CHAPTER 13 SELECTION OF OPTIMUM ALTERNATIVE

13.1 Assessment of Optimum Road Alignment

For the road alignment (horizontal), three alternative alignments were considered. The first one is avoiding the area of the military barracks, but because of this, the alignment interfere with the wild park on the Botswana side.

The second one interfere with a part of military barracks with the awareness of utilizing a part of the military area by both the Ministry of Defence and Ministry of Works, Transport and Communications of Botswana. This alignment intends to minimize the interference to natural and wildlife areas and maximise the utilisation of the areas where natural forest has already been cut and is utilised for the existing road and other facilities.

The third one interferes with the area of military barracks. This alignment intends to most minimize the interference to natural and wildlife areas and maximise the utilisation of the areas where natural forest has already been cut and is utilised for the existing road and other facilities.

13.2 Assessment of Bridge Type

To select optimum bridge type, four bridge types were considered among the eight possible bridge types in accordance with the optimum span length (cost minimum) from 180 m to 320 m. The technical features of each type of bridge are highlighted for the assessment in terms of economic, social, and environmental aspect. The four bridge types are (A) PC-Box Girder (Ls = 180m), (B) PC-Box Girder (Ls = 220m), (C) PC-Extra–dosed (220m), and (D) PC Cable-stayed (320m). The main bridge of (A) and (B) have two pier locations in the river, and the rectangular – shaped section with concrete structure. The main bridge of (C) is structured with the external prestressing tendons to hold the eccentricity from the centroid of the girder section. The pier locations are as for the previous bridge types. The structural system of (D) bridge type is to lift and compress the concrete girder section by stay cables.

13.3 Assessment of Border Posts

The Project involves the construction of three border posts: (1) Kazungula bridge border posts both in Zambia and Botswana sides, (2) Kazungula road border post in Zimbabwe. In the course of the field investigation survey trips to the existing border posts located around the proposed new project site, the Study Team encountered various issues on the operation and management. Among those, the delay of border processing procedure is one of the most prominent issues since it is reportedly stagnating the economic growth of the Southern African regional countries. In this respect, the new Project is proposed to be adopted with the one-stop border system in line with the recommendation of the SADC.

On the basis of the one-stop border system, three alternative border types were then proposed for determination of the optimum border post: (1) Separate type, (2) Integrated type, and (3) Semi-integrated type. They have been compared with each other in terms of the following aspects: site area to be occupied, type of facilities required, simplicity of road alignment, number of formality processes required, user's convenience, easiness of operation and maintenance, legal aspect, economic aspect and construction period required.

The location of border posts have been likewise proposed in consideration of the availability of the existing lots, environmental conditions in the adjacent wildlife area and the nature of the proposed border posts. Thus, the optimum border posts for the proposed Project has been assessed.

13.4 Result of Assessment

The alternatives were assessed in terms of technical features, economic interpretation and environmental impact. The results of assessment were as below:

(1) Road Alignment

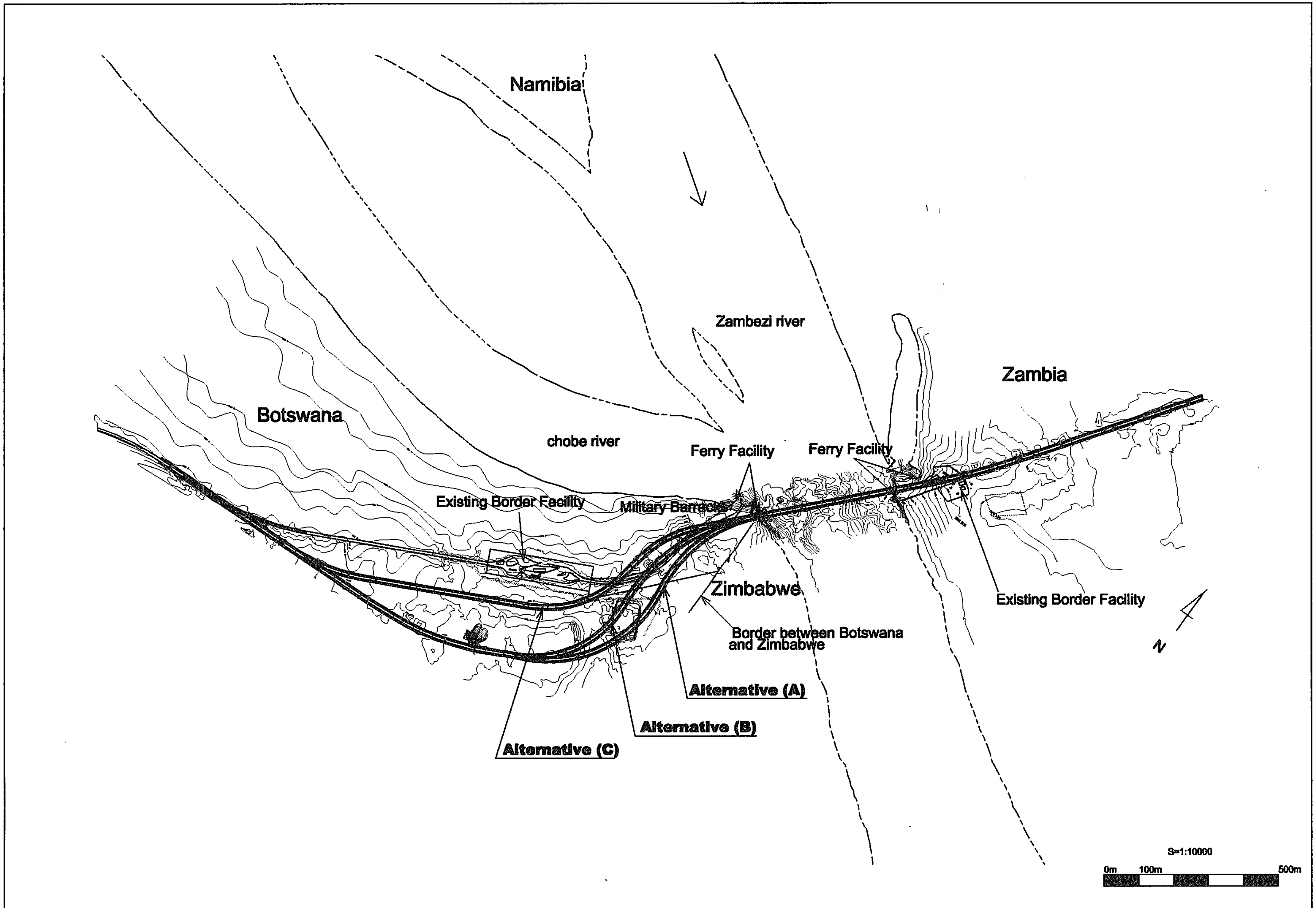
Alternative (B) is recommended for geotechnical reasons, although this case requires demolition cost. This case reduces impact on wild life.

(2) Bridge Type

Alternative of (C) PC Extra-dosed (Ls=220m) was recommended because of less hydrodynamic issues contained in these cases. These cases shall produce moderate sizes of economic return. No significant environmental impact exists in these cases.

(3) Border Post

Alternative (A) of the separated type of border post is recommended because of no requirements of grade-separated road structure. Easy procedure of border clearance shall be realized due to streamlined traffic flow realized in this case. Relatively small scale of facilities exert less environmental impact.



PROJECT NAME	IMPLEMENTATION AGENCY	EXECUTING AGENCY	JICA STUDY TEAM	DRAWING TITLE	DWG NO.
THE FEASIBILITY STUDY ON THE PROPOSED KAZUNGULA BRIDGE OVER THE ZAMBEZI RIVER BETWEEN BOTSWANA AND ZAMBIA	JICA JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	MINISTRY OF WORKS, TRANSPORT AND COMMUNICATIONS REPUBLIC OF BOTSWANA MINISTRY OF WORKS AND SUPPLY REPUBLIC OF ZAMBIA	NIPPON KOEI CO.,LTD. ORIENTAL CONSULTANTS CO.,LTD	Figure 13.1.1 Alternative Route	

Figure 13.1.2 Evaluation of Road Alignment

Alternatives	Technical Description	Economic Interpretation	Environmental Impact
Alternative (A)	- Road Length : 3 km - Minimum Radius of Curve : 300 m - Maximum Embankment Height : 5 m (1) Alignment avoids military barracks. (2) Alignment of bridge section in Botswana side is smaller than Alternative 2 (R=300m). (3) Wild park area is bigger than Alternative 2.	(1) Passage of the access road on the side of wild park shall require land reclamation and levelling at the edge of the park, which shall result in cost increase at this case. (2) Traffic accidents involving wild animals are prone to occur in this case due to close alignment of the road to the wild park. (3) Relatively wider spaces to be created in between this road alignment and existing military barracks can accommodate larger border facilities, community spaces and so on.	(1) This alignment can avoid the demolition of existing military barracks on Botswana side (2) Though this area is not a part of National Park, this alignment can disturb animal tracks on Botswana side such as elephants, buffalos and lions, which go to water points in the area. Especially because of the gradient of the road, animals have to choose gentle gradient point to go to water points. (3) Since the width of the road is about 12m, large scale of land must be acquired and accordingly certain amount of bush, which feeds animals, must be cleared. (4) On Zambia side, this alignment might affect the existing border control facility. In case that the Project have to demolish the existing one, Kazungula people would be against the plan, since this facility is a “sentimental monument” for them.
Alternative (B)	- Road Length : 3 km - Minimum Radius of Curve : 300 m - Maximum Embankment Height : 5 m (1) Alignment pass in a part of military barracks. (2) Alignment of bridge section in Botswana side is bigger than Alternative 1 and 3 (R=500m). (3) Wild park area is smaller than Alternative 1.	(1) Passage of the access road inside the military yard require demolition of existing facilities and their relocation which shall result in cost increase of this case. Compensation for the existing facilities is also inevitable. (2) Relatively narrow spaces in between this road alignment and existing military barracks shall limit new location of buildings and facilities.	(1) This alignment has to demolish the existing military barracks on Botswana side. As a result Botswana side has to move the barrack in somewhere else. This new development activity might cause other environmental impact. (2) This alignment might not significantly disturb animal tracks on Botswana side such as elephants, buffalos and lions, which go to water points in the area. (3) Since the width of the road is about 12m, large scale of land must be acquired and accordingly certain amount of bush, which feeds animals, must be cleared. (4) On Zambia side, this alignment might affect the existing border control facility. In case that the Project have to demolish the existing one, Kazungula people would be against the plan, since this facility is a “sentimental monument” for them.
Alternative (C)	- Road Length : 3 km - Minimum Radius of Curve : 300 m - Maximum Embankment Height : 5 m (1) Alignment pass in the area of military barracks. (2) Alignment of bridge section in Botswana side is almost straight. (3) Wild park area is smallest than other Alternatives.	(1) Straight alignment shall allow vehicles to be driven faster speed and shall reduce travel time. (2) Should no access control be introduce, this alignment shall induce new location of building, commercial development on both sides of the road. Especially, land development towards the Chobe River shall be proceeded more rapidly. (3) This alignment shall require complete demolition of the military barracks of Botswana side. The construct of new barrack at nearby area is inevitable.	(1) This alignment has to demolish the existing military barracks on Botswana side. As a result Botswana side has to move the barrack in somewhere else. This new development activity might cause other environmental impact. (2) This alignment might not significantly disturb animal tracks on Botswana side such as elephants, buffalos and lions, which go to water points in the area. (3) Since the width of the road is about 12m, large scale of land must be acquired and accordingly certain amount of bush, which feeds animals, must be cleared. (4) On Zambia side, this alignment might affect the existing border control facility. In case that the Project have to demolish the existing one, Kazungula people would be against the plan, since this facility is a “sentimental monument” for them. (5) In overall, this alignment would have least environmental impact, since this is already developed area.

Figure 13.2.1 Assessment for Optimum Bridge Type

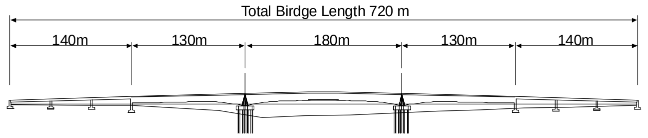
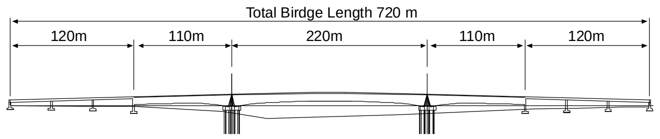
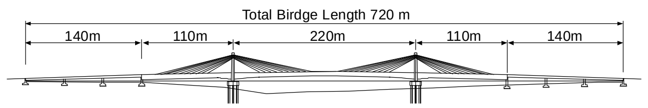
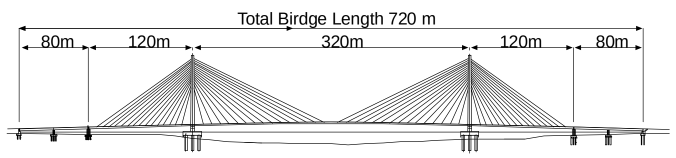
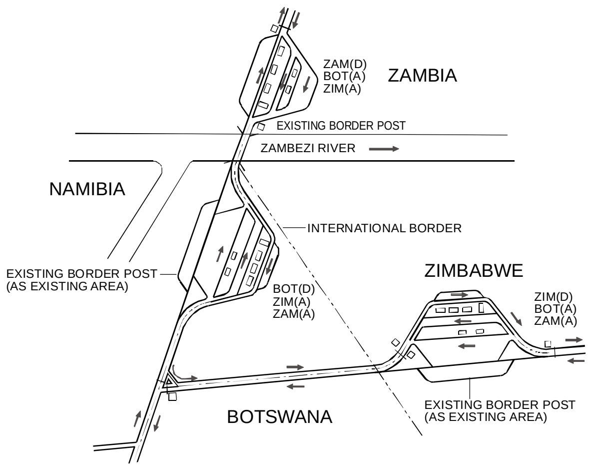
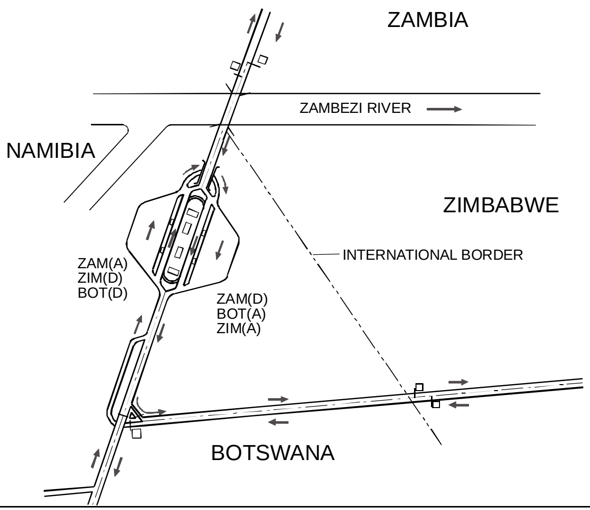
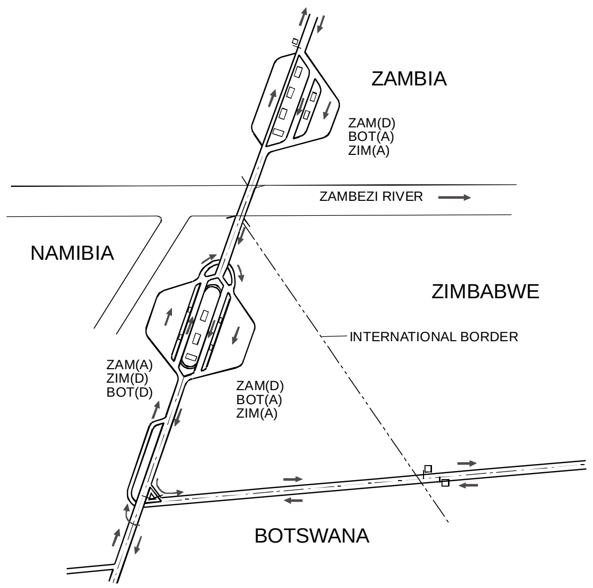
Features of Bridge	Technical description	Economic Interpretation	Environmental Impact
(A) PC- Box Girder (Ls =185m) 	(1) The main girder is concrete box and its depth is 9m at supporting point, (2) The pier in the river is 2 locations. (3) Total bridge length is 720m including 440m long of the main bridge. (4) The approach span bridges with 47m span length are provided on both sides of the main bridge. (5) The shorter central span length require more treble and longer period of works in the river.	(1) Longest jetties (130m x 2) shall require additional construction cost compared with that in other 3 cases. Total construction cost shall be of medium size among the cases. (2) The height of the carriageway is at medium level which requires moderate amount of vehicle operating cost at the approach road. (3) Preliminary cost per one square meter (cost ratio): 6,360US$/m^2 (1.00) (4) Vehicle operation cost is smaller than that of case (B).	(During the construction) (1) Since, for the construction of piers, cofferdam will be constructed, drilling noise is such that it might annoy both people and animals in the area. (2) Unless otherwise the water that will be used for the construction will be properly managed, it might contaminate the river water. (3) Dust that will be caused by construction activity might worse air quality of the area. (After completion) (1) Since the gradient of the bridge is 3%, which is relatively steep compared with the Type C and D, traffic noise and emission might cause more noise and air pollution. (2) Since two piers are relatively thicker than Type C and D, they might disturb the movement of fish and animals such as hippopotamus and crocodiles.
(B) PC-Box Girder (Ls = 220m) 	(1) The main girder is concrete box and its depth is 14m (2) The pier in the river is 2 locations. (3) Total bridge length is 720m including 440m long of the main bridge. (4) The approach span bridges with 47m span length are provided on both sides of the main bridge. (5) The construction period is normal.	(1) Longer centre span (220m) shall require additional construction cost on this segment compared with that in case (A). However, reduced jetty length (110.0m x 2) shall reduce the cost on this segment. (2) Deepest girder (14.0m) among the four cases requires sharp slope at the approach road which shall result in higher vehicle operation cost and lower vehicle speed. (3) Preliminary cost per one square meter (cost ratio): 6,741US$/m^2 (1.06) (4) Highest vehicle operation cost is expended.	(During the construction) (1) Since, for the construction of piers, cofferdam will be constructed, drilling noise is such that it might annoy both people and animals in the area. (2) Unless otherwise the water that will be used for the construction will be properly managed, it might contaminate the river water. (3) Dust that will be caused by construction activity might worse air quality of the area. (After completion) (1) Since the gradient of the bridge is 3%, which is relatively steep compared with the Type C and D, traffic noise and emission might cause more noise and air pollution. (2) Since two piers are relatively thicker than Type C and D, they might disturb the movement of fish and animals such as hippopotamus and crocodiles. (3) Since the space between the two piers is wider than the Type A, impact on aquatic life is relatively smaller than that of Type A.
(C) PC- Extra –dosed (Ls = 220m) 	(1) The main girder is concrete shallow box and its depth is 6m at supporting point. (2) The height of pylon is 22m above the bridge deck. (3) The pier in the river is 2 locations. (4) Total bridge length is 720m including 440m long of the main bridge. (5) The approach span bridges with 47m span length are provided on both sides of the main bridge. (6) The construction period is normal.	(1) Lower construction costs on jetties and main girder are expected of due to shorter length of jetties and shallow depth of main girder. 22.0m high pylon requires additional construction cost and resultant large expenditure for its maintenance. (2) Lower level of carriageway shall reduce the magnitude of vehicle operation cost compared with those in former 2 cases. (3) Preliminary cost per one square meter (cost ratio): 5,724US$/m^2 (0.90) (4) Second smallest vehicle operation cost among the 4 cases is expended.	(During the construction) (1) Since, for the construction of piers, cofferdam will be constructed, drilling noise is such that it might annoy both people and animals in the area. (2) Unless otherwise the water that will be used for the construction will be properly managed, it might contaminate the river water. (3) Dust that will be caused by construction activity might worse air quality of the area. (After completion) (1) Since the gradient of the bridge is 2%, which is relatively gentle compared with the Type A and B, traffic noise and emission might cause less noise and air pollution than Type A and B. (2) Though two piers are relatively thinner than Type A and B, they still might disturb the movement of fish and animals such as hippopotamus and crocodiles. (3) Since the height of pylon is 22m above the bridge deck, it might affect aesthetic view of the area. However, there are divided opinions on it. There are those who think this bridge type is aesthetically favourable and, on the other hand, there are others who think this type of bridge might cause aesthetic pollution. Accordingly through public consultation in terms of selection of bridge type will be essential.
(D) PC – Cable – Stayed (Ls = 320m) 	• The main girder is shallow concrete box and its depth is 4m at supporting point. • The height of pylon is 55m above the bridge deck. • The pier in the river is 2 locations at the low velocity area of the river flow. • Total bridge length is 720m including 560m long of the main bridge. • The approach span bridges with 40m span length are provided on both sides of the main bridge. • The construction period is longer due to the installation and adjustment of prestressing of stay cables.	(1) Greatest construction cost is expected of due to great magnitude of construction cost of stayed cables and their maintenance works, although the shallow depth of girder require less cost. (2) Shallow depth of girder reduce vehicle operating cost due to small gradient at approach road. (3) Preliminary cost per one square meter (cost ratio): 8,268US$/m^2 (1.30) (4) Smallest vehicle operation cost among the 4 cases is expended.	(During the construction) (1) Since, for the construction of piers, cofferdam will be constructed, drilling noise is such that it might annoy both people and animals in the area. (2) Unless otherwise the water that will be used for the construction will be properly managed, it might contaminate the river water. (3) Dust that will be caused by construction activity might worse air quality of the area. (After completion) (1) Since the gradient of the bridge is 2%, which is relatively gentle compared with the Type A and B, traffic noise and emission might cause less noise and air pollution than Type A and B. (2) Though two piers are relatively thinner than Type A and B, they still might disturb the movement of fish and animals such as hippopotamus and crocodiles. (3) Since the height of pylon is 55m above the bridge deck, it might significantly affect aesthetic view of the area. (4) Since the space between the two piers is wider than the Type C, impact on aquatic life is relatively smaller than that of the Type C.

Figure 13.3.1 Assessment for Optimum Type of Border Post

Type of Border Post	Technical Description	Economic Interpretation	Environmental Impact
(A) SEPARATED BORDER POST  	(1) The site area of each border post is required normal size. (2) Border facilities will be simple. (3) Road alignment is plane and not crossing and so economic. (4) Formality for custom and immigration could be done at one time at one border post (minimizing time). (5) Need mutual agreement about legislative matters. (6) Existing border could be operational while new borders are being constructed.	(1) One-stop border facilities at each country shall streamline the border traffic stream due to simple and clear-cut series of procedure to be realized by this system. (2) Traffic signs/boards to conduct the Zambia–Zimbabwe traffic to proper lane is inevitable to be introduced. (3) Smallest construction cost, due to small scale of facilities for each country, is expected of.	(1) Zambian side (During the construction) - Some tribal land, should be acquired and certain amount of trees must be removed. Though there is no regulation in Zambia to compensate tree cutting, the project must seek some measures of compensation. - There is no resettlement involved - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken (During the operation) - The existing border control facility is a "sentimental monument" for Kazungula people. Accordingly, it should remain as it is and should be used for other purposes. - New border facility might generate employment opportunities for local people. (2) Botswana side (During the construction) - Some tribal land, should be acquired and certain amount of trees must be cut off. Though there is no regulation in Botswana to compensate tree cuttings, the project must seek some measures of compensation. - There is no resettlement involved - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken - Though this area is not a part of national park, animals such as elephants, buffalos and lions are straying to fetch water. During the construction, unless construction camps site are properly planned, these animals can attack workers. At the same time, construction work hour should be restricted from 6 am to 5 pm to avoid the disturbance of animal movement. (During the operation) - New border facility might generate employment opportunities for local people. - Certain protection measures will be necessary against the damage by animals. - Local people are worried about the transmission of HIV (AIDS) and other sexually transmitted diseases (STD) by truck drivers, who stay at the facility or its surrounding area (3) Zimbabwe side (During the construction) - Some national park land, should be acquired and certain amount of trees must be removed. The project must follow necessary measures to do development activities in national park according to legislations and regulations of national parks in Zimbabwe. - There is no resettlement involved - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken - Since this is a part of national park, animals such as elephants, buffalos and lions are straying. During the construction, unless construction camps site are properly planned, these animals can attack workers. At the same time, construction work hour should be restricted according to the movement of animals. (During the operation) - Certain protection measures will be necessary against the damage by animals. - Life and traffic noise might cause adverse impact on animals.
(B) INTEGRATED BORDER POST  	(1) All borders are integrated at one place. (2) Huge site area is needed. (3) Legislative agreement is needed. (3) 2-Underpass will be needed which may entail cost increase. (4) User's convenience is high since all formalities could be done at one time. (5) During construction, it may need some arrangement for maintaining existing border post.	(1) One but large scale facility has to be constructed which requires large extent of land and its preparation. Large construction cost is expected of, among the 3 systems described herein. (2) Notice, traffic signs and signboards to conduct users to proper direction also have to be introduced. (3) Grade-separated pass way to conduct cross border vehicles to proper direction is inevitable to be constructed. Construction of this kind of pass way requires considerable amount of cost.	(During the construction) - Large scale of land than Type A and C, which is tribal land, should be acquired and certain amount of trees must be cut off. Though there is no regulation in Botswana to compensate tree cuttings, the project must seek some measures of compensation. - There is no resettlement involved - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken - Though this area is not a part of national park, animals such as elephants, buffalos and lions are straying to fetch water. During the construction, unless otherwise construction camps site will not be properly planned, these animals can attack workers. At the same time, construction work hour should be restricted from 6 am to 5 pm to avoid the disturbance of animal movement. - Since underpasses will be constructed, drainage should be appropriately planned. (During the operation) - New border facility might generate employment opportunities for local people. - Certain protection measures will be necessary against the vandalism of animals. - Local people are worried about the transmission of HIV (AIDS) and other sexually transmitted diseases (STD) by trackers, who stay at the facility or its surrounding area

(Continued)

Type of Border Post	Technical Description	Economic Interpretation	Environmental Impact
(C) SEMI-INTEGRATED BORDER POST  	(1) One separate type border post combining with semi-integrated border post. (2) 2-Underpass will be needed which may increase construction cost. (3) Legislative agreement is needed (4) During construction, some arrangement on the semi-integrated post is needed.	(1) Relatively large scale facility on Botswana side has to be constructed to perform the formalities for Botswana and Zimbabwe at one time. (2) Large construction cost than that of case (A), but smaller cost than case (B), is expected.	(1) Zambian side: (During the construction) - Some tribal land, should be acquired and certain amount of trees must be removed. Though there is no regulation in Zambia to compensate tree cuttings, the project must seek some measures of compensation. - There is no resettlement involved - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken (During the operation) - The existing border control facility is a "sentimental monument" for Kazungula people. Accordingly, it should remain as it is and should be used for other purposes. - New border facility might generate employment opportunities for local people. (2) Botswana side: (During the construction) - Some tribal land, should be acquired and certain amount of trees must be cut off. Though there is no regulation in Botswana to compensate tree cuttings, the project must seek some measures of compensation. - There is no resettlement involved - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken - Though this area is not a part of national park, animals such as elephants, buffalos and lions are straying to fetch water. During the construction, unless otherwise construction camps site will not be properly planned, these animals can attack workers. At the same time, construction work hour should be restricted from 6 am to 5 pm to avoid the disturbance of animal movement. - Since underpasses will be constructed, drainage should be appropriately planned. (During the operation) - New border facility might generate employment opportunities for local people. - Certain protection measures will be necessary against the vandalism of animals. - Local people are worried about the transmission of HIV (AIDS) and other sexually transmitted diseases (STD) by truck drivers, who stay at the facility or its surrounding area. (3) Zimbabwe side (During the demolition) - Water, air, noise pollution can be expected unless appropriate measures should otherwise be taken - Demolished materials should be appropriately dealt with

CHAPTER 14 PRELIMINARY DESIGN

14.1 Bridge Design for Main and Approach Span Bridge

14.1.1 Arrangement of Bridges

In the dry season, Zambezi River width at project site is around 400 m, and it widens to 800 m in flood season. The average water depth of river is about 7m in dry season and rises by around 5m in flood season. The riverside terrain on both sides is very flat and, in flood season is covered with water but the water depth is not very deep. The length of the main bridge is 465 m and approach span bridges are arranged on both sides. The Proposed Bridge has total length of 720m.

