4 PHYSICAL CONDITIONS OF THE STUDY AREA

4 PHYSICAL CONDITIONS OF THE STUDY AREA

4.1. TOPOGRAPHIC CONDITION

The Zambezi River flows down generally from north to south in the Study area, but near existing Otto Beit Bridge, it changes from north-east to south-west and bends to south-east after passing the existing Bridge. The existing Otto Beit Bridge is located at the narrowest point of the Zambezi River around the Project site. At upstream of the Bridge, the riverbank at right side (Zimbabwean side) is a gentle to steep cliff with riverside woods but at left side (Zambian side) is a steep cliff with riverside woods and swampy area. At downstream of the Bridge, relatively gentle slopes ascend from the river edges. On the Zambian side privately developed township is formed on the riverside slope, however, on the opposite side, Zimbabwean side, relatively thick bush covers the river bank, without artificial structure except for the floating police jetty and the public boat launching pad.

The river width changes from about 1,100 m at 2.5 km upstream, to 370 m at Otto Beit Bridge site and widens to 800 m at 1.5 km downstream. However, within 500 m distance from existing Bridge (both up- and downstream), the river width is less than 400 m (refer to Figure 4.1).

4.2. HYDROLOGICAL CONDITION

4.2.1. DESIGN FLOOD

The bridge site is situated approximately 60 km downstream from Kariba Dam on the Zambezi River (refer to Figure 4.2). The part of the catchment upstream of Kariba Dam has a size of 664,000 km^2.

The Kariba Dam will have a major impact on flood peaks at the site. Due to its huge storage capacity of 1.85 x 10^{11} m^3 significant flood attenuation will take place and flood peaks downstream of the dam will depend on the operation rules of six (6) gated spillways of the dam. Information obtained from the Zambezi River Authority at Kariba Dam indicate that each of six spillways has a capacity of 1,574.2 m^3/s.

The part of catchment downstream of Kariba to Chirundu is located in the Kovacs homogeneous hydrological region 4 for Zimbabwe. This region covers the north-western part of the country, which has a hilly to flat relief with mainly permeable soils. The longest stream contributing to this catchment is the Lesuto River (Zambia) with a stream length of 112 km. The mean annual rainfall (based on data at Chirundu) is 766 mm per annum.

The estimated floods calculated for the part of the catchment downstream of Kariba on the basis of Kovacs (1988) are as follows; (Refer to Table 4.1)

Table 4.1 Floods Generated in Part of Catchment Downstream of Kariba Dam

1 in 50 years flood	997 m^3/s
1 in 100 years flood	1,280 m^3/s
1 in 200 years flood	1,541 m^3/s

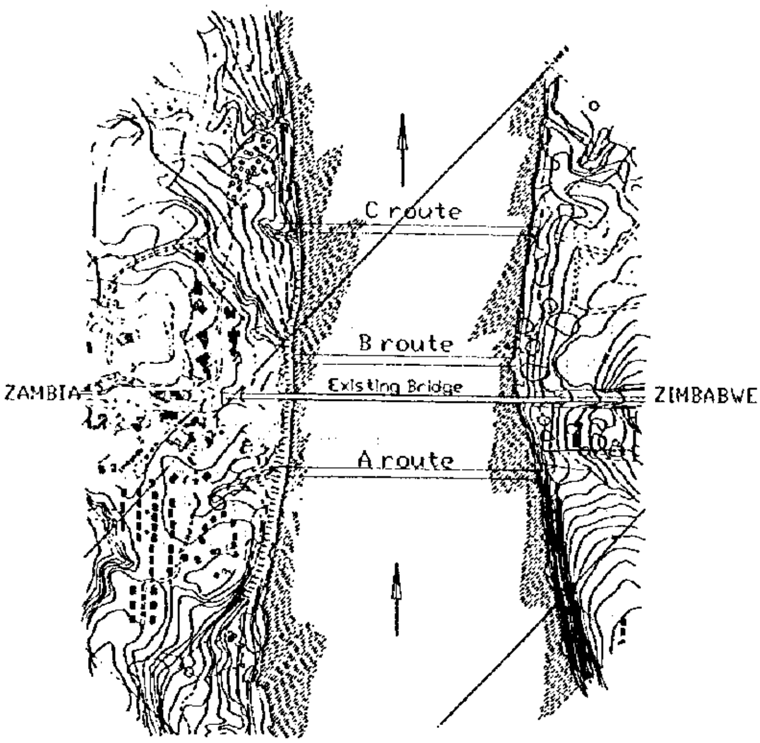


Figure 4.1 Bridge Site at Chirundu (Zimbabwe)

