravel)	New Alignment
8	No. 27 + 534	2) Inter-regional Road (planned)	2) W = 11.3 (A/C)	New Alignment
9	No.29 + 060	Feeder Road	W = 6.5 (Gravel)	New Alignment
10	No.48 + 600	Feeder Road	W = 4.0 (Gravel)	New Alignment
11	No.58 + 150	Regional Road - 95 (R95)	W = 9.0 (Gravel)	New Alignment
12	No.67 + 027	National Road - 2 (N2) National Road - 5 (N5)	Intersection (Ac)	New Alignment

Source: Study Team

b) KIP Road to Banana Estates

The location of the KIP road to the Golden Exotics Banana Estates is shown in Figure 7-2.

(4) Comparison of Horizontal Alignment

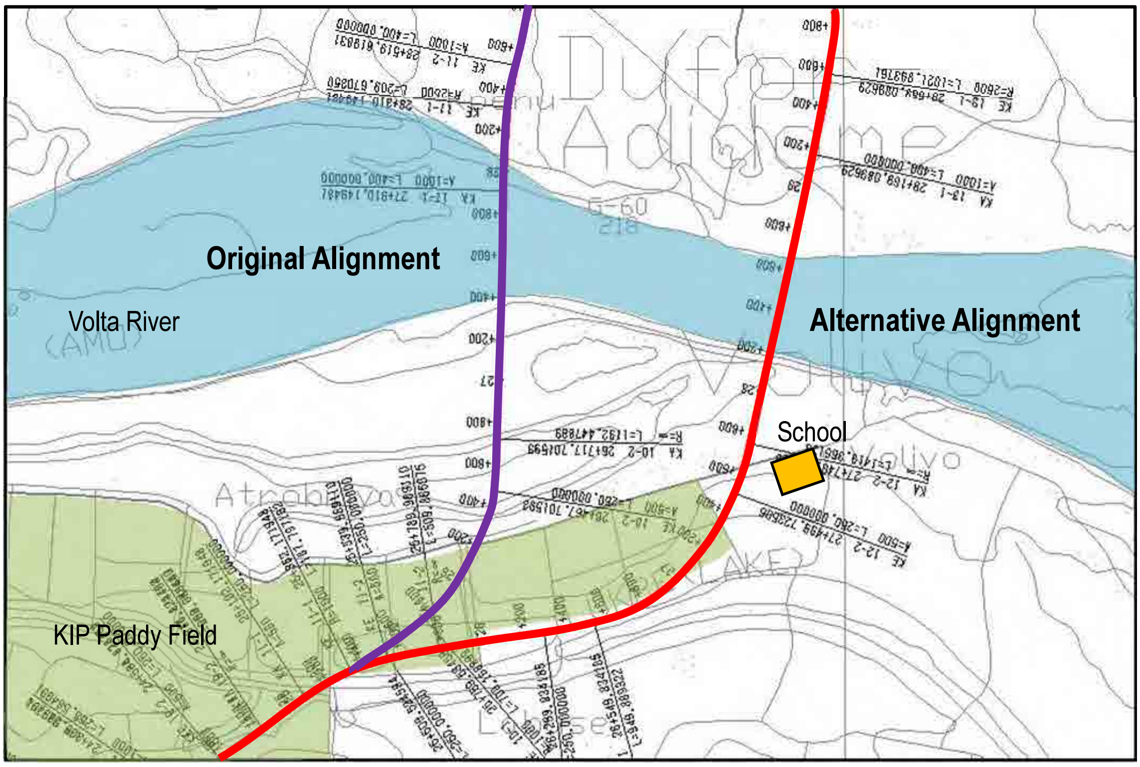
From the results of the topographic survey and the detailed site investigation after the first Workshop held on 18th May 2012, the proposed horizontal alignment of the Eastern Corridor was set based on the route of Alternative 4 (Alt. 4) as discussed in Chapter 6.

a) Section between KIP Paddy Fields and Northern Part of Volta River

The Study Team compared the original alignment, for which a desirable route was selected by the first Workshop, and an alternative alignment in order to reduce the impact on the paddy fields of the KIP in the southern part of the Volta River. The alternative alignment is advantageous in terms of construction cost and traffic safety for agricultural traffic in the KIP. The original alignment and alternative alignment are compared in Table 7-4 and Figure 7-3.

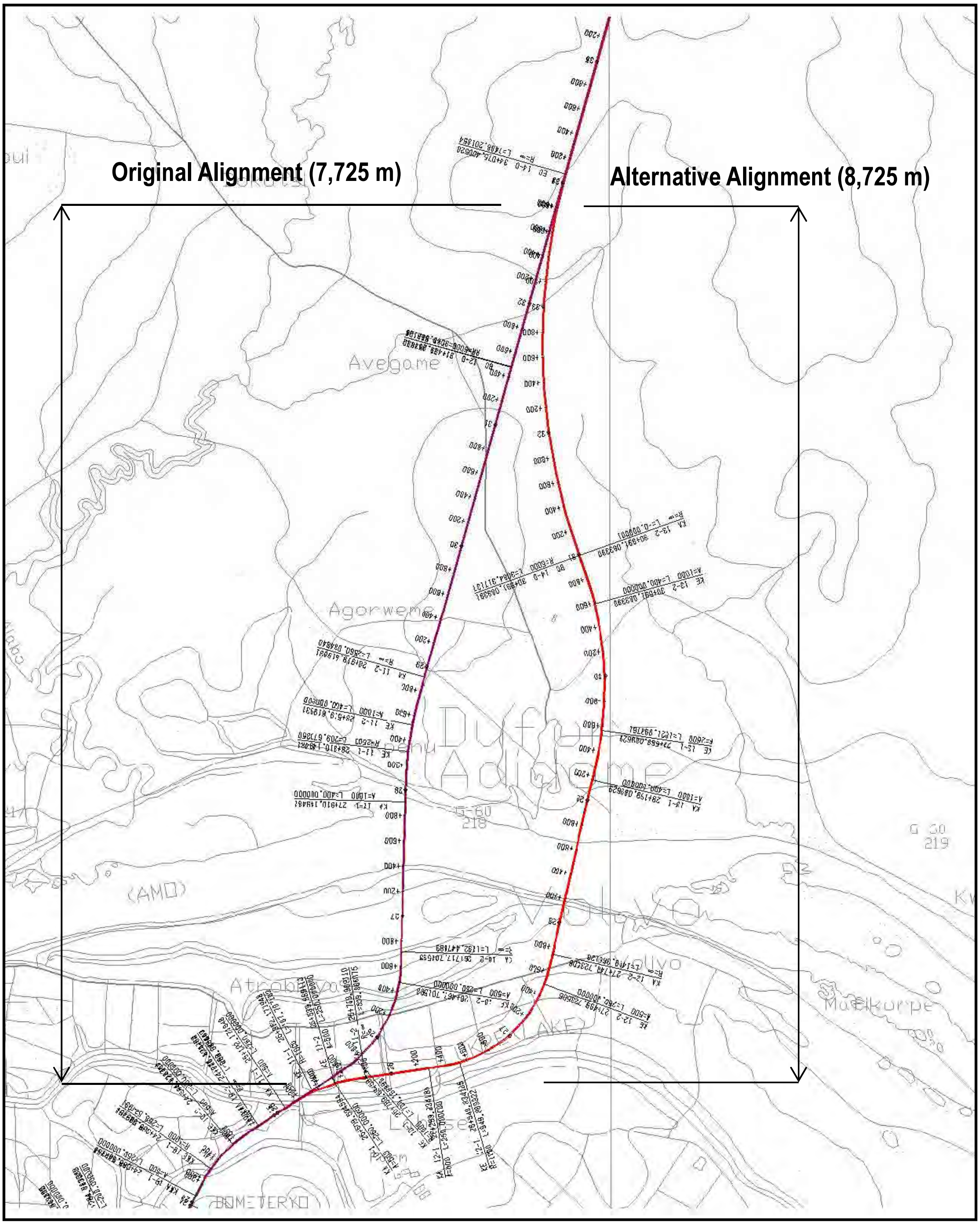
As a result, the location of the Volta River Bridge is set according to the alternative alignment.

Table 7-4 Comparison of Original Alignment and Alternative Alignment



Item	Original Alignment		Alternative Alignment	
Alignment (Station)	Gentle alignment (25 km+350 to 33 km+075)		Gentle alignment (25 km+350 to 34 km+075)	
Route length (Ratio) 1) Earth section 2) Volta River Bridge	7,725 m (0.89) 7,080 m 645 m		8,725 m (1.00) 8,205 m 520 m	
Construction cost of 1) and 2) (Ratio)	US$ 100 million (1.19)		US$ 84 million (1.00)	++
Area of affected KIP paddy fields (Ratio)	112,000 m^2 (3.20)		35,000 m^2 (1.00)	++
Agricultural traffic in KIP	Passing over the proposed road		No passing over	+
Township/communities	No passing through	+	No passing through	+
Social facilities	No passing nearby	+	Passes near a secondary school	
Evaluation	**2 +**		**6 +**	
	The alternative alignment is advantageous.			

Note: The whole section of the two alignments is shown in Figure 7-3.
Source: Study Team



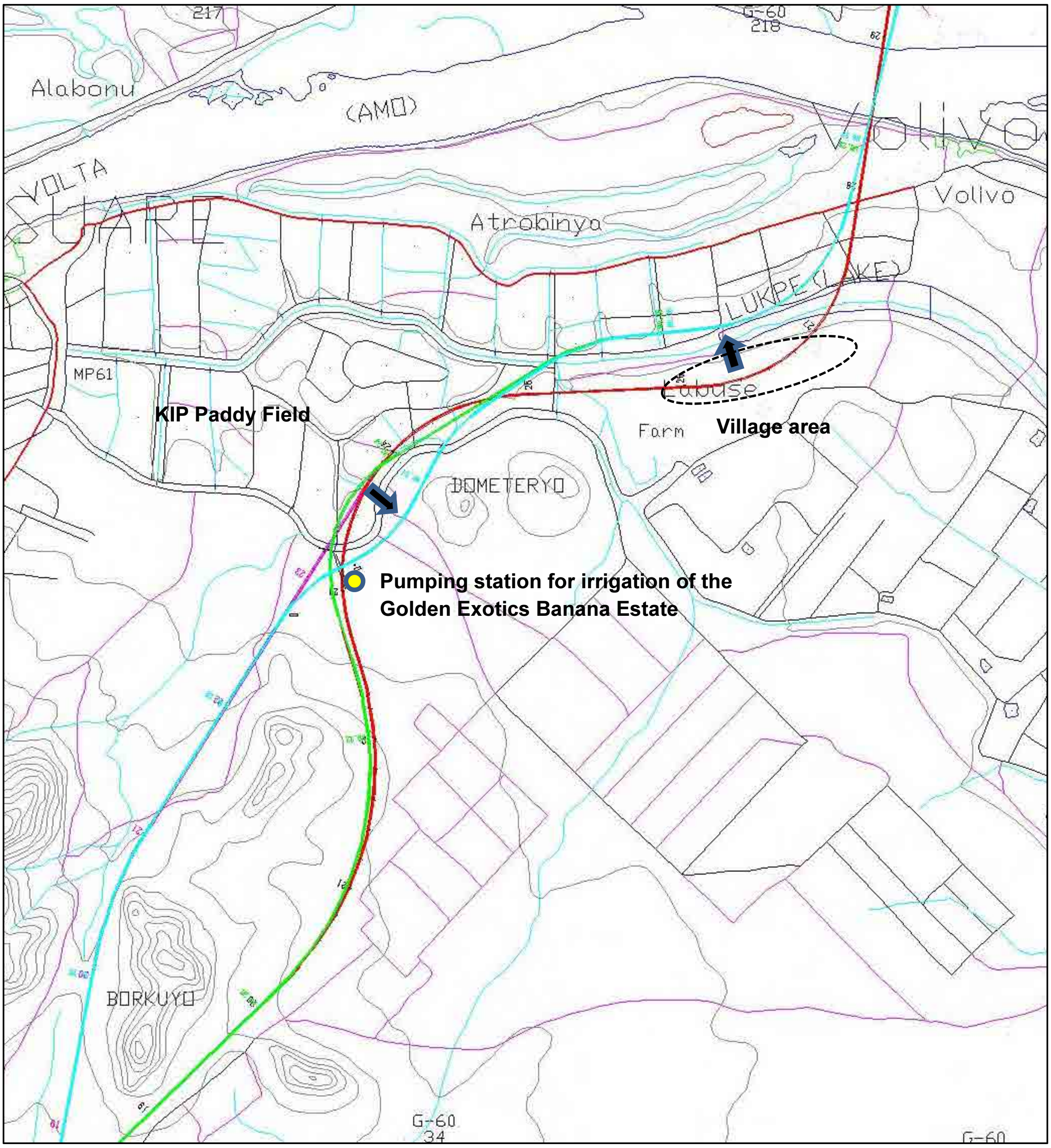
Source: Study Team

Figure 7-3 Locations of the Two Alignments

b) Section between Osuwem and Volta River

The following items must be considered when setting the alignment between Osuwem and the Volta River (see Figure 7-4):

- Avoiding all houses, schools, and agricultural facilities in the village area
- Avoiding the KIP paddy fields as much as possible
- Avoiding the pumping station for irrigation of the Golden Exotics Banana Estate



Source: Study Team

Figure 7-4 Section between Osuwem and Volta River

7.2.2 Pavement Design

(1) Design Approach

a) Design Criteria

The Ghana Pavement Design Manual presents methods for the pavement design of new roads and rehabilitation of existing ones. This manual is an adaptation of the AASHTO design manual (1993) for local conditions. Thus, the pavement design is examined based on the Ghana Pavement Design Manual and the AASHTO Design Manual.

b) Type of Works

[Segment 1] 00 km+000 (Asutsuare Jct.) to 10 km+800 : Upgrading

[Segment 2] 10 km+800 to Volta River : New construction (No existing road)

[Segment 3] Volta River to 67 km+027 (Asikuma Jct.) : New construction (No existing road)

c) Design Period

The performance period of a pavement is from the time of construction until the pavement needs to be reconstructed or rehabilitated. It can also be considered as the length of time that it takes for the pavement to deteriorate from its initial serviceability to its terminal serviceability.

The design period (analysis period) is 20 years, from the year of starting traffic service in 2016 to the project development target year of 2036.

(2) Design Conditions

a) Design Traffic

1) Asutsuare Jct. – Volta River

The design traffic for the pavement design is based on the forecast of traffic demand shown in Table 7-5. ADT on the section between Asutsuare Jct. and the Volta River of the Eastern Corridor is 8,221 vehicles per day in 2016 and 8,676 in 2036.

Table 7-5 Design Traffic between Asutsuare Jct. and Volta River

Year	2016	2036
	ADT (vehicles per day)	
Passenger Car/Pick-up	2,531	2,845
Minibus	2,379	1,881
Bus	524	381
Medium truck	565	457
Heavy truck	472	482
Trailer	1,264	1,794
Others	486	836
Total	**8,221**	**8,676**

Source: Study Team

2) Volta River – Asikuma Jct.

The design traffic for the pavement design is based on the forecast of traffic demand shown in Table 7-6. ADT on the section between the Volta River and Asikuma Jct. of the Eastern Corridor is 7,997 vehicles per day in 2016 and 10,552 in 2036.

Table 7-6 Design Traffic between Volta River and Asikuma Jct.

Year	2016	2036
	ADT (vehicles per day)	
Passenger Car/Pick-up	2,170	2,593
Minibus	2,937	3,196
Bus	386	552
Medium truck	572	656
Heavy truck	311	512
Trailer	1,134	2,203
Others	487	840
Total	**7,997**	**10,552**

Source: Study Team

b) Design ESAL

1) Asutsuare Jct. – Volta River

Design Equivalent Single Axle Load (ESAL) is calculated based on the design traffic and 80 kN Load Equivalency Factor (LEF), which is set taking into account the weighted average by type of vehicle running on the trunk road networks in Ghana. The design ESAL between Asutsuare Jct. and the Volta River is shown in Table 7-7.