14.1.2 Main Bridge

(1) Structural Features

a) The superstructure is Prestressed Concrete Extra-dosed type that is included in the Cable-stayed bridge category. For this Project, the pylon was lowered to reduce the forces transferred to stay cables and more forces to concrete girder due to the overall vertical loadings. Accordingly this enables the rigidity of concrete girder to be maintained so that girder deflection induced by heavier truck loading will be mitigated.

b) The main girder itself is a continuous girder system supported by elastic shoes, which provides a solution for the temperature restriction to the substructures.

c) The material of the stay cable is strand cables of 37S15.2, and tensile capacity due to fatigue is 60% of the ultimate strength of cable. The stress variation of the cables will be kept within 10 kgf/seq.mm.

(2) Configuration

a) Span arrangement: 122.500+220.000+122.5=465.000m
b) Trapezoidal girder shape with two (2) cells
c) The girder depth: 3.0m at the middle of central span
6.0m at the supporting point of the piers

(3) Foundation

The foundation type is multi-column (cast-in-situ) pile with diameter of 3.0 m in accordance based on technical and economical comparisons. The penetration depth of the pile should reach to the basalt rock layer below alluvial sand which is being found in the weathered basalt rock.

14.1.3 Approach Span Bridges

The approach span bridges on the backward land from the riverside adopted 3-spans-continuous-prestressed concrete girder system with trapezoidal cross section. The foundation is cast-in-situ piles with diameter 1.0 m, which should be penetrated into the weathered basalt rock. However, the final depth of the design pile should be determined in accordance with the geological judgement of Rock Quality Designation (RQD).

14.2 Approach Roads

According to CHAPTER 11,12,13, preliminary design of road was executed for optimum route as follows:

14.2.1 Horizontal Alignment

Horizontal alignment was designed as follows:
a) Minimum radius of curve was used 300 m.
b) Alignment on the bridge section is almost straight.
c) Design length between existing road in Botswana and existing road in Zambia is 3.1 km.
d) Clothoid curve was used.

14.2.2 Vertical Alignment

Vertical alignment was designed as follows:

a) Maximum gradient was 2.2 % for passage of heavy vehicles.
b) Minimum gradient used was 0 % from the viewpoint of the economy.
c) Minimum vertical curves are 5000 m in crest point and 5000 m in sag point.
d) Navigation clearance was kept 7 m height.
e) Vertical alignment on bridge section was designed based on the factors of bridge design such as height of guarder, height of abutment, foundation type and pavement thickness.

14.2.3 Road Design Results

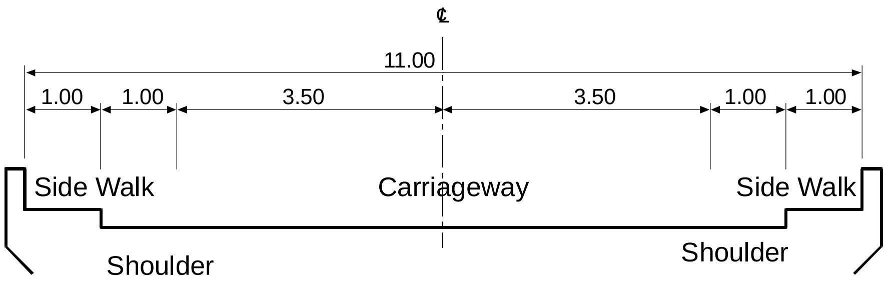
Based on the design policies and the design criteria, basic design results is shown in Table 14.2.1.

Table 14.2.1 Basic Design Results

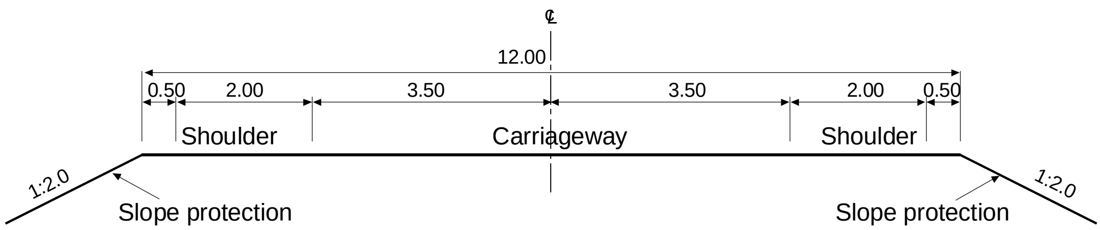
Items	Unit	Design
Design Speed	Km/hr	80
Number of Lanes	Lane	2
Road Length	M	Botswana side :1,597m Zambia side:1,383m
Maximum Gradient	%	2.2
Minimum radius of Curve	M	300
Minimum vertical curve	M	Crest : 5000 Sag : 5000

14.2.4 Typical Cross Section

Typical cross sections for bridge section and approach road section were proposed based on standards of Botswana and Zambia. Figure 14.2.1 shows typical cross section.



Bridge Section



Embankment Section

Figure 14.2.1 Typical cross Section

14.2.5 Drainage design

(1) Crossing Pipe Culverts

On earthwork section, crossing pipe culverts were installed at intervals of 500 m. Size of pipe culverts is 1.00 m.

(2) Side Ditch

Side ditches were designed at edge of both embankment slopes. Type and size are shown in Figure 14.2.2.

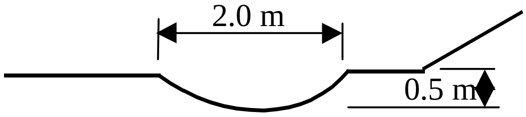


Figure 14.2.2 Side Ditch

This ditch was designed so animals can cross.

14.2.6 Slope Protection

Slope protection by sodding was design to prevent the slope erosion. However, the slope on the 50 m section from abutment was designed for rip-rap protection under flood water level with 100 year return period discharge to prevent the erosion by flooding.

14.2.7 Pavement Design

Pavement was designed based on Chapter 11.4.3 Figure 11.4.1.

(1) Design Traffic Volume

ESAL was calculated based on the results of traffic analysis in this study as followings:

AADT in 2000	: 137 vehicles/day
AADT in 2015	: 475 vehicles/day
ESAL	: 860,000 (Design value : 1 x 106)

(2) Design Structure Number (DSN)

log---10W18 = ZR x So + 9.36 x log10(SN + 1) – 0.20

$$+ \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40+\frac{1094}{(DSN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

W_{18} : Predicated number of 18-kip equivalent single axle load application, (=1 x 106)

Z_R : Standard normal deviate, (= 95 %)

S_o : Combined standard error of the traffic prediction and performance predication, (= 0.35)

ΔPSI : difference between the initial design serviceability index, (2.0)

M_R : Resilient modulus (= 6500 psi)

SN = 2.55

(3) Pavement Structure Design

SN = a1D1 + a2D2m2 + a3D3m3

SN : Structure number indicative of total pavement thickness
a : Layer coefficient
D : Layer thickness
m : Layer drainage coefficient

SN = 0.40 x 2 + 0.14 x 7.9 x 1.0 + 0.11 x 7.9 x 1.0 = 2.78 > 2.55

As a result, pavement structure was proposed as follows:

Asphalt Concrete t = 5cm
Base Course t = 20 cm
Subbase Course t = 20 cm

14.2.8 Other Facilities

As other facilities, road lighting, road marking and traffic sign etc. are included in cost estimation. Road lightings are proposed to be installed at 25 m intervals as shown in Figure 14.2.3.

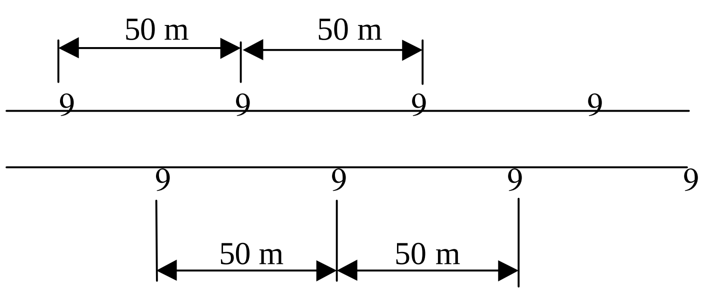


Figure 14.2.3 Installation of Road Lighting

14.2.9 Major Quantity

Major quantity of the bridge and approach roads is shown below.

Item	Unit	App. Road Botswana	App. Bridge Botswana	Main Bridge	App. Bridge Zambia	App. Road Zambia	Total
Concrete (40Mpa)	m3	N/A	1,725	6,790	1,725	N/A	10,240
Concrete (30Mpa)	m3	N/A	148	3,575	298	N/A	4,021
Concrete (24Mpa)	m3	N/A	1,027	4,790	1,252	N/A	7,069
Stay Cable	t	N/A	N/A	408	N/A	N/A	408
PC tendon	t	N/A	259	1,019	259	N/A	1,536
Re-bar	t	N/A	487	1,854	575	N/A	2,916
Embankemnt	m3	20,000	N/A	N/A	N/A	31,200	31,200
Pavement	m2	10,800	1,148	4,185	1,148	5,200	11,681

14.3 Design of New Border Facilities

14.3.1 General Design Factors and Objectives

(1) Key Factors Affecting Planning

The most important factors which affect the planning of the border facilities are:

(a) The type of immigration, inspection and recording procedures to be implemented
(b) The expected traffic flows to be handled (both volume and mode)

Both the above are dependent on factors beyond the designers control, but one must understand and interpret them correctly in order to design the facilities. Adopting the decision to implement the one-stop system, an analysis of the traffic flow estimates allows the planning to be made. This section describes the methodology taken to arrive at the proposed design solution.

(2) Key Design Objectives

The main design objectives of the border facilities are to:

(a) Allow smooth and delay-free passing for passengers and goods under future (year 2015) expected traffic volumes.
(b) Provide comfortable and user-friendly facilities for travellers and workers alike
(c) Provide safe, durable and maintenance-free structures
(d) To be as economic as possible, whilst maintaining prime user objectives
(e) Aesthetically pleasing and in harmony with the natural surroundings

(f) Flexible in planning, allowing for future expansion of the facilities
(g) Provide secure and efficient border facilities

14.3.2 Analysis of Traffic Flow and Border Posts Capacity Factors

(1) Traffic Flow Movement

Based on traffic movement studies contained elsewhere in the report, the current and expected traffic movements passing through the border posts have been summarised (shown in Table 14.3.1). The following features can be noted.

(a) The largest volume of traffic, both current and projected, is between Botswana and Zimbabwe. The bulk of this traffic appears to be tourist in nature, and few trucks follow this route. This route creates the biggest demand on passenger border post processing.
(b) The largest amount of truck traffic is between Botswana and Zambia (i.e. across the planned bridge) and thus require a larger capacity for handling truck traffic. This route would also expect the biggest increase in traffic, due to increased 'latent' traffic demand the bridge would bring.
(c) The smallest volume of traffic is between Zambia and Zimbabwe, both in terms of passengers and vehicles. This is likely to remain so in the future, but with some increase likely to arise from tourist traffic making a 'cycle' to/from Victoria Falls and Livingstone.
(d) As with all traffic projections, uncertainty exists for all the estimates. Political factors, such as instability in a neighbouring country, could significantly affect the projections. Similarly, institutional factors such as changes to current delays at neighbouring countries' borders, can also affect traffic flows. Economic conditions also cause traffic flows to vary. Changes to other nearby routes also have an affect. The completion of The Chirundu Bridge may affect traffic flows on the current Kazungula traffic. For the purposes of this feasibility study, however, whilst such scenarios can and should be considered, the final basis for the design planning of the border facilities is based on the traffic forecasts as derived from the traffic studies conducted as part of this Study.

(2) Border Posts Capacity Factors

The following points need to be considered in interpreting the traffic data and facility design:

(a) To a great extent, the capacity of the border posts will depend on the processing capacity and efficiency of the immigration and customs operations that will be implemented. This study has been based on the one-stop operating system, and also the implementation of a computerised process so that current processing times are reduced.

(b) The capacity of the border posts will be constrained by the proposed 12-hour daily operating period. This makes it important that daily estimated traffic volumes can be handled in one day, otherwise accumulative delays could increase to intolerable levels, and lead to diversion of traffic to other routes, reducing the usefulness of the project.

(c) Daily traffic is not constant throughout the day, and at certain occasional peaks some increased delays may possibly occur. However, if overall daily processing capacity exceeds the daily estimated traffic then such delays will be temporary and not be accumulative.

(d) The usefulness of the one-stop system would be enhanced by the provision of in-car processing, so that car passengers, in standard circumstances, need not leave their vehicle in order to be processed. For this, the future provision of car booths is made.

(e) This planning study is based on the assumption that detailed customs inspections for goods may still be carried out at other more distant existing locations (such as Livingstone). However, provision is still made for standard truck inspections at the facility to be made.

14.3.3 Determination of Target Capacity

Based on surveys at the existing facilities, current average processing times for immigration and customs were recorded. These varied to between 5-10 minutes to over 30 – 40 minutes for more crowded cases. The time for truck processing was generally much longer, with periods ranging u to and over 2-3 hours, and on occasions much more. Trucks waiting to cross the ferry often have to queue over night.

Factors affecting the total processing time include:

- the processing time and system itself (filling in forms and processing by staff)
- the number of operating staff (both customs and immigration) at both departure and entry points
- the extent (if any) of vehicle or luggage inspections
- traffic volumes
- layout planning of the facilities (distance from parking, distance between different processing sections)

Table 14.3.1 Expected traffic volumes (2015)   (figures in brackets for 2-way flow)

	Car	Bus	Truck	Total Vehicle	Passengers
Zambia-Botswana	56 (112)	12 (24)	154 (308)	222 (444)	540 (1040)
Botswana-Zimbabwe	142 (284)	51 (102)	44 (88)	237 (474)	882 (1764)
Zimbabwe-Zambia	11 (22)	1 (2)	4 (8)	16 (32)	40 (80)

For the planning of the new facilities, it has been decided that even with the expected increase in traffic (which would range from around to 2 or more than 3 times depending on route and mode of traffic), that overall processing times not increase and instead be reduced.

Adopting the one-stop system will partly help in this, as all processing is mainly done at one location. In addition, improvements to the processing system (further computerisation), improvements to the plan layouts, and increased capacity to the facilities to avoid overcrowding will all help reduce processing times and allow increased traffic flows without compromising security.

Detailed studies were carried out to determine the expected traffic volumes for all modes of traffic, expected and desired waiting times, target operating capacities, required staffing numbers and improved layout design in order to maximise the capacity and create an easy-to-use and easy-to manage border facility system.

The details of the calculations are not attached in this report, but the results are summarised below, in terms of required capacity for each of the facilities.

Some related comments are as follows:

(Existing situation)

- In most cases, the average arrival interval of vehicles is close to the average processing time for immigration and customs formalities. This indicates that overall, the current border posts are operating at near capacity levels.
- The primary exception to this is for truck traffic travelling north (in particular) from Botswana to Zambia, for which excessive delays (average approx. 4 hours) are occurring. This appears to be a constant backlog, probably constrained as much by the ferry capacity than the immigration and customs processing time.

- In most cases, the current average immigration and customs processing time for cars is around 15 minutes, and more than 20 minutes for trucks. This reflects the more lengthy customs procedures for trucks.
- The Zambian side has a greater number of staff per passenger, but this may also be related to procedural factors and the higher proportion of trucks

(Future situation)

- As future traffic is forecast to increase more than 2 - 3 times by 2015, it is clear that the facilities will also need a significant increase in capacity to cope.
- It is thought that 5-10 minutes processing time is achievable, but the studies were made to allow for a 15 minute processing, which can be met with increased operating capacity and further computerisation, and improved layout.
- It can be seen that some increase in total staff is inevitable in order to meet capacity demands, but that the specified increases in workload are not excessive and should be obtainable.

Design of Future Facilities

As the characteristics of each if the three facilities are different, mainly due to different traffic movements, but also due to other planning, procedural and other regulatory differences, each facility will end up with a different design.

While traffic differences are readily determined, other planning differences that may arise in the building designs are of a more detailed matter, and are beyond the scope of this Feasibility Study. Thus, it has been decided to adopt a ‘Standardised Layout” which is adaptable to all three countries during the detailed design stage.

For the overall facility layout, in terms of traffic movements, vehicle parking capacity and overall size, the expected differences can be estimated and these are reflected in the different design layouts.

(a) Main building, principal space requirements

From the above-mentioned studies The following expected operating staff numbers can be derived.

Zambia side

Zambia immigration	4
Zambia customs	4
Botswana immigration	4
Botswana customs	4
Zimbabwe immigration	1-2
Zimbabwe customs	1-2

Total	18-20

Botswana side

Botswana immigration	6
Botswana customs	6
Zimbabwe immigration	6
Zimbabwe customs	6
Zambia immigration	5
Zambia customs	5
Total	34

Zimbabwe side

Zimbabwe immigration	6
Zimbabwe customs	6
Zambia immigration	1-2
Zambia customs	1-2
Botswana immigration	6
Zambia customs	6
Total	26-28

Therefore the average number of staff office processing workers for a standardised building design is about 21. Then, assuming an average required office space of 8 m^2 for the main office room, or 12 m^2 overall. It can be thus seen that providing a main processing office to accommodate all the processing staff of area = 8 x 21 = **168 m^2** would be adequate. However, most of the workers would be working at passenger counters, so even this figure could be reduced. Individual counter booths can be only be 1m wide.

As the final seating arrangements of the 3-border one-stop system still remain to be confirmed, some allowance is preferable. Thus the equivalent of a 6m wide room x 6m deep for each country's department (i.e., customs and immigration) has been provided. This gives a total area of 6 x 6 x 6 = **216 m^2**, (greater than 168 m^2 required) (which could accommodate 25-35 workers, depending on the final arrangement. From this, the rest of the size of the main building is then determined.. By adopting a standard building based on this 'average' size with margin of allowance (1.3 times), then it is almost big enough without further adjustment for the busiest of the facilities. However, to mitigate against crowding at peak times, this will be adopted as the base.

Provision of space is made for the immigration, customs and police for all three countries at each facility, including meeting and inspection rooms and chief offices.

For the passenger area, a wide and open high foyer has been designed, with a space extending the whole length of the immigration/customs counters (36 m) and 8 m deep, and extending beyond.

This has an area of 36 x 8 = 288 m^2, or enough to accommodate up to about 150 waiting passengers at peak periods.

The total estimated daily passengers at each of the three facilities are:

Zambia	580
Botswana	1422
Zimbabwe	922
(an average of)	975

Thus even assuming a total waiting time for all processing of 5mins x 4 stages, = 20 minutes, then in any one 20 minute period, one could expect an average of 975/12 = 81 people per hour, or 27 in any one 20 minute period, much less than 150 capacity. Thus the waiting area is assumed to provide adequate capacity for even the most congested of peak periods, and in a pleasantly spacious area.

Note that both the above trial capacity calculations are based on assuming no in-vehicle processing, whose future incorporation has also been accommodated in the design by allowing future booths to be installed under the main inspection canopies adjacent to the main building. This would also further tend to decrease building space requirements, so it is thought that the principal building room sizes are adequate, and allow even greater capacity for future growth.

The rest of the main building space is taken up by separate individual rooms, based on user requirements as determined from studies and meetings with the involved parties. The result is a 2-storey building which houses all the main processing and office facilities, with public related space concentrated on the ground floor and internal office space on the first. A more detailed description of the function of the buildings is given later in the report. Similarly, the detailed room sizes have been determined based on the overall total occupant requirements, and are not shown in detail in this report text.

(b) Outside space requirements

The external space requirements are mainly determined by the required parking capacity and the space for the additional outer buildings, (such as the truck unloading /inspection building). In addition, the existing site conditions and restrictions also determine the overall form and site area.

Parking requirements can be determined from the expected (2015) traffic volumes, and number of provided places are summarised below:

At Zambia (totals for both Botswana and Zimbabwe destinations)

Cars	67 /day	Provide 64 No.
Buses	13 /day	Provide 8 No.
Trucks	158 /day	Provide 36 No.

At Botswana (totals for both Zimbabwe and Zambia destinations)

Cars	198 /day	Provide 80 No.
Buses	63 /day	Provide 16 No.
Trucks	198 /day	Provide 40 No.

At Zimbabwe (totals for both Zambia and Botswana and destinations)

Cars	153 /day	Provide 80 No.
Buses	52 /day	Provide 14 No.
Trucks	48 /day	Provide 20 No.

Note that mini-buses will be able to use the car size parking spaces, as the 'bus' parking spaces are designed for full-size coaches.

Furthermore, expansion parking zones are allowed for all three modes, so the design is also flexible for further growth.

Based on the above basic considerations, the standard border design facility can now be designed. The following sections describe in more detail the building and external works layout, design criteria, function and features.

14.3.4 Design of Border Facilities

(1) Facility Layout Plan

The main objective for the layout plan of the facilities is to allow for simple and controlled flows of passengers and vehicles to undergo the required formalities in a short and as comfortable manner as possible whilst satisfying all regulatory and security requirements. Furthermore, the facility design should have the following characteristics.

- be of economical design
- be compact, to reduce land and construction costs, to reduce flow distances and to minimise any negative environmental impact.
- allow for future expansion
- to utilise, where practical, the existing facilities (and their use during expansion construction)
- create a pleasant environment for passengers and workers alike.

- be simple and logical to facilitate efficient and easy use.

To achieve this, the chosen design has incorporated the following strategy:

- Have a central passenger control building, where all passenger immigration and customs processing, workers and controlling officers are housed in a central location
- Create a large sheltered lobby for passengers for a pleasant waiting area
- Split vehicle movements between passenger (car and bus) and cargo (truck) traffic, due to their different size and processing procedures.
- Minimise walking distances between vehicles and processing offices.
- To provide for sheltered inspection facilities for passenger and truck vehicles alike.
- Maximise use of green landscaping, to create a pleasant environment and to minimise the effect of heat build-up on the parking areas.
- Allow for simple onward traffic movement once all immigration and customs formalities are complete
- Provide for U-turn movements for non-compliant or erroneous vehicles.
- Locate the new facilities so that their construction can be done without causing too much disruption to the functioning of the existing facilities.

In compliance with the one-stop system, all procedures for immigration and customs for departure and arrival are conducted for all three counties on the exit side of the departure country. From thereon, passengers are assumed to be handed a check pass which authorises their movement up to the final arrival check point, at which point the check pass is simply verified, and, from where the passenger and vehicle is authorised to proceed. This final arrival check point allows for return U-turns to be made in case of non-compliant cases..

In meeting the above objectives, various plan layouts for each of the three proposed facilities were prepared and analysed, in order to arrive at the most favourable plan.

The final sizing of each of the buildings and layout of the parking areas etc. may eventually vary due to localised differences. Final adjustments to each may be required to suit final regulatory and procedural requirements.

(2) Facility Layout: Common Features:

The following features are common to all 3 layouts:

- At entry to the facility, traffic is split between car/bus and truck vehicles.
- Car passengers are directed towards the proximity of the main passenger control building. From there, two alternative processing options are allowed for:
    - ‘Standard’ processing where by passengers park their car, then proceed on foot to the passenger control building where immigration and custom

procedures are completed for both exit and entry. After returning to their car, they drive to the inspection canopy where standard inspection procedures can be completed, prior to being given clearance to advance to their destination. In the case of suspect cases requiring closer inspection, cars are directed to the vehicle inspection building, which is close by.

  - ‘In-car’ processing, where car passengers can complete all immigration and customs formalities while waiting in their car. This would require the construction of simple booth houses for the workers. Once complete, the process is similar to as above.

- Bus passengers proceed to the bus parking zone. Again two procedures can be accommodated
  - ‘Standard’ processing where passengers walk from the parked bus to the passenger control building. They can return to the bus either in the bus park, or by passing through the passenger flow booths, and re-boarding the bus under the inspection canopy in the bus lane. Suspect buses may be asked to go to the vehicle inspection building for a more detailed check.
  - ‘In-bus’ processing, where a bus would park under the canopy, and all formalities are completed while waiting in the bus. Once complete, the bus proceeds as above
- Trucks are directed to pass through the weigh bridge, with parking space provided both before and after the weigh bridge, according to possible congestion conditions.
- After the weigh-bridge, trucks park and the driver walks to the passenger control building to complete immigration and custom procedures. The driver can also walk to the freight office building where clearing agents are housed.
- In cases, where a detailed truck inspection is required, the truck unloading and freight inspection allows for a systemised unloading and inspection under sheltered conditions, and with large storage space provided for each of the three countries (including refrigerated storage).
- More standard final inspections are conducted under the truck canopy, which can also be similarly equipped with booths in case ‘in-truck’ inspection procedures are also introduced at a later date.
- A public facility building in front of the passenger control building houses public toilets, tourist offices and commercial banks etc.
- Expansion and overflow parking space is provided at the facility entrance area.
- Expansion space to accommodate possible state bonded warehouses and/or worker accommodation is allowed for, with the final location depending on the features of each individual site and optional layout (see plans).
- Other buildings (maintenance building, quarantine house etc.) are strategically located within the site, with use made of existing facilities where appropriate.
- The plan features green landscape areas and U-turn routes are also provided for.

a) Zambia side facilities: Special features

The Zambia side area lies just north of the existing facility, at the point where the bridge approach viaduct ends. The land slopes gently to the south and offers south-facing views to the Zambezi River and the future bridge.