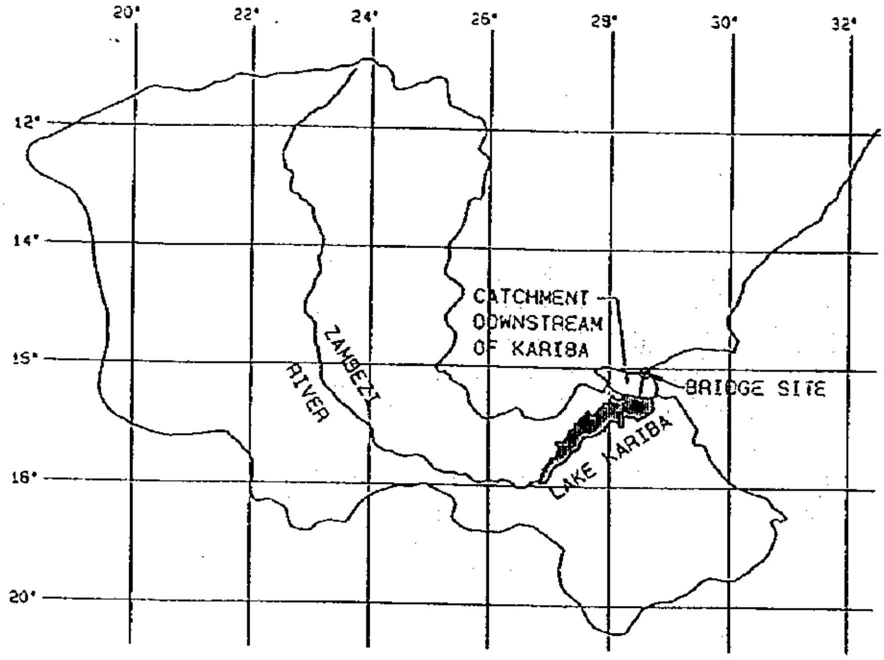


Figure 4.2 Catchment Area

When these flood magnitudes are compared to the 9,445 m3/s which may be released from Kariba, it should be clear that the floods released from the Dam will play a dominant role in establishing the maximum floods at the Chirundu bridge site, with the floods generated from the catchment below Kariba Dam being of secondary magnitude. This was confirmed during interviews with inhabitants of Chirundu who claim that since the previous closure of the gates at Kariba in 1981, no significant flooding has occurred at Chirundu. Prior to closure of the gates, average monthly flows of as high as 6,312 m3/s (February 1975) were measured. For the purpose of power generation, 4,070 to 7,480 m^3/s of discharge from the Dam is maintained during April 1996 and June 1997. This discharge is current water flow down stream of Kariba Dam during dry season from April to October.

(1) HH-Flood

For the HH-Flood, the gates at Kariba are assumed to be fully open with discharge at a maximum of 9,445 m^3/s. To compensate for any flash floods generated in the catchment below Kariba, a flood component for this part of catchment was added to the maximum discharge from the dam spillways.

The 1 in 200 years flood was therefore added to the spillway discharge, giving a total flood of 11,585 m^3/s. This should be adequate when the design lifetime of the bridge of 120 years (British Standards) is considered.

(2) H-Flood

For H-Flood, the flood gates at Kariba are assumed partly open during a wet season. The maximum mean monthly flow of 6,312 m^3/s measured in February 1975 is considered representative of such a situation.

(3) M-Flood

For M-Flood, the 1 in 200 years flood from the catchment below Kariba Dam is recommended. This is 1,541 m^3/s.

(4) L-Flood

The L-Flood is taken as the combined discharge via the north and south bank tributes at Kariba Dam. This is 337 m^3/s.

The recommended design floods are therefore as shown below in Table 4.2.

Table 4.2 Recommended Design Floods for Bridge Site at Chirundu

HH-Flood	11,585 m^3/s
H-Flood	6,312 m^3/s
M-Flood	1,541 m^3/s
L-Flood	337 m^3/s

4.2.2. WATER LEVEL AND FLOW VELOCITIES

The determination of water levels and flow velocities for the bridge site was based on the 1:2,500 scale survey map of the area and the sonic survey which was performed as part of geotechnical study.

Backwater calculations were performed for the stretch of the river for which sufficient information is available, i.e. for a distance of 300 m both upstream and downstream of the existing bridge site. The sections were taken at distances of 100 m apart. Backwater profiles were calculated by means of computer program (Channel Flow Profiles, Infodeck Solutions, 1995) which is the state of the art programme widely used for backwater calculations in Southern Africa. Roughness for the river was estimated on the basis of the alluvial nature of the river and Manning 'n' values of 0.045 to 0.050 were used.