Table 7-7 Design ESAL between Asutsuare Jct. and Volta River

Type	Design Traffic	Load Equivalency Factor	Design ESAL
Passenger Car/Pick-up	9,806,936	0.0071	70,060
Minibus	7,743,070	0.0106	82,077
Bus	1,638,268	0.2453	401,819
Medium truck	1,861,899	0.7318	1,362,617
Heavy truck	1,740,923	2.5591	4,455,196
Trailer	5,527,443	6.5953	36,455,366
Others	2,357,976	0.0071	16,845
Total			**42,843,980**

Source: Study Team

2) Volta River – Asikuma Jct.

The design ESAL between the Volta River and Asikuma Jct. is shown in Table 7-8.

Table 7-8 Design ESAL between Volta River and Asikuma Jct.

Type	Design Traffic	Load Equivalency Factor	Design ESAL
PC/Pick-up	8,669,335	0.0071	61,933
Minibus	11,189,381	0.0106	118,607
Bus	1,694,688	0.2453	415,657
Medium truck	2,238,050	0.7318	1,637,900
Heavy truck	1,478,169	2.5591	3,782,782
Trailer	5,885,809	6.5953	38,818,912
Others	2,372,853	0.0071	16,952
Total			**44,852,743**

Source: Study Team

c) Subgrade Strength (Design CBR)

1) [Segment 1] 00 km+000 (Asutsuare Jct.) to 10 km+800

Subgrade strength defined by the design CBR is calculated based on the results of CBR testing of this upgrading section by the Study Team as follows:

PIT-1 10% (CBR testing)

PIT-2 18% (CBR testing)

Design CBR 8% (< 8.3%)

2) [Segment 2] 10 km+800 to Volta River

Since this section is to be newly constructed, it is recommended that the GHA adopts a minimum laboratory CBR of 15% according to the Ghana Pavement Design Manual.

3) [Segment 3] Volta River to 67 km+027 (Asikuma Jct.)

Since this section is to be newly constructed, it is recommended that the GHA adopts a minimum laboratory CBR of 15% according to the Ghana Pavement Design Manual.

d) Resilient Modulus

A resilient modulus test was carried out in order to determine the effective road soil M_R for the upgrading section from Asutsuare Jct. to 10 km+800, i.e. Segment 1, by the Study Team with the cooperation of the GHA. From the results of calculations based on the Ghana Pavement Design Manual, the effective road soil M_R was 19 MPa, which is equivalent to 2,740 psi.

e) Structural Number

The basic formula for the pavement structural number to determine flexible pavement thickness is as follows. The structural number of each section is shown in Table 7-9.

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32\log_{10}(M_R) - 8.07$$

where:

W_{18}	: Number of 80 kN single axle load applications
Z_R	: Standard normal deviation corresponding to selected reliability
S_O	: Overall standard deviation
SN	: Structural number
ΔPSI	: Design serviceability loss
M_R	: Roadbed soil resilient modulus (psi)

Table 7-9 Structural Number

Item		Segment 1	Segment 2	Segment 3
W_{18}	Number of 80 kN single axle load applications (million ESAL)	42.844	42.844	44.853
R	Reliability level (%)	95	95	95
Z_R	Standard normal deviation corresponding to selected reliability	-1.645	-1.645	-1.645
S_O	Overall standard deviation	0.45	0.45	0.45
CBR	California Bearing Ratio (%)	8	15	15
M_R	Roadbed soil resilient modulus	2,740	12,374	12,370
P_O	Initial serviceability	4.5	4.5	4.5
P_T	Terminal serviceability	2.50	2.50	2.5
ΔPSI	Design serviceability loss	2.0	2.0	2.0
SN	**Structural Number**	**8.12**	**5.21**	**5.23**

NOTE: The value of M_R for Segment 1 is based on the results of the resilient modulus test; other M_R values are obtained from correlations between resilient modulus and soil property referring to the FHWA Geotechnical Aspects of Pavement Reference Manual.

Source: Study Team

(3) Pavement Thickness

a) Minimum Pavement Thickness

The minimum pavement thickness is shown in Table 7-10.

Table 7-10 Minimum Pavement Thickness

ESAL	Minimum Thickness, mm (in)		
	Asphalt Concrete	Aggregate Base	Subbase
50,001 - 150,000	50 (2.0)	150 (6.0)	150 (6.0)
150,000 - 1,000,000	50 (2.0)	150 (6.0)	150 (6.0)
1,000,000 - 2,000,000	50 (2.0)	200 (8.0)	200 (8.0)
2,000,000 - 5,000,000	76 (3.0)	200 (8.0)	200 (8.0)
5,000,000 - 9,000,000	102 (4.0)	200 (8.0)	200 (8.0)

Source: Ghana Pavement Design Manual

b) Strength Coefficient

- Asphalt concrete wearing a = 0.44
- Asphalt concrete binder a = 0.34
- Base course (crushed stone) a = 0.14
- Cement stabilised sub-base a = 0.28
- Subbase a = 0.13

c) Pavement Structure

The Structural Number (SN) is equal to the structural number indicative of the total pavement thickness required, and is given by:

$$\text{SN} = a_1 d_1 + a_2 d_2 + a_3 d_3 m_3$$

where:

a_i : i^{th} layer coefficient
d_i : i^{th} layer thickness (inches)
m_i : i^{th} layer drainage coefficient

d) Recommended Pavement Thickness

As it has become common practice to use cement stabilised gravel sub-base course for trunk road improvement works by the GHA and the GHA requested the Study Team to adopt this concept for the pavement design for the new road between Asutsuare Jct. and Asikuma Jct., the Study Team is considering doing so.

Table 7-11 Recommended Pavement Thickness of Segment 1

Segment 1	Option 1	Option 2	Option 3
Asphalt Concrete Wearing	5 cm	5 cm	5 cm
Asphalt Concrete Binder	5 cm	10 cm	10 cm
Base Course	25 cm	40 cm	20 cm
Cement Stabilised sub-base Course	25 cm	-	20 cm
Sub-base Course	48 cm	73 cm	51 cm
SN	8.14 > 8.12…OK	8.15 > 8.12…OK	8.12 ≥ 8.12…OK
Cost (ratio)	US$ 64.07/m^2 (1.00)	US$ 66.66/m^2 (1.04)	US$ 77.44/m^2 (1.21)
Evaluation	**Recommended**		

Source: Study Team

Option 1 is recommended for the pavement thickness of Segment 1 for economic reasons as well as greater durability against the weather thanks to its higher impermeability and strength of sub-base course.

Table 7-12 Recommended Pavement Thickness of Segment 2

Segment 2	Option 1	Option 2	Option 3
Asphalt Concrete Wearing	5 cm	5 cm	5 cm
Asphalt Concrete Binder	5 cm	10 cm	10 cm
Base Course	20 cm	25 cm	20 cm
Cement Stabilised sub-base Course	24 cm	-	20 cm
Sub-base Course	-	35 cm	-
SN	5.29 > 5.21…OK	5.38 > 5.21…OK	5.51 > 5.21…OK
Cost (ratio)	US$ 57.29 /m^2 (1.00)	US$ 60.14 /m^2 (1.05)	US$ 71.93 /m^2 (1.26)
Evaluation	**Recommended**		

Source: Study Team

Option 1 is recommended for the pavement thickness of Segment 2 for economic reasons as well as greater durability against the weather thanks to its higher impermeability and strength of sub-base course.

Table 7-13 Recommended Pavement Thickness of Segment 3

Segment 3	Option 1	Option 2	Option 3
Asphalt Concrete Wearing	5 cm	5 cm	5 cm
Asphalt Concrete Binder	5 cm	10 cm	10 cm
Base Course	20 cm	25 cm	20 cm
Cement Stabilised sub-base Course	24cm	-	20 cm
Sub-base Course	-	35 cm	-
SN	5.29 > 5.23…OK	5.38 > 5.23…OK	5.51 > 5.23…OK
Cost (ratio)	US$ 57.29 /m^2 (1.00)	US$ 60.14 /m^2 (1.05)	US$ 71.93 /m^2 (1.26)
Evaluation	**Recommended**		

Source: Study Team

Option 1 is recommended for the pavement thickness of Segment 3 for economic reasons as well as greater durability against the weather thanks to its higher impermeability and strength of sub-base course.

7.2.3 Road Drainage

a) Maximum Discharge

The catchment area is obtained from 1/50,000 scale topographic maps, and the frequency of occurrence for road culverts crossing the proposed road between Asutsuare Jct. and Asikuma Jct. such as watercourses, branches of the Romen River and branches of the Alabo River is determined as 10 years based on the Ghana Road Design Guide as shown in Table 7-14.

Table 7-14 Frequency of Occurrence

Frequency of Occurrence (years)	Application
5	General road drainage structures such as gutters, street gullies, etc.
10	Important drainage structures such as road crossing drainage

Source: Ghana Road Design Guide

Time of concentration (minutes) is calculated using the following Bransby-Williams formula and the factor of this equation has been confirmed by the GHA:

$$t_c = \frac{58.5 \times L}{A^{0.1} \times S_e^{0.2}}$$

where:

L : Main stream length (km)
A : Catchment area (km^2)
Se : Slope of main stream (m/km)

The maximum discharge (m^3/sec) is calculated using the rational equation (run-off coefficient is 0.2), and hence the minimum required inner size of road culverts is obtained as shown in Table 7-15.

Table 7-15 Minimum Requirements for Road Culverts

Station	Catchment Area A (km^2)	Catchment Length L (km)	Slope of Main Stream Se (m/km)	Concentration Time t (min)	Rainfall Intensity I_{10} (mm/hr)	Maximum Discharge Q (m^3/sec)	Minimum Requirement (m)
No.00 + 660	2.05	2.436	9.14	101.81	5.08	0.58	B0.9 H0.7 @1
No.01 + 710	4.59	3.320	9.14	136.19	4.06	1.04	B1.2 H0.9 @1
No.07 + 100	24.47	2.417	7.62	81.63	5.59	7.6	B1.8 H1.8 @2
No.08 + 000	3.78	2.492	7.62	102.06	5.08	1.07	B1.2 H0.9 @1
No.10 + 410	13.67	5.254	15.24	191.23	1.25	0.95	B1.2 H1.2 @1
No.12 + 780	2.84	2.360	7.62	98.38	2	0.32	B0.9 H0.7 @1
No.15 + 340	12.83	5.700	15.24	212.21	1.15	0.82	B1.2 H0.9 @1
No.15 + 700	10.16	4.892	7.62	207.7	1.15	0.65	B1.2 H0.9 @1
No.33 + 000	7.11	3.819	7.62	159.93	1.4	0.55	B1.2 H0.9 @1
No.45 + 890	2.00	2.037	6.00	89.58	2.1	0.23	B0.9 H0.7 @1
No.47 + 800	4.89	4.812	0.30	418.86	0.66	0.18	B0.9 H0.7 @1
No.49 + 540	24.21	7.962	15.24	297.43	0.87	1.17	B1.8 H1.25 @1
No.50 + 157	4.23	5.038	15.24	204.47	1.2	0.28	B0.9 H0.7 @1
No.54 + 910	4.94	4.062	7.62	178.6	3.3	0.91	B1.2 H1.2 @1
No.60 + 500	1.04	1.169	7.62	46.82	1.9	0.11	B0.9 H0.7 @1
No.62 + 000	13.28	4.397	30.50	134.82	4.06	3	B1.8 H1.25 @1
No.62 + 770	41.77	12.569	91.44	340.41	0.8	1.86	B1.8 H1.25 @1
No.65 + 510	1.02	1.582	7.62	67.44	2.6	0.15	B0.9 H0.7 @1

Source: Study Team

b) Planned Facilities

The inner sizes of planned facilities such as road culverts are determined taking into account the following:

- Compare the inner sizes of existing facilities with the calculated minimum requirement of facilities, and then adopt the planned facilities as shown in Table 7-16.
- Secure an inner size of planned box culverts of at least B1.0 H1.0 and planned pipe culverts of at least D900 considering efficiency of maintenance works.

- Secure an inner size of planned box culverts for canals and drains in the KIP considering the size of existing facilities or at least B1.0 H1.0.

Table 7-16 Planned Culverts between Asutsuare Jct. and Asikuma Jct.

Station		Existing Facilities	Minimum Requirement	Planned Facilities	Remarks
1	No.00 + 660	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage
2	No.01 + 710	None	Box B1.2 H0.9 @1	Box B1.2 H1.0 @1	Drainage
3	No.07 + 100	Box B2.0 H1.2 @3	Box B1.8 H1.8 @2	Box B2.0 H1.2 @3	Drainage (Replacement)
4	No.08 + 000	Box B1.4 H0.9 @3	Box B1.2 H0.9 @1	Box B1.4 H1.0 @3	Drainage (Replacement)
5	No.10 + 410	Box B2.5 H1.0 @1	Box B1.2 H1.2 @1	Box B2.5 H1.0 @1	Drainage (Replacement)
6	No.12 + 780	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage
7	No.15 + 340	None	Box B1.2 H0.9 @1	Box B1.2 H1.0 @1	Drainage
8	No.15 + 700	None	Box B1.2 H0.9 @1	Box B1.2 H1.0 @1	Drainage
9	No.24 + 320	B8.0 H1.1 (H: water depth)	Box B4.0 H2.6 (existing gate)	Box B4.0 H2.6 @1	Canal
10	No.25 + 210	B16.0 H0.9 (H: water depth)	Box B7.0 H1.2 @2 (existing culvert)	Box B5.0 H2.0 @3	KIP Main Drain
11	No.26 + 700	None	Box B1.0 H1.0 @1	Box B1.0 H1.0 @1	KIP Drain
12	No.33 + 000	None	Box B1.2 H0.9 @1	Box B1.2 H1.0 @1	Drainage
13	No.45 + 890	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage
14	No.47 + 800	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage
15	No.49 + 540	None	Box B1.8 H1.25 @1	Box B1.8 H1.3 @1	Drainage
16	No.50 + 157	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage
17	No.54 + 910	None	Box B1.2 H1.2 @1	Box B1.2 H1.2 @1	Drainage
18	No.60 + 500	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage
19	No.62 + 000	None	Box B1.8 H1.25 @1	Box B1.8 H1.3 @1	Drainage
20	No.62 + 770	None	Box B1.8 H1.25 @1	Box B1.8 H1.3 @1	Drainage
21	No.65 + 510	None	Box B0.9 H0.7 @1	Box B1.0 H1.0 @1	Drainage

Source: Study Team

7.2.4 Intersection Design

(1) Intersections to be Considered

There are three intersections where two or more trunk roads join or cross to be considered in the Study Area as a result of newly constructing the road between Asutsuare Jct. and Asikuma Jct.

a) Asutsuare Jct.

- The existing Asutsuare Jct. is an at-grade intersection with three arms where the Feeder Road between Asutsuare Jct. and Asutsuare Township joins with N2.
- The future Asutsuare Jct. will be an intersection with three arms where the Eastern Corridor, which will be reconstructed partially improving the existing Feeder Road, and N2 cross.

b) Volivo Intersection

- Volivo Intersection is a new intersection with four arms where the Eastern Corridor and the planned Inter-regional Road between Asutsuare Township and Aveyime Township cross, which will be upgraded by the GHA after reconstructing the existing Feeder Road between Asutsuare Township and Aveyime Township.
- The new Volivo Intersection will be opened to traffic in 2016.

c) Asikuma Jct.

- The existing Asikuma Jct. is an at-grade intersection with three arms where N2 (National Road 2) and N5 (National Road 5) cross.
- The future Asikuma Jct. will be an intersection with four arms crossing the Eastern Corridor, N2 and N5, due to the proposed Eastern Corridor connecting with the existing Asikuma Jct.

(2) Design Policy of Intersection

- To secure preferential traffic flow at the intersections of the Eastern Corridor as a major road. Both major and minor roads at each intersection are shown in Table 7-17.