The main significant obstacle to development are the existing overhead electricity lines which carry international main lines towards Botswana and beyond. As these lines lie on the east-side of the approach road, i.e. the side of the road to which traffic must be diverted to enter the departure side facility, then either the pylons must be moved, or the approach road must be shifted to the west, together with the through road, thus avoiding any cost penalties associated with moving the pylons.

This additional costs for moving the pylons are quite significant, both for the construction work involved, and possible compensatory costs due to temporary power loss during moving, which presumably would be borne by the project.

It has thus been decided to shift the facilities away from the power lines, and the approach road shifted north-west to accommodate the border facility. Some existing cattle dip structures on the west of the existing road would need to be demolished, though this is not a significant impediment. The curved approach road entails some additional (minor) road construction costs, but also allows the control of speeds of through traffic, and provides for wider perspective views of the bridge.

The chosen plan also allows for right-handed truck parking, which is a simpler manoeuvre for large right-hand drive trucks.

Furthermore, the selected plan allows for a large unrestricted expansion area, providing greater flexibility.

b) Botswana Facilities

The planned Botswana side facilities lie to the south of the Bridge, on an existing ridge of high land, which slopes to the north and west to the Zambezi and Chobe rivers. The existing facilities, around which the new site will lie, are currently restricted by the Botswana Defence Force barracks which lie to the north-west of the site. It has been mentioned that these facilities may be vacated in any redevelopment of the area, potentially freeing the area for less restricted expansion.

To the south-east of the existing facilities there is a small depression (marsh) which has been designated as a ‘wetland’ and has been mentioned as possibly being worthy of environmental protection. At the time of the survey, however, no significant ‘wetland’ was observed, and most of the surrounding terrain was dry and semi-arid in nature. Furthermore, the depression only covers a small area, and is thought not to be a significant obstacle to development of the facilities.

Another feature of the Botswana side facility is that its location is such that vehicles travelling from Botswana to Zimbabwe, having completed their exit/entry formalities, will need to U-turn and re-join the main return road. They can then proceed to the Zimbabwe entry final check point, which is situated further uphill and further away from the bridge (see overall site plan). Also, vehicles travelling from Zimbabwe to Zambia will have already completed their entry and exit formalities, and thus would not be required to pass through the Botswana-side facilities for further checks. Thus a by-pass route should be provided for such vehicles, with perhaps only a simple check pass verification stop to be made.

The final selection for the Botswana layout was chosen for the following:

This plan layout can accommodate a through road route which passes close to the existing facilities, and thus take up less space and incur less cost in acquiring land.

The new facilities are located to the west of the existing, and their construction can be made while keeping the existing facilities operating. The existing Botswana Self Defence Force barracks need not be vacated (hence reduced initial costs), but doing so would allow for easier future expansion of the new facilities to the north.

Environmental impact to the surrounding wildlife area to the east is avoided, and also there is hardly any encroachment to the River Chobe area to the north.

The land further to the north sloping to the river is less suitable for new development as the steeper slopes would entail increased earthworks cost

The plan also allows for easy right-hand truck parking.

c) Zimbabwe Side facilities

The international boundary, which runs both to the west and (partly) to the south of the existing facility, restricts the space available to the south of the road for redevelopment if the original road alignment were to be kept. It was thus decided to shift the line of the new road to the north, creating more space for the new facilities.

A small brook runs within the planned facility zone. To avoid constructing any buildings over this brook, the new facilities are located as far west as possible, so that the brook would only run under parking areas, which would avoid potential building foundation complications and simplify any brook re-diverting work required. In doing so, the new facility is brought closer to the existing facilities, allowing greater scope for utilisation of these buildings within the new facility.

Truck traffic on the Zimbabwe side is markedly less than for the other two facilities, and thus a significant reduction in space for truck parking can be made, and the size of the truck unloading/inspection building reduced, saving costs.

The preferred plan layout features right-hand truck parking for the large trucks, with the car parking area located on the northern side, allowing car passengers to have a clearer view of the vista to the north where the river Zambezi can be seen.

The expansion area for trucks (and possible warehouses) is less restrained by the alignment of the return road. The new facilities are close to the existing buildings, advantageous where these have passenger-related function (e.g. quarantine)

The plan allows for easy operation of the existing facilities during construction of the new, and the overall area of the new facility is kept to a functional minimum.

14.3.5 Building Design

The primary objectives for the building design are summarised as follows

- functional planning for main operations, providing user and worker comfort
- satisfying the main criteria for the building design (regulatory and technical)
- consideration of adequate shelter from the tropical climate
- design for durability and minimal maintenance
- economical construction suitable for locality
- flexibility for future use
- aesthetics and identity for the facilities

These are each considered in further detail below:

(1) Functionality

The primary functions of each building have been determined based on studies of the existing facilities and improvements required upon implementation of the foreseen future procedures. Some details of the future procedures, particularly relating to the one-stop system, are not fully known at this stage, so the design layouts developed for this feasibility study can not be considered as final. The concept of staff of three countries working together in a single facility will also require further consideration of whether they are able to work integrally or separately, which also has an impact on the final planning. Despite this, and even allowing for some uncertainty on how the detailed future work procedures for immigration, customs and policing would be implemented, the total required floor areas and room layouts were determined based on the planned functional requirements and the expected occupancies. Planning has been made to provide a user-friendly environment.

Main building plans and elevations are shown in the attached drawings.

(2) Principal Building Design Criteria

The attached descriptions given below are not intended as a definitive list, but as a summary of the principal factors to be considered. During detailed design, these items will require further evaluation and clarification

a) Planning Arrangements

- Must satisfy local regulations, where applicable (escape route distances, fire planning, evacuation routes, floor areas, heights etc).
- The typical floor-to-floor height to be 4.0 m. Special buildings shall have higher dimensions to suit requirements.

b) Structure

Structural design is to satisfy all applicable regulations. The following have been considered in this feasibility study. All should be reconfirmed during detail design:

Foundations	:	Reinforced concrete (RC) shallow strip or pad foundations
Framing	:	RC frame, with slab/beam sub-framing (for flexibility and economy). Typical column spacing around 6m for economy.
Lateral Stability	:	RC moment frames, and/or with shear walls (at stairs or partitions)
Roof structures	:	pitched steel trusses or suspension-hanger framing for canopies. Timber roof trusses are also to be considered.
Codes and standards	:	British Standards (BS 8110, BS 8004, BS 5950) or local equivalents
Imposed floor loads	:	As per BS. Typical imposed floor loading: 3.0 kN/m^2
Wind loads	:	As per BS codes. Wind speeds from local meteorological data.
Earthquake loads	:	Adopt base shear coefficient of 0.06g (max.). U.S. UBC, Japanese or S. African seismic codes for details.

- Materials

Concrete	:	C30
Reinforcing bars	:	High-yield deformed bars and mild steel round bars
Structural steel	:	BS gr 43 or equivalent

- Performance requirements

Durability	:	to suit local conditions (50 year standard design life)
Fire protection	:	to suit local regulations (1 or 2 hour, using minimum RC member thickness

Deflections	:	to satisfy local regulations (L/360 and L/240 etc.)
Insulation	:	maximise use of passive structural properties

c) Building Finishes

- External Walls: Typically brick (especially major public buildings)
- Internal walls: Lightweight concrete block or lightweight partitions
- Floor finishes: Concrete screed, with PVC flooring or tiles in occupied zones
- Roofing: Thin-gauge profiled steel/galvanised sheeting (or asbestos-cement type), with insulation. Roof tiles also to be considered
- Ceilings: lightweight acoustic type in offices
- Glazing: Steel security grilles to be provided for important buildings

d) Building Services

- Electrical: supply adequate for air-conditioned computerised office use
- Plumbing: as standard, use immersion heaters for hot water in bathrooms
- Air-conditioning/ventilation: individual wall-mounted units for offices, ceiling fans and wall vents for less intensely occupied spaces
- Telephone and computer line networks to be provided.
- Security wiring for important buildings to be provided
- Toilets: Western type. Waste to septic tank and soak-away

(3) Consideration of tropical climate

The hot tropical climate is considered in the building design. Whilst most of the details of this are for the detailed design stage, some points are worth mentioning as they may affect the basic building design:

The passive properties of the building structure and finishes should be utilised to prevent heat accumulation of occupied spaces. The cooling effects of air movements should be utilised. The following should also be considered:

- Solar radiation heat gain through windows be minimised, by a combination of shading devices such as louvers, balconies, canopies, wall fins, window grilles and other screens. All have a significant impact of the façade design.

- Prevent internal heat gain (from sources such as humans and lights etc.). This is best achieved with the aid of air-conditioning, though natural ventilation, where practical, should also be considered, for improved economy.
- Prevent heat gain of building, by using lighter reflective colours for roofing.
- For non-air conditioned spaces, maximise natural ventilation by having open design to facilitate cross air flows (any air movement will have cooling effect). Air flows should be directed to where people will be, not just at ceiling level.
- Have adequate shelter from rain, e.g. providing outer perimeter overhangs, reveals in window ledges etc. Eaves overhangs also prevent heat accumulation on facades. Pitched roofs minimise rain leakage risks compared to flat.
- By avoiding the arrangement of buildings in regular lines, wind ‘shadows’ are prevented, so all buildings can receive natural cooling from wind movements.
- Minimise light glare through windows, minimising the amount of direct light on facades, by use of overhangs, canopies and placing windows at high ceiling and using non-reflective finishes on the underside of canopies Corner vertical strip windows are also effective at reducing glare.
- Where possible, orientated buildings on an east-west axis to minimise heat build –up on the east and west facades, which are subject to greater heat load than the south facing wall, due to acting angle of the sun.
- Provide outdoor landscaping and greenery to reduce heat gain.

(4) Durability and Maintenance-Free design

As the buildings will be symbolic of the three nations, it is essential they provide a favourable image to travellers. Despite possible higher initial construction cost, this is still desirable due to the very public nature of the buildings, and the remote location will maintenance work more costly.

The following items indicate how this has been considered.

- Building façade: As the most visible aspect of the buildings, low-maintenance is especially required. Using brickwork for external walls provides an almost maintenance-free and attractive façade for only a minimal initial extra cost. The alternative of plaster on block walls requires regular maintenance and looks less attractive. The large amount of vehicle fumes will also lead to rapid discolouring of plaster finish walls.
- Roofing: galvanised steel roofing is very durable and has low

maintenance compared to flat built-up roofing, especially in the hot and wet climate.

- Internal block walls could be painted instead of plastered, and so less subject to surface cracking (and reduce cost).
- Exposed structural steel in the inspection canopies, should receive a durable paint treatment, or alternatively be galvanised

Further energy-saving measures, such as solar cells, should also be considered during the detail design stage.

(5) Economical construction

The design is fairly simple and regular and has minimal cost premiums. The selected materials are readily available, either locally or imported from South Africa, and does not require any particular skilled labour for the construction.

The design can be built in a relatively short period, which, excluding site preparatory work, should not exceed 12-15 months. The design also does not require any specialised plant or equipment, nor complicated temporary works, nor any extensive areas for site storage. Further detailed planning should consider in more detail the use of the existing facilities during construction.

(6) Flexibility for future use

The regular layout nature of most of the buildings mean that the internal arrangement can be quite easily adjusted to suit any changes in use. The planned layout of the buildings, and the overall site arrangement of the facility allows some buildings to be expanded, and sufficient space exists to accommodate the extension of parking areas etc. to increase the capacity of the facility.

(7) Aesthetic Design

At this Feasibility Stage, it is not possible to go into detail on building aesthetics. The attached concept drawings, however, show that the proposed design is reasonably attractive and can be developed during the design to create attractive buildings. The main inspection canopies on either side of the main building provide a ‘high-tech’ suspension steel structure, which compliments the structural from of the main bridge, though it remains simple and economical.

Apart from the passenger control building, the most distinctive is the Public facility building, which has been designed with an African flavour, featuring a large grass-like roof and vertical-stripe accented façade. At detailed design, the buildings can be developed to further reflect the host country of each facility.

The Waiting Lobby, with its high ceiling and open nature, is an attractive space, and can feature overhanging greenery on the exposed RC frame.

The extensive landscaping also provides a soft and attractive ambience to the whole facility, and also helps to shield the intrusion of some of the more ‘industrial’ buildings such as the Truck Unloading and Inspection Building.

The following summarises the features of the main buildings in the design.

(8) Building Descriptions

a) Passenger Control Building (marked number ‘1’ in layout plans)

- 2-storey RC frame building housing all the immigration, custom offices and police offices etc. Serves as the central main passenger building.
- The passenger waiting lobby, an open-walled high-ceiling area, is adjacent to the immigration and customs processing office areas
- Foot and also bus passengers can pass through the passenger control booths. Inspection tables are provided in the far end of the lobby for checking the luggage of foot and bus passengers, before they proceed onwards or re-board a bus.
- Other rooms with other passenger-interface functions are also located on the ground-floor, and the public facility building is very close by.
- Non-public interface offices, e.g. department chief offices, main police rooms, meeting rooms, computing rooms and the building administrators room etc. are on the 2Fl The Building Administrator organises the room-use schedule for rooms which are common (conference & meeting rooms etc.)

b) Public Facility Building (6)

- Accommodates public amenity functions e.g. public toilets, convenience/snack store, tourist information and banks, (which serve as money-changers and for processing truck customs fees etc). Building is designed to have a localised style to give the facilities and authentic African flavour.
- Spare space for possible retail stores (e.g. duty free, souvenirs) also provided.

c) Car/bus and truck inspection canopies (2, 3, 4)

- Structural steel canopy structures designed to provide shelter for the standard inspection of vehicles. Design features tension hanger framing, providing an economic long-span column-free space, which complements the exposed cables of the PC extra-dosed bridge.
- In-car processing booths can be easily accommodated under the canopy, which would greatly increase the capacity and processing speed of the facility. Provision to be made to prevent excessive vehicle fumes affecting booth workers (e.g. switching-off engines, providing air-blower/fans, or air filters to the booths).

d) Vehicle Inspection Building (14)

- Where suspect cars and buses undergo more detailed inspections. The building is an open steel roof type, with attached offices and toilets. Inspection pits for buses and pole-jacks for cars to be provided.

e) Staff parking Shelter (5)

- Sheltered parking area (simple steel roofing on wooden cantilever framing).

f) Freight Inspection/Unloading and Storage building (10)

- Where trucks requiring detailed inspection or unloading of goods are handled. The structure is a simple steel braced/moment frame type, with part open or block-work cladding for economy.
- Raised unloading platform and large storage sheds for each of the three countries.
- Offices, X-ray inspection facilities and refrigerated inspection/unloading/storage zone to handle perishable goods. The building can be extended in case of expansion requirements.
- Public toilets for truck drivers parked nearby are also provided.

g) Weigh Bridge/House (11)

- Small office and toilet building adjacent to weigh bridge machine (digital type).

h) Freight Office /Clearing Agents Building (15)

- 2-story RC frame office building for freight clearing agents and related customs offices of the three countries. Current design allows for 28 separate offices

i) Maintenance Building (19)

- 1-storey building : Offices for facility maintenance staff, storage , toilets, garage etc.

j) Existing Buildings (12)

- The existing buildings at the present facilities will be incorporated into the new layout as much as possible. Due to smaller size of these structures, they are unlikely to be able accommodate any of the central functions, but can serve as Plant/Quarantine Building or similar.

14.3.6 Outdoor Area Design

The outdoor area and civil work design elements form a significant part of the overall design and take up the largest area of the facilities. Most is taken by the parking pavement areas, particularly for trucks, and also includes utilities such as water supply, electrical supply and waste water treatment. These are each described below:

(1) Car and Bus Parking

- Car and bus parking is located as close as practical to the passenger control and public facility buildings, with capacity for around 60 - 90 cars and around 10 or more buses, with zones for possible expansion also provided. An overflow parking area exists at the entrance to the facility.
- The parking pavement is, for economy, designed as an asphalt paving surface, on top of prepared sub-base and sub-grade layers, with the Zambian side foreseen to require a 3.5% lime mix in the existing/made-up ground. Interlocking block is not favoured due to the potential cracking problems. Reinforced concrete paving is provided in the inspection canopy areas, due to the higher abrasion loads here.

(2) Truck Parking

- Truck parking areas require a much larger area than for car or bus parking due to the larger vehicle size (up to 25m long) and the larger turning circles. The planned facilities have space for up to 40 trucks, not including side and peripheral road parking, plus an expansion/overfill area at the entrance area. There are additional parking places provided in the inspection and truck unloading areas.
- Reinforced concrete pavement surface is provided due to the greater abrasion resistance for trucks and increased impermeability against possible oil spillage.

(3) Landscaping and Pedestrian Paving

- Green landscaping is provided for improved aesthetics and to mitigate against excess heat build-up on the site. It is economical, requiring only the provision of topsoil and vegetation. Where there are pedestrian movements (e.g. between buildings and car parking) paving blocks are provided instead.

(4) Road Furniture

- This includes crash barriers parallel to certain sections of road within the facility, lampposts, handrails and signage to direct the traffic flows.

(5) Perimeter Security Fencing

- 2.0m high wire chain-link security fence with barbed wire topping (with lasers) around site perimeter. Large lined ditch running parallel to the fence acts as an animal intrusion precaution, and as a perimeter storm water drain.

(6) Water Supply

- On the Zambian side, a new water source is provided as the existing facility, which takes water from the Zambezi River, is too small. For lower costs, two new bore-hole well sources are designed. No underground tank is foreseen, as the underground water itself acts as a reservoir. Chlorination tanks provide water purification.
- On the Botswana and Zimbabwe sides, it is thought the existing facilities take water from piped sources, which, with booster pumps, can be used for the new facilities.
- On all three sites, new larger water tank towers are required, each with a capacity of over 15m^3, to provide the 12 hour needs of the workers,

passengers and 30 minute fire extinguishing capacity. From here, water is distributed by gravity.

- An adjacent water pump building housing related equipment will be built.

(7) Waste Water

- Waste water from the buildings will be directed to central septic tanks (around three in numbers), and then to soak-aways, situated away from the bore-hole water sources.

(8) Electrical Power

- New diesel power generators, with back-up generators are provided for each new facility, with capacity for 600 –700 kW of power, together with switching equipment and connection facilities to the existing electrical power networks
- The generator houses are located on the site perimeter at a central position to allow access from the outside of the facility by the power network companies.
- The generator building houses an emergency back-up generator and switch-gear equipment, and small office and toilet

(9) General Site Drainage and Underground Lines

- Other buried drainage lines, electricity and telephone lines are provided.

14.3.7 Cost Estimate of Border Facilities

The total direct construction cost of the facilities is estimated as the US dollar equivalent of \$15.9 million. The breakdown of this figure including three border control facilities is shown below:

Building Work	:	\$6.4 million
Outdoor Civil Work	:	\$9.0 million
Total	:	\$15.4 million

(x $1,000 USD)

Building Work	Zambia	Botswana	Zimbabwe
Passenger Control Building	262	693	442
Passenger Lobby	54	144	92
Inspection Canopy Roofs	84	223	142
Inspection Booths (optional)	13	35	22
Public Facility Building	60	161	102
Maintenance Building	11	30	19
Guard Huts (6 No.)	5	14	9
Vehicle Inspection Building	49	130	83
Freight Office/Clearing Agents Building	344	524	220
Freight Unloading/Inspection Building	707	1,077	452
Weight House	5	6	5
Plant/Quarantine Building	83	65	50
Total	1,683	3,106	1,643

Note:

1. Cost of renovation of existing buildings will be more than balanced by savings in construction of a new building. Thus final estimate can be reduced
2. ‘Building Work’ is total construction cost, including foundations, structure, walls, roof, external and internal finishes, all electrical (lighting, telephone etc.), plumbing and unit air-conditioning.

(x $1,000 USD)

Outdoor Civil Work	Zambia	Botswana	Zimbabwe
Earthworks	438	515	374
Crash Barriers	53	73	17
Passenger Hand Rails	18	25	6
RC kerbs	64	88	21
Outdoor lighting	21	29	7
Signage	32	44	10
Fixed seats	2	2	1
Perimeter Security Fence	39	53	12
Perimeter Ditch (storm drain, stone lined)	149	203	48
Water Supply (incl. Tank, pump house etc.)	86	117	28
Waste Water Disposal (incl. Septic tanks etc)	118	161	38
Surface drainage (within site)	107	147	35
Security Gates	43	58	14
Generator, (incl. Back-up, house etc.)	107	147	35
Electrical connection charges	43	58	14
Weigh Bridge	43	58	14
Reinforced concrete paving and sub-base etc.	1,241	1,696	407
Asphalt paving and sub-base etc.	529	723	173
Landscaping	147	201	48
Total	3,288	4,406	1,308

(x 1,000 US $)

TOTALS	Zambia	Botswana	Zimbabwe
Building Work	1,683	3,106	1,643
Civil Work	3,288	4,406	1,308
TOTAL	4,971	7,513	2,952

Comments on above

1) Unit rates are based on competitive average 'upper-bound' current market rates.
2) Building costs are based on total cost/m^2.
3) Civil costs are based on unit rates for each item
4) Approx. half of total costs will be in local currency equivalent, half in foreign USD
5) Unit costs for all three countries will be approximately the same (differences will likely average out). This is explained and verified by the fact that although there are distinct variations between the unit costs for different items between the three countries, the general tendency is that while labour and simple material costs are cheaper in Zambia (upon which detailed unit costs were derived and used in the calculations), costs for imported goods and for items involving dollar costs (e.g. oil for transportation costs) are much higher, especially in view of taxes and duties. There are also differences in plant and efficiency of construction, and studies have shown that adopting the Zambian unit costs for all three facilities will lead to estimates which are close to actual expected costs in the other two countries (within 10%). By quoting all costs in equivalent US Dollars allows this ratio of equivalence to be maintained.

14.3.8 Institutional Factors

Other institutional factors should be considered in detailed design and planning, e.g.

(1) Cultural Factors

The working arrangements for staff from three countries of differing socio-cultural and economic background will require careful planning and management.

(2) Training

Training of workers to operate in the one-stop system will also be essential

(3) Funding

Planning of how the facility will be funded, including running costs and maintenance, is required. One solution is to create a three-country 'kitty', funded by bridge tolls or government grants, which will then be divided between the facilities.

Separate funding and maintenance of the three facilities may lead to diverging standards of upkeep and create a less uniform impression.

(4) Implementation of the One-Stop System

It is important that there is further consultation between the three countries and SADC to ensure that the planning described in this feasibility study can be made to work, and to allow possible adjustments to incorporate during the detailed design.

14.3.9 Out of Scope Items (space only foreseen)

- Accommodation buildings for workers
- Large State bonded warehouses
- Duty free shops (this is considered to be part of private sector)

14.4 Ferry Facilities

The preliminary design for ferry facilities should be examined two cases such as “temporary works in relation to the bridge construction” case and “improvement of ferry facilities” case in order to execute the ideal ferry operation.

For the “temporary works” case, construction of ferry facilities should be kept to a minimum because the ferry operation will be discontinued at Kazungula after the bridge opened. On the other hand, in the “improvement of ferry facilities” case, suitable ferry facilities should be provided in order to ease traffic congestion based on future traffic demand described in Chapter-8.

The work items for ferry improvement plan are summarised as follows.

“Temporary Works” Case	“Improvement of Ferry Facilities” Case
1) Replacement of onshore ramp	1) Reconstruction of onshore ramp
2) Dredging work of basin	2) Reconstruction and expansion of parking lot
	3) Construction of storage facility
	4) Replacement of engine
	5) Improvement of upper deck
	6) Replacement of propeller
	7) Improvement of ramp
	8) Replacement of safety equipment
	9) Construction of onshore ramp
	10) Construction of parking lot
	11) Installation of new ferries

	12) Replacement of engine 13) Improvement of upper deck 14) Replacement of propeller 15) Improvement of ramp 16) Demobilisation of ferry

14.4.1 Preliminary Design for "Temporary Works" Case

(1) Replacement of onshore ramp

a) Location of onshore ramp

The onshore ramp should be replaced to the upstream side as described in Section 12.4 (3). The location of onshore ramp at Zambia side is shown in Figure 14.4.1. It is not necessary to replace the onshore ramp of Botswana side because alignment of road and bridge will not block the existing onshore ramp.

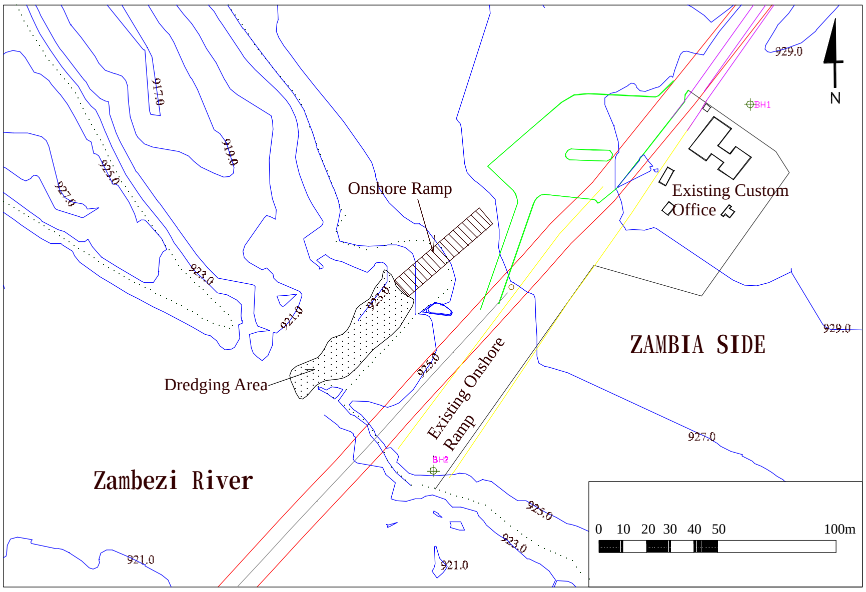


Figure 14.4.1 Location of Onshore Ramp (Zambia Side)

b) Typical cross section of onshore ramp

The cross section of onshore ramp should be determined as a temporary facility because it will be utilised for a short period. When determining elevation of toe and top of onshore ramp, a 2.33 year return period of water level should be applied because it is a temporary facility.

Level of Toe: L.W.L – Full Draft –Clearance

= 924.81m - 1.1m – 0.5m = 923.21

Level of Top: H.W.L = 927.15m

Where:

L.W.L	= 924.81 m (2.33 year return period)
H.W.L	= 927.15 m (2.33 year return period)
Full Draft	= 1.1m
Clearance	= 0.5m

The adopted levels of the toe and top of the ramp were therefore derived as 923.21 m and 927.15 m respectively, the range being 3.94 m. Typical cross section is shown in Figure 14.4.2.