The recommended water levels for design purposes are based on energy levels at the various cross sections (refer to Figure 4.3) for the design floods and are therefore slightly conservative. Sensitivity testing for various parameters was done. (Refer to Table 4.3~Table 4.9)

Table 4.3 Section 1, 300 m Upstream from Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	378.2	2.68
H-Flood	6,312	377.3	2.02
M-Flood	1,541	372.6	1.17
L-Flood	337	371.2	0.43

Table 4.4 Section 2, 200 m Upstream from Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	378.1	2.96
H-Flood	6,312	377.3	2.20
M-Flood	1,541	372.5	1.20
L-Flood	337	371.2	0.94

Table 4.5 Section 3, 100 m Upstream from Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	378.0	2.81
H-Flood	6,312	377.2	1.99
M-Flood	1,541	372.5	0.90
L-Flood	337	371.2	0.53

Table 4.6 Section 4, At Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	377.9	3.35
H-Flood	6,312	377.2	2.38
M-Flood	1,541	372.5	1.10
L-Flood	337	371.2	0.62

Table 4.7 Section 5, 100 m Downstream from Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	377.8	3.39
H-Flood	6,312	377.2	2.43
M-Flood	1,541	372.5	1.14
L-Flood	337	371.2	0.56

Table 4.8 Section 6, 200 m Downstream from Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	377.6	3.84
H-Flood	6,312	377.1	2.84
M-Flood	1,541	372.5	1.52
L-Flood	337	371.2	1.15

Table 4.9 Section 7, 300 m Downstream from Existing Bridge

Description	Discharge (m3/s)	Water Level (m)	Average Velocity (m/s)
HH-Flood	11,585	377.4	3.71
H-Flood	6,312	377.0	2.77
M-Flood	1,541	372.5	1.60
L-Flood	337	371.2	1.09

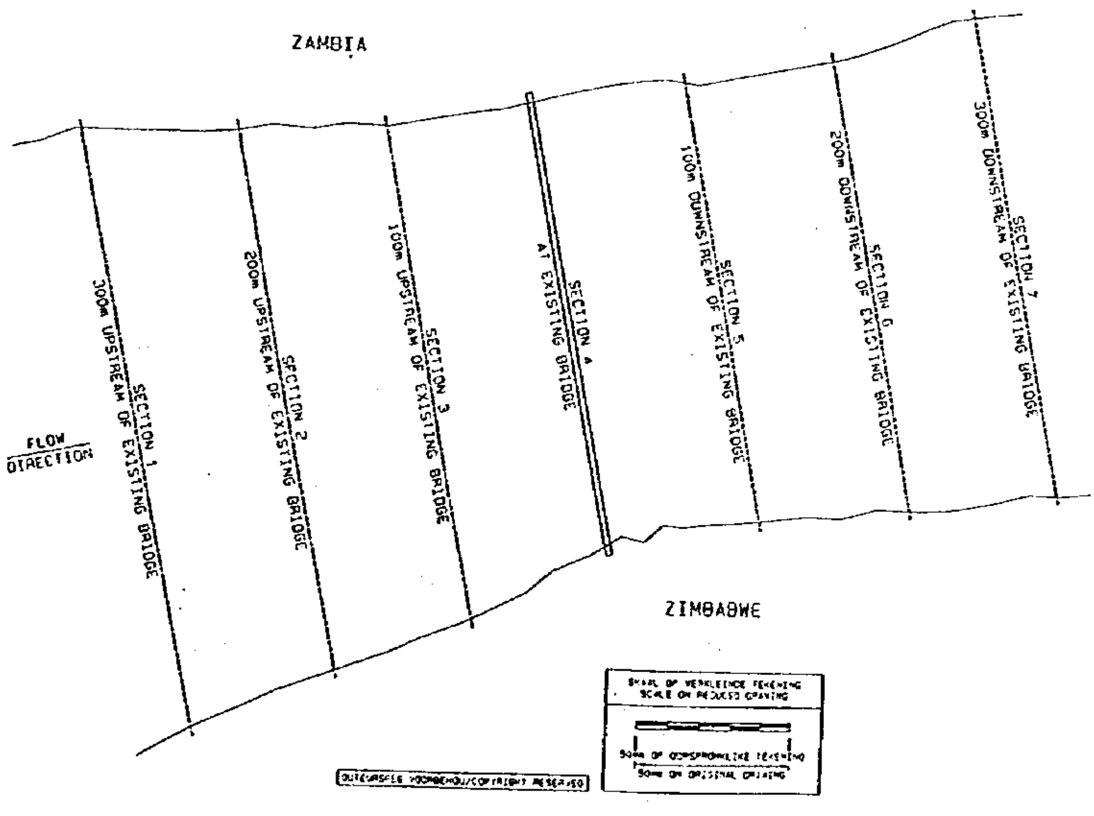


Figure 4.3 Location of Cross Sections for Hydraulic Analysis

4.2.3. SCOUR AND SEDIMENT MOVEMENT

The river has a highly alluvial nature, with large amounts of sediment that are transported. The origin of the sediment is probably farming activity on the Zambian side of the part of the catchment downstream of Kariba Dam.