Table 7-17 Road Components (Major and Minor) by Intersection

Intersection	Major Road	Minor Road
Asutsuare Jct.	Eastern Corridor	N2 heading north (to Juapong)
Volivo Intersection	Eastern Corridor	Asutsuare – Aveyime Road
Asikuma Jct.	Eastern Corridor	N5 heading north (to Ho) N2 heading south (to Juapong)

Source: Study Team

- To establish traffic flows of intersections based on the forecast of future traffic demand of the Eastern Corridor in 2036 (20 years after the start of traffic service).
- To select a type of intersection considering not only technical aspects such as capacity, geometry and the traffic control system of each intersection but also Ghana's improvement and maintenance policy.
  - ➢ The Study Team examined and compared various types of unsignalised/signalised intersections and roundabouts, and held a series of discussions with the Ghanaian side. The results of the comparison of intersections are summarised in Table 7-18

Table 7-18 Comparison of Intersection

Intersection	Type	Level of Service (LOS) 1) / Volume-to-Capacity (v/c)	
Asutsuare Jct.	Unsignalised Intersection [case 1]	LOS "E" [case 1: existing Model]	NG
	Unsignalised Intersection [case 2]	LOS "A" [case 2: improved Model]	OK
	Roundabout	v/c of each approach is less than 0.9	OK
Volivo Intersection	Unsignalised Intersection	LOS "E" 2)	NG
	Signalised Intersection	Critical v/c of intersection is 0.44	OK
	Roundabout	v/c of each approach is less than 0.9	OK
Asikuma Jct.	Unsignalszed Intersection	LOS "F"	NG
	Signalised Intersection	Critical v/c of intersection 0.49	OK
	Roundabout	v/c of each approach is less than 0.9	OK

Note: 1) With reference to Highway Capacity Manual (HCM).
2) It may not be necessary to introduce traffic signals when the LOS of an intersection is evaluated as "C" or more.
Source: Study Team

  - ➢ Finally, the GHA strongly recommended roundabouts for all three intersections on the ground: that 1) roundabouts are far safer than signalised intersections; in particular, the frequency and severity of accidents at roundabouts are far lower based on traffic observations, and 2) signalised intersections might not function all the time due to power outages, which ultimately might cause inconvenience especially to motorists.

(3) Future Traffic Flows of Intersections (in 2036)

- The peak traffic flows by direction of travel at Asutsuare Jct., Volivo intersection and Asikuma Jct. are shown in Figures 7-5 to 7-8, and Tables 7-19 to 7-22, respectively. These traffic flows are based on 10% of the peak ratio and 50% of the heavier-direction traffic ratio.
- The existing traffic system of Asutsuare Jct. may be inadequate because the traffic flow will change drastically with the construction of the Eastern Corridor. Therefore, the Study Team considered the following two cases:
  - Case 1 [Existing Model]: Left-turn traffic from Afienya to Asutsuare
  - Case 2 [Improved Model]: Through traffic from Afienya to Asutsuare

a) Asutsuare Jct.

1) Case 1 [Existing Model]: Left-turn Traffic from Afienya to Asutsuare

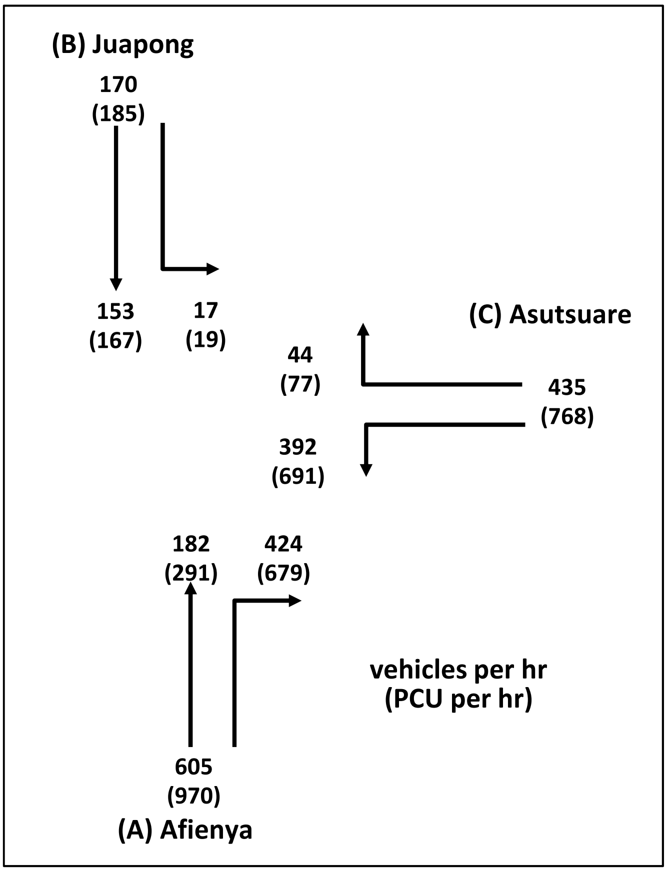


Figure 7-5 Traffic Flow by Direction of Travel at Asutsuare Jct. (Case 1)

Table 7-19 Traffic Flow by Direction of Travel at Asutsuare Jct. (Case 1)

Approach	Vehicles/hr	Commercial Vehicle Ratio	Direction	Ratio	Vehicles/hr	PCU/hr
(A) Afienya	605	31.8%	Left	-	-	-
			Through	30%	182	291
			Right	70%	424	679
(B) Juapong	170	4.7%	Left	10%	17	19
			Through	90%	153	167
			Right	-		-
(C) Asutsuare	435	40.3%	Left	90%	392	691
			Through	10%	44	77
			Right		-	-

Source: Study Team

2) Case 2 [Improved Model]: Through Traffic from Afienya to Asutsuare

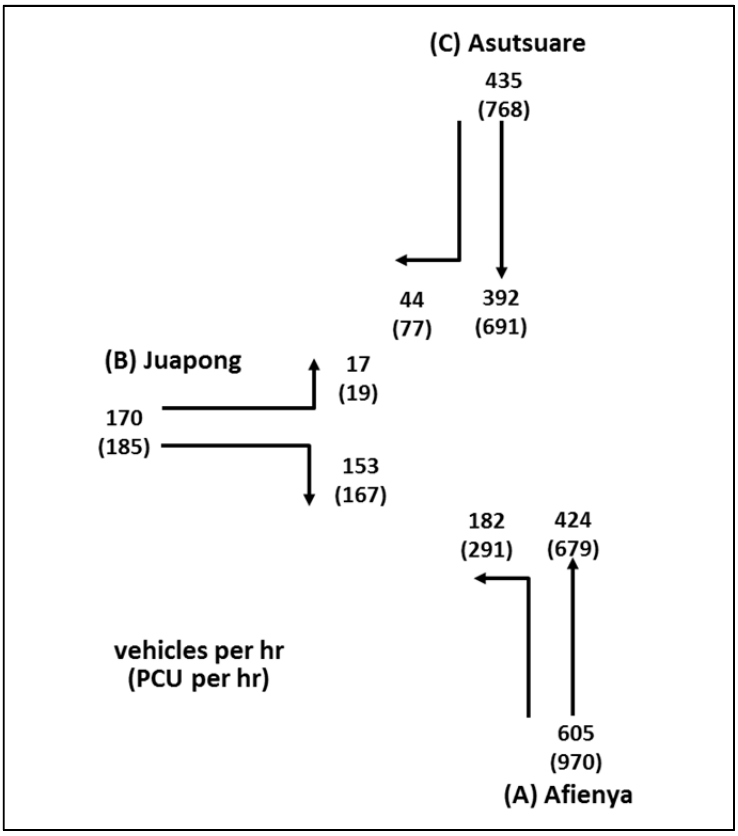


Figure 7-6 Traffic Flow by Direction of Travel at Asutsuare Jct. (Case 2)

Table 7-20 Traffic Flow by Direction of Travel at Asutsuare Jct. (Case 2)

Approach	Vehicles/hr	Commercial Vehicle Ratio	Direction	Ratio	Vehicles/hr	PCU/hr
(A) Afienya	605	31.8%	Left	30%	182	291
			Through	70%	424	679
			Right	-	-	-
(B) Juapong	170	4.7%	Left	10%	17	19
			Through	-	-	-
			Right	90%	153	167
(C) Asutsuare	435	40.3%	Left	-	-	-
			Through	90%	392	691
			Right	10%	44	77

Source: Study Team

b) Volivo Intersection

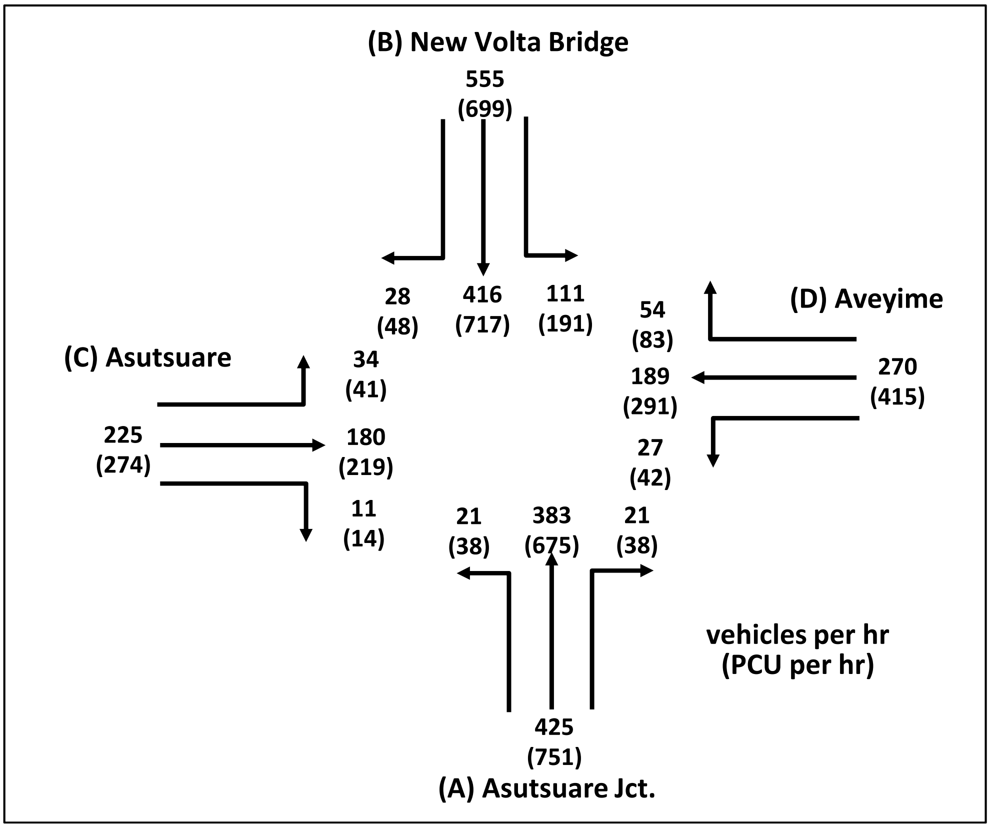


Figure 7-7 Traffic Flow by Direction of Travel at Volivo Intersection

Table 7-21 Traffic Flow by Direction of Travel at Volivo Intersection

Approach	Vehicles/hr	Commercial Vehicle Ratio	Direction	Rate	Vehicles/hr	PCU/hr
(A) Asutsuare Jct.	425	40.3%	Left	5%	21	38
			Through	90%	383	675
			Right	5%	21	38
(B) New Volta Bridge	555	38.0%	Left	20%	111	191
			Through	75%	416	717
			Right	5%	28	48
(C) Asutsuare	225	11.4%	Left	15%	34	41
			Through	80%	180	219
			Right	5%	11	14
(D) Aveyime	270	28.3%	Left	10%	27	42
			Through	70%	189	291
			Right	20%	54	83

Source: Study Team

c) Asikuma Jct.

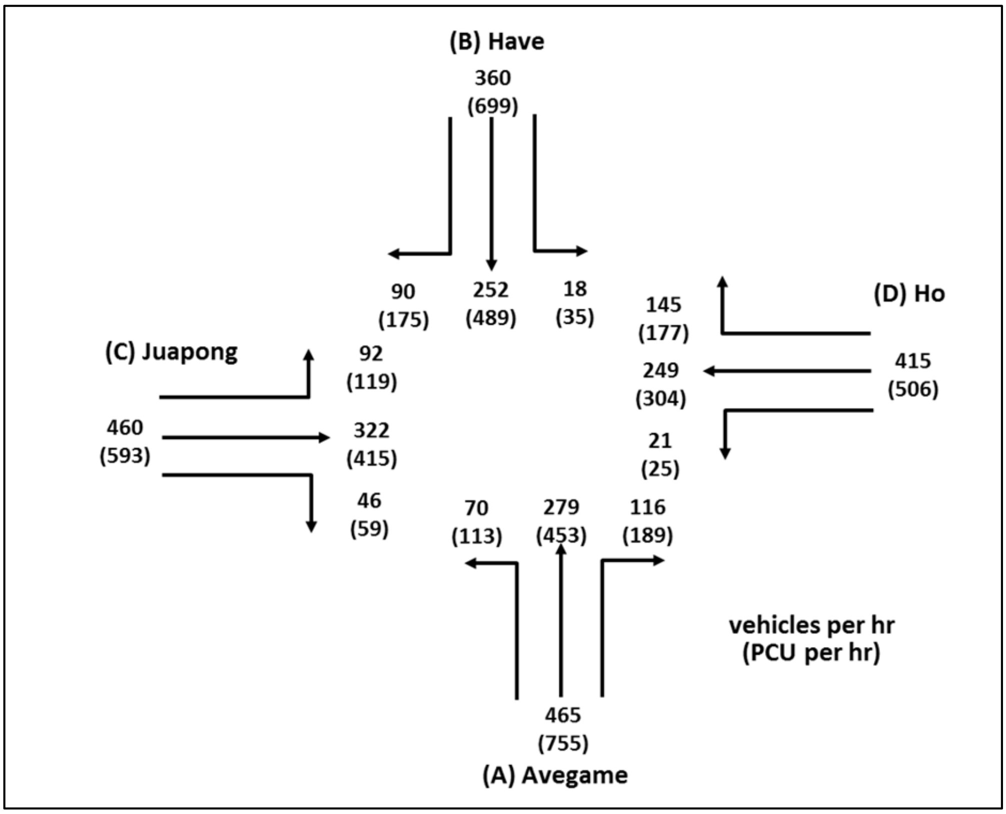


Figure 7-8 Traffic Flow by Direction of Travel at Asikuma Jct.

Table 7-22 Traffic Flow by Direction of Travel at Asikuma Jct.

Approach	Vehicles/hr	Commercial Vehicle Ratio	Direction	Ratio	Vehicles/hr	PCU/hr
(A) Avegame	465	32.8%	Left	15%	70	113
			Through	60%	279	453
			Right	25%	116	189
(B) Have	360	49.6%	Left	5%	18	35
			Through	70%	252	489
			Right	25%	90	175
(C) Juapong	460	15.2%	Left	20%	92	119
			Through	70%	322	415
			Right	10%	46	59
(D) Ho	415	11.6%	Left	35%	145	177
			Through	60%	249	304
			Right	5%	21	25

Source: Study Team

(4) Future Traffic Capacity of Roundabouts

a) Methodology

The capacity at a roundabout can be estimated using gap acceptance techniques with the basic parameters of critical gap and follow-up time. It has generally been assumed that the performance of each arm of a roundabout can be analysed independently of the other arms, and consequently most techniques tend to use information on only one arm.

The capacity of a single-lane roundabout approach is estimated using the following equation, referring to the HCM:

$$c_a = \frac{v_c e^{-v_c t_c/3600}}{1 - e^{-v_c t_f/3600}}$$

where:

c_a = approach capacity (veh/h)
v_c = conflicting circulating traffic (veh/h)
t_c = critical gap (s) 4.1 (s)
t_f = follow-up time (s) 2.6 (s)

b) Asutsuare Jct.

The future traffic capacity of a roundabout for Asutsuare Jct. is evaluated by the volume-to-capacity ratio for a given approach because single-lane entries can be calculated by dividing the calculated approach capacity into the entry volume for the given approach.

The volume-to-capacity ratio of each approach at Asutsuare Jct. is less than 0.9 shown in Table 7-23. These values indicate that the intersections would operate under capacity and excessive delays would not be experienced.

The GHA has an upgrading plan (two lanes to four lanes) for the existing road between Tema Roundabout and Asutsuare Jct. Therefore, traffic operation and management of the roundabout at Asutsuare Jct. should take this into consideration.

Table 7-23 Evaluation of Capacity at Asutsuare Jct. (Roundabout)

Approach	Conflicting circulating traffic (veh./h)	Approach capacity (veh./h) (a)	Entry volume in subject approach (veh./h) (b)	Volume-to-capacity ratio (v/c ratio) (b/a)
(A) Afienya	17	1,366	606	0.44
(B) Juapong	392	1,017	170	0.17
(C) Asutsuare	182	1,201	436	0.36

Source: Study Team

c) Volivo Intersection

The future traffic capacity of a roundabout for Volivo Intersection is evaluated by the volume-to-capacity ratio for a given approach because single-lane entries can be calculated by dividing the calculated approach capacity into the entry volume for the given approach.