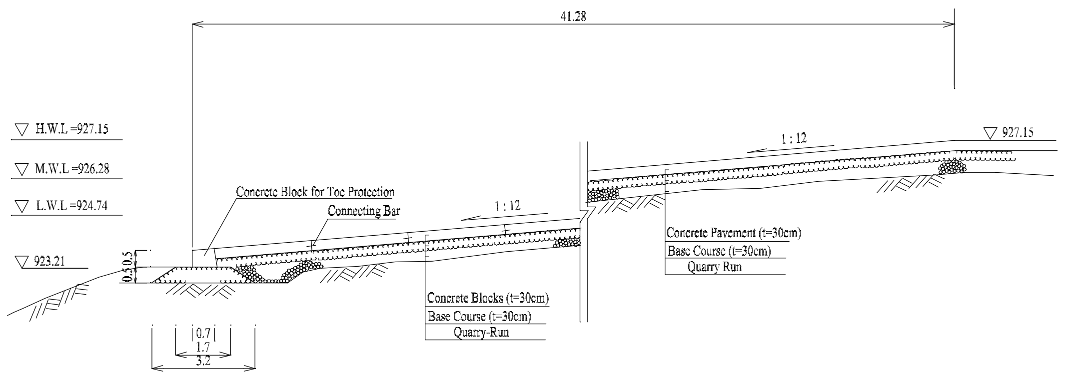


Figure 14.4.2 Typical Cross Section of Onshore Ramp

(2) Dredging Work of Basin

a) Depth of Basin

In order to navigate in safety, it is necessary to secure sufficient depth in the basin and navigation channel. The basin of Botswana side does not need to be dredged because the depth is sufficient, however, the basin of Zambia side should be deepened to 923.21 m because there is a shallow area in front of onshore ramp.

b) Dredging Area

The dredging area is shown in Figure 14.4.1, and dredging a total volume of is approximately 2,500 m^3.

14.4.2 Preliminary Design for "Improvement of Ferry Facilities" Case

(1) Reconstruction of onshore ramp

a) Location of onshore ramp

The onshore ramp should remain in the existing location in order to be advantageous geologically. The locations of onshore ramp on Zambia side and Botswana side are shown in Figure 14.4.3.

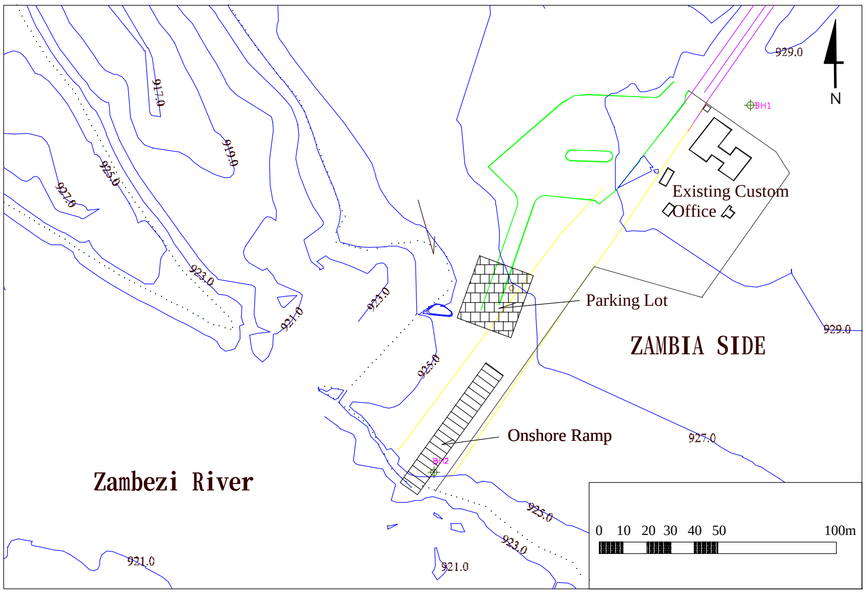


Figure 14.4.3 (1) Location of Onshore Ramp (Zambia Side)

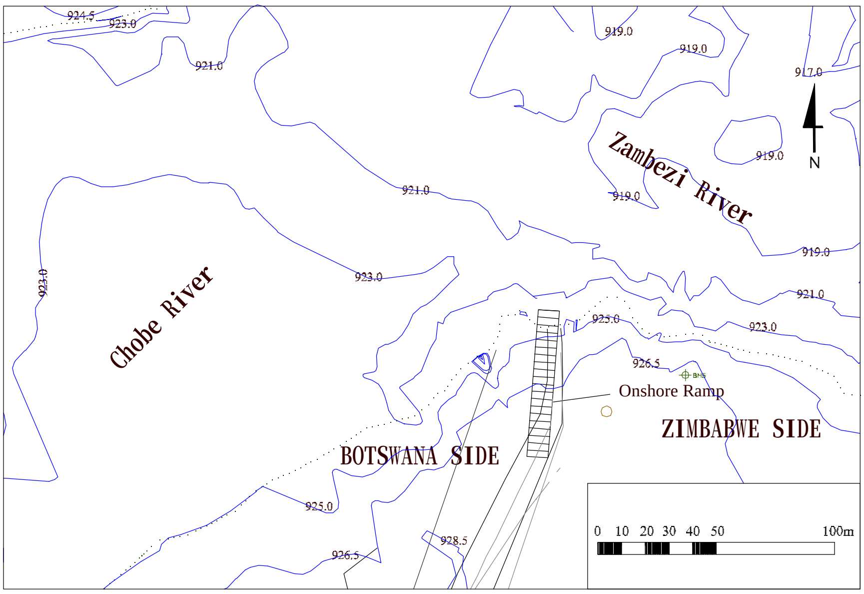


Figure 14.4.3 (2) Location of Onshore Ramp (Botswana Side)

b) Typical cross section of onshore ramp

In assessing the upper and lower elevations of the ramp, the range in river levels at the project site as determined in the hydrological analyses (see Chapter 6) was considered. This fixed the transition point and level of toe and top of the onshore ramp.

The calculation method for these parameters was based on the following:

Level of Toe: L.W.L – Full Draft – Clearance
Level of Top: H.W.L + Clearance

where:

L.W.L =	low flow water level, 5 year return period	: 924.74m
H.W.L =	high flow water level, 5 year return period	: 927.82m
Full Draft		: 1.5m
Clearance		: 0.5m

The adopted levels of the toe and top of the ramp were therefore derived as 922.74 m and 928.32 m respectively, the range being 5.58 m. This is illustrated below in Figure 14.4.4.

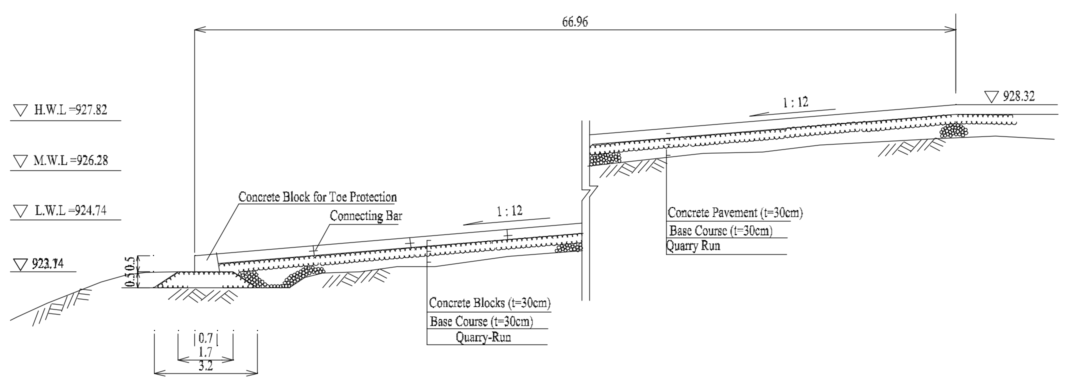


Figure 14.4.4 Typical Cross Section of Onshore Ramp

(3) Reconstruction of expansion of parking lot

The proportion of traffic being truck with semi trailer has been accounted for as more than 50% of the whole traffic volume. Therefore, the planning of parking space should take account of dimension and number of truck with semi trailer. In according to field survey of ferry operation by JICA study team in 2000, the number of waiting truck with semi trailer was maximum four, however, the capacity of parking lot should be determined in consideration of future traffic volume and conditions of entry formalities. As a result, parking lot should be space for eight tracks with trailer in consideration of them. The design conditions of parking lot are as follows.

Length of maximum truck with semi trailer	: 28 m
Width of maximum truck with semi trailer	: 2.5 m
Clearance between parking lot	: 0.6m
Area of parking lot 28 m x 24.2 m	: 677.6m^2

The layout plan of parking lot is shown in Figure 14.4.5.

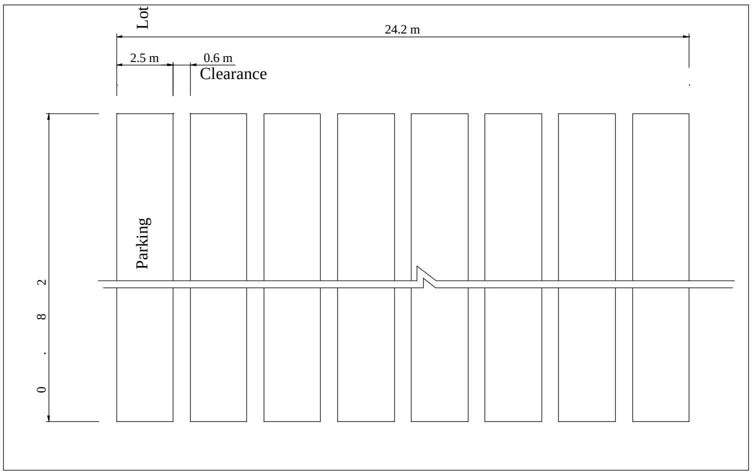


Figure 14.4.5 Layout plan for parking lot

(4) Construction of storage facility

According to design criteria as shown in 10.3.2, the layout plan for storage facility is illustrated in Figure 14.4.6. The storage facility consists of three rooms such as management room, fuel storeroom and parts storeroom as follows.

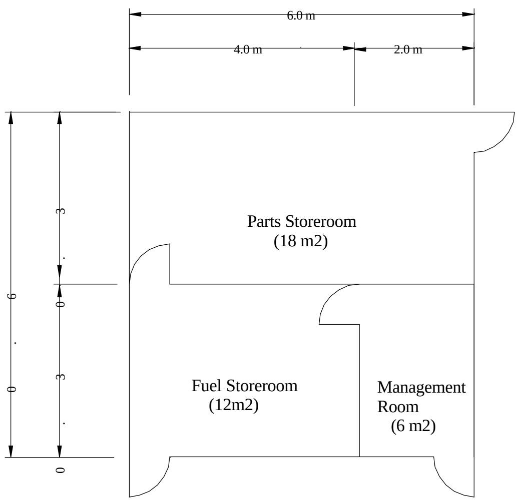


Figure 14.4.6 Layout plan for storage facility

(5) Installation of 2 new ferries

As described in Section 10.3.4, a new ferry are installed as additional ferry in 2006 due to a capacity shortage of the ferry in case of the high growth scenario. Moreover, a new ferry are installed in 2014. These ferries are replaced in 2026 and 2034 respectively, considering the ferry lifetimes. While in case of low growth scenario, new ferries are installed in 2008 and 2022. The new ferry in 2008 are replaced in 2028. Figure 14.4.7 shows new ferry of 160 tons type.

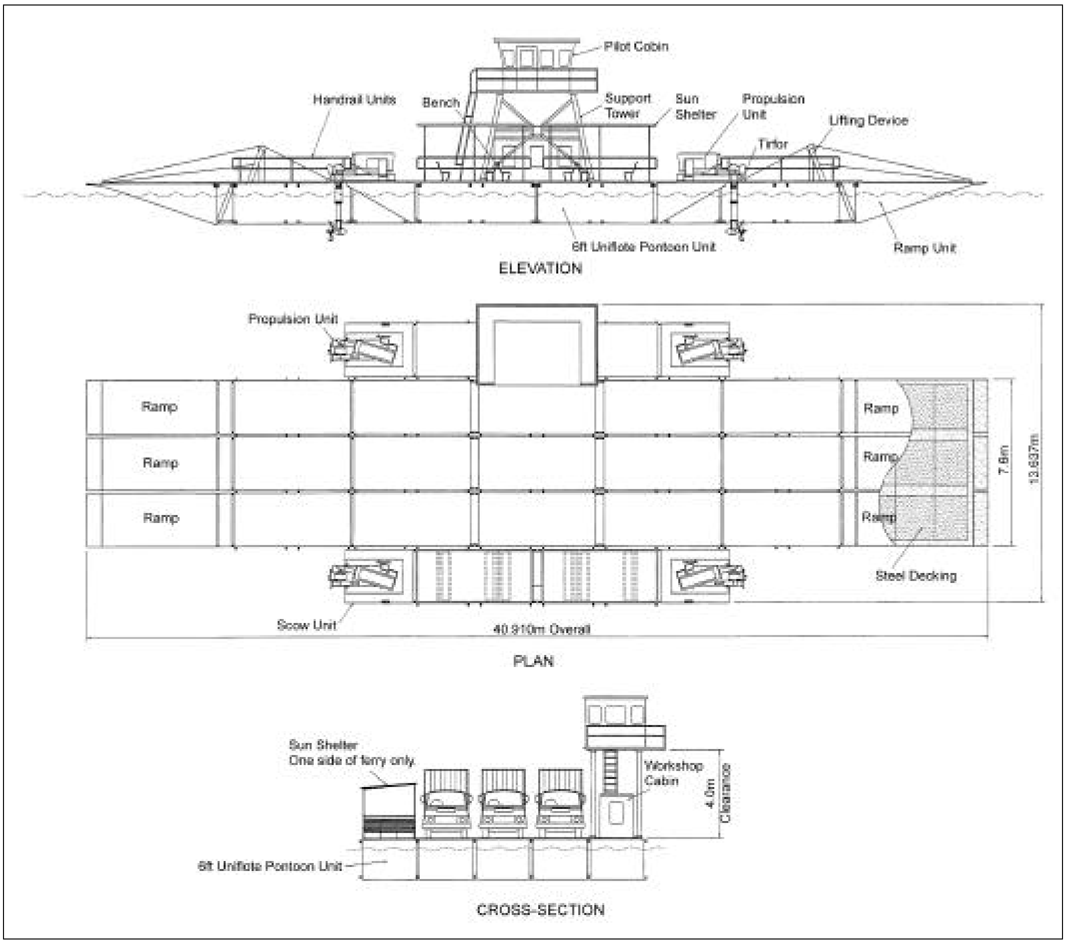


Figure 14.4.7 New Ferry of 160 tons Type

(6) Improvement and maintenance of ferry facilities

a) Onshore facilities

As installation of new ferry, the following works should be maintained because it is thought that there will be cracks, rutting, pot holes, etc. in the onshore ramp and parking lot.

- Maintenance of onshore ramp
- Maintenance of parking lot

b) Offshore facilities

The main components of the ferry are recommended for maintenance and improvement at the following interval according to field survey and past maintenance records by ESCO.

- Replacement of engine for existing ferry : Every 10 years
- Improvement of upper deck for existing ferry : Every 4 years
- Replacement of propeller for existing ferry : Every 4 years
- Improvement of ramp for existing ferry : Every 10 years
- Replacement of safety equipment : Every 5 years
- Replacement of engine for new ferry : Every 10 years
- Improvement of upper deck for new ferry : Every 5 years
- Replacement of propeller for new ferry : Every 5 years
- Improvement of ramp for new ferry : Every 5 years

In conclusion, the schedule of improvement program for “Temporary Works” Case and “Improvement of Ferry Facilities” Case for high and low growth scenario are shown in Table 14.4.1 and Table 14.4.2.

Table 14.4.1 Schedule of Improvements (High Growth Scenario)

Work Items \ Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Temporary Works																																		
Replacement of onshore ramp				▬																														
Dredgeing work on basin				▬																														
Improvement of Fetty Facilities																																		
Reconstruction of onshore ramp		▬																																
Reconstruction and expansion of parking lot		▬																																
Construction of storage facility		▬																																
Replacement of engine			▽										▽																					
Improvement of upper deck		▽				▽				▽				▽																				
Replacement of propeller			▽				▽				▽				▽																			
Improvement of ramp	▽																																	
Replacement of safety equipment		▽					▽					▽					▽					▽					▽					▽		
Maintenance of onshore ramp						▬																												
Maintenance of parking lot						▬																												
Installation of New Pontoons						▽								▽												▽								▽
Replacement of engine																▽								▽										
Improvement of upper deck											▽					▽			▽		▽			▽					▽		▽			
Replacement of propeller											▽					▽			▽		▽			▽					▽		▽			
Improvement of ramp											▽					▽			▽		▽			▽					▽		▽			
Demobilization of ramp																										▽								▽

Table 14.4.2 Schedule of Improvements (Low Growth Scenario)

Work Items \ Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Temporary Works																	
Replacement of onshore ramp				▬													
Dredgeing work on basin				▬													
Improvement of Fetty Facilities																	
Reconstruction of onshore ramp		▬															
Reconstruction and expansion of parking lot		▬															
Construction of storage facility		▬															
Replacement of engine			▽										▽				
Improvement of upper deck		▽				▽				▽				▽			
Replacement of propeller			▽				▽				▽				▽		
Improvement of ramp	▽																
Replacement of safety equipment		▽					▽					▽					▽
Maintenance of onshore ramp								▬									
Maintenance of parking lot								▬									
Installation of New Pontoons								▽									
Replacement of engine																	
Improvement of upper deck													▽				
Replacement of propeller													▽				
Improvement of ramp													▽				
Demobilization of ramp																	

Work Items \ Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Temporary Works																	
Replacement of onshore ramp																	
Dredgeing work on basin																	
Improvement of Fetty Facilities																	
Reconstruction of onshore ramp																	
Reconstruction and expansion of parking lot																	
Construction of storage facility																	
Replacement of engine																	
Improvement of upper deck																	
Replacement of propeller																	
Improvement of ramp																	
Replacement of safety equipment					▽					▽					▽		
Maintenance of onshore ramp																	
Maintenance of parking lot																	
Installation of New Pontoons					▽						▽						
Replacement of engine	▽														▽		
Improvement of upper deck	▽						▽			▽					▽	▽	
Replacement of propeller	▽						▽			▽					▽	▽	
Improvement of ramp	▽						▽			▽					▽	▽	
Demobilization of ramp					▽						▽						

CHAPTER 15 CONSTRUCTION PLANNING

15.1 Construction Methods

15.1.1 Main Bridge Construction

(1) Construction of Foundation

Since the average water depth at the construction location of the piers is 8.0m, the temporary bridge supported by steel pipes will be prepared from each riverbank toward the central part of the river up to the pier location. The construction sequence of the foundations which will be built in the river is as below:

a) Setting up the Rotary Casing

The full-perimeter rotary casing supported by a main body and control unit will be set up at the designed location of pile.

b) Excavation of the Hole using Rotary Casing

The rotary casing with a cutter edge which is rotated at high torque level, and chisel and hammer bucket inside casing excavate the riverbed sedimentation and weathered basalt rock to the designed elevation of foundation bottom.

c) Measurement of the Design Depth

The design depth required for the foundation pile will be measured by steel measurement rod and inside hole will be cleaned by air lift tube.

d) Inserting Reinforcing Cage

An inner casing is lowered to the predetermined depth and reinforcement bar cage is inserted inside the inner casing.

e) Inserting the Tremie Pipe and Pouring Concrete

The tremie pipe will be set inside the inner casing and concrete be poured through the tremie pipe. After finishing pouring the concrete to form cast-in-place pile, the tremie pipe will be removed.

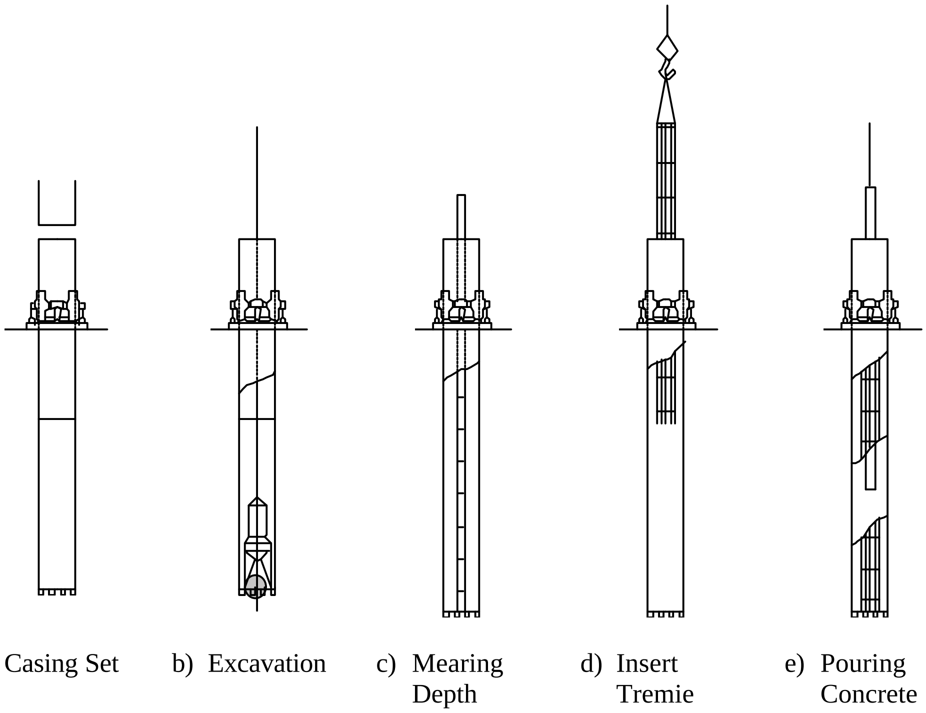


Figure 15.1.1 Construction of Foundation Pile

(2) Construction of Superstructure

The superstructure will be built after preparing the support section on the pier and move toward outside direction using form travelling with which pouring in-situ concrete. Since the concrete segments move side by side simultaneously, it does not require the falseworks in the river, which is able to contribute to avoid the damages by flooding of the river and to reduce the construction duration.

a) Preparation of Temporary Bridge

The temporary bridge is used for passage of the construction materials and equipment, and for working space.

b) Construction of Support Segment and Placing Form Traveller

Above each pier, the support section is concreted on falsework by steel or concrete corbels fixed by prestressing on the top of pier. The two form travellers are placed side by side.

c) Providing Temporary Stay Cable and Construction of Concrete Segment

The temporary stay cable are provided to support the concrete segment and its works up to the first stay cable.

d) Removing Temporary Stay Cable and Continuing Concrete Work

The temporary stay cable is removed when the works of the concrete segment supported by the first permanent stay cable start. The concrete segment works continued side by side up to the segment supported by the last permanent stay cable.

e) Construction of Side Span and Closure Section

Finally, the concrete segment of the side span part to be supported by scaffoldings and the closure part of the central, which will be supported by the temporary steel girders, span will be constructed.

15.1.2 Approach Span Bridge Construction

(1) Construction of Foundation

On the Zambia side, where the alluvial soil is comparatively shallow (from 3.5 m to 6.0 m), the in-situ concrete pile foundation will be constructed in the alluvial gravel layer up to a depth of approx. 7.0 m.

On the Botswana side, the concrete pile foundation will be constructed up to the weathered basalt rock (approx. 7.0 m deep). The in-situ concrete piles are constructed in drilled holes.

(2) Construction of Superstructure

Since the location of the approach span bridge is not affected by flood water, and soil condition is sufficiently strong to support the falseworks above, the superstructure will be constructed by using scaffolding and in-situ concrete.

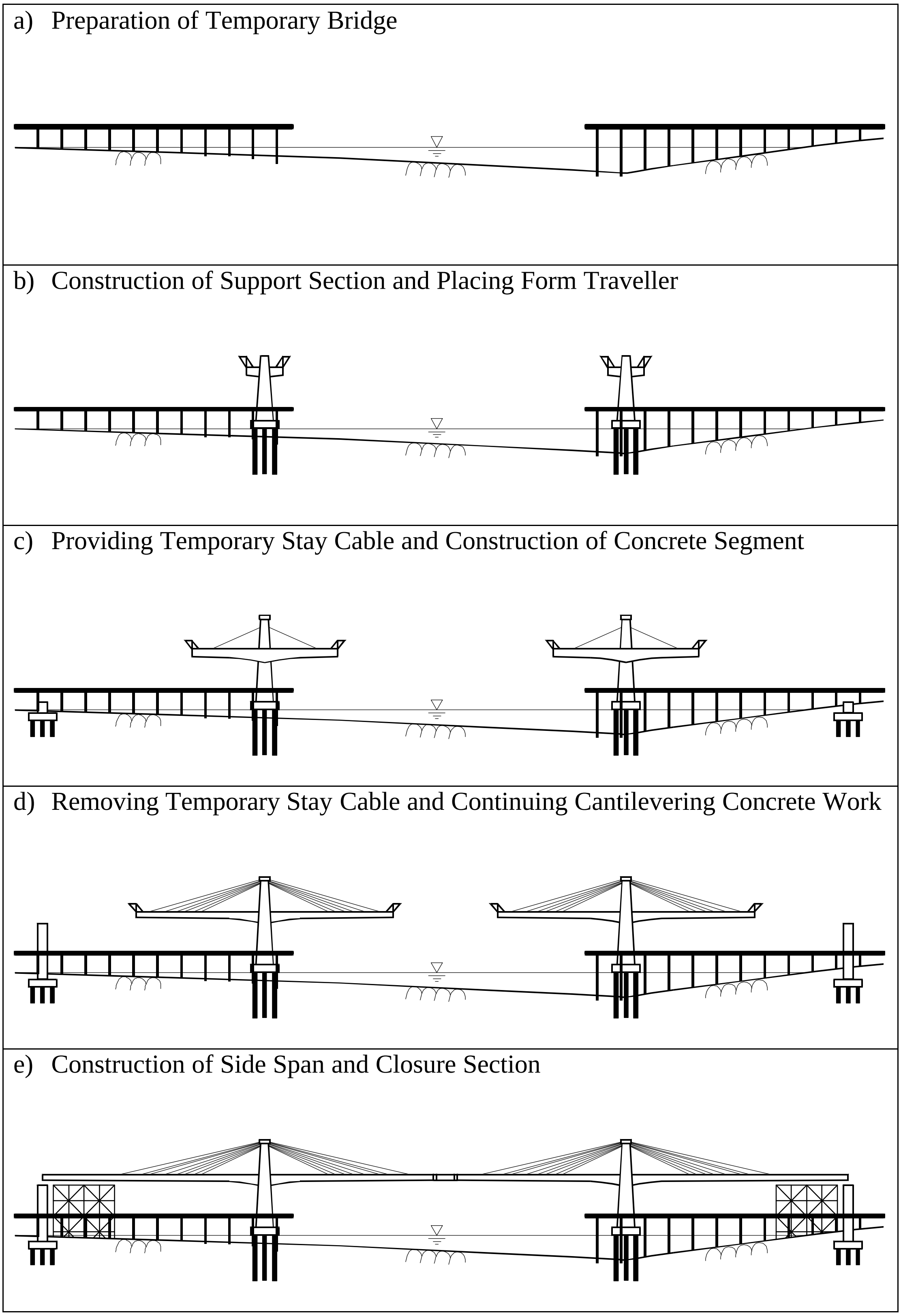


Figure 15.1.2 Construction Sequence of the Main Bridge

15.2 Procurement of Construction Labour and Materials

15.2.1 Labour

Semi-skilled and common labour for the works will be recruited from the surrounding area of the job site in Zambia, Botswana, and Zimbabwe. However, the amount of skilled labour for construction of a large scale bridge is inadequate in Zambia, Botswana, and Zimbabwe, so they will have to be recruited from Republic of South Africa (RSA) or possibly from other countries.

15.2.2 Construction Materials

(1) Concrete aggregate materials for bridge and road structure

Coarse aggregate for concrete will be available in both Zambia and Botswana.

There are three quarry sites near the construction site in Zambia (Q-1, Q-4, Q-5), one of them belongs to Zambia government (Q-1). Although the (Q-1) is the nearest quarry site from the construction site, it is required to reconstruct a crusher plant for the coarse aggregate since it is now closed and not working. The coarse aggregate, therefore, will be provided from quarry (Q-5) which is the second nearest to the construction site.

There are two quarry sites near the construction site in Botswana (Q-6, Q-7), these quarry sites are owned by the same company. On the Botswana side, therefore, it will be provided from the (Q-6) site which is the nearest to the construction site.

Fine aggregate for concrete will only be provided from the Zambia side because it is not available in Botswana. On the Zambia side, it is available at two locations and will be collected from site (Q-2) which is the nearest to the construction site.

Table 15.2.1 Quarry Sites

Distance from site	No.	Location	Type of Material	Remarks
Zambia Side				
20km	Q – 1	Katombora	Rock (Basalt)	Abandoned quarry site
45km	Q – 2	Ngwezi	River Sand	Ngwazi River
10km	Q – 3	Mambova	River Sand	River Terrace
85km	Q – 4	Senkoba	Rock (Basalt)	J.J.Lowe Company
60km	Q – 5	Livingstone	Rock (Basalt)	Southern Quarry LTD.
Botswana Side				
12km	Q – 6	Kasane	Rock (Basalt)	4 ways Garage & Filling Station
90km	Q – 7	Panda	Rock (Basalt)	4 ways Garage & Filling Station

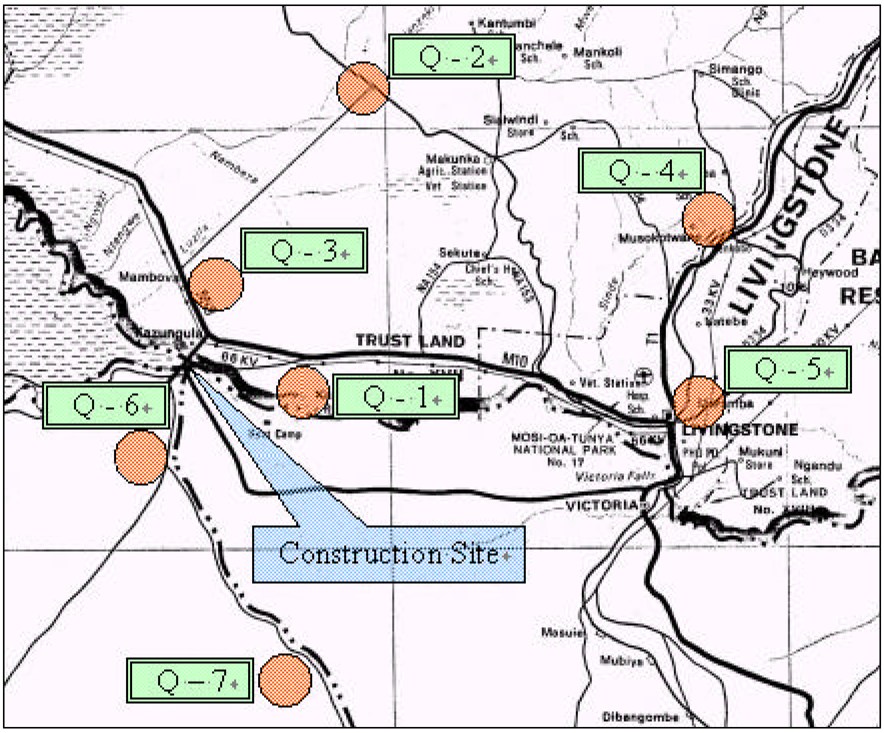


Figure 15.2.1 Location Map of Quarry Site

(2) Embankment materials

The embankment soil for the sub-grade and the base course of the approach roads will be transported from borrow areas near the construction site.

(3) Wooden materials

The wooden materials for the construction are available from each country (Zambia, Botswana, Zimbabwe) except for water-proof plywood. The water-proof plywood will be purchased in Republic of South Africa (RSA).

(4) Cement and Concrete admixtures

Cement is available in Zambia and Zimbabwe but not Botswana. The cement which is produced in both countries has enough strength to provide the 45N/mm strength (the 28th days strength) for pre-stressed concrete.

Concrete admixtures is not available in each country (Zambia, Botswana, Zimbabwe). The concrete admixtures, therefore, are planned to be imported from Republic of South Africa (RSA) or other countries.

(5) Steel materials

Almost all the major steel materials for construction except for deformed bar and minor steel materials will be imported from Republic of South Africa (RSA) or other countries. The deformed bar and minor steel materials will be procured from Zimbabwe since they are not produced in Zambia or Botswana at all.

(6) Procurement of materials

Major materials for the construction to be available in each country are shown in Table 15.2.2.

Table 15.2.2 Procurement of Materials

Item	Unit	Zambia	Botswana	Zimbabwe	Remarks
Cement	T	+	+	+	
Fine Aggregate	m^3	+	---	+	
Coarse Aggregate	m^3	+	+	+	
Re-bar	T	---	---	+	
Timber	m^3	+	---	+	
Gasoline	L	+	+	+	
PC Strand	T	---	---	---	From RSA

15.3 Procurement of Construction Equipment

Some of the equipment to be used for the construction of bridge, road and border control facilities will be available from each country (Zambia, Botswana and Zimbabwe). In Zambia, the equipment of just road construction will be available. In Botswana, most of the equipment will be available on account of bordering on Republic of South Africa (RSA). In Zimbabwe, small equipment only will be available. Heavy equipment and/or special equipment will be basically procured from Republic of South Africa (RSA). However, if some of the equipment for necessity of construction is unavailable in RSA, it will be procured from other African or other countries.

15.4 Time Schedule of Construction

Construction schedule for the bridge and approach roads will be planned to consider the flood records as following Figure 15.4.1. The Figure 15.4.1 shows the monthly water flows at the Kazungula Bridge site, based on the records of the Victoria Falls (Zambian side). The duration from February to June is flood season, and the preparation of false work such as the temporary bridge to be built in the river should consider these flood water levels when the deck level of the temporary bridge is determined. Construction of all of the bridge substructures and approach roads therefore, will be during the dry season from July to January. Meanwhile, construction of border control facilities will not need to consider flood and/or rainy season.

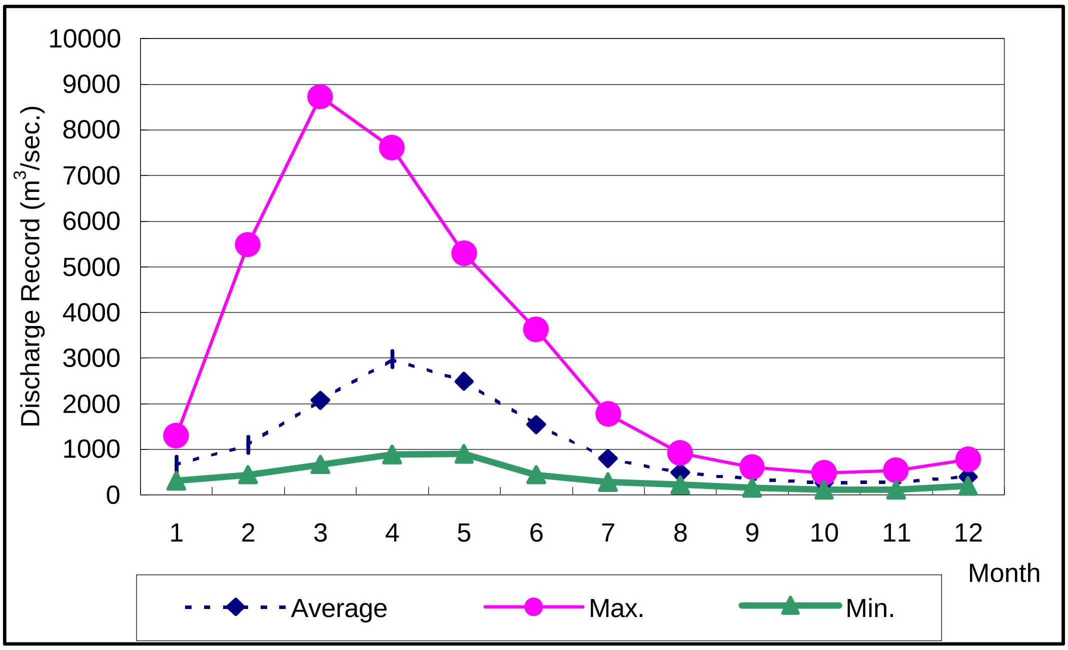


Figure 15.4.1 Monthly Water Flows at Kazungula

The tentative construction schedule for the bridge and approach roads are shown as follows in Figure 15.4.2

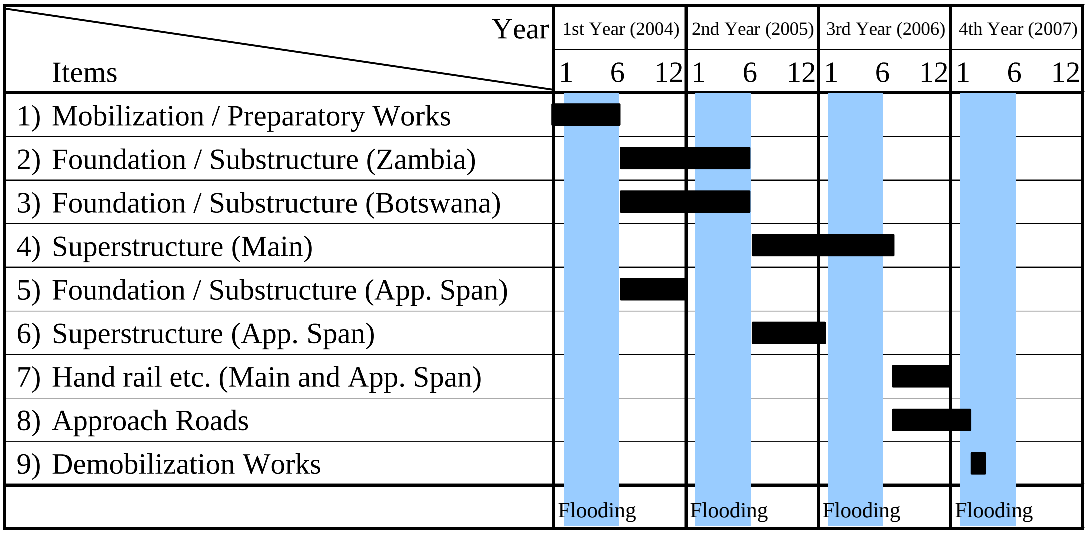


Figure 15.4.2 Tentative Construction Schedule for Bridge and Approach Roads

The tentative construction schedule for the border control facilities are as following in Figure 15.4.3

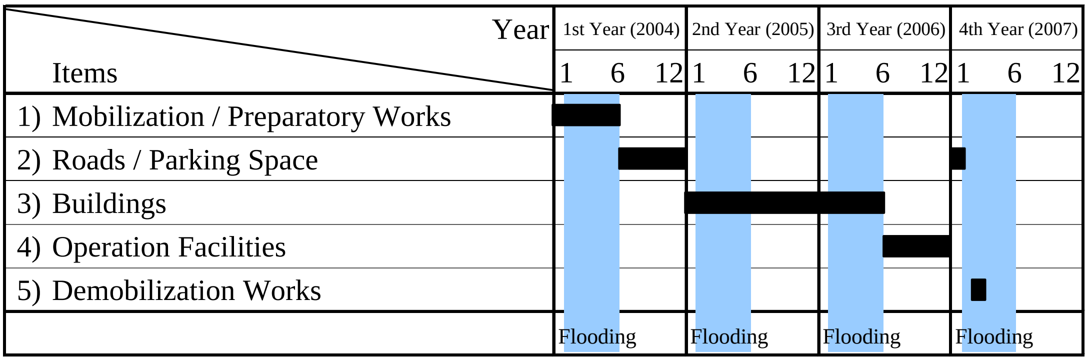


Figure 15.4.3 Tentative Construction Schedule for Border Control Facilities

CHAPTER 16 MAINTENANCE PROGRAMMING

16.1 Existing Organization for Maintenance

A maintenance organization is necessary to ensure the effective implementation of all maintenance activities. The system for maintenance should accommodate with the existing organization.

The administration systems for the public roads of the countries concerned are represented with organization charts, and the relationship between the maintenance department in charge of road and bridge and other related departments is shown in the charts.

16.1.1 Administration of Roads in Botswana

Administration system for public roads in Botswana is divided into the following areas of responsibility:

- the national road network is the responsibility of the Roads Department under the Ministry of Works, Transport and Communications.
- the other public roads in the District and Municipal areas are the responsibility of District and Town Councils under the Ministry of Local Government, Land and Housing.
- the non-national roads within the National Parks and Game Reserves areas are the responsibility of the Department of Wildlife and National Parks.

(1) Ministry of works, Transport and Communications

The Ministry is headed by the Minister and the Permanent Secretary (PS). The PS is assisted by two Deputy Permanent Secretary (DPS).

The Department of Architecture and Buildings Services, Electrical and Mechanical Services, the Central Transport Organization (CTO) and Department of Meteorological Services are coordinated by a Deputy Permanent Secretary. The Departments of National Transport and Communications, Roads, Civil Aviation and Postal Services are coordinated by a Deputy Permanent Secretary of Transport and Communications. The Departments of Ministry Management and Botswana Railways and the Planning, Statistics and Research Unit reports directly to the Permanents Secretary.

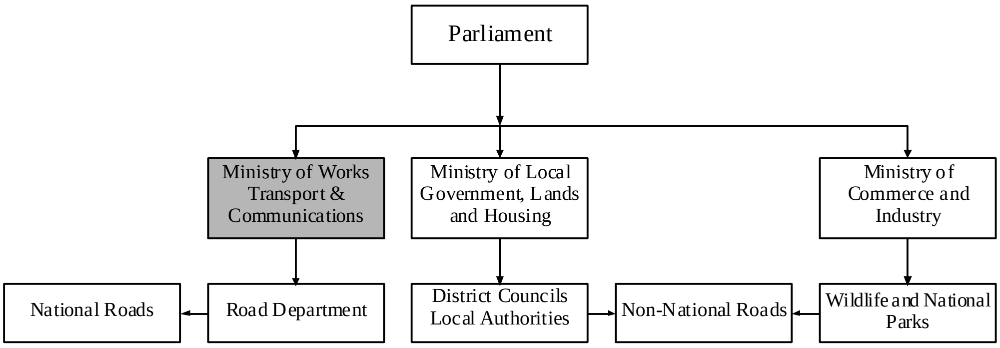


Figure 16.1.1 Public Roads Organization (Botswana)

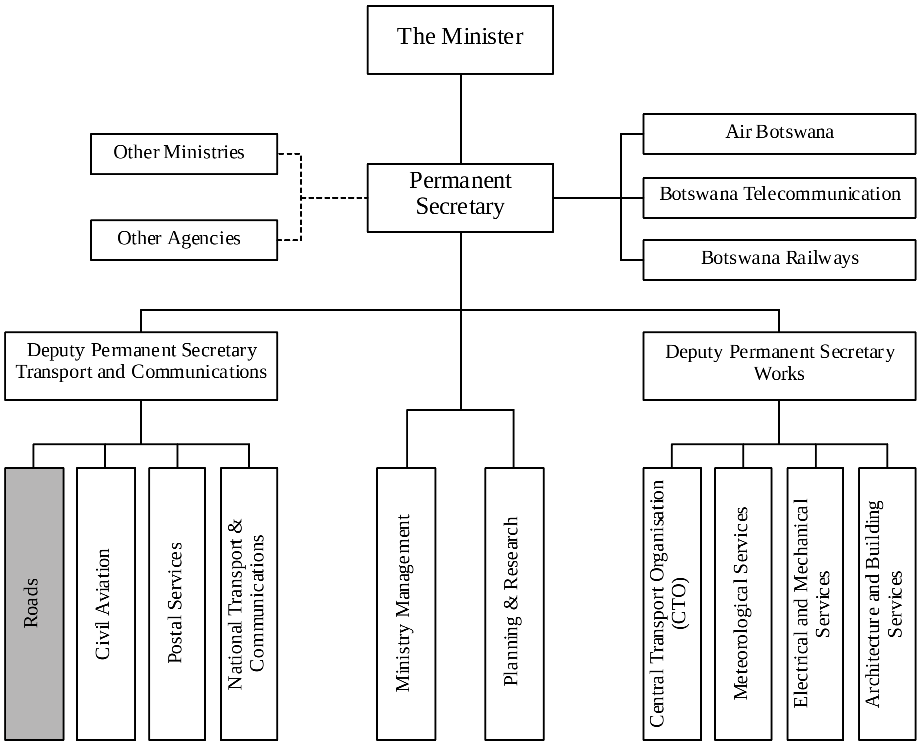


Figure 16.1.2 Ministry of Works, Transport and Communications (Botswana)

(2) Roads Department

The overall objective of the Roads Department, including bridge division, is to provide adequate road communications within the country as well as with neighbouring countries by planning, designing, constructing and maintaining all national roads. In order to fulfil the above mentioned objectives, the Roads Department has six divisions which are responsible for specific delegated function.

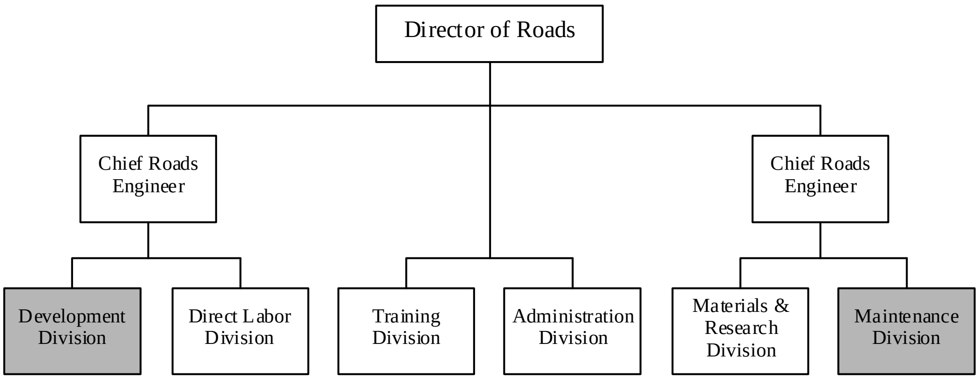


Figure 16.1.3 Organization of Roads Department (Botswana)

16.1.2 Administration of Roads in Zambia

Administration system for public roads (including bridge) in Zambia is under the Ministry of Works and Supply. The overall organizations of the Ministry of works and Supply under the Permanent Secretary and the Roads Department Headquarters are shown as below.

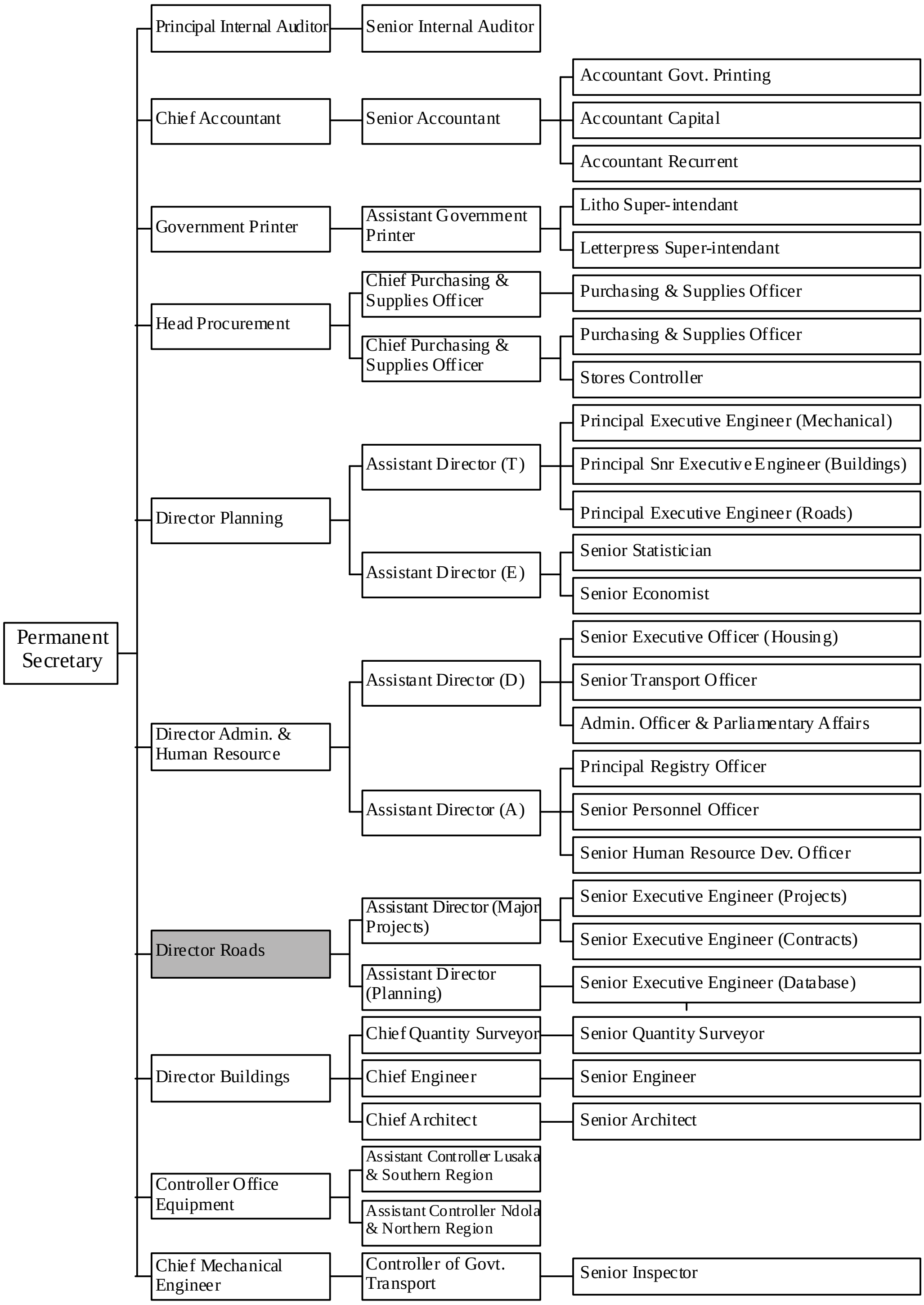


Figure 16.1.4 Organization of Ministry of Works and Supply (Zambia)

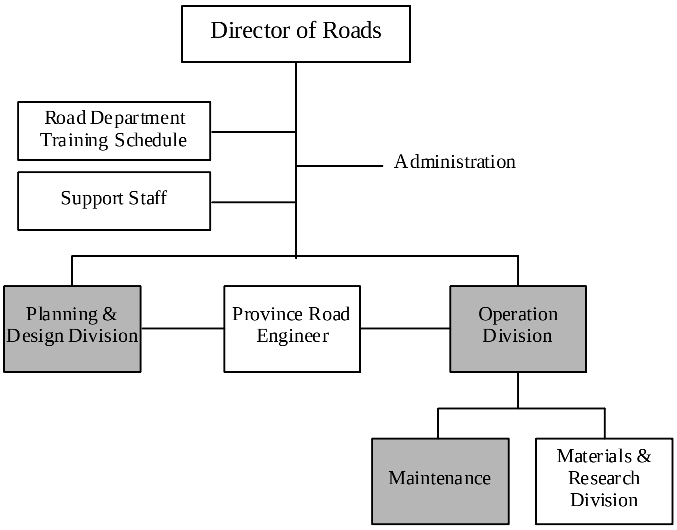


Figure 16.1.5 Organization of Roads Department (Zambia)

16.1.3 Administration of Roads in Zimbabwe

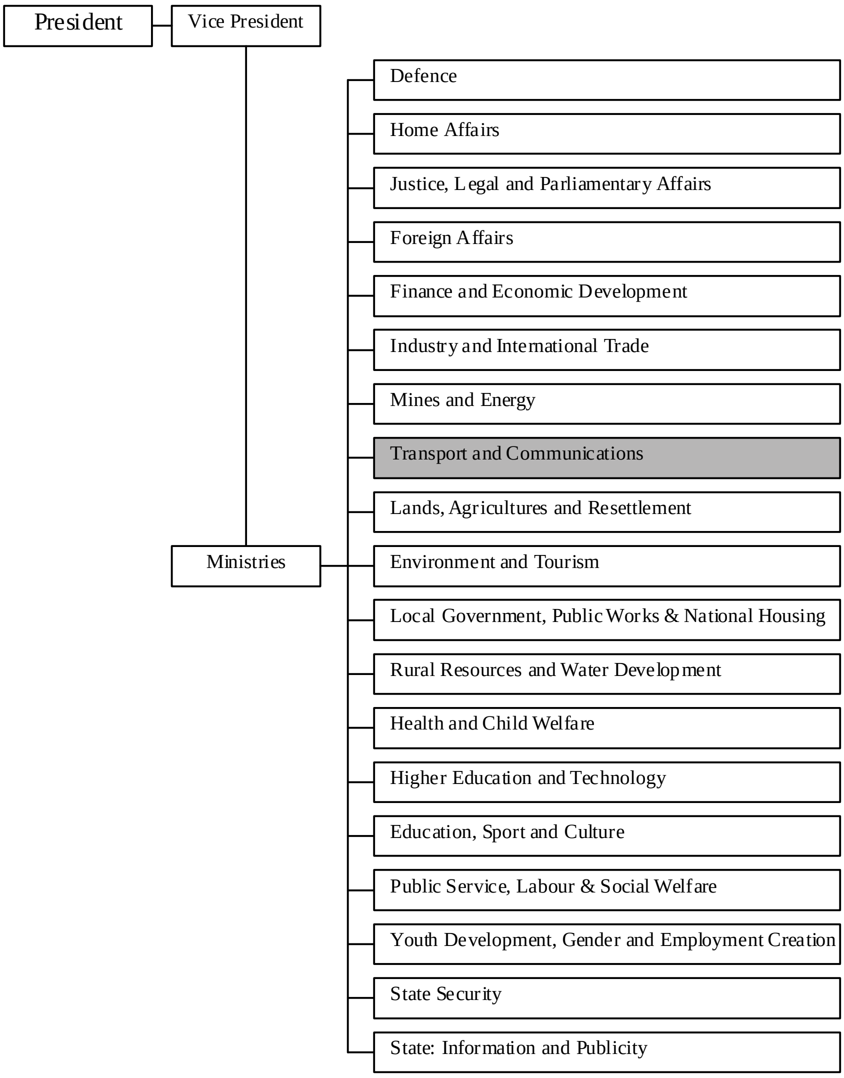


Figure 16.1.6 Government Organization (Zimbabwe)