The volume-to-capacity ratio of each approach at Volivo Intersection is less than 0.9 shown in Table 7-24. These values indicate that the intersection would operate under capacity and excessive delays would not be experienced.

Table 7-24 Evaluation of Capacity at Volivo Intersection (Roundabout)

Approach	Conflicting circulating traffic (veh./h)	Approach capacity (veh./h) (a)	Entry volume in subject approach (veh./h) (b)	Volume-to-capacity ratio (v/c ratio) (b/a)
(A) Asutsuare Jct.	325	1,073	425	0.40
(B) New Volta Bridge	237	1,150	555	0.48
(C) Asutsuare	554	894	225	0.25
(D) Aveyime	438	981	270	0.28

Source: Study Team

d) Asikuma Jct.

The future traffic capacity of a roundabout for Asikuma Jct. is evaluated by the volume-to-capacity ratio for a given approach because single-lane entries can be calculated by dividing the calculated approach capacity into the entry volume for the given approach.

The volume-to-capacity ratio of each approach at Asikuma Jct. is less than 0.9 shown in Table 7-25. These values indicate that the intersection would operate under capacity and excessive delays would not be experienced.

Table 7-25 Evaluation of Capacity at Asikuma Jct. (Roundabout)

Approach	Conflicting circulating traffic (veh./h)	Approach capacity (veh./h) (a)	Entry volume in subject approach (veh./h) (b)	Volume-to-capacity ratio (v/c ratio) (b/a)
(A) Avegame	432	985	465	0.47
(B) Have	340	1,060	360	0.34
(C) Juapong	363	1,041	460	0.44
(D) Ho	441	978	415	0.42

Source: Study Team

7.2.5 Traffic Safety and Management

(1) Traffic Safety and Management

a) Guardrails

Guardrails are required where there is a high embankment of more than 3 m and at other necessary sections. The embankment height of the approach roads to the bridge (No. 23 km+259.9 – No. 23 km+311.6) is approximately 6 m from the ground level, and so the installation of guardrails is proposed on both sides of these approach roads. Guardrails are located at outside shoulders of 2.5 m.

b) Road Signs and Pavement Markings

Appropriate pavement markings are provided to control traffic movement, and to warn and guide motorists and pedestrians. Generally, a broken guiding line is provided as a centreline where the sight distance is adequate. Where the sight distance is inadequate, a continuous full marked centreline is provided. Edge line markings are also provided on both sides of the road.

The following road signs are placed in appropriate locations:

- Danger Warning signs such as Hump Ridge, Pedestrian Crossing, Road Crossing and Traffic Signals
- Regulatory signs such as Maximum Speed Limit
- Mandatory signs such as Give Way (major road ahead)
- Information signs such as direction of destination at proper locations

c) Pedestrian Crossing

In large settlements where pedestrians cross the road, apart from the mandatory speed limit sign of 50 km/h, grade separations by footbridges for pedestrian crossings are recommended in order to minimise the frequency and severity of accidents in settlements based on the strong request by the GHA.

d) Traffic Calming Measures

The speed of vehicles travelling through populated areas is likely to be one of the most important safety issues. Because one of the main problems will be conflict between vehicles and pedestrians, pedestrian crossing points should be separated from through traffic. This should be done by using speed humps and/or a raised carriageway with pedestrian crossings. Humps should be used on roads with speed limits of 50 km/h or less through town or village areas with many pedestrians on roads. It is recommended that humps should be constructed as trapezoidal humps (4.0 m in width and 75 mm in height) at pedestrian crossings.

d) Bus Bays

Bus bays are provided along the proposed road where necessary such as around Asutsuare Jct., Osuwem, Volivo, Dufor Adidome, Kpolukope (crossing at R19) and Asikuma Jct.

e) Toll Plaza

It is proposed to place a toll plaza near the Volta River Bridge for collecting the toll from vehicles crossing the river. It could be constructed between the edge of the bridge (No. 28 km+685) and the crossing of the feeder road (No. 29 km+060), Juapong – Dufor Adidome.

The length of the proposed toll plaza is 210 m including approach lanes to toll booths. The number of toll booths is five: a central booth for both directions, and two outside booths in each direction.

(2) Rest Stop

a) Size

The Linda Dor rest stop currently in use on the Central Corridor is an appropriate model for the proposed rest stop on the Eastern Corridor. In view of the daily traffic volume on both corridors, the assumed size of the proposed rest stop is based on the Linda Dor rest stop which has a site area of approximately 16,000 m^2 including the paved parking area (7,700 m^2) and commercial buildings and offices area (8,300 m^2) measured by Google Map.

b) Functions and Services

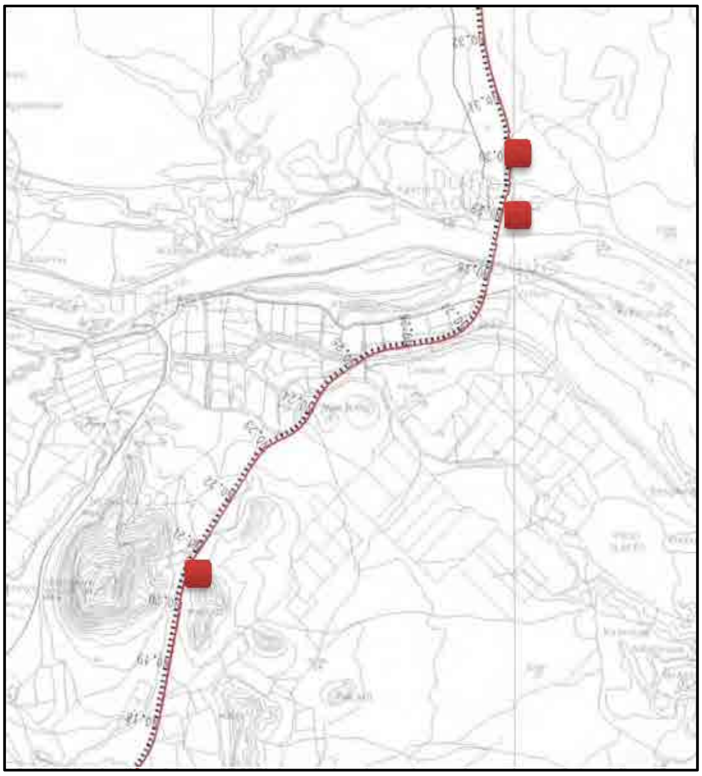
The functions and services of the proposed rest stop are also based on the Linda Dor rest stop. The Study Team visited the Linda Dor and confirmed that its main functions and services are as follows:

- Rest and parking service for users
- Information provision for users
- Regional economic collaboration between users and local residents

3) Location

The proposed location of the rest stop is as close to the new Volta Bridge as possible. One rest stop is enough for the distance of 67 km between Asutsuare Jct. and Asikuma Jct. The site along the left riverside is mostly expected to provide higher added value such as good landscape, creating a new destination in itself, and collaborating with possible private investors along the riverside. In the case of introducing a toll gate at around Sta. No. 29 km instead of the rest stop, the proposed rest stop will be connected with the Eastern Corridor by a paved access road.

- Around Sta. No. 20 km from Asutsuare Jct. to Volivo
- Around Sta. No. 29 km of along the Volta River (left side of the river bank)
- Around Sta. No. 30 km of from Dufor Adidome to Asikuma Jct.



Source: Study Team

Figure 7-9 Proposed Location of the Rest Stop

7.2.6 Replacement of Black Cotton Soil

(1) Section between 00 km+000 and 10 km+800

The proposed road will be reconstructed by building on the existing paved road. Thus, replacement of black cotton soil is basically not required in this section.

(2) Section between 10 km+800 and 27 km+600

From the results of boring tests and laboratory testing of BH-6, the layer (top soil) of 0.30 m from the ground level consists of soft dark brown sandy clay, and the layer from 0.30 m to 1.80 m consists of very stiff dark brown clay with traces of sand and gravel. The obtained values of Liquid Limit and Free Swell at the depth of 1.50 m from the ground were 43% and 64%, respectively (refer to Chapter 5). Thus, according to boring tests, black cotton soil may be deposited up to 1.8 m from the ground, of which the top 1.10 m (60% of the black cotton layer[26]) may need to be replaced by suitable materials.

The placement of suitable materials for a total of up to 2.3 m under pavement structure should be considered as follows, and the width of replacement should be considered as the whole bottom of filling.

For an embankment height of 1.80 m from ground level:

Pavement thickness:	0.54 m	
Subgrade and filling:	1.26 m	Ground level
Replacement:	1.10 m	

(3) Section between 28 km+700 and 48 km+000

From the results of boring tests and laboratory testing of BH-4, the layer (top soil) of 0.20 m from the ground level consists of moist loose dark black silty clay, the layer from 0.20 m to 1.00 m consists of moist dense brown silty clay, and the layer from 1.00 m to 3.00 m consists of moist firm dark brown silty clay. The obtained values of Liquid Limit and Free Swell at the depth of 1.00 m from the ground were 49% and 47%, respectively. Thus, according to boring tests, black cotton soil could may be deposited up to 3.0 m from the ground, of which the top 1.80 m (60% of the black cotton layer) may need to be replaced by suitable materials.

The placement of suitable materials for a total of up to 2.8 m under the pavement structure should be considered as follows, and the width of replacement should be considered as the whole bottom of filling.

For an embankment height of 1.61 m from ground level:

Pavement thickness:	0.54 m	
Subgrade and filling:	1.07 m	Ground level
Replacement:	1.80 m	

(4) Section between 48 km+000 and 50 km+000

From the results of boring tests and laboratory testing of BH-5, the layer (top soil) of 0.20 m

[26] As the results of discussion with Material Department of GHA, thickness of replacement of the assumed back cotton soil layer was decided based on GHA's experiences through the past projects.

from the ground level consists of soft moist dark brown sandy clay, and the layer from 0.20 m to 1.00 m consists of stiff moist dark brown clay with traces of sand and gravel. The obtained values of Liquid Limit and Free Swell at the depth of 1.50 m from the ground were 37% and 41%, respectively. Thus, according to boring tests, black cotton soil may be deposited up to 1.00 m from the ground, of which the top 0.60 m (60% of the black cotton layer) may be replaced by suitable materials.

The placement of suitable materials for a total of up to 1.6 m under the pavement structure should be considered as follows, and the width of replacement should be considered as the whole bottom of filling.

For an embankment height of 1.47 m from ground level:

Pavement thickness:	0.54 m	
Subgrade and filling:	0.93 m	Ground level
Replacement:	0.60 m	

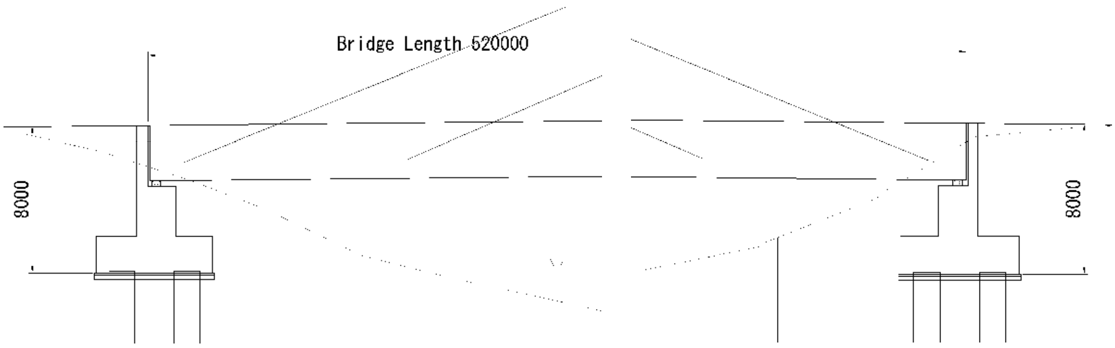
7.3 Preliminary Design of Bridge

7.3.1 Preliminary Design of Bridge across the Volta River

(1) Design Conditions

a) Bridge Length

The bridge length was determined as 520 m based on the results of the bathymetric survey on the final bridge location in consideration of the following points (see Figure 7-10):



Source: Study Team

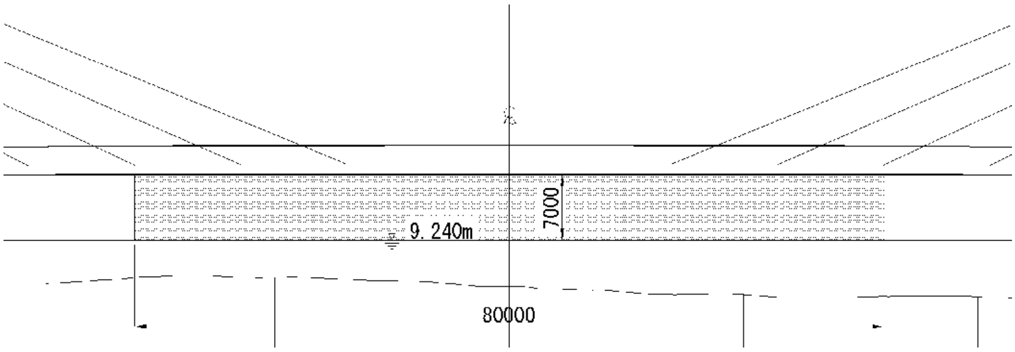
Figure 7-10 Length of the Bridge Across the Volta River

- In order to improve the safety against scouring of the natural embankment, a piling foundation structure is adopted, utilising all-casing piling equipment, which will be used for the coffering works for the pier construction. In this case, the distance between the river and abutment is planned to be minimised in order to reduce the total construction cost by reducing the bridge length.
- The height of abutment was determined as 8 m, in order to avoid excavation below the water level during construction.

- Sufficient earth covering of about 2 m was secured to avoid scouring by the river on the upper part of the footing of the abutment.
- The minimum space for construction works and maintenance works of 10 m was secure between the river and abutments.

b) Bridge Height

The Study Team set up the fairway on the Volta River to secure clearance under the bridge. The height of the fairway was determined as 7 m (see Figure 7-11) to maintain consistency with the existing Lower Volta Bridge. The width of the fairway was determined as 80 m which is approximately double the length of a span of the Lower Volta Bridge, to allow the coming and going of ships.



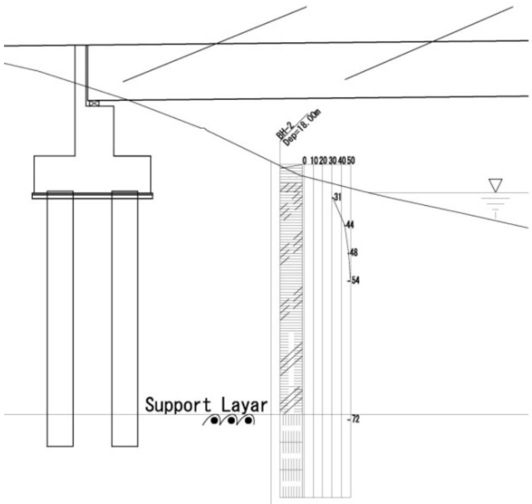
Source: Study Team

Figure 7-11 Fairway in the Volta River

(2) Topographical and Geological Conditions

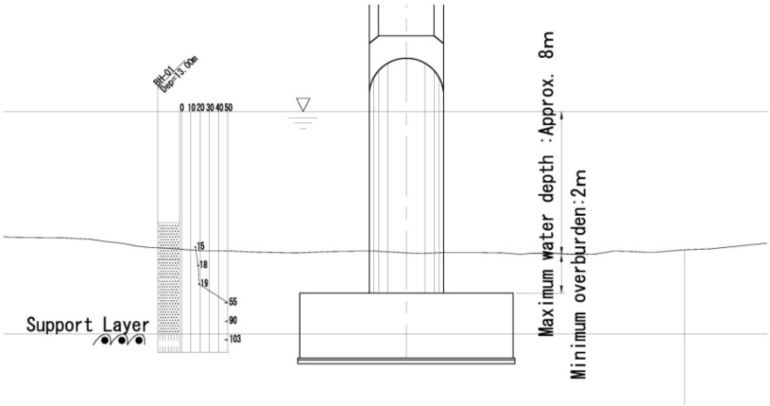
The bathymetric survey and geotechnical investigation revealed the following natural conditions at the final bridge location.