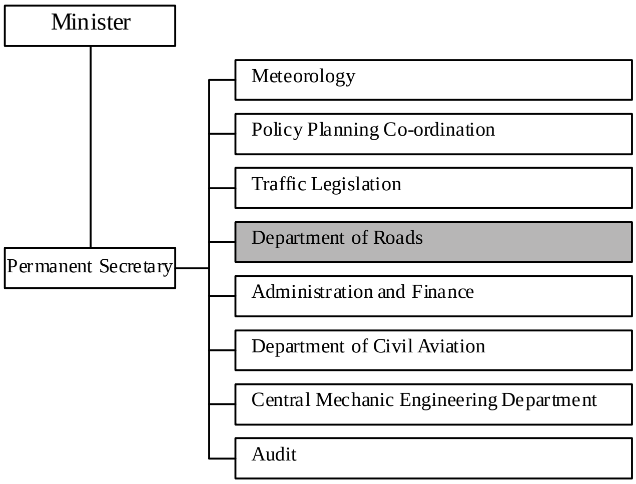


Figure 16.1.7 Organization of Ministry of Transport and Communications (Zimbabwe)

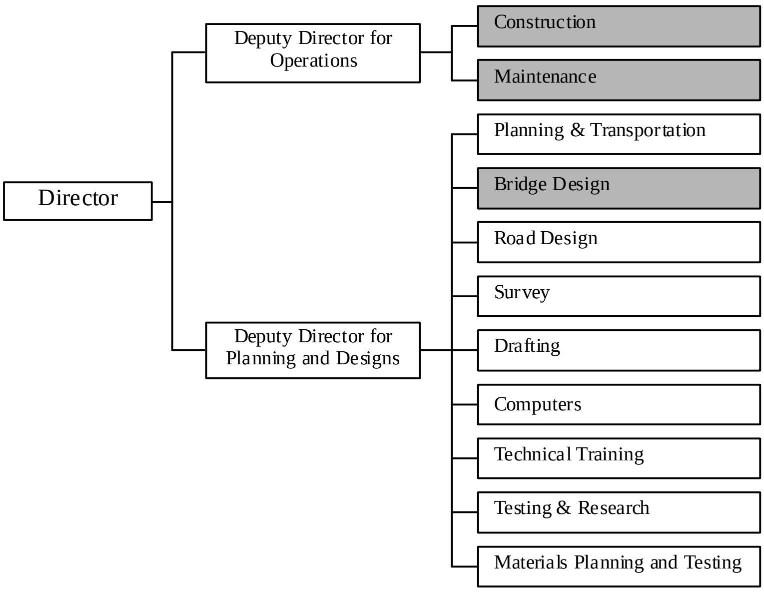


Figure 16.1.8 Organization of Department of Roads (Zimbabwe)

16.2 Technical Inspections

Technical inspections can be categorized into bridge, approach roads and border control facilities. The judgement and result records are useful for the appraisal for the future repair schedule or immediate actions required. The technical inspections and its budgetary allotment are normally under control of the organizations related.

16.2.1 Inspection for Bridge Structures

Inspections for bridge structures can be categorized into three types of inspection.

(1) Normal Inspection

The inspection to be performed visually in order to detect damage to the bridge at an early stage. It is performed at the same time as daily patrols of the road.

(2) Periodic Inspection

The inspection to be performed periodically in order to maintain the bridge. It is mainly done visually or by using simple inspection equipment.

(3) Special Inspection

The inspection to be performed in order to assure the safety of the bridge after the occurrence of a disaster, such as earthquake, flood, localized torrential downpour, or when any abnormal condition has been detected.

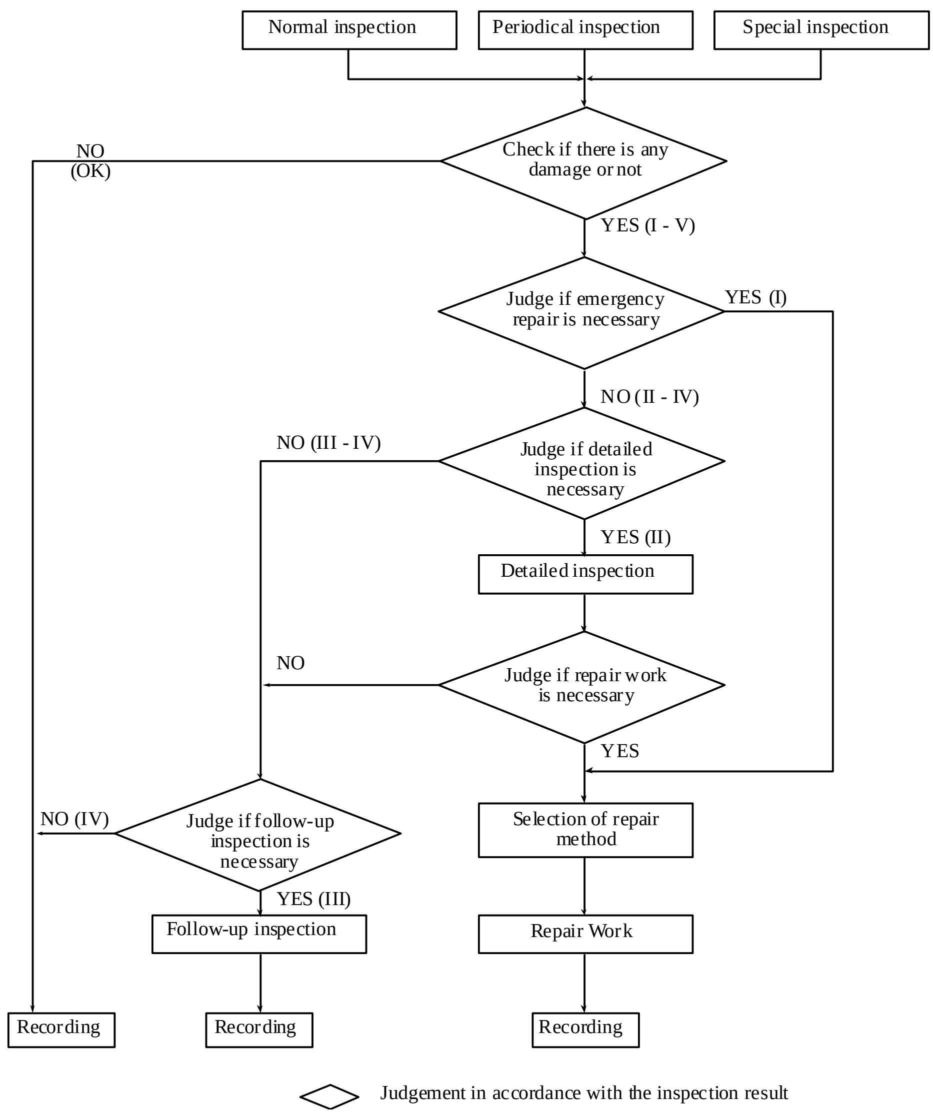


Figure 16.2.1 Inspection Work Flow

Table 16.2.1 Criteria for Grade of Damage

Grade	General Conditions
I	Being heavily damaged, affecting or possibly affecting the safety of traffic, or causing or possibly causing trouble to third parties, it is necessary to carry out an emergency repair.
II	Being damaged in a large part, it is necessary to carry out a detailed inspection for studying whether or not any repairs are required.
III	Damaged being found, it is necessary to carry out follow-up inspection.
IV	Damage being found, it is necessary to record the conditions thereof.
V (O.K.)	No damage found as the result of inspection.

(4) Follow-up Inspection

The inspection to be performed repeatedly of a damaged part whose condition of deterioration needs to be known. It is performed visually or by using simple inspection equipment and tools.

(5) Detailed Inspection

The inspection to be performed in order to determine necessity of any repair or reinforcement. It is performed by using inspection equipment and tools.

16.2.2 Inspection of Cable System Bridge

An Extra-dosed bridge is a bridge in which the superstructure is prestressed by external cables, or stays, passing over or attached directly to pylons located at the main piers. The superstructure generally consists of an orthotropic deck and continuous girders. There are several special elements that are unique inspection to cable-stayed bridges.

(1) Cable System

The inspection of the cable system should include:

- Exterior of the cables (cable wrapping)
- Cable anchorage
- Anchor pipe clearances
- Flange joints
- Sheathing pipe welds (polyethylene or steel)
- Sheathing expansion joints
- Wrap ends near the pylon and deck
- Reading the load cells and recording the forces in the cables, noting the loads on the deck at the time of the readings
- Type and amplitude of cable vibrations, noting the direction and speed of wind

(2) Inspect the cable pipes for Cable Piles

- Corrosion
- Splitting
- Cracking
- Excessive bulging

Cable pipes should be inspected carefully. Special concern should be given to the connections with the cable dampers, the tower exists, and anywhere pipes are welded together.

(3) Cable Damper System

The commonly used cable damper system is a rubber damper type. Inspect this cable damper system for:

- Corrosion
- Tightness in the connection to the cable pipe
- Excessive in deformation
- Torque in the bolts

(4) Cable Anchorages: Inspect the Cable Anchorages for:

- Water tightness of neoprene boots at the upper ends of the guide pipes
- Drainage between the guide pipe and transition pipe
- Corrosion of the anchor system
- Defects, such as splits and tears, in the neoprene boots
- Sufficient clearance between the anchor pipe and cable, noting rub marks and kinks
- Cracks and nut rotation at the socket and bearing plate
- Seepage of grease from the protective hood

16.2.3 Inspection of Approach Roads

Maintenance for approach road is proposed to be divided into the inspection, evaluation and repair work as follows:

(1) Inspection

Damage types for road inspection are shown in Table 16.2.2.

Table 16.2.2 Damage Type for Inspection

Damage Type	Description
(1) Embankment	(a) Submerge (b) Collapse
(2) Pavement	(a) Settlement (b) Cracking (c) Potholes (d) Rutting (e) Wave
(3) Shoulder	(a) Washing out
(4) Side ditch	(a) Accumulation (b) Settlement (c) Collapse
(5) Retaining wall	(a) Cricking (b) Settlement (c) Collapse
(6) Slope	(a) Landslide (b) Collapse of protection (c) Crocking (d) Erosion
(7) Culvert	(a) Accumulation (b) Settlement (c) Collapse

The inspections are carried out using the inspection sheet.

(2) Evaluation

In order to judge the necessity of repair work, observations of damage or deterioration are categorized into three ranks according to the following guidelines:

"A" : Inspection finds major damage
Damage is serious and problem is obvious.
Remedial action must be taken as soon as possible.

"B" : Inspection finds damage.
Damage notes and requires investigation into the cause of the problem before any remedial work proposed.

"C" : Inspection finds minor damage.
Damage noted but not serious and does not warrant remedial actions.
Continue with monitoring.

(3) Repair works

Typical repair work methods for each damage type are shown in Table 16.2.3.

Table 16.2.3 Typical Repair Work

Items	Repair Work Method	Purpose
(1) Embankment	Refill Embankment	- to lift the road surface above the normal flood level
	Improvement of Culvert	- to increase discharge capacity by the removal of debris and sediment from the culvert inlet
(2) Pavement	Sealing/Filling	- to prevent water penetration from crack and regain pavement strength
	Patching	- to prevent widening the damage from existing pothole and prevent the water penetrating to lower layer
	Milling and Overlay	- longer term repair to remove the materials and provide a new road surface for improvement ride condition
	Overlay	- longer term repair to improve surface ride quality
	Reconstruction	- permanent repair
	Surface Treatment	- to improve surface texture
(3) Shoulder	Asphalt Kerb or Kerb Ditch	- to prevent the shoulder washing out by surface water
(4) Slope	Recutting/Refilling	- to recover the slope stability
	Additional or Build Slope Drainage	- to prevent the slope from scouring and eroding by water
	Slope Protection	- to protect the slope surface from eroding and weathering by surface water
	Weight Shifting	- to prevent the embankment slope from slipping
	Structural Support	- to keep slope stability and prevent the slope from the rock avalanche or any soil sliding
(5) Other Structure/ Retaining Wall/ Drainage/ Gully/Side Ditch Culvert	Sealing/Filling	- using synthetic resin or cement mortal, to seal or to fill into the crack or depression to keep structural capacity
	Partial/Overall Reconstruction	- to regain adequate structural strength
	Reinforcement to increase the Structure Strength	- to reinforce to increase the structural strength

16.2.4 Inspection and Maintenance for Riverbank and Riverbed

Determining an effective solution to a riverbed or river problem is difficult and careful consideration will be needed. Settlement of foundations, local scour, bank erosion, and channel degradation are complex problems and cannot be solved by one or two methods. A geologist, hydraulic engineer, and structural engineer are all needed for consultation prior to undertaking the solution of a serious maintenance problem. In some cases, certain remedial work could actually be detrimental to the structure.

(1) Maintenance

Erosion may be controlled by using rock or stone slope protection, grouted rock, interlocking sheet piles, pile retards, tetrahedrons, wire enclosed rock, broken concrete, etc. The type of protection should be compatible with the location and natural roughness of the bank and other site considerations, making use of local material is suitable solution when available. The velocity of flow, site material and direction of the current are critical factors in selecting the materials.

In preventing or limiting scour, the engineer should make a scour analysis to assess the situation prior to undertaking any corrective action. Possibly the damage was caused by a flood well in excess of the design event. In this case, the only remedial action justified may be to return the structure to its original configuration, provided no significant channel modifications have occurred or are anticipated.

(2) Survey Methods of Scouring Depth

To prevent the problems of the riverbed around the abutments and piers of bridge, the following survey methods, mainly, can be conducted for analyzing causes and determining solution.

a) Radio Control Boat

The equipment consists of radio control boat (RCB) equipped with sonic wave sound and personal computer. By remote control system, the RCB will be moved around the abutment or the pier and measure the water depth. The measured data is collected into a personal computer. The contour map of the riverbed is printed automatically. It is useful output for analysis on the scoured riverbed.

b) Ultrasonic Sounding

The equipment consists of ultrasonic sensor and personal computer. The riverbed condition and the bridge pier can be represented on the display through imaging sonar.

c) Magnetic Ring

The equipment consists of measurement pipe with the magnetic ring and magnetic sensor. The measurement can be carried out through the sensor provided inside of pipe which can trace the movement of the magnetic ring.

d) Electrical Magnet Sensor

The equipment consist of measurement pipe and magnetic pieces provided on the measurement pipe. If the magnetic piece is removed by the river flow from the pipe, the sensor can catch its removal which will tell scouring condition.

16.3 Maintenance Programme for Borer Control Facilities

Maintenance of Border Control Facilities will be performed by the Contractor under the conditions of the contract, however after its termination, the maintenance will have to be carried out by the government maintenance organization or private sector hired. The objective of the maintenance is to keep any structures and utilities in good conditions for possible long life.

The maintenance works of the Border Control Facilities will be substantially made in line with the pre-established Maintenance Manual which contains various maintenance items, period and procedural description as well as the list of name and telephone directory of manufacturers of the construction materials and equipment. The maintenance works will be mainly made for cleaning the interior and exterior of the building, repairing finishes, supply and feeding of lubricants and chemicals and checking, repairing/replacing parts of electrical and mechanical facilities.

The principal inspection items and recommended approximate maintenance periods of the Border Control Facilities are summarized below:

Table 16.3.1 Inspection items and period for building facilities

No.	Items	Period
1	Cleaning of floor finishes	Daily
2	Watering lawn and planting	Daily
3	Cleaning of wall and ceiling	Yearly
4	Repainting of exterior walls	Every 3 years
5	Repainting to rusted portion	Every 3 years
6	Checking of level, vertical and horizontal alignment of the land/ structure	Yearly
7	Visual checking of any cracks, water leakage and deterioration of materials	Anytime

Table 16.3.2 Inspection items and period for building utilities

No.	Work Items	Inspection	Period
1	Power receiving facility	Regular inspection	6 months
		Grounding resistance measurement	1 year
2	Emergency diesel generator	Test running	2 months
		Regular inspection	6 months
3	Uninterruptible Power Supply System	Battery replacement	5 years
4	High mast lighting pole	Lighting fixture cleaning	6 months
		Lamp replacement	At any time
		Grounding resistance measurement	1 year
5	High bay lighting pole	Lighting fixture cleaning	6 months
		Lamp replacement	At any time
6	Internal lighting	Lighting fixture cleaning	1 year
		Lamp replacement	At any time
7	Lightning protection systems	Grounding resistance measurement	1 year
8	Water tower	Tank cleaning	1 year
		Pump regular inspection	2 months
		Grounding resistance measurement	1 year
9	Septic tank	Filter replacement	Supplier's Recommend
		Outlet water inspection	6 months
10	Air-conditioner	Filter cleaning	Half months
11	Fire hydrant systems	Test running	6 months
		Regular inspection	6 months
12	Weigh Scale	Regular inspection	6 moths

16.4 Estimation of Maintenance Costs

16.4.1 Bridge and Approach Road

Maintenance costs will be divided into bridge maintenance cost and approach road maintenance cost on this project. The bridge maintenance cost will be mainly consisted of bridge pavement, expansion joint, drainage, bearings, stay cables, and technical inspection. The maintenance cost of approach road will mainly be for road pavement, embankment slope protection, drainage and technical inspection. The maintenance of the bridge and approach road commonly shall be done annually, the cost for the bridge maintenance will be estimated 0.2% of the bridge construction cost, and for the approach road maintenance will be estimated 2.0% of the construction cost of approach road. Maintenance cost for the bridge and approach road is shown in Table 16.4.1.

Table 16.4.1 Maintenance costs for the bridge and approach road

Maintenance Cost

Maintenance item	Maintenance Interval	Maintenance Cost (US$)
- Bridge	Annual	93,024
- Approach road	Annual	44,754
Total		137,778

16.4.2 Border Control Facility

Maintenance cost for border control facility will consist of utility that is included water supply system, drainage and electric, and building that is included office, toilet, parking lot and road pavement. The maintenance cost is estimated at 2.0% of the construction cost of border control facility, maintenance interval will be annual. Maintenance cost for the border control facility is shown in Table 16.4.2.

Table 16.4.2 Maintenance costs for the border control facility

Maintenance Cost

Maintenance item	Maintenance Interval	Maintenance Cost (US$)
- Border Control Facility	Annual	304,962
Total		304,962

CHAPTER 17 PRELIMINARY COST ESTIMATE

17.1 Formulation of Cost Estimate Procedures

The formation of cost estimate procedure is shown in Figure 17.1.1.

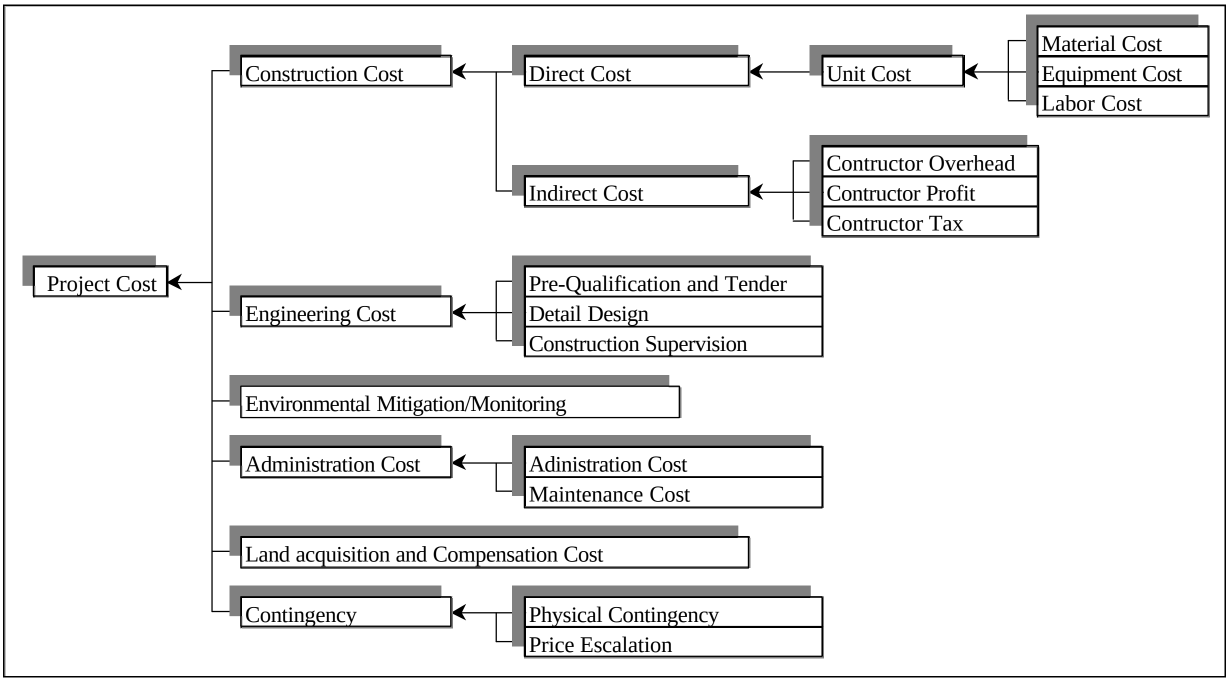


Figure 17.1.1 Formation of Cost Estimate Procedure

17.2 Basic Data and Exchange Rate of Currency

The currency exchange rates adopted to the cost estimation for construction cost were based on the day of November 1st, 2000.

1 US$	=	3600.0	Kwacha (Zambia)
1 US$	=	5.5	Pula (Botswana)
1 US$	=	55.0	Z$ (Zimbabwe)
1 US$	=	110.0	Yen (Japan)

(1 US$ = 3,600Kwacha = 5.5Pula = 55Z$ = 110Yen)

17.3 Study on Unit Prices

The unit price for labour, construction material and construction equipment were investigated during the feasibility study stage.

The unit prices in relation to the bridge cost estimation used were average price in both countries, since the bridge on this project is an international bridge that crosses between Zambia and Botswana.

In case of approach roads and border control facilities, the unit price was based on the standard market price in each country.

17.3.1 Labour Cost

The labour costs used for the cost estimation were based on the current market average prices, which were verified by each government standard price respectively. Major costs of each country for the construction are shown Table 7.3.1. These prices were obtained through each government.

Table 17.3.1 Unit Labour Cost

Item	Unit	Zambia		Botswana		Zimbabwe	
		Kwacha	US$	Pula	US$	Zim$	US$
Foreman	M/day	15,000	4.2	65	11.8	542	9.8
Special worker	M/day	10,000	2.8	65	11.8	323	5.9
Common labour	M/day	8,000	1.7	25	4.5	237	4.3
Re-bar man	M/day	6,000	2.2	50	9.1	323	5.9
Driver	M/day	5,000	1.4	50	9.1	475	8.6

M/day: man/day

(1 US$ = 3,600Kwacha = 5.5Pula = 55Z$ = 110Yen)

17.3.2 Material Cost

Materials to be used for the construction are classified into two ways, one is domestic product, the other is imported material from other countries. The prices for the construction materials were based on the current standard local market prices, when the materials are available in local market. The materials to be imported for the construction were based on the price in Republic of South Africa (RSA). Major costs of each country for the construction are shown in Table 17.3.2.

Table 17.3.2 Material Cost

Item	Unit	Zambia		Botswana		Zimbabwe	
		Kwacha	US$	Pula	US$	Zim$	US$
Cement	t	400,000	111.1	---	---	4,000	72.7
Fine Aggregate	m^3	---	16.0	35.0	6.4	500	9.1
Coarse Aggregate	m^3	---	14.8	60.0	10.9	800	14.5
Re-bar	t	---	---	---	---	22,000	400
Timber	m^3	15,000	4.2	---	---	1,500	27.3
Gasoline	l	4,891	1.4	2.2	0.4	100	1.8
PC Strand	t	---	---	---	---	---	---

(1 US$ = 3,600Kwacha = 5.5Pula = 55Z$ = 110Yen)

17.3.3 Equipment Cost

Equipment costs for the construction to be used generally were estimated basically on the basis of the local market price of each country. The prices for the special equipment which are not available or difficult to procure in the local markets were based on the equipment prices in the Republic of South Africa (RSA). Major costs of each country for the construction are shown in Table 17.3.3.

Table 17.3.3 Equipment Cost

Item	Spec.	Unit	Zambia		Botswana		Zimbabwe		Rem.
			Kwach	US$	Pula	US$	Zim$	US$	
Bulldozer	15 t	hr	75,000	20.8	250	45.5	5,509	100.2	
Backhoe	0.6 m^3	Hr	55,000	15.3	250	45.5	2,000	36.4	
Dump truck	10 t	hr	60,000	16.7	175	31.8	2,500	45.5	
Crawler crane	50 t	hr	100,000	27.8	200	36.4	2,735	49.7	
Tyre roller	8-20 t	hr	50,000	13.9	100	18.2	1,200	21.8	
Road roller	10-21 t	hr	50,000	13.9	100	18.2	1,200	21.8	
Vibration roller	3 t	hr	20,000	5.6	100	18.2	300	5.5	
Electric welding machine	300 A	day	40,000	11.1	75	13.6	1,000	18.2	

(1 US$ = 3,600Kwacha = 5.5Pula = 55Z$ = 110Yen)

17.3.4 Data for Estimation of Construction Costs

It is difficult to procure the skilled labour, special construction equipment, construction material for high strength and sophisticated technique required in relation to the bridge construction, because there is no experience of building large scale bridge such as over the 150 meter bridge span length in each country (Zambia, Botswana, and Zimbabwe). Therefore, engineer, foreman, skilled labour, special construction equipment and construction materials will be procured from Republic of South Africa (RSA) and / or other countries.

17.4 Cost Estimate of Bridge and Approach Roads

Summary of Construction cost of bridge and approach roads is shown in Table 17.4.1.

Table 17.4.1 Construction Cost of Bridge and Approach Roads

Construction Cost	Amount (1,000US$)
Bridge	
1) Main Bridge	35,171
- Superstructure	*24,428*
- Substructure	*10,743*
2) Approach Span Bridge (Zambia side)	5,348
- Superstructure	*3,838*
- Substructure	*1,509*
3) Approach Span Bridge (Botswana side)	4,821
- Superstructure	*3,839*
- Substructure	*982*
Approach Road	
1) Zambia Side	756
- Earth Works	*100*
- Pavement Works	*444*
- Drainage	*25*
- Slope Protection	*121*
- Removal	*66*
2) Botswana Side	1,514
- Earth Works	*287*
- Pavement Works	*921*
- Drainage	*49*
- Slope Protection	*133*
- Removal	*124*
Total	47,610

17.5 Cost Estimate of Border Control Facilities

Summary of Construction cost of border control facilities is shown in Table 17.5.1.

Table 17.5.1 Construction Cost of Border Control Facilities

Construction Cost of Border Control Facilities	Amount (1,000US$)
Border Control Facility	
1) Zambia Side	4,971
- Building Works	*2,244*
- Outdoor Civil Works	*3,288*
2) Botswana Side	7,513
- Building Works	*3,106*
- Outdoor Civil Works	*4,406*
3) Zimbabwe Side	2,952
- Building Works	*1,643*
- Outdoor Civil Works	*1,308*
Total	15,437

17.6 Cost Estimate of Temporary Works of Ferry Facilities

Construction cost of temporary works of ferry facilities for the bridge construction is shown in Table 17.6.1.

Table 17.6.1 Construction Cost of Temporary Works

Construction Cost of Temporary Works	Amount (1,000US$)
Temporary Works (Zambia Side)	
- Reonstruction Onshore Ramp	41
- Dredging	16
Total	57

17.7 Construction Packages and Project Cost

The appropriate size and type of the package for the construction should be established in consideration of the following conditions:

- Proper size in consideration of cost requirements
- Proper size from the point of view of technical content for the civil works
- Proper size and location in terms of handling
- Concentration o the management at one head office
- Minimizing the number of construction yards and offices
- Maintaining effective communication system

From the type of construction, the project can be divided into; approach roads, the bridge, and border control facilities. A portion of the approach roads will be used for construction of the bridge, therefore, of the construction approach roads should be included in the bridge construction. The construction of bridge and approach roads differ from the construction of the border control facilities in terms of construction characteristic of methods and materials. Therefore, the construction of the border control facilities should be independent from that of bridge and approach roads.

The project packages can be tentatively scheduled as below:

1) Package-1 Bridge and Approach Road

	Construction Cost (1,000US$)
- Approach Road (Zambia side)	756
- Main Bridge and Approach Span Bridge	45,339
- Approach Road (Botswana side)	1,514
- Ferry facility	58
Package-1 Total	47,668

2) Package-2 Border Control Facilities

	Construction Cost (1,000US$)
- Border Control Facility (in Zambia)	4,971
- Border Control Facility (in Botswana)	7,513
- Border Control Facility (in Zimbabwe)	2,952
Package-2 Total	15,437

Note: Exchange Rate (1 US$ = 3,600Kwacha = 5.5Pula = 55Z$ = 110Yen)

17.8 Cost Estimate of Improvement of Ferry Facilities (Non-Bridge Construction Case)

In case of non-bridge construction, construction cost and ferry facility cost of improvement in accordance with ferry facilities for high and low growth scenario are shown in Table 17.8.1.

Table 17.8.1 Construction Cost and Ferry Facility Cost of Improvement of Ferry Facilities for High and Low Growth Scenario

(1,000US$)

Improvement Cost of Ferry Facilities	High Growth	Low Growth
1) Construction Cost		
- Reconstruction of Onshore Ramp	86	86
- Reconstruction and expansion of Parking Lot	25	25
- Construction of Storage Facility	11	11
- Construction of Onshore Ramp	86	86
- Construction of Parking Lot	25	25
2) Ferry Facility Cost		
- Replacement of engine	1,760	1,760
- Improvement of Upper deck	65	59
- Replacement of Propeller	109	97
- Improvement of Ramp	55	48
- Replacement of Safety Equipment	20	20
- Installation New Ferries	4,538	3,403
- Demobilisation of Ferries	667	170
Total	7,447	5,790

Note: 4 new ferries for high growth and 3 new ferries for low growth are installed respectively, considering the timing of replacement of the ferries (pontoons).
Operation cost related to this implement is considered in the economic analysis.

CHAPTER 18 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

18.1 Assessment of Anticipated Environmental Impacts

18.1.1 Impact on Soils and Hydrology - Botswana and Zambia

(1) Land and Soils

The soil on which construction activities will take place on both sides of the Zambezi River is very fragile. The soil has very high silt content and is thus highly erodible and will easily compact and harden. This soil type extends for 1.5 km from the pontoon on the Zambian side, and approximately 2 km on the Botswana side. During the construction period vegetation will be cleared for the construction of the approach roads, temporary roads (detours) and the new border offices.

During the dry season, pulverising of these soils by machinery will raise a lot of dust. The surrounding flora and fauna habitats will be severely affected. During the rainy season there will be an increased risk of soil erosion which could result in the loss of topsoil and gullying.

Mitigation measures include watering of work sites as well as minimising the area of vegetation cleared as far as possible. Bare grounds created by land clearing should be replanted with good ground covering vegetation to reduce rainfall impact. As the soils are extremely fragile if worked when very wet causing almost permanent compaction, excavation and earthworks should be carried out during the dry season as far as possible.

On the Zambian side, the land on which the approach roads and all other activities will take place belong to Kazungula District Council, and the border facilities fall under the Council's proposed town plan. Existing villages within the vicinity of the construction site have already been served with notices to move in order to create room for the new council development.

On the Botswana side, the present road from the pontoon to a stretch of up to approximately 1.4 km towards Kasane township marks a planning area boundary. The land on the north-western side of the road belongs to the state, and community development. The land on the south-eastern side has been reserved as tribal land for agricultural activities. The new road will pass on the existing military compound in order to avoid impact on fauna and flora in the area. There might be objection from the local people in terms of moving the border force due to security reasons.

(2) Landscape Character

The topography of the Kazungula areas on both sides of the Zambezi River can be divided into three zones. The first is the upland plateau with slope breaks of 3-8% slopes dominated by sandy soils. The second is the middle to low-lying lands, which have generally flat to gentle sloping, and characterised by black silty loams, silty sand clay loams or silty sandy clays. This land type is the most productive on both sides of the river, and it is impacted on by agricultural activities, fuel wood collection, cattle grazing, cutting of trees for poles as well as being the first choice for human settlements.

All the villages in the proposed Kazungula town are on the Zambian side. Large irrigation projects are located in this zone on the Botswana side. Increased development on both sides will naturally increase land pressure in this zone. This too will increase general land degradation such as deforestation, for fuel wood and other activities such as soil mining on croplands. There is also a threat of pollution to underground water as the water table is quite close to the surface.

The third land type is the flood plains. This is a very important ecological zone in as far as birds and insect habitats are concerned. They are important grazing areas as they provide green grass and drinking water to cattle during the dry season. They are also an important source of domestic water as well as vegetable production especially on the Zambian side.

(3) Policy Considerations

The first issue to be considered seriously in Kazungula in Zambia side is town planning. As a new district, it is an opportunity for both the Local Council and the Ministry of Local Government and Housing to put in place a proper plan. The District Council is considering regrouping villages in the district so as to provide services such as water, roads, health and education facilities to as many people as possible. The impacts of village regrouping where a large population, especially rural, as is the case in Kazungula where the people depend almost entirely on the local natural resources, will need serious planning. The negative and positive impacts must be weighed to assist the council to make well informed sustainable development decisions.

As for Botswana side, District Council also has various town planning including development of the area alongside of Zambezi River in Kazungula area. The project must consider these planning requirements.

The second consideration is on agricultural land use. Crop production in the Kazungula area is marginal due to the poor status of the soil, in terms of the biological, chemical and physical parameters. This is compounded by the erratic and low rainfall in the area in addition to the very high temperatures during the growing period. Emphasis should be placed on educating the people in appropriate conservation farming techniques such as minimum tillage, water harvesting, and organic matter retention. This will increase land productivity and reduce demand on land.

(4) Cumulative and Synergistic Effects.

The combined effect of the various impacts on the physical environment can best be looked at from the holistic standpoint. Firstly, it is desirable socially, economically, and politically that the bridge be constructed on the Zambezi River in order to link the two countries to foster development and boost economic activities. Construction of the bridge is, however, going to have negative impacts on the land and soils, water resources, the air and eventually on man. Soil erosion, for example, will not only disfigure the landscape but will also take away valuable soil and thus reduce soil fertility. All these interactions will affect the landscape character as well as affect the fresh water system. Soil erosion, again, will increase siltation in both the flood plains as well as in the Zambezi River. Fish sets nests in still waters, meaning on the river edge. This is the same zone, which receives siltation, thus disturbing the breeding as well as the feeding systems of many fish species.

Air pollution from the work sites, especially from graders, bulldozers and construction trucks ferrying gravel material for the embankment will affect flora, fauna as well as human population within the vicinity of the construction site especially on the Zambian side. The dust settling on grasses and plant leaves will disturb birds and insect habitats, as well as reduce photosynthesis. Nearby human settlements will be covered in dust, and thus affect human breathing, and will settle on roof tops and even inside of houses.

(5) Enhancement of Positive Characteristics.

The major positive characteristics of the bridge and access road are socio-economic. It is expected that population in general and influx of people in particular will increase. This, automatically will increase business activities, create employment and improve the welfare of the Kazungula and Kasani communities. The coming of the bridge will also enhance or help growth of the newly planned town on the Zambian side and the expanding Kasane town as more settlers and investors are likely to be encouraged by the construction of the bridge.

Presently, the pontoon engines leak a lot of oil in the water, produce a lot of smoke and also raise a lot of mud as it stirs the water particularly on docking or departing. This mud is washed away every time and as it settles it buries fish nests. This is expected to stop once the bridge is constructed. This will be a very important positive characteristic.

18.1.2 Impact on Flora and Fauna - Botswana and Zambia

(1) Vegetation

On the Zambian side, there is a likelihood of a substantial loss of dense thickets of *Dichrostachys cinerea* during construction for either the approach road or the temporary road (detour) or even both. On the western side of the present road, the thicket stretches for over 1 km from near the riverbank. This side of the road is an important nesting area for many bird species, and clearing a stretch of 300m x 15m will result in the loss of nesting areas. There is also a likelihood of clearing more riverine grasses such as reeds on the same western side of the road. This too will result in the loss of substantial habitats for birds, insects, and some reptiles. Presently this zone is heavily polluted with human excreta for lack of public toilets at the border facility.

Once the bridge is completed, it is expected that settlements and the population will increase. More charcoal and fuel wood will be needed. All these will exert pressure on the vegetation, and thus increase deforestation, particularly in the surrounding areas.

On the Botswana side, the new road is proposed to be aligned through a well-developed *Acacia erioloba* woodland. There will be a great deal of loss of mature trees and bush during construction of the approach road. This woodland is an important nesting area for many bird species, and clearing a stretch of 1.4 km long by at least 15 to 20 m wide will result in the loss of important nesting areas, as well as a critical habitat for birds, insects and monkeys. The vegetation on the south-eastern side of the road is, in contrast, severely degraded by elephants, and therefore will not provide an exact option for many bird species. The amount of riverine vegetation on this side of the river is not as dense, and the loss will not be as substantial as for the trees.

(2) Animal Communities

Cattle population in the Kazungula area is low, and unless the herds increase two-fold within the next five years, there is no threat of overgrazing in either the floodplains or in the munga woodlands.

(3) Natural Animal Communities

There are no particular game corridors on the Zambian side. On the Botswana and Zimbabwean sides of the Zambezi River there are national parks close to the proposed site. Game, like elephants and buffalos do cross the Zambezi River on to the Zambian side in search of greener pastures. The construction of the bridge, the approach road and the border facility are, therefore, not considered to have any significant effect on these movements. However, with increased human settlements, poaching of 'stray' elephants and buffalos will increase. There is also a significant number of hippopotamus who graze the banks of the Zambezi River. Their numbers are not considered to have any significant effect on the grass species on which they depend.

Smaller mammals such as the velvet monkey, the scrub hare, duickers, bush babies, squirrels, etc are common in the study area. The duicker and the scrub hare are endangered species, and therefore require special protection. Increased human settlements in the area will wipe out these two species.

(4) Semi-natural Animal Communities

The hippopotamus in the river and the monkeys in the upland could be the only animal species, which are semi-natural as they can tolerate human noise and other activities within reasonable distance without feeling threatened. As discussed earlier, the construction of the bridge will have very little negative impact on these two species.

(5) Recreation Areas

There are no active designated recreation facilities on both sides of the Kazungula study area. The District Council on the Zambia side, however, has included in the town plan some stadia and other sporting facilities. At the moment, the pontoon serves as a recreation facility, but only to those travelling. On both sides of the river, the harbour is a border entry and therefore a restricted and controlled area.

(6) Policy Consideration

Forest pollution from human excreta on the Zambian side is a serious threat to human health in the border facility area. The Kazungula District Council needs to take urgent measures to build public toilets. This polluted zone is located upstream from the water pumping station. All this dirt is washed into the river, only 300 m before the pump station. The water pumped to the Kazungula township is not centrally treated so those who do not boil or add chlorine consume contaminated water.

Poaching was described as a threat to wildlife in the area. Considering that the Zambian side is a game management area (GMA) while the Zimbabwean and the Botswana sides are fully-fledged national parks, Game Scout patrols should be increased. The police should be involved as the scourge is very organised.

Recreation facilities need to be put in place urgently. Community members who do not drink alcohol have literally nothing to do or nowhere to go after hours.

18.1.3 Potential Impacts on Freshwater Quality

The impacts expected as a result of the construction and subsequent operation of the bridge include some negative effects but are mostly positive. This is owing to the fact that during construction the effects will be mostly negative as compared to the whole positive impacts expected during the operation phase. These are explained in more detail below.

(1) Construction Phase

During this phase, numerous activities will be taking place as has been mentioned in the project description and activity outline. Those worth noting are that:

- The pontoon will still be operational but new pontoon rumps built; there will be extensive land clearance for the construction of embankments, for the new approach roads which will be about 300 m long on the Zambian side and 1.5 km long on the Botswana side.
- The water system will be subjected to a lot of siltation as a result of land clearance eroding soil into the river and in a very minimal way slowing down the flow of the river.
- There will be wide use of heavy equipment such as crusher plants, excavators, bulldozers, front end loaders, grader and other big machines of high horsepower.

Resulting from these and many other activities currently going on in the area, there are expected to be a number of deleterious effects on water quality which will be both long and short term. These are summarized in Table 18.1.1 below.

(2) Operation Phase:

During this phase, there are a lot of positive impacts expected. This is because of the other synergistic impacts that are expected to follow the operation of the bridge such as the increment in population and consequent improvement of health services and other infrastructure such as even a waste handling facility to handle waste before discharge into the river. Currently, there are practices such as the disposal of "after birth" in the river due to cultural beliefs and a lack of proper incinerator at the health centre. It is expected that more pit latrines will be built as a more enlightened population comes into the area and in this way, reduce the amount of faecal waste being deposited in the river every day. These impacts are summarized in Table 18.1.1 below.

Table 18.1.1 Potential Impacts on Water Quality of the Project without Mitigation Measures

Phase	Description of impact	Cause of impact	Type of impact	Extent of impact
Construction	Presence of oil and other suspended solids on the river	The day to day operations of the pontoon leading to oil leakage coupled with illegal smuggling of fuel using water as a carrier	Negative; reversible with natural mixing and cleaning of the river.	On both the Zambian and Botswana sides
	Siltation of the river	This will be a result of clearance of vegetation to pave the way for approach roads and detour roads	Negative; reversible in the long run due to river's ability to clean itself and regulate it self.	Both Botswana and Zambian sides.
	Increase in prevalence of diarrhoea and other water borne diseases	This will be due to increased population including the construction team exposed to untreated drinking water	Negative; irreversible and long term as long as treatment is not done to the water which may lead to death of people.	Zambian side
Operation				
	Reduced oil and other suspended solids	This is because the pontoon will no longer be operational and hence all related effects finished.	Positive	Both Zambian and Botswana side.
	Better drinking water quality	Due to the increase in population and business expected from this activity, there will be need for safer drinking water and overall sanitation will improve	Positive	Zambian side

18.1.4 Potential Air Quality Impacts

There are definitely some positive as well as negative impacts on air quality that will result for the construction and subsequent operation of the bridge. These are discussed separately in both the Construction and Operation phases of the project.

Table 18.1.2 Potential Impacts on Air Quality

Impact	Cause of Impact	Type of Impact	Extent of Impact
Construction Phase			
Emissions of smoke from engine of pontoon	Since the pontoon will still be running during this phase, pollution from this will continue.	Negative; reversible	Both the Zambian and Botswana side.
Generation of more dust	This will be as a result of construction activity and also the movement of heavy machinery.	Negative; reversible	Both sides, though a little bit more on the Zambian side where most of the building materials will be sourced.
Operation Phase			
Increased air pollution	This will be as a result of increased traffic on the bridge with most trucks having inadequate combustion systems.	Negative; irreversible unless stringent measures are put in place.	Both Zambian and Botswana side.
Reduced engine emissions	Since the pontoon will no longer be in use, it will greatly reduce smoke emissions.	Positive	Both Zambian and Botswana side.
Increased dust generation.	With the increase in traffic flows, there will be a corresponding increase in level of dust generated.	Negative; irreversible unless mitigation measures are put in place	Both Zambian and Botswana side, though more on the Botswana side where there is a longer dust road leading from the pontoon to the border facilities.

As can be seen from the Table 18.1.2 above, there will definitely be some adverse impacts on air quality as a result of both the construction and operation of the bridge. However, the biggest advantage in this respect is that the pollution that had been previously caused by the pontoon engines will be eliminated completely in the operation phase.

18.1.5 Waste Management and Aesthetic characteristics

The Kazungula area on both the Zambian and Botswana side has a natural landscape unmarred by dense infrastructure. The beautiful view of the river from the banks gives it a very relaxing appeal. However, there are a number of factors currently threatening to disturb the beauty of the area. These are:

- Large amount of solid waste scattered all over the place, this is especially seen around the border area and nearby market. The types of waste found littered are aluminium drinking cans, paper, plastic and other things;

- The lack of proper toilets: this means that people use the “bush” for defecation purposes and in this way, it’s very disturbing to walk around as you find heaps of human excreta scattered all around, it also gives a bad odour around affected areas;

- Presence of borrow and quarry pits: these are pits left behind as a result of previous work in the area, which needed gravel or other kinds of soil during construction. These are found as you go along the road to Mambova from Kazungula Road. They disfigure the beautiful and natural landscape.

It must be noted that most of these factors only apply to the Zambian side as the Botswana side has a number of waste bins placed strategically around the pontoon area where people can take their waste. The Botswana side also has a Game Reserve around the area giving it a more natural look. There are a number of campers that camp at the pontoon but their tents are fairly small and so blend into the landscape very well.

It is expected that increase in traffic and population flow in the area will lead to increased waste disposal the both sides. This will require a waste disposal management and monitoring systems to minimise the adverse disfiguring of the local landscape due to litter and faecal material

Table 18.1.3 indicates potential impacts on landscape of the proposed bridge.

Table 18.1.3 Potential Impacts on Landscape Characteristics

Phase	Description of Impact	Cause of Impact	Type of Impact	Extent of Impact
Construction Phase	Scarring of landscape with quarry and borrow pits.	Need for gravel and other kinds of building materials and these will be sourced locally on the Zambian side.	Negative, reversible if mitigations are put in place.	Zambian side where all the building materials will be sourced.
	Aesthetic and scenic disfigurement due to the erection of tents.	Since the construction crew will camp somewhere, they will erect living quarters and most likely, this will be in form of big tents.	Negative, reversible.	Zambian side where construction crew will camp
Operation Phase				
	Increased litter around pontoon and border areas.	This will be due to increased traffic and population in the area.	Negative, reversible if mitigations are put in place.	Both Zambian and Botswana side, though mostly on Zambian side where communities live very near border facility and just come and spend the day there.
	Disfigurement of the landscape	This will be as a result of borrow and quarry pits created during construction.	Negative, reversible if mitigations are put in place.	Zambian side where quarry and borrow pits will be created.
	Aesthetic disfigurement as a result of increased infrastructure	Due to the construction of the bridge, there will be more traffic coming into Kazungula and more people coming to settle here, thus there will be need for more modern infrastructure in terms of hotels, offices etc	Negative, irreversible.	On Zambian side mostly because the Botswana side is more developed in this respect and the town of Kasane is some distance from the bridge site.

18.1.6 Noise Impacts

The primary sources of the current noise levels are the heavy trucks always moving in the area as well as the noise generated from the pontoon. The movement of people as well as their day-to-day noises also raises the noise levels.

The expected increases in noise levels will occur both during the construction phase and the operational phase of the project.

1) Construction Phase

These will to a very large extent depend on the level of activity but as has been highlighted in the project description, there is likely to be a lot of noise generated as a result of various construction processes and also as a result of the construction equipment to be used. CSIR, 1998 gives typical construction equipment noise ranges.

Table 18.1.4 Showing Construction Equipment Noise Ranges

EQUIPMENT	NOISE LEVEL AT 20 M DISTANCE IN D(B)A					
	60	70	80	90	100	110
Compactors (rollers)		*****				
Front End Loaders		**********	*****			
Excavators and Bulldozers		**********	***********	***		
Tractors, scrapers and graders		***	***********	******		
Trucks and heavy vehicles			***********	***		
Concrete mixers		*****	*********			
Concrete pumps			***			
Cranes, movable		***	********			
Cranes, derrick			*****			
Pumps	*	**				
Generators		***********	**			
Compressors		******	*********			
Pneumatic wrenches			*******			
Jackhammers and rock drills			***********	*********		
Impact pile drivers				***	******	
Electric saws		*******	*			
Concrete vibrators	*	********	*			

Source: CSIR, 1998

As can be seen from Table 18.1.4 above and also from the project description, there will be a lot of noise generated during the construction phase of the project. The average level of noise is in the range of 85dB(A) which is clearly above the World Health Organization (WHO) recommended levels of 55 dB(A). According to the Dobris Assessment of 1995, it clearly states that above 70 dB(A), normal speech is rendered impossible.

This increase of noise in particular will adversely affect wild animals and people living in the vicinity.

2) Operation Phase

During this phase, several activities have been identified that could affect the existing noise levels. These are:

a) Due to increased and smooth flow of traffic along the bridge and also at the improved border facilities, its safe to predict that there will be a corresponding higher noise level as a result of the movement of trucks and so on;

b) More people will be using the bridge for trading purposes and so there will be an increase in day to day noise levels which currently ranges between 60 and 62 dB(A) taken at the market;

c) Due to the proximity of some houses to the bridge, there is likely to be direct intrusions from noise coming from the traffic and all other related noises, therefore people will definitely be affected as well as wild animals.

18.1.7 Significance of Selected Environmental Impacts

(1) Flora

On the Zambian side it is perceived that the construction of the bridge and access road will not disturb the present customs and immigration structures until after the new facility is completed. This means that the temporary road (detour) will be constructed east or west of the present structures, thus calling for a lot of dense bush destruction, and clearance of lots of grasses and some big trees of significant importance to birds and insects. It has not yet been established where the construction team camp will be.

It is expected that a considerable area of land will be cleared to allow for construction of temporary accommodation, recreation facilities, storage facilities and access roads. The workforce will require fuel wood and charcoal for cooking. These needs will certainly increase deforestation in the area, and these activities are considered to be significant enough to cause some temporary as well as permanent damage to flora. The destruction of riverine grasses during the construction of the bridge as well as during the rehabilitation and/or construction of pontoon ramps is not considered very significant.

The destruction of the well preserved Acacia woodland on the Botswana side and the dense thickets of *Dischrostachys cirerea* on the Zambian side will significantly result in the loss of breeding sites of birds, especially the weavers as well as loss of diversity from the ecosystem fragmentation.

(2) Fauna

The Zambian side of Kazungula is not host to any large mammals, other than those that cross from the Botswana and Zimbabwean sides. Smaller mammals are also not in abundance within the vicinity of the construction site. The construction of the bridge, the approach road and the temporary road will remove significant vegetation, which are important habitats for many bird species and smaller animals. The number of birds and smaller animals expected to be dislocated cannot be determined, but in addition to the expected increase in human activities, disturbance to natural animal communities will be significant.

(3) Land Use Changes

On the Zambia side the Kazungula District Council has a town plan for the area, and it is hoped that the construction of the bridge and approach road are part of that plan. The bridge and approach road construction are unlikely to take up farmland as the design has allowed use of the present road. The new customs and immigration site was supposed to replace or take up farm land but these villages fall within the planned town and have since been given notices of relocation by the council. No significant land use changes are therefore expected as a result of the construction of the bridge and approach road. On the Botswana side, the affected area is only shown as earmarked for civic and community use but does not show any demarcated plots. The new road, therefore, will form the base for further and subsequent sub-divisions.

(4) Impacts on freshwater systems

The impacts identified are significant in that they enhance the positive features of the bridge in relation to water quality. The ones identified during the construction phase are short term and so are reversible. The positive ones however, have far wider benefits as they relate to the socio-economic status of the whole area.

(5) Impacts on Air Quality

These are very difficult to evaluate in terms of significance as they are qualitative but suffice to say, the impacts from the dust are very significant and they might lead to a lot of irritation both physically as well the sense of general well being.

The emission of smoke from the pontoon engine though not exceeding standard levels causes a lot of irritation to travellers and also, if continuing at current rate, will contribute substantially in the emissions of greenhouse causing gases that lead to global warming and the depletion of the ozone layer.

(6) Impacts on Landscape Characteristics

The impacts on the landscape characteristic of the area unless mitigated will severely affect the area. The generation and disposal of waste is currently a problem due to the litter around the area and also the improper toilet and other sanitation facilities can lead or contribute to the prevalence of water borne diseases such as diarrhoea, cholera and dysentery.

The elevated bridge will also affect the aesthetic view of the area either positively or negatively.