- The Volta River, with a maximum riverbed depth of approximately 8 m (see Figures 7-12 and 7-13).



Source: Study Team

Figure 7-12 Relation between the Result of Geotechnical Investigation and Abutment



Source: Study Team

Figure 7-13 Relation between the Result of Geotechnical Investigation and Pier

- The Volta River has a uniform current which is controlled by the Kpong Dam and the velocity is approximately 0.6 m/s.
- The river water is not saline.
- The support layer is very near to the river bed, with a minimum depth of 7–4 m from the river bed.
- The support layer is a very hard rock layer with an N-value of more than 300.

(3) Seismic Load

Please refer to Section 6.3.3 for the seismic load.

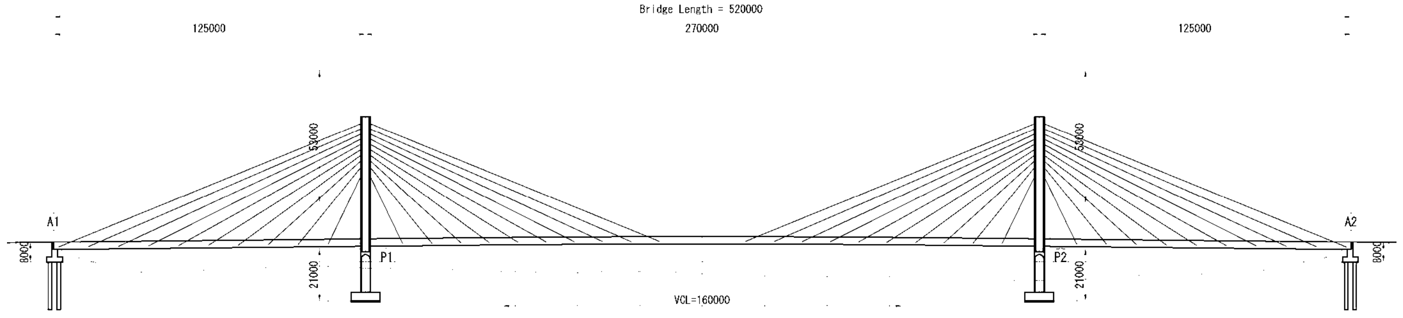
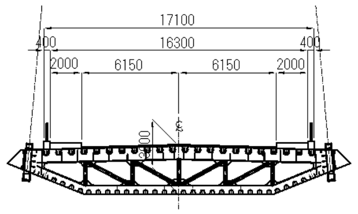
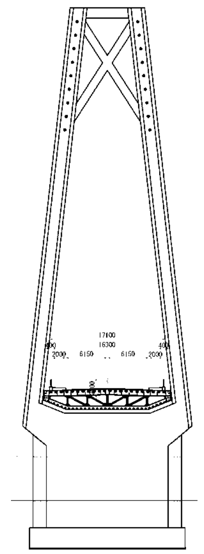
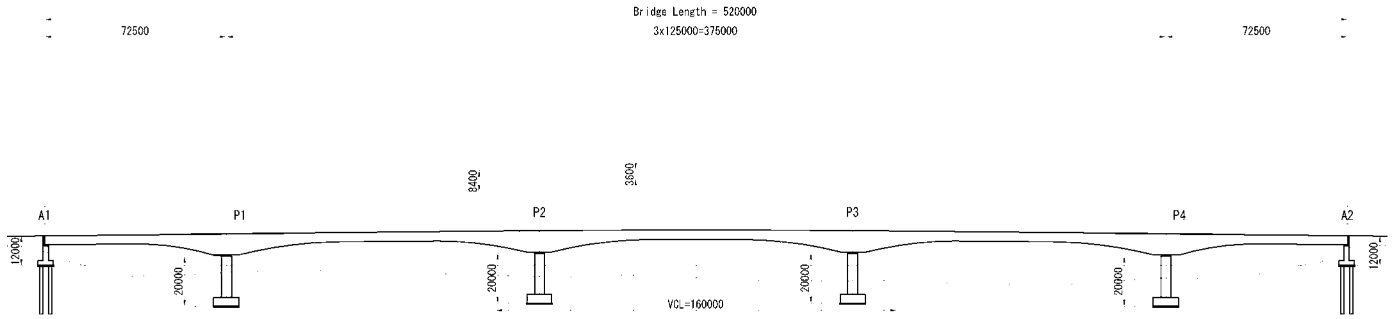
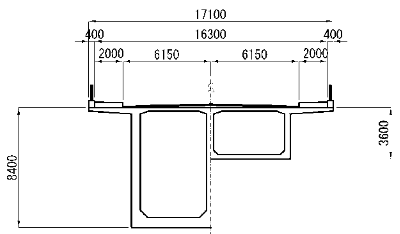
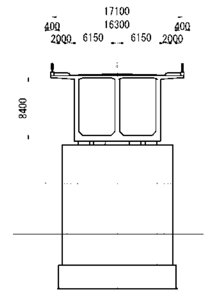
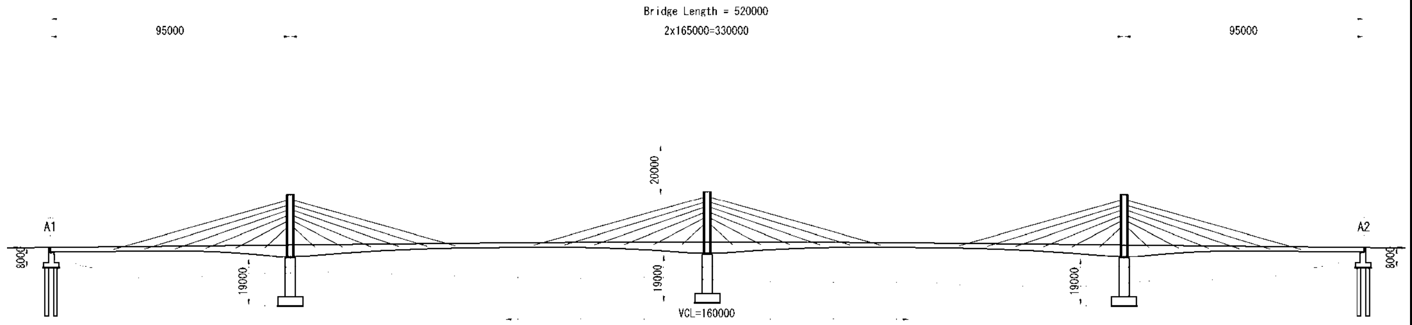
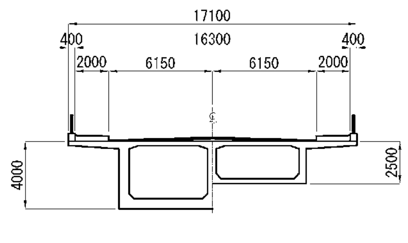
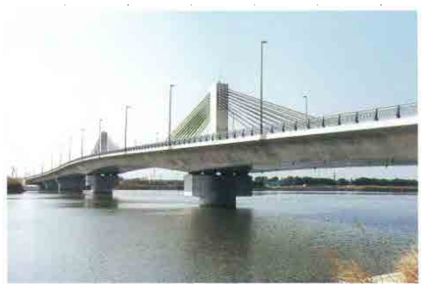
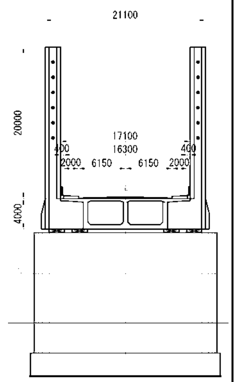
(4) Second-Step Comparison of Superstructure

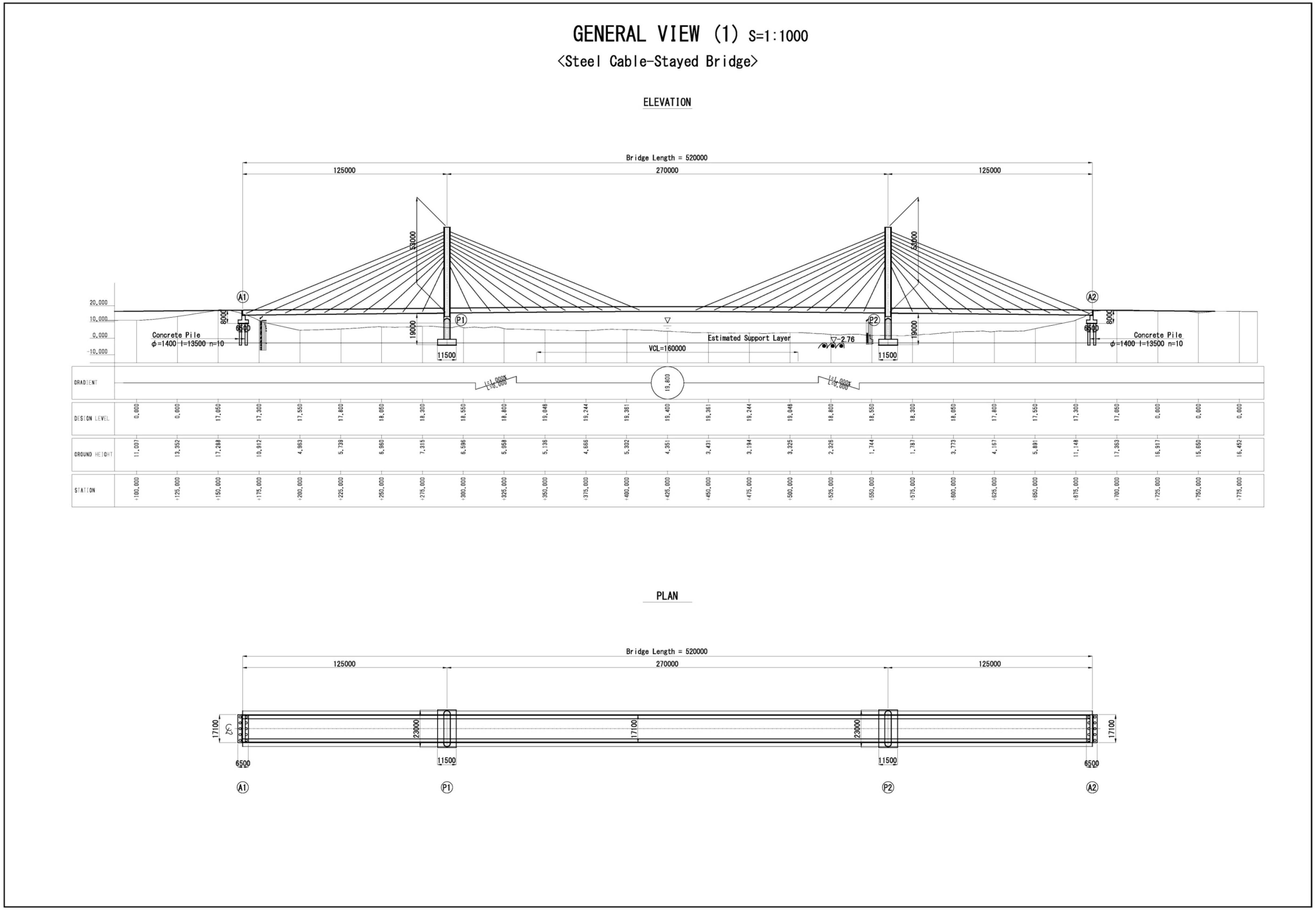
Based on the three alternative superstructure types selected by the first-step comparison, the Study Team carried out the second-step comparison to select the most suitable superstructure type in consideration of the design conditions mentioned above.

Table 7-26 summarises the second-step comparison of superstructures. As a result, Proposal 1 (Figure 7-14): continuous cable-stayed bridge was selected for the following reasons:

- Proposal 1 has better constructability with limited construction works in the river, and superior landscape aesthetic value with a monumental and landmark landscape for the surrounding area by the main tower of more than 50 m in height in the area along the Eastern Corridor, where the topography is mostly flat. Even though the construction cost is slightly higher than Proposal 2, this advantage is judged to be superior.
- Proposal 2 is the cheapest construction cost, however, its landscape aesthetic value is not favourable. In addition, it would be necessary to raise the vertical alignment of the road by more than 3 m in order to secure the clearance under the girder, which would be constructed by the cantilever method. As a result, a high embankment would be necessary for the approach sections of the bridge. Thus, other than its lower construction cost, this proposal is unfavourable.
- Proposal 3 is less favourable in terms of constructability and landscape aesthetic value than Proposal 1, even though its construction cost is almost the same.

Table 7-26 Comparison of Bridge Structures over the Volta River (Second-Step)

	Side-view Drawing, Main Girder Cross-section, and Concept Image	Midpoint bridge pier cross-section	Structural features	Constructability	Aesthetic value and impact on surrounding environment	Cost performance	Judgment
Proposal 1 Continuous cable-stayed bridge Main girders: steel-floor box girder Main towers: reinforced concrete Foundation: spread footing (steel pipe sheet pile cofferdam)	  		•Large spans exceeding 200 m with a relatively large number of past examples. •There is no problem in the fatigue durability of the steel floor plate, as highly-durable steel floor plate that has passed a two-million cycle fatigue test is planned. •Using a box-girder structure with high torsional rigidity as a base, sufficient wind resistance is possible if wind-tunnel testing is conducted. (Good)	•Since many parts can be fabricated in highly-controlled factories, the quality can be secured. •With the least volume of in-river work, the safety and precision of construction can be secured. (Very Good)	•The main towers and cables have a monumental presence to effectively function as an area landmark. •The balance between the scale of the bridge (length/width, etc.), the height of the towers, and the number of cables is good, giving it aesthetically pleasing proportions. (Very Good)	Ratio: 1.06 (Good)	**Very Good**
Proposal 2 Precast Concrete Box-girder Bridge (cantilever method) Main girders: concrete Piers: reinforced concrete (rubber bearing support) Foundation: spread footing (steel pipe sheet pile cofferdam)	  		•Spans of approximately 100 m with a very large number of past examples. •Piers are short compared to the length of the bridge, making thermal stress relief difficult. Therefore, a reaction force dispersion structure using rubber bearings must be used. (Due to this, this structure type does not have sufficient cost advantages.) (Good)	•Since many parts are constructed at the site, quality control is not easy. • Since there are many in-river works, the safety and precision of construction are lower. (Fair)	• The unique rhythmical appearance of a non-uniform cross section is an aesthetically pleasing type of structure. However, for this bridge, there are almost no vantage points offering this view, giving it less landscaping value. •The increased beam height makes the bridge 4 m higher than the road, which worsens the approach to the road at the ends of the bridge. (Fair)	Ratio: 1.00 (Very Good)	**Fair**
Proposal 3 Precast Concrete Extradosed Bridge Main girders: concrete Piers: RC piers (rubber bearing support) Foundation: spread footing (steel pipe sheet pile cofferdam)	  		•Bridges with 150-250 m spans have rapidly increased in recent years. •Bridge piers are short compared to the length of the bridge, making thermal stress relief difficult. Therefore, a reaction force dispersion structure using rubber bearings must be used. (Due to this, this structure type does not have sufficient cost advantages.) (Good)	•Since many parts are constructed at the site, quality control is not easy. • Since there are many in-river works, the safety and precision of construction are lower. (Fair)	•The towers and cables on the bridge surface give a monumental presence, but with its small scale, it lacks effectiveness as a landmark. •Towers are short compared to the bridge width, giving it poor aesthetic balance. (Good)	Ratio: 1.07 (Good)	**Good**



Source: Study Team

Figure 7-14 General Plan of Bridge Across the Volta River

(5) Second-Step Comparison of Substructure

a) Selection of Abutment Type

The reverse T-style abutment was selected based on Table 7-27, since the height of abutments will become about 10 m. The piling foundation was selected at this stage, instead of the direct foundation, in order to secure the safety of abutments, in case scouring occurs on the natural embankment in front of the abutments. Placing of ø1400 diameter piles by the cast-in-place piling method is planned by using all-casing piling equipment, which will be used for the coffering works for the pier construction, in order to reduce the construction cost by reusing equipment at the site.

b) Selection of Pier Type

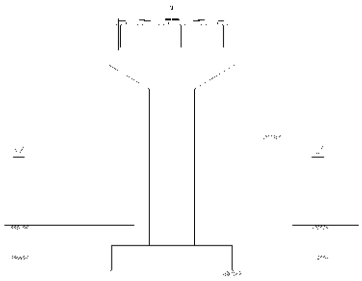
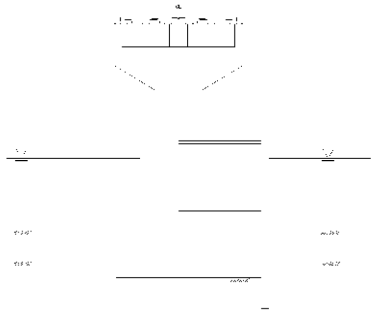
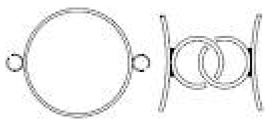
The column type elliptical pier was selected as the pier type, in order to minimise the obstruction of river flow, as most of the piers will be constructed in the river, the same as in the first-step comparison. The economical direct foundation was also adopted for the foundation, because a hard rock layer was found at a shallow level. Proposal 2: single steel pipe sheet pile cofferdam method was selected for the cofferdam method for constructing the piers, based on the results of comparison of cofferdam methods in the deep river as shown in Table 7-28.

Table 7-27 Comparison of Substructure Types and Applicable Heights of Bridges

Bridge part	Substructure type	Applicable height (m) 10 20 30	Characteristics
Abutment	1. Gravity type		With shallow support ground, the gravity type is suitable for direct foundations.
	2. Reverse T-style		Used in many bridges. Suitable for direct foundations and pile foundations.
	3. Buttressed type		Suitable for tall abutments. Few materials are used for this type, but the lead time is long.
	4. Box type		Designed for tall abutments. The lead time is somewhat long.
Pier	1. Column type		Low piers. Suitable for stringent intersection conditions and installation in a river.
	2. Rigid frame type		Relatively tall piers. Suitable for wide bridges, but their installation in a river may hinder water flow during flooding.
	3. Pile bent type		The most cost efficient, but not suitable for bridges with high horizontal force. Their installation in a river may hinder water flow during flooding.
	4. Elliptical type		Tall bridge piers. Suitable for bridges with high external force.

Source: Study Team

Table 7-28 Comparison of Cofferdam Methods for Pier Construction

Item	Proposal 1 Double Sheet Pile Cofferdam	Proposal 2 Single Steel Pipe Sheet Pile Cofferdam
Cross Section		
Outline of Structure	The capability of preventing water leaks and stability is improved, by placing two double sheet piles with soil/sand placed in between. Sheet piles are fixed by tie-rods. Special rock excavation equipment, such as a Down Hole Hammer, is required for penetrating the sheet piles into the rock layer.	A high capability of preventing water leaks is secured by steel pipes with high stiffness and joints between pipes, as shown below. Large scale rock excavation equipment, such as all casing piling equipment, is required for penetrating the steel piles into the rock layer. 
Constructability	Excavation of rock layer with ø500 diameter under the water level by wrapping sheet piles is considered to be technically difficult. In addition, placing and removing of soil/sand between sheet piles are also complicated works. (Fair)	Excavation of rock layer with ø1400 diameter under the water level by wrapping steel pipes is easier, because the tolerance is larger. Also, works to prevent water leaks are easier. (Good)
Construction Cost	Ratio: 1.13 (Fair)	Ratio: 1.00 (Good)
Judgment	Fair	Good

Source: Study Team

7.3.2 Preliminary Design of Bridge across the Alabo River

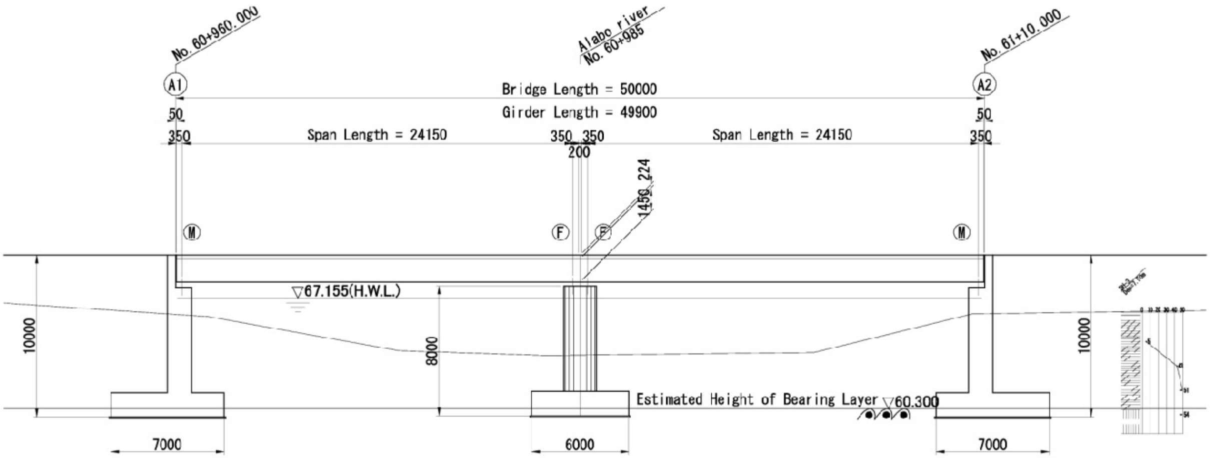
(1) Design Condition

a) Bridge Placing Plan

- The Study Team adopted the H.W.L. of 67.155 m, which was used for the design of the M11 Bridge, located about 300 m downstream of the planned bridge location, in the "Construction of Medium and Small Scale Bridges in the Republic of Ghana" under the donation programme of the Government of Japan.
- The bridge length should be longer than the M11 Bridge (46.940m).

b) Geotechnical Conditions

- According to the results of geotechnical investigation near the planned bridge site, a clay layer with an N-value of more than 50 (see Figure 7-15) was found at about GL-5 m and a rock layer was found at GL-6 m. Since the river channel has often changed, the foundation should be placed on a stable layer. Thus, the rock layer from GL-6 m was considered as the bearing layer of the substructure.



Source: Study Team

Figure 7-15 Relation between Result of Geotechnical Investigation, and Location of Abutments and Pier

(2) Bridge Planning

The bridge length was determined as 50 m = 2@25 m, considering the length of more than 46.940 m shown in Figure 7-16, as well as to be the same length as the Bridge across the planned APGIP Main Canal, described below, in order to reduce the cost by reusing materials such as formworks.

(3) Selection of Superstructure Type

The continuous T-girder type was selected based on Table 7-29 for the following reasons:

- The continuous girder type was mainly compared because of its seismic resistance.
- Concrete bridges require less maintenance and are economical.
- The continuous composite girder type has problems such as difficulty of construction and quality control
- This type of bridges is commonly used in Ghana.

(4) Selection of Substructure Type

a) Selection of Abutment Type

The reverse T-style abutment was selected based on Table 7-27, since the height of the abutment will be 10 m. The economical direct foundation was selected for the foundation type, as a rock layer with an N-Value of more than exists at the bottom of planned footings.

b) Selection of Pier Type

The column type elliptical pier was selected as the pier type, in order to minimise obstruction of river flow, as the piers will be constructed in the river. The economical direct foundation was adopted for the foundation, because a hard rock layer was found at a very shallow level.

Table 7-29 Comparison of Superstructure Types and Standard Spans of Bridge

Superstructure Type		Standard Span (25m / 50 m / 100 m / 150 m)	Possibility of Curves: Main Structure	Possibility of Curves: Bridge Deck	Girder height Span ratio
Steel bridge	Simple composite plate girder		○	○	1/18
Steel bridge	Simple plate girder		○	○	1/17
Steel bridge	Continuous plate girder		○	○	1/18
Steel bridge	Simple box girder		○	○	1/22
Steel bridge	Continuous box girder		○	○	1/23
Steel bridge	Simple truss		×	○	1/ 9
Steel bridge	Continuous truss		×	○	1/10
Steel bridge	Reverse Langer girder		×	○	1/6,5
Steel bridge	Reverse Lohse girder		×	○	1/6,5
Steel bridge	Arch		×	○	1/6,5
PC bridge	Pretensioned girder		×	○	1/15
PC bridge	Hollow slab		○	○	1/22
PC bridge	Simple T girder		×	○	1/17,5
PC bridge	Simple composite girder		×	○	1/15
PC bridge	Continuous T girder,		×	○	1/15
PC bridge	Continuous composite girder		×	○	1/16
PC bridge	Simple box girder		○	○	1/20
PC bridge	Continuous box girder (cantilever method)		○	○	1/18
PC bridge	Continuous box girder (Push-out or support method)		○	○	1/18
PC bridge	π shaped rigid frame ridge		×	○	1/32
RC bridge	Hollow slab		○	○	1/20
RC bridge	Continuous spandrel-filled arch		○	○	1/ 2

Source: Study Team

7.3.3 Preliminary Design of Bridge across the Planned APGIP Main Canal

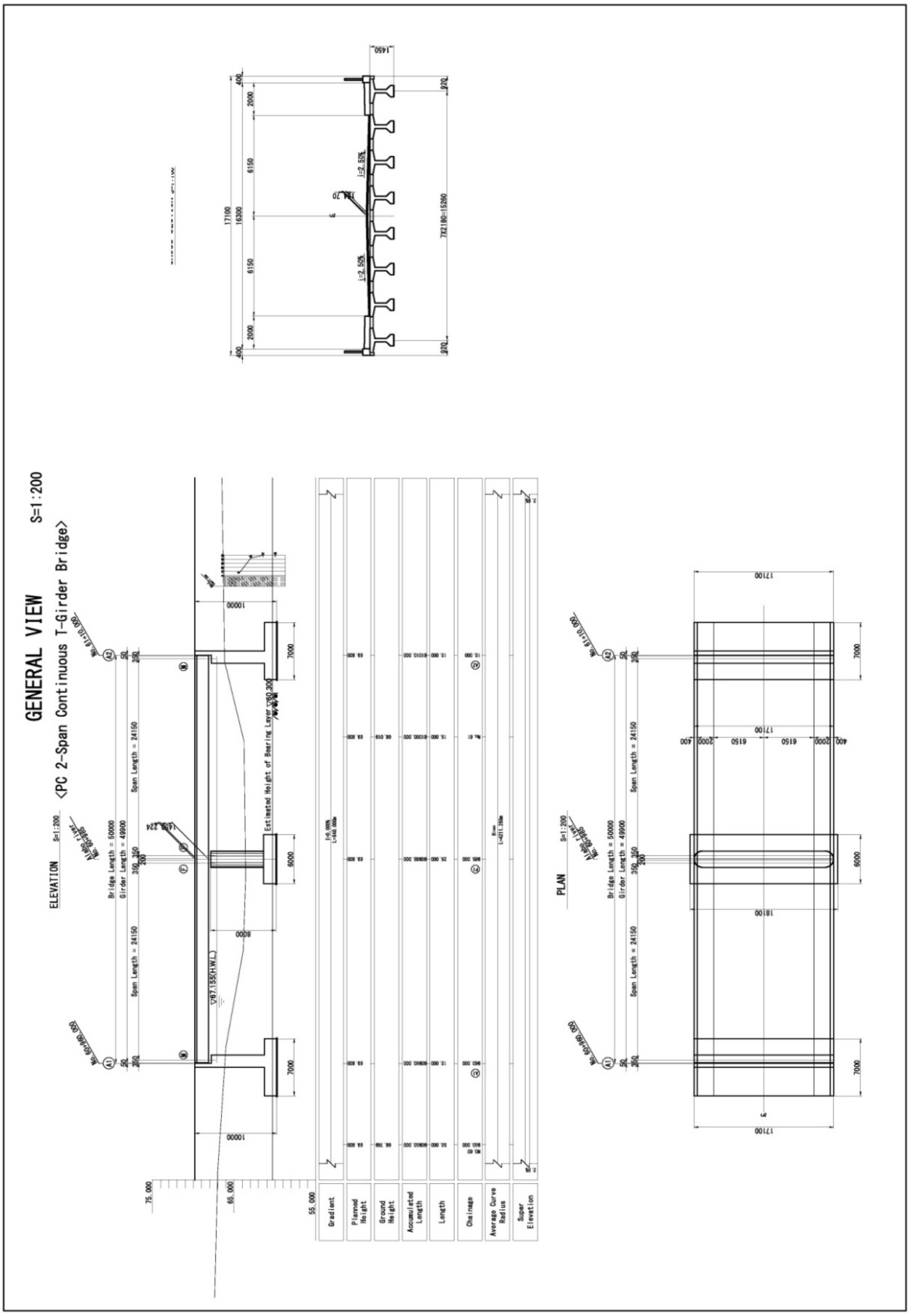
(1) Design Conditions

a) Bridge Placing Plan

- To secure the marginal allowance to cross both the existing canal (W = 16 m) and planned canal (W = 15 m).

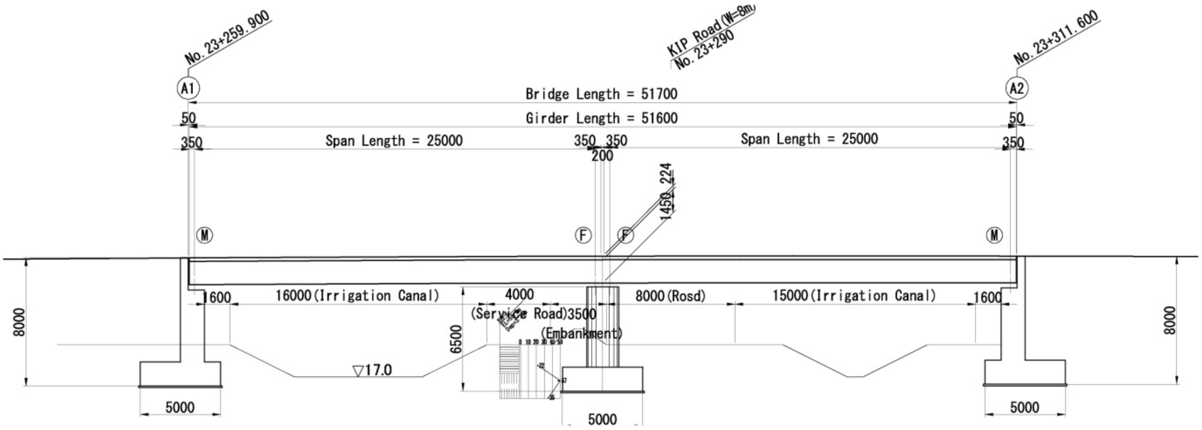
b) Geotechnical Conditions

- According to the result of a geotechnical investigation near the planned bridge site, a rock layer with an N-value of more than 30 (Figure 7-17) was found at about GL-2 m. This rock layer is considered to be appropriate bearing layer because of small ground reaction, even though the N-value of this layer is relatively low. The footings of the foundation are planned to be placed below the deepest level of the canals in view of the effects of excavating the planned canal.



Source: Study Team

Figure 7-16 General Plan of Bridge across the Alabo River



Source: Study Team

Figure 7-17 Relation between Result of Geotechnical Investigation, and Location of Abutments and Pier

(2) Bridge Planning

The bridge length was determined as 50 m = 2@25 m, in consideration of the location of the existing and planned canals shown in Figure 7-18.

(3) Selection of Superstructure Type

The continuous T-girder type was selected based on Table 7-29 for the following reasons:

- The continuous girder type was mainly compared because of its seismic resistance.
- Concrete bridges require less maintenance and are economical.
- The continuous composite girder type has problems such as difficulty of construction and quality control.
- This type of bridge is commonly used in Ghana.

(4) Selection of Substructure Type

a) Selection of Abutment Type

The reverse T-style abutment was selected based on Table 7-27, since the height of the abutments will be 8 m. The economical direct foundation was selected for the foundation type, as a rock layer with an N-value of more than 30 exists at the bottom of the planned footings.

b) Selection of Pier Type

The column type wall pier was selected because it is more economical and easier to construct than other types. The economical direct foundation was adopted because there is a hard rock layer at a very shallow level.