(7) Impacts due to Noise

It is very difficult to quantify the impacts due to noise as people's tolerance to noise levels varies widely and it also to a larger extent depends on the type of noise generated. Some common impacts include:

Annoyance: which is the most common reaction in people. This also relates to sleep disturbance and a general feeling of being disturbed:

- Interference with communication: as has already been alluded to, interference with communication occurs at noise levels of about 35 dB(A) and at levels of about 70 dB(A), normal speech is rendered virtually impossible;

- Extra auditory effects may also include physiological stress, cardiovascular reactions at very high noise levels and even raise blood pressure; and

- High noise levels lower the economic worth of property.

Reduction in wildlife: high noise levels also chase away wildlife and generally causes a stress on the environment.

Table18.1.5 below gives an initial environmental examination in order to show the significance of the various potential environmental impacts.

Table 18.1.5 Initial Environmental Impact Examination

Element to be impacted	Potential impact	Status of impact	Extent of impact	Duration of impact	Intensity of impact
Land and soil	Soil erosion and/or soil compaction arising from formation of the approach road embankment and formation of the temporary road.	Negative	Along approach road and along the temporary road.	short term	medium
Fresh water system	-Pollution from oil leakages disturbing aquatic fauna during construction. -Turbidity from drilling and from spillages of gravel materials into the river and from construction of coffer dams. -Siltation from erosion thus burying fish breeding nests and changing aquatic ecosystems.	Negative	Up to 100m down stream from drilling points	Short term	Medium to high
Air pollution	-Dust from excavators, bull dozers, graders and dump trucks will cover green plants and disturb photosynthesis, and also disturb important habitats for birds and insects. -Increased air pollution as traffic levels increase.	Negative	Up to 2km from work sites	Short term	Medium to high
Landscape character	Land degradation from planned settlements such as the contractors' compounds and borrow pits; temporary road to disfigure landscape.	Negative	Immediate areas of development	Short to long term	Medium to high
Vegetation	-Loss of mature trees and dense thickets. -Increased demand for charcoal and fuel wood.	Negative	Immediate areas of development	Short to long term	Medium to high
Animal communities	Disturbance to birds and smaller animals during construction and loss of habitat.	Negative	Up to 2 km from work sites	Short	Medium
Recreation areas	No recreation facilities exist in the area.	N/A	N/A	N/A	N/A
Noise & vibration	Noise dust and vibration during construction	Negative	Up to 2 km from worksites	Short	Low to medium

18.2 Assessment of Anticipated Impacts on Socio-Economic and Human Settlement

Participatory Rural Appraisal exercises were conducted in the local communities surrounding the project site to obtain the perception of the local people on how the bridge construction project would affect them. Various PRA tools were used.

18.2.1 Perceived Losses/Problems

- More diseases - because of the increase in traffic there will be more people coming into the area. Thus, more chances for the transfer of sexually transmitted diseases like HIV/AIDS.
- More thieves - increase in population will also mean increase in crime in the area.
- More smuggling - because of the increased cross-border trade that is being anticipated with the bridge, there is likelihood of more goods illegally crossing the borders.
- Poor international relationships - vices like smuggling will increase suspicion between the two countries thus straining international relationships.
- Death - caused by a synergy of issues: diseases, hunger and poverty, poor health, lack of water and crime.
- Transport to cross the bridge- actually many Zambian people go to Kasane to do shopping. While pontoon is operating they have no problem with transport, however, once the bridge has been constructed they have no public transport on the bridge.

18.2.2 Perceived Gains/ Benefits

- Employment creation - many local people will be able to find employment during bridge construction.
- No more pontoon problems - the pontoon is usually beset with problems of delays, breakdowns and engine failures.
- Boost in cross-border trade - for those who are engaged in buying of goods from Botswana for sell here in Zambia.
- Boost in local trade - things will sell faster due to increased population/ local customer base.
- Boost in tourism - for easy access, in particular Botswana side will have more tourists in the area who will visit national parks
- Ease of movement - Movements will be made much easier for people will just walk across the bridge.
- Less costly to cross - If there will be no fee for pedestrians using the bridge unlike the case with the pontoon.
- With more traffic there will be increased access to goods in the country.
- Improved livelihoods - caused by a synergy of issues: employment, improved trade, and easier and cheaper movements across the border.

18.2.3 Impacts on Border Facility

According to the bridge and approach road designs, the present customs and immigration offices will have to be demolished or drastically improved. The proposed approach road will be too close to the present structures on Zambian side that the offices will be a hazard to human life. The demolition of the present offices is of great significance as it will deny the growing town of an already existing structure, which could have been taken up for use by other institutions, which are unable to move to Kazungula for lack of money to build offices.

Some of the structures at the site are relatively new and cherished. The institutions suggested these buildings could be preserved for other uses instead destroying them completely. The road leading from the offices to the pontoon dock is also being constructed by PRINCE Constructors. This is going to be destroyed during bridge construction. The council and the institutions at the border expressed concern with this waste of resources due to lack of advance planning by the relevant authorities in Government.

The project is planning a one-stop border facility. In this system, immigration officials from Zambia, Botswana and Zimbabwe work in a office together. There are many concerns about it. Below are examples:

- how people from three countries can work in harmony
- where these officials live
- how to get work permit, etc

Though SADC has been promoting one-stop border facility, there still are only a few examples in the region and more discussion and clarification will be necessary in terms of legal and operational issues.

18.2.4 Impacts on Cultural Resources

The area on Zambian side has two main gravesites. The first one is for the ‘mazamai’ - the people living near the border. They use these common burying sites.

Attachment to ancestral lands is quite strong. This is especially related to the fact that their ancestors were buried in the same area; some of the locals feel that because of this the land is blessed and they are therefore very sceptical of any allusion to resettlement. Then there is the general attachment that one develops to a place where they were born and have been raised.

On Botswana side there is no significant cultural resources.

18.2.5 Pontoon Related Concerns

Most of the stakeholders are concerned with the use of the pontoon during the construction of the bridge. They are afraid that it may pose a hazard to the construction work and the workers if it will be moved to the proposed place upstream. The pontoon sometimes deflects in its course due to:

- high currents during the rainy season;
- the frequent engine failures or breakdowns; and
- loading of the pontoon with cargo that is too great for its horse power, another frequent occurrence.

Some stakeholders suggested that the pontoon course be placed downstream below the bridge to avert such tragedy.

18.2.6 Improvement of Transport and Communications

Improvements in the area of transport and communications due to the bridge project are one of the major benefits that almost all the stakeholders identify with. Zambia Postal Services (Zampost) is currently planning to be bringing in international mail through the Namibian border. But with the establishment of a bridge at the Kazungula border post, the company would have a faster and cheaper route to bring in mail.

The general feeling amongst the stakeholders is that this is a project that has been long overdue. To most of them the improvement of cross-border movements means easier access to cheaper goods from other countries; less congestion at both border posts; faster movements across the border; less risks to life and cargo; and more development to the area among other advantages.

18.2.7 Crime and Prostitution

The two major social vices that were cited as likely to increase tremendously with a project of this magnitude are crime and prostitution. Hence the need for corresponding services to be introduced or developed in the existing institutional framework.

18.3 Proposed Environmental Management Plan and Mitigation Measures

18.3.1 Environmental Management Plan

The Environmental Management Plan (EMP) for the management of the identified environmental issues associated with the project consist of three main components:

1) Implementing specific environmental mitigation measures
2) Establishing an institutional framework for implementing the EMP

3) Monitoring implementation of the EMP

18.3.2 Implementing Physical measures and Cost of Mitigation

The mitigation measures for the construction phase of the project are presented in this chapter. The measures address the negative impacts generated by the construction works. Most impacts are of a temporary nature lasting only for the duration of the construction period, estimated to take about 3 years. Some of the impacts, however, are long term, for example, borrow pits. The major mitigatory measures proposed in this report are given in Table 7.1 below.

(1) Mitigation Measures for Noise Impacts

In terms of mitigating the noise impacts during both the construction and operation stage, a number of factors have to be put in place; these will be given as follows:

During construction phase, the following are proposed as measures to mitigate the high noise levels:

a) Restrict the working hours of construction activities to daylight hours only and restrict those during night time to an absolute minimum;
b) Bearing in mind that the level of sound diminishes by a factor of four or by 6 decibels with doubling distance from the source, it is suggested that some of the most noisy equipment are placed at far away points from sensitive areas such as the border offices, market and residential areas or human settlements. This will help in reducing the amount or volume of sound reaching the people and in so doing, reduce effects such as disruption of normal communication and sense of well being;
c) Traffic for construction equipment must be re-routed and not disturb the normal flow of traffic, hence alternative routes must be arrived at;
d) Siting of the camp for construction workers must be done with care so as to reduce on the disturbance that might be caused by the workers as they chat and entertain themselves.

During the operation phase, the following measures should be considered:

a) Operational hours for the bridge must be restricted to daylight hours only or if need be, very early in night time. The proposal is for the bridge to cease operations at 19:00hrs everyday;
b) Immigration office should cooperate closely with the customs and see that every traveller adheres to the operational hours of the bridge;
c) Trucks must be monitored to maintain a certain speed limit when crossing the bridge and also when using the road that comes to and from bridge, this will reduce noise that emanates from revving of engines as

the trucks accelerate

(2) Mitigation Measures For Air Quality

These will be addressed in both the construction and operational phases of the project.

The impacts relating to smoke emissions from pontoon can be mitigated by;

a) Regular maintenance of the pontoon engine;
b) Ensuring that there is complete combustion of fuel by inserting catalytic converters on it or by making sure only unleaded fuel is used.

The dust emissions can be mitigated by:

a) Making sure that the construction site is watered down most of the time;
b) Restricting the use of heavy machinery to the minimum;

During the operational phase, the following mitigation measures are proposed:

For the dust emissions,

a) The roads can be paved on both the Zambian side and Botswana side to reduce the length of dusty road;
b) Alternatively, the sides of the road could have lawn on them to restrict the movement of dust from surrounding areas.

(3) Mitigation Measures for Freshwater Systems

The impacts during the construction phase have been outlined above and the following are some proposed measures to mitigate them.

a) to mitigate impacts related to oil spills, pontoon operators should ensure regular service and maintenance of the same and customs officials should conduct regular spot checks of smuggling activities of fuel on the river;
b) impacts related to siltation and erosion:
    (i) construction should be avoided during rainy season;
    (ii) riparian areas should be out of bounds for clearance of vegetation unless otherwise authority is given;
    (iii) after the construction period, areas cleared must be revegetated and rehabilitated to their former state or as close as can get;
    (iv) if gullies appear as a sign of erosion, that specific site must be immediately abandoned to prevent further distraction of the same

(v) there should always be an ecologist to monitor and perform early warning functions.

c) impacts related to untreated drinking water and unsafe waste disposal into the river: very little can be done to mitigate this as it is an age old problem, but chlorine can be bought off of the counter and used in drinking water to minimize risk of disease and also residents could be encouraged to build pit latrines to minimize the amount of waste finally ending up in the river.

Since all anticipated impacts in the operation phase are favourable to water quality, no mitigation measures have to be put in place. The major mitigatory measures proposed in this report are given in Table 18.3.1 below.

Table 18.3.1 Summary of Mitigatory Measures

Element	Negative impact	Mitigatory Measure	Residual impact	Responsible institution	Implementation schedule
Land and soil	Risk of soil erosion and/or soil compaction during and after construction	-Undertake all earth works during the dry season -Storm drains must be constructed along both approach road and the temporary road. -Heavy construction equipment to avoid farm plots so as to avoid compacting the soils	-Soil erosion minimised. -Soil compaction in farm plots avoided	Contractor	On-going during construction
Fresh water system	Risk of pollution to river Zambezi during construction	-Use of interceptors -bunding around areas where hazardous liquids (such as oil or petrol) are stored. -neutralisation of water from the concrete batching plant. -Careful disposal of waste water used to wash down sites. -Contractor to submit written details of the procedures proposed to be used in the event of a pollution incident	Risk of pollution minimised	Contractor	On-going during construction
Air pollution	Dust during construction	-Use of water sprays where levels become unacceptable. -Give advance warning for any blasting activities.	Dust levels controlled	Contractor	On-going during construction period
	Increased air pollution as traffic levels increase	-Air pollution effects from increased traffic levels are likely to be negligible. -Improved facilities at the border will assist trucks to spend as short time as possible with their engines running while waiting to clear through customs and immigration	Gradual increase in air pollution	ECZ	After bridge construction
Landscape character	Increased land to be disturbed through land formation and temporary settlements	-Site for the contractors' camp be chosen properly. -Heavy construction equipment should be limited to construction sites. -Borrow pits must be filled graded so that water does accumulate in them.	-Land to be disturbed to be minimised. -Corrective measures be done for areas excavated.	Contractor	On-going during construction

Element	Negative impact	Mitigatory Measure	Residual impact	Responsible institution	Implementation schedule
Vegetation	Loss of mature tress and dense thickets	-Avoid unnecessary felling of trees, by confining to agreed areas to be bush cleared. -Avoid aligning temporary road on to areas with too many mature trees	Reduction in the number of trees to be felled and limited amount of land to be cleared of thickets	Contractor	On-going during construction
	Destruction of riverine vegetation	-Areas to be cleared for both the bridge and the new pontoon ramps must be agreed with the site Engineer, and the area to be cleared should be well marked to ensure that the area cleared is kept to the minimum possible.	Destruction of riverine vegetation reduced to minimum	Contractor	On-going during construction
	Location of housing for workforce could encroach on to vegetated areas.	-Consultation with the council should be made. -Avoid areas on the western side of the road as they have more mature vegetation	Mature trees on the western side undisturbed	Contractor	Implement before construction begins.
Animals	Loss of habitat and breeding grounds for birds and small animals due to vegetation destruction	-The loss will be minor and small animals will relocate to areas further away from the construction site.	Small animals will move away.	N/A	N/A
Birds	Disturbance to birds and small animals during construction.	-The loss will be minor and birds will relocate away from the construction site.	Birds will move away	N/A	N/A
Fish	Disturbance to fisheries during construction	-Fish disturbed during construction are likely to move to quieter reaches of the river. -Local fish spawning grounds may be affected by siltation.	-Fish will move away -Spawning grounds close to the construction site will be buried	N/A	N/A
Aquatic Fauna	Risk from pollution to aquatic fauna during the construction period.	-Ensure contaminants do not enter the river or any other water courses. - The concrete batching plant must be located away from the riverbank. -Use oil interceptors	-Risk from pollution reduced.	Contractor	On-going during construction
Recreation areas	None	None	None	N/A	N/A
Noise and vibration	Noise and vibration during construction.	-Working hours limited to daylight only. -World Bank standards for construction sites be adhered to.	Noise nuisance reduced and controlled	Contractor	On-going during construction period.

18.3.3 Establishing an Institutional Framework for implementing the EM

In order to ensure that the identified environmental issues are addressed both during and after construction of the bridge, the Joint Project Technical Committee should establish an Environmental Management Sub-Committee.

Membership of the committee would comprise of representatives of the Roads Departments from the two countries; representatives of the Environmental Council of Zambia and the Conservation Strategy Unit of Botswana and representatives from the local district authorities of Kazungula and Kasane. The main responsibilities of such a committee will include: ensuring the contractors implement the mitigation measures recommended in the report; sensitise the communities with regard to environmental problems and their obligations; liase with respective government agencies on environmental issues which may arise during the construction and the operation of the bridge.

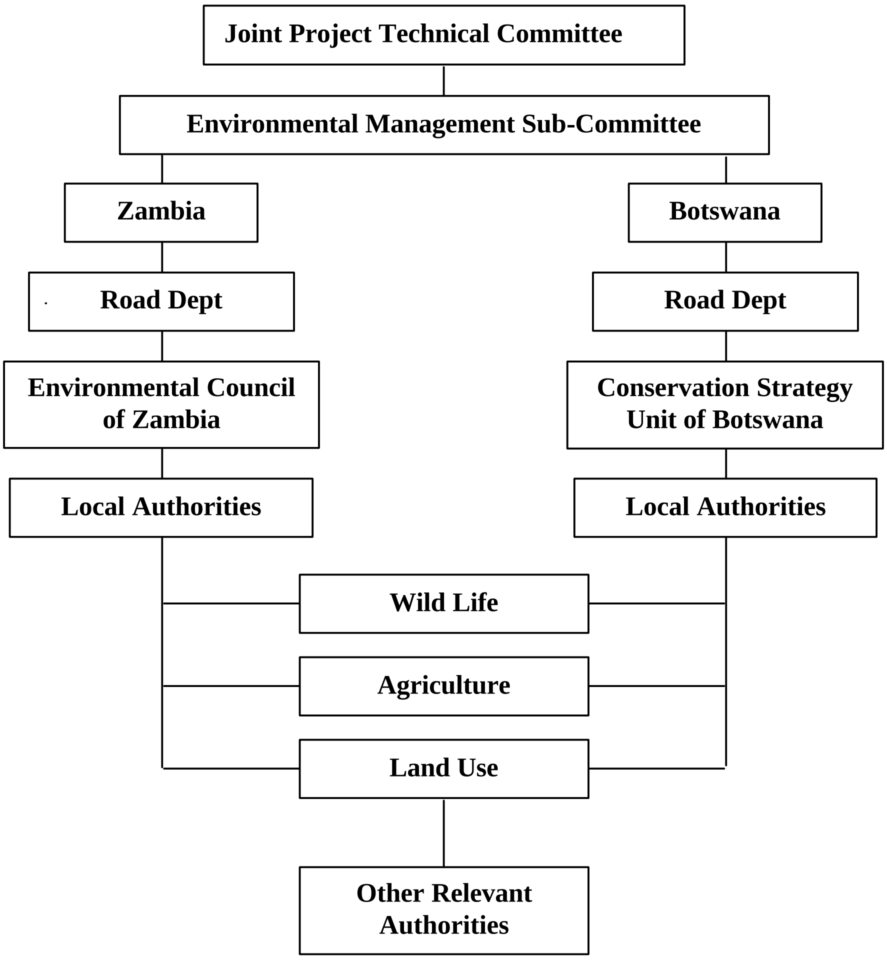


Figure 18.3.1 Environmental Management Institution

18.3.4 Monitoring Programme

The monitoring needs of the project will address the negative impacts expected to be generated by the construction works. The negative impacts to be monitored are presented in Table 18.3.2

The activities to be monitored can be divided into two groups, those that can be carried out through measurements, and those that will be carried out through observation. Out of the 10 elements to be monitored, only two i.e. water and noise will be monitored through measurements, while the rest will be carried out through observation.

A successful monitoring of the environmental effects of the programme will require equipment and material. The committee will identify the necessary equipment and materials and work out modalities for ensuring the identified variables are monitored on a regular basis. The details of the activities to be undertaken for each of the monitoring requirements are provided in Table 18.3.2 below.

The committee will require to undergo a tailor-made environmental analysis and sensitisation training programme which will focus on the identified environmental issues associated with the Kazungula project.

Table 18.3.2 Monitoring Activities and Indicators

		Country of Relevance		Positive Indicator
Element to be monitored	Method of Monitoring	Botswana	Zambia	
Land and soil	The Site Engineer to make a daily inspection of earthworks, and ensure that slopes are graded to specifications. Once earthworks are completed, the Site Engineer should monitor the restoration measures to be implemented, such as re-vegetation or use of geotextiles. Site Engineer to ensure that heavy construction equipment are confined to operation areas only, and avoid crop lands	x	x	Absence of rills, gullies or other erosion features. Absence of caterpillar tramplings in crop lands.
Fresh water system	Site Engineer to inspect and satisfy that: (i) Interceptors are put in place (ii) Areas where hazardous liquids are stored are bunded. (iii) Water from concrete batching plants is treated. (iv) Waste water used to wash down sites is carefully disposed off. (vi) Written details of the procedures to be used in the event of a pollution incident be given to the Site Engineer by contractor. (vii) Measurement of quality	x	x	Clean water supply maintained throughout the construction period.
Air pollution	Site Engineer to observe the level of dust generated during construction. Damping down should be carried out if levels are	x	x	Deposition of dust on surfaces such as grasses, shrubs,

	unacceptable. Measurement of quality			trees and roof tops should decrease with increased dampening.
Landscape character	Site Engineer to make visual inspection of earth works to ensure that excessive excavation other than those agreed upon is not carried out, particularly at borrow pit sites, approach and temporary roads as well as around contractor's compound.	x	x	Landscape alterations reduced to a minimum.
Vegetation	Site Engineer to ensure that excessive clearance of vegetation is avoided. Excess clearance of vegetation must be discussed and extent of clearance clearly marked.	x	x	The area of vegetation cleared is minimised
Animal communities	The Site Engineer is to carryout regular inspections and report evidence of animal intrusion onto the site, and to check that animal access to the river is maintained. If animal intrusion on to the site becomes a significant problem consultation should be made with the Botswana Wildlife and National Parks Department.	x		Animal damage to site reduced to a minimum.
Birds	No monitoring required as birds would have moved.			
Fish	The Site Engineer to monitor the procedures for preventing polluted water from flowing into the Zambezi River. Mechanisms to be put in place to take water samples from the Zambezi River for analysis.	x	x	No dead fish or other aquatic fauna found along river banks. Water quality in the river maintained.
Recreation areas	No monitoring required			
Noise and vibration	Site Engineer to monitor noise and vibrations on an ad-hoc basis in order to establish noise levels at the centre of the works areas, at the boundary of the site and at the nearest sensitive receiver.	x	x	Noise levels at the nearest sensitive receiver should not exceed the levels suggested in the previous chapter.

18.4 Mitigation Cost

Based on the above mitigation measures, the Study Team calculated the mitigation cost.

(1) Revegetation of Cleared Area

Vegetation species in the Study area are *Prosopis* (algoroba) and *Azadiracta indica* (neem tree). As a result of site survey, the average number of these trees in $81m^2$ is 16 and 12 respectively. The price of each tree is 0.3 and 0.8 US$ respectively. In short, unit cost of revegetation of trees per m^2 can be summarized as follows:

Tree species	Area (m^2)	Number of Trees	Price per tree (US$)	Total cost per $81m^2$	Unit cost
Prosopis	81	16	0.3	4.8	0.06
Azadiracta Indica	81	12	0.8	9.6	0.12

Cleared space for border facilities is approximately $25,000m^2$ for each. The philosophy of revegetation is that the same amount of cut off trees should be revegetated around the border facilities. That means for the total cleared area for border facilities, the cost of revegetation can be calculated as follows:

$25,000m^2$ x \$0.06= \$ 1,500
$25,000m^2$ x \$0.12= \$ 3,000
\$1,500 + \$3,000 = \$4,500
\$4,500 x 3 (border facilities) = \$13,500 -(1)

Revegetation of cleared space for border facilities \$13,500

For the cleared space for the approach roads is $75,000m^2$. Accordingly, the total cost of revegetation of cleared space for approach roads can be calculated as follows:

$75,000m^2$ x \$0.06= \$ 4,500
$75,000m^2$ x \$0.12= \$ 9,000
\$4,500 + \$9,000 = \$13,500 -(2)

As a result, the total revegetation of cleared area for both the border facilities and roads is:

(1) + (2)=\$27,000

On the above, labour cost and other overhead should be added. Thus this cost is multiplied by 1.5.

\$27,000 x 1.5 = \$40,500

The total revegetation cost: \$40,500

(2) Vegetation on Fill Slopes to Avoid Erosion

In order to avoid erosion, vegetation of fill slopes of roads is important. However, this cost is already included in the temporary engineering work for road construction, so there is no need to reiterate as an environmental mitigation cost.

(3) Construction of Storm Drainage along both Approach Roads and Temporary Roads

Storm drainage work is already included in the construction cost, accordingly, it is not necessary to consider here. The drainage slope is mild so that wild animals can easily pass.

(4) Interceptors Avoiding Water Contamination of Fresh Water System

As an interceptor, sump pit will be dug so that contaminated water will be stored and impurities will be separated from water by the penetration of the water into the soil. The impurities will be properly disposed later. This work is already included in the temporary work, so there is no need to reiterate the cost here.

(5) Water Sprays to Avoid Extreme Dust

When there is extreme amount of dust, water from Zambezi River will be pumped up and sprayed. This work is already included in the temporary work, so there is no need to reiterate the cost here.

Summary of Mitigation Cost

- Revegetation of Cleared Area (Border Facilities)	$13,500
- Overhead of the above	$ 6,750
- Revegetation of Cleared Area (Roads)	$13,500
- Overhead of the above	$ 6,750
- Vegetation of Fills to Avoid Erosion	$ 0
- Construction of Storm Drainage	$ 0
- Interceptors	$ 0
- Water Sprays	$ 0
Total	$40,500

18.5 Monitoring Cost

(1) Water quality monitoring (twice a year for three years)

-	Equipment hire	US$80	
-	Materials	US$60	
-	Professional fees	US$120	
-	Travel cost	US$1,280 (Lusaka-Kazungula)	
-	Accommodation (3 nights)	US$240	Total: US$1,780
US$1,780 x 2 x 3 =US$10,680			Grand total: US$10,680

(2) Air quality monitoring

-	Equipment hire	US$80	
-	Materials	US$30	
-	Professional fees	US$120	
-	Travel cost	US$1,280 (Lusaka-Kazungula)	
-	Accommodation (3 nights)	US$240	Total: US$1,750

US$1,750 x 2 x 3 =US$10,500 Grand total: US$10,500

(3) Noise monitoring

-	Equipment hire	US$100	
-	Materials	US$20	
-	Professional fees	US$140	
-	Travel cost	US$1,280 (Lusaka-Kazungula)	
-	Accommodation (3 nights)	US$240	Total: US$1,780

US$1,780 x 2 x 3 =US$10,680 Grand total: US$10,680

(4) Transport and accommodation cost of officials in Lusaka and Gaborone, who come to Kazungula to monitor. These monitoring will be required twice a year for three years.

a) Zambia (Officials from Environmental Council and Roads Department)

-	Travel cost	US$1,280 (Lusaka-Kazungula)	
-	Accommodation (3 nights)	US$240	Total: US$1,520

US$1,520 x 2 x 3 =US$9,120 Grand total: US$9,120

b) Botswana (Officials from National Conservation Strategy and Roads Department)

-	Travel cost	US$1,440 (Gaborone-Kazungula)	
-	Accommodation (3 nights)	US$300	Total: US$1,740

US$1,740 x 2 x 3 =US$10,440 Grand total: US$10,440

(5) Monitoring by local authorities

Monitoring by local authorities is included in their day to day work, accordingly no additional cost will incur.

Summary of Monitoring Cost

- Water quality monitoring	$10,680
- Air quality monitoring	$10,500
- Noise monitoring	$10,680
- Transport and accommodation cost of officials	
a)Zambia	$ 9,120
b)Botswana	$10,440
- Monitoring by local authorities	$ 0
Total	$51,420