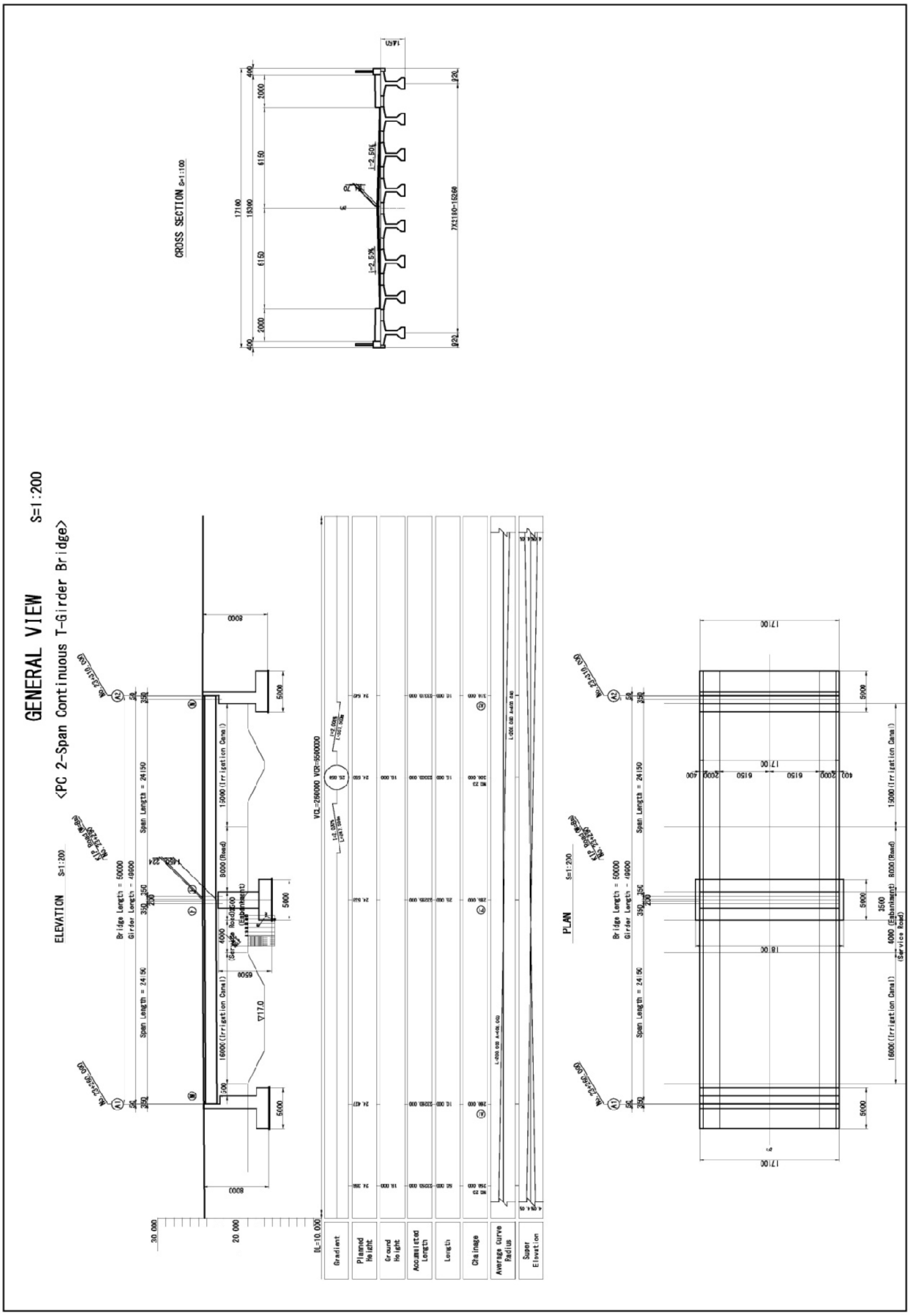


Figure 7-18 General Plan of Bridge across the Planned APGIP Main Canal

7.4 Implementation Programme for Construction of Road between Asutsuare Jct. and Asikuma Jct.

7.4.1 Construction Method

(1) Timing of Construction

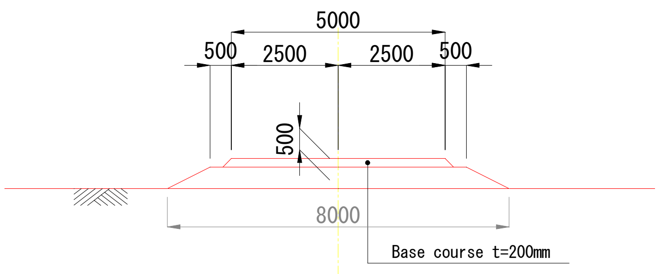
Annual rainfall of the project site is approximately 600 mm and monthly rainfall during rainy season from May to September is approximately 100 mm. Water level of the Volta River is stable through the year because the Akosombo Dam above the project site is regulating the discharge of the river. On the other hand, water level of other rivers related to the project rises during rainy season. Under this situation, implementation of major works such as earth works and pavement works should be considered to avoid rainy season. Regarding bridge construction other than the bridge over the Volta River, it should avoid to construct substructures and abutments during rainy season where the water level rises.

(2) Quality Management of Concrete Works

The project site is tropical climate. Under such warm temperature, there are possibilities to drop slump value of concrete mixtures and bring rapid moisture evaporation, which result in deteriorating concrete quality. Thus, it is recommended to use hot weather concrete in aspects of quality management of concrete works.

(3) Traffic Control during Construction

Proposed alignment of 11 km from Asutsuare Jct. is based on the existing centreline. Although there could be less traffic flows during under construction, it is required to secure proper traffic during under construction by providing detours as shown Figure 7-19.



Source: Study Team

Figure 7-19 Typical Cross Section of Detour

(4) Relocation and Removal

There are some sections to be set electric poles and lines on roadsides. There are possibilities that they are obstacles to constructing the proposed road of 11 km from Asutsuare Jct.. Relocation and removal of the existing electric poles and lines are needed if electric poles are within the road width.

The high tension line in the east-west directions runs around Kpomkpo where the proposed road will be constructed under this line. The Study Team confirmed that height from ground to the lowest level of line is approximately 10 m as well as there is not any vertical steel towers within both sides of 100 m form the proposed centreline.

7.4.2 Material and Equipment Procurement

(1) Construction Material Procurement

The situations of major construction procurement in Ghana are as follows.

- Since quarry sites for procurement of aggregate are dotted around the project site, aggregate could be available relatively easily. However, it should be examined procurement in detailed at the construction stage considering stable supply qualitatively and quantitatively.
- There are some cement production companies in Ghana. It should be examined procurement in detailed at the construction stage considering stable supply qualitatively and quantitatively.
- Bitumen materials will be procured from foreign countries because local procurement is not possible for the entire amount.
- Bridge construction materials such as PC steel materials, steel pipes, cables, bearing and expansion devices will be procured from foreign countries because local procurement is not possible completely.
- It is desirable that filling materials will be procured from near the project site for workability and economic reasons. The Study Team carried out surveys for two borrow pits located as shown in Figure 7-20 and results of survey are shown in Table 7-30.

(2) Procurement of Construction Equipment

- General construction equipment such as backhoe and 50 ton crane are available for local procurement. However, equipment such as crane more than 100 tonne and benoto boring equipment will be procured form foreign countries because local procurement is not possible completely.

Source: Study Team

Figure 7-20 Location of Borrow Pits Sites

Table 7-30 Results of Laboratory Test of Materials from Borrow Pits

No.1

Sample/ Hole No.	Liquid Limit (%)	Plasticity Index (%)	Sieve Sizes (mm)									O.M.C.	M.D.D.	CBR %	
			75	50	37.5	20	10	5	2.36	0.425	0.075	%	g/cm3	95%R.C.	98% R.C.
1	50.0	24.0				100	93	60	37	24	18	7.5	2.250	70	

No.2

Sample/ Hole No.	Liquid Limit (%)	Plasticity Index (%)	Sieve Sizes (mm)									O.M.C.	M.D.D.	CBR %	
			75	50	37.5	20	10	5	2.36	0.425	0.075	%	g/cm3	95%R.C.	98% R.C.
2	30.4	13.8				99	89	56.6	38.6	32.6	25.4	9.60	2.263	41	53

Note: The materials of the above borrow pits are available for filling materials since modified CBR shows a value high at least 41 %

Source: Study Team

(3) Contractors in Ghana

There are one thousand and some hundred construction companies in Ghana, which are classified in five of from “A” to “E” considering a scale, technology and capital. Some major construction companies in Ghana are adequate abilities as a subcontractor of roads and bridges projects since they have many experiences of road construction works.

7.4.3 Implementation Programme for Construction

(1) Construction of Main Towers

a) Working conditions

Each main tower of the bridge consists of two slightly inclined reinforced concrete (RC) shafts of 3.0 m by 4.5 m sections which are connected by a RC beam at the top. The height of the tower is 53 m from the top surface of the pier and about 56 m above the temporary deck. Most of the works required for tower construction will have to be carried out within the top surface of the completed pier, which has a rectangular area of only 22 m long and 6 m wide.

b) Arrangement of Crane

It is recommended that a crawler crane be employed for constructing the tower. As the final tower height will come to 56 m above the deck level, a 100 tonne class crawler crane equipped with a 60 m main boom and 10 m jib boom at the top of the main boom will be required.

c) Construction Joint

A construction joint is expected to be provided every 5 m in height; therefore, the volume of placing concrete at one time for one shaft will be 67.5 m^3. As the placing of concrete is expected to be carried out at both shafts together, the concrete volume per time of pouring will be 135 m^3 in total. Under these conditions, concreting work at each tower including the connection beam will be completed by pouring 12 times.

d) Concrete Form Shoring

In consideration of the tower’s size, shape, height, works area space and interval of construction joints, large-size fabricated steel panels will be the most preferred arrangement for formwork. Thirty panels (20 plus 10 spare) of the recommended size of 1.5 m by 2.5 m will be required as a set for a shaft. Formworks will be preassembled on the temporary deck together with the reinforcing frame and lifted by crane for fixing to the proposed concrete location.

To support the shoring for the RC connection beam at the top of the tower, it is strongly recommended to arrange large-size steel beams between the shafts which are supported by steel brackets fixed at the constructed shafts by anchors. This method will eliminate the need for the 50 m high structural support required in the conventional method.

e) Scaffolding

Steel frame scaffolding will be set up as a working platform around the proposed shafts from the top of the pier and will be gradually extended above the top of the tower as the concrete work progress.

f) Consideration

Installation of a tower crane on the completed pier may be an alternative method to a 100 tonne crane. However, as the proposed connection beam at the top of the tower occupies the central zone of the pier area, the crane location will be seriously restricted. If the tower crane is located underneath the beam's location, it cannot be used for construction of the beam itself. Therefore, the actual available space for the tower crane should be carefully studied, especially for the space of the crane base if a tower crane is to be used.

(2) Transportation of bridge girder components (20 m wide, 4 m long and 3 m high, 50 tonnes) from Tema Port to the assembling yard

Both inland and marine/river transportation methods could be considered feasible.

a) Inland Transportation by Trailer

The following three routes were studied (see Figure 7-21).

Source: Study Team, Length data are based on Google Earth

Figure 7-21 Transportation Route from Tema Port to the Bridge Location

1) Route-1 (70 km) - Feasible and Recommended

Tema Port - N2 - Asutsuare Junction - Asutsuare - Volivo (assembling yard)

This route is the best route. It is preferable that the proposed road improvement work between Asutsuare Junction – Asutsuare – Volivo is completed before transportation is commenced. If the improvement work is not completed, the following additional measures have to be taken:

- Repair and maintain the partially damaged Double Bituminous Surface Treatment (DBST) roads between Asutsuare Junction and Asutsuare.
- Carry out regular maintenance on earth roads between Asutsuare and Volivo

2) Route -2 (80 km) - Not Feasible

- Tema Port - N2 – Akuse Junction - Akuse - Asutsuare - Volivo (assembling yard)
- It was found by investigation on site that the existing Bailey Bridge near Akuse is clearly not strong enough to bear the load of a trailer with 50-tonne girder. Reinforcement of the bridge is not realistic structurally in the view of its length (58m).

3) Route-3 (95km) - Feasible, Contingency route -1

Tema Port - N1 – Sege – Aveyime - Volivo (assembling yard)

This route is about 25 km longer than Route-1. Due to the current busy traffic conditions caused by heavy transport vehicles between Sege and Aveyime, the road is expected to be damaged and frequent repair work will become necessary. The overall road condition is observed to be similar to that of Route-1, so its longer distance will be a disadvantage. However, this route is contingency plan for Route 1.

b) Marine + River Transportation by Barge (150km) feasible–Contingency plan-2

In this option, imported girders from the manufacturing country should be temporarily stocked at the port and loaded onto barges (flat pontoons) by means of port facilities. The barges carrying the girders will be towed by tug boat up the Volta River to the assembling yard. A 200 tonne crane is required to unload them at the yard.

Due to towing against the river stream and the considerably longer transportation distance, one trip, including loading and unloading time, may take two days. However, it is a valuable contingency route in case the land routes become difficult due to unforeseen incidents. The following potential hazards should be taken into consideration if it becomes necessary to use this route.

- There is space restriction underneath the Lower Volta Bridge (horizontally 28 m and vertically 7m)
- There may be shallow spots of less than 2 m water depth within the intended course in the river.
- Schedule management for usage of the facility is required, as the unloading facility at the assembling yard will also be used for loading of assembled girders and construction materials for the pier on the opposite side.

It is concluded that land transportation will be more economical and faster even though some additional cost is required for repair and maintenance of roads.

(3) Consideration on Construction Plants

a) Cost Estimates for Construction Plants

The cost estimation for the main construction plants should be based on the assumption of importation from other countries including Japan because there are no plant manufacturers in Ghana. The leasing cost of such plants is therefore extremely high.

b) Concrete Batching Plant

The quantity of concrete required for the proposed new bridge across the Volta River will be around 8,000– 9,000 m^3 in total including both side abutments. It will not be economical to establish batching plants for this quantity. However, for the assurance of quality and timely supply of concrete, it is recommended to establish one batching plant somewhere on both sides of the river. These batching plants can also be used for the construction of other concrete structures such as small bridges, middle bridges, box culverts and so on for the project.

7.4.4 Temporary Work for Construction of Bridge across the Volta River

In comparison with the road construction sections, construction of a long bridge across the Volta River will require a greater variety and larger scale of temporary works, which will consequently account for a considerable share of the total cost of bridge construction. Some examples of temporary works are introduced below, and are used as assumptions for estimating the cost of temporary works in the Study.

(1) Steel-pipe Pile Cofferdam for Footing and Pier Construction

The proposed main piers are located in the river about 120 m away from both riverbanks. The foundation of the reinforced concrete piers is designed as a spread footing, which is placed directly on the rock bed underneath the riverbed. As all of the construction activities related to such structures have to be carried out in the river, a cofferdam must be provided so that the works can be carried out in dry conditions.

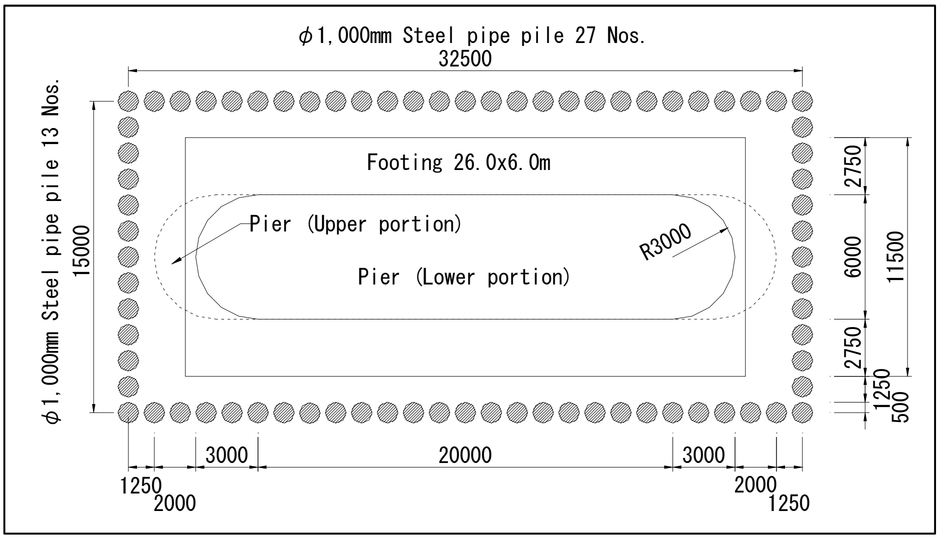
In order to carry out piling work effectively to overcome the existing rock bed and to completely exclude the river water, a steel pipe pile cofferdam is considered to be the most suitable method.

a) Shape and Size of Cofferdam

Considering the size of the inner structure, the horizontal area of the cofferdam is required to be about 32 m by 15 m. 1,000 mm diameter steel pipe piles will be used (see Figure 7-22).

b) Method of Piling

Piling will be performed on the temporary deck as described below. The piles must be penetrated into the rock through the riverbed to ensure that no water penetrates 1,400 mm diameter holes will be drilled 3 m deep into the rock bed by a rock boring machine for installing the 1,000 mm diameter steel pipe piles with connection accessories. Upon completion of piling work and completely closing the cofferdam, the gaps around the piles and pile connections will be thoroughly filled with cement mortar by grouting to protect the cofferdam from water ingress. The pile heads will be cut off at the same level as the temporary deck surface.



Source: Study Team

Figure 7-22 Planned Layout of Steel Pipe Cofferdam

c) Considerations

Boring into the rock bed and grouting for sealing the gaps between the rock holes and the steel piles are very important activities for safety during construction of the footings and piers. The method of these works should be carefully chosen in consultation with piling specialists.

(2) Temporary Staging over the Volta River for Bridge Pier and Cofferdam Construction

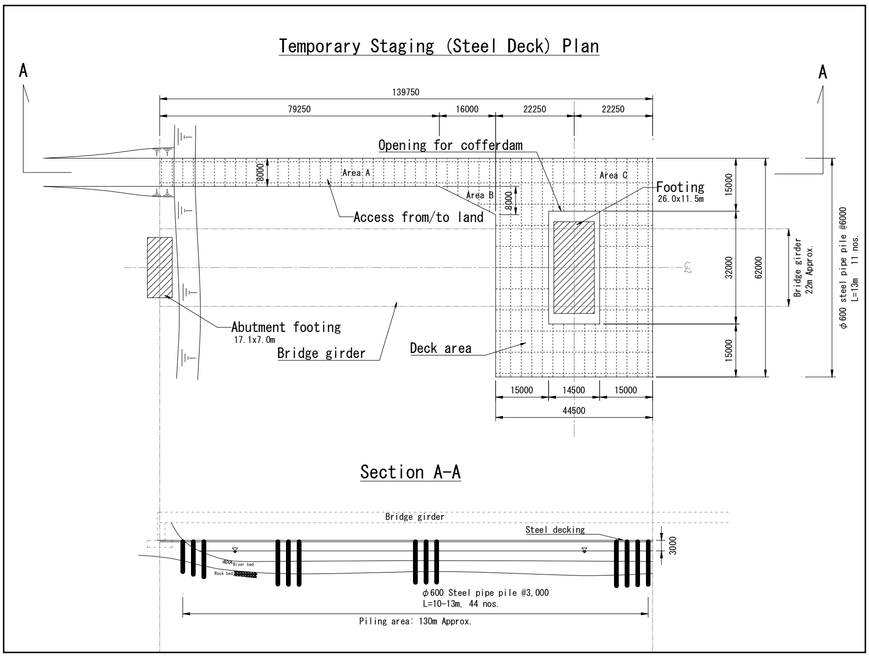
As mentioned above, all of the construction activities have to be carried out in and above river water. However, it is not recommended to carry out the works using construction vessels judging from the study on basic construction factors such as effectiveness of works, safety, transportation of materials including concrete, and height restriction of the existing Lower Volta Bridge. The best solution will be to set up temporary decking above the river water around the pier location and to link it with the riverbank. A deck will be needed at both tower locations. They will be used for construction of not only the footings and piers but also the towers, even for initial installation of bridge girders.

a) Location, Shape and Size

Temporary staging will consist of two combined portions. One is for construction of the pier in the river, which will be a rectangular are of about 45 m by 62 m around the proposed pier. The other is an access road to link the pier construction area with the river bank and will be 8 m wide and about 114 m long (see Figure 7-23). The access deck will be built alongside the proposed bridge but it should be kept at a certain distance from the edge of the proposed steel girder so as not to obstruct the movement of the girder transport barge and tug boat. As a bridge girder assembling yard is planned to be set up somewhere along the lower stream of the proposed bridge, the access staging should be located in the upper stream of the proposed bridge so as to facilitate girder transport.

b) Considerations

The whole staging will be built about 3 m above the river water level and the existing height of the riverbank at the location is observed to be about 6 m to 7 m above water level. Therefore, slope forming work to the riverbank will inevitably be required in order for land access to make smooth vertical connection to the decking level. The gradient of the forming slope should be designed taking into account the type and size of the vehicles together with their gradability.



Source: Study Team

Figure 7-23 Example of Temporary Staging

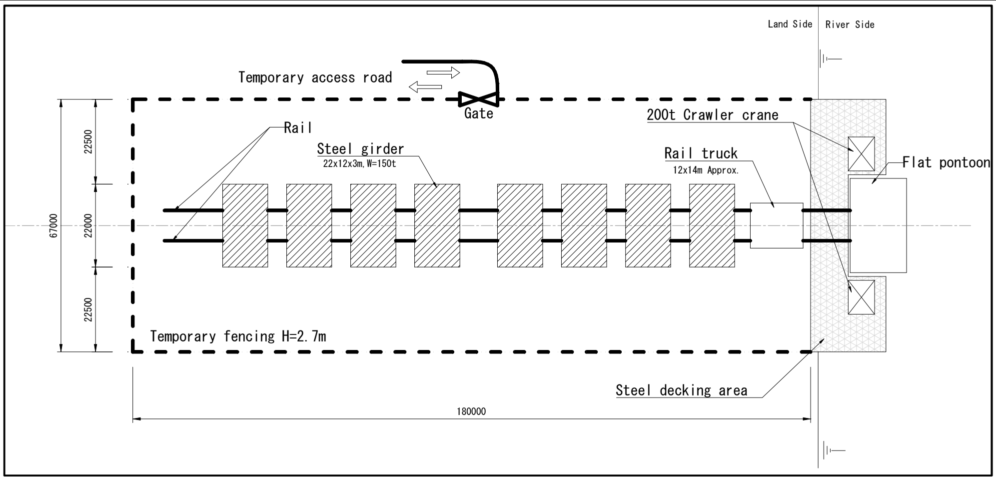
(3) Girder Assembling Yard and Girder Loading Facilities

Bridge girders will be manufactured in another country and transported by vessel to Tema Port. The width of the girder component is designed to be approximately 3.0 m when exported. As the installation of approximately 3-m width girders is less effective, a yard must be established for combining the girder components to make them of suitable width. Although the girder installation work will takes place at two locations, only one yard is required because the combined girders are transported on the river by barge to the installation locations.

a) Location and Size of the Yard

For economical land transportation of girder components and easy loading of assembled girders onto barges for river transportation, the desirable location of the yard is the right side of the river and somewhere between the proposed bridge and the existing Lower Volta Bridge. In order to save time for river transportation, a location closer to the proposed bridge is preferable. At the location of the yard, it is preferable that a water depth of 2 m can be secured within 10 m from the river bank so that the area of temporary decking can minimised.

The required size of the yard is about 180 m by 63 m with extra area for unloading facilities. The size of each piece of assembled bridge girder is expected to be 22 m by 12 m and the weight will be about 150 tonnes. The required yard size is planned based on the assumption that 8 units can be assembled concurrently to match the numbers of units of each shipping (see Figure 7-24).



Source: Study Team

Figure 7-24 Planned Layout of Girder Assembling Yard

b) Loading Facilities

The assembled 150 tonnes girder will be loaded onto a rail truck using a lifting jack and shifted to the loading deck. In order to bear the heavy weight of girders, the rails will be installed on a reinforced concrete foundation. Two 200-tonne crawler cranes will work together to load the girder safely onto the barge. The barge is towed by tug boat to the installation point. The length of the barge will be limited to 24 to 26 m to allow the 200 tonne cranes to be able to handle the 150 tonne girders within a safe working radius (maximum safety radius is 12 m for a weight of 75 tonnes). These 200 tonne cranes will be used for assembling steel girders as well.

The loading facility can also be used for the following purposes:

- Transportation of materials across the river by barge for constructing of the tower on the opposite side.
- Transportation of any materials directly from Tema Port including girder components as a contingency method in case inland transportation becomes unfavourable.

7.5 Implementation Schedule

7.5.1 Construction by Sections

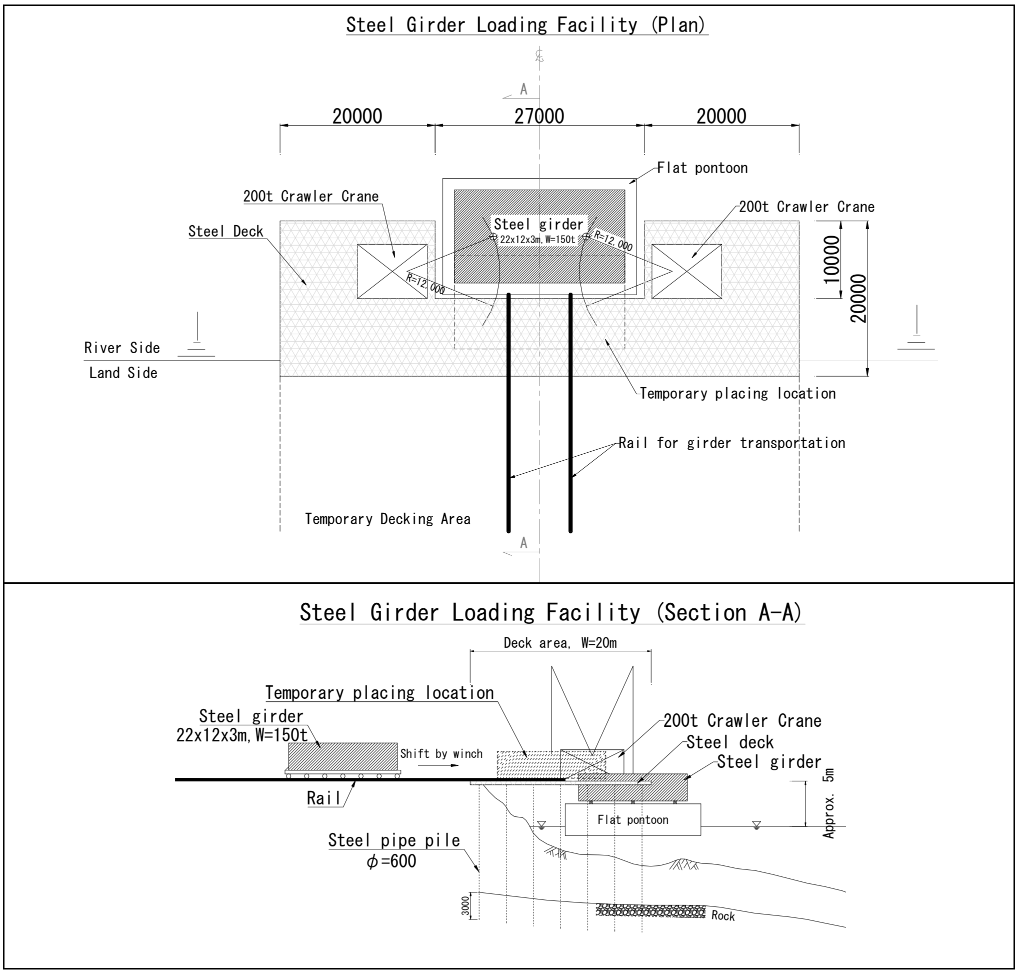
Construction of sections is divided into three as shown in Table 7-31, considering the following items:

- Project site is separated into two by the Volta River in terms of carrying materials and equipment

Table 7-31 Construction of Sections

Section	Starting Point	Ending Point	Length (km)
Section 1	Asutsuare Jct.	Volivo	28.30
Section 2	Bridge across the Volta River		0.52
Section 3	Dufor Adidome	Asikuma Jct.	38.40
Total			67.22

Source: Study Team



Source: Study Team

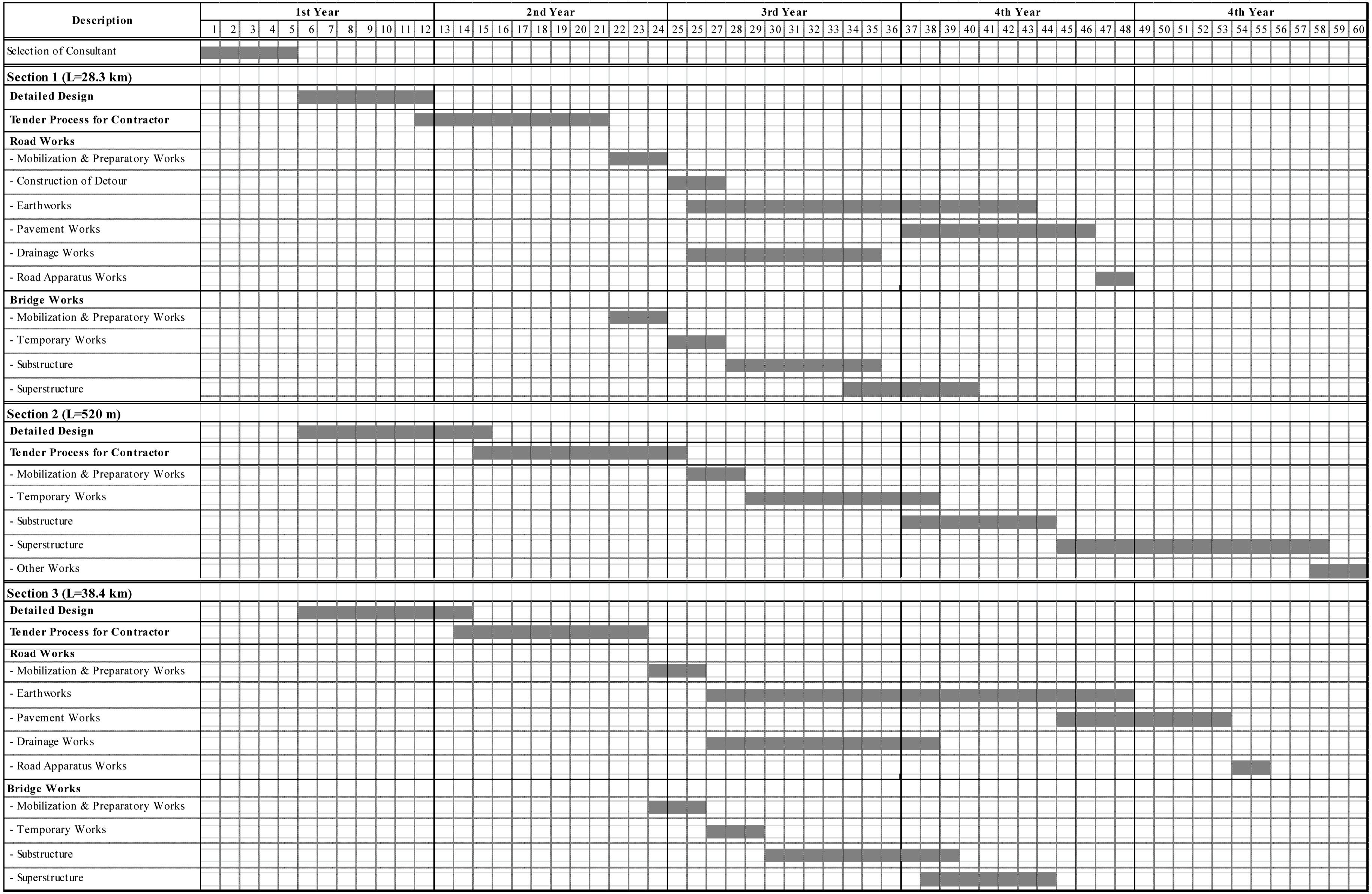
Figure 7-25 Steel Girder Loading Facility

- Construction duration of the proposed project is assumed as three years from 2014 to 2016.
- Construction cost of bridge over the Volta River is high (approximately 50% of the project cost), and construction duration of this bridge takes three years at least.

7.5.2 Implementation Schedule

Overall implementation schedule for construction of road between Asutsuare Jct. and Asikuma Jct. is shown in Table 7-32, considering ordering of three sections at the same time.

Table 7-32 Implementation Schedule for Construction of Road and Bridges between Asutsuare Jct. and Asikuma Jct.



Source: Study Team