Sediment movement was analysed by means of two methods;

Applied stream power method (Le Grange and Rooseboom, 1993).

An empirical method (Parker 1979) based on regime theory with coefficients as determined for African alluvial rivers by Le Grange and Rooseboom.

The material transported in the river was assumed to be fine sand with a representative particle size of approximately 0.12 mm. Expected sand wave height in the river under flood conditions are expected to range between 3 and 5 meters. Based on the boring test carried out in the river bed, the characteristics of the soil layers 3 to 5 meters below the river bed are dense sand and pebbles, and stiff clay and gravel. No scouring is expected to occur in these layers.

4.3. GEOLOGICAL CONDITION

Geological survey composed of dynamic cone penetration test and sonic prospecting survey was carried out in July 1997, and boring test was carried out in October/November 1997.

4.3.1. WATER DEPTH

The results by sonic prospecting survey indicate that the river flow center shifts toward the Zambian side (left side) as shown in Figure 4.4. The water surface elevation is 371.4 m and the river bed elevation at water flow center is about 355 to 359 m. The water depth is around 12 to 16 meters. The shallow river bed area occupies some 3/4 of the total river width and its water depth is 2 to 4 meters.

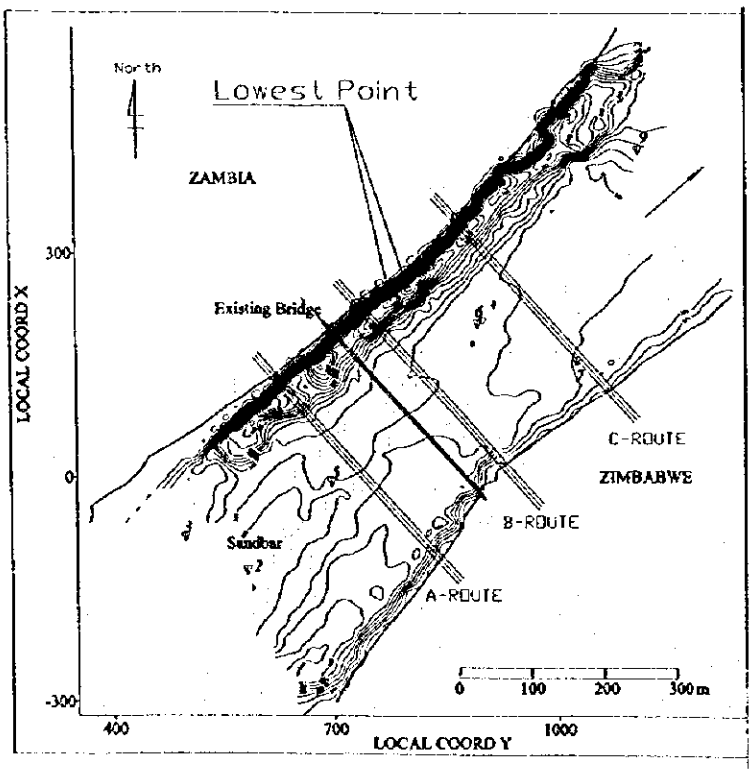


Figure 4.4 River Bed Elevation

4.3.2. GEOLOGICAL CONDITION

(1) Dynamic Cone Penetration Test

Dynamic penetration tests at seven (7) locations inside the river were carried out. The tests near the water flow center were abandoned due to the difficulties of equipment installation in the fast water current (refer to Figure 4.5). Based on the results of the Tests, geology of the river bed is composed of two (2) layers of river sediment and dense sandy layer or weathered rock. The numbers of penetration blows (N_d) show three (3) layers, upper surface layer (N_d less than 5), middle layer (N_d 15 to 30) and bottom layer of very stiff soil (N_d more than 50). The results of the tests are shown in Figure 4.6.

(2) Sonic Prospecting Survey

Sonic prospecting survey was carried out on the lines along the river flow. Based on the survey results, geological cross sections perpendicular to the river flow are developed. The boundaries of the soil layers are shown in Figures 4.7 and 4.8. The sections X-X, Y-Y and Z-Z indicate the sections of 210 m downstream (Borehole No.7) , 150 m downstream (Borehole No.6) and 150 m upstream (Borehole No.5) from the existing bridge, respectively. Compared with the results of dynamic cone penetration tests, the lower boundary of the sonic wave reflection corresponds to the layer of N_d of 50 or more and is considered to be the bearing strata for bridge foundation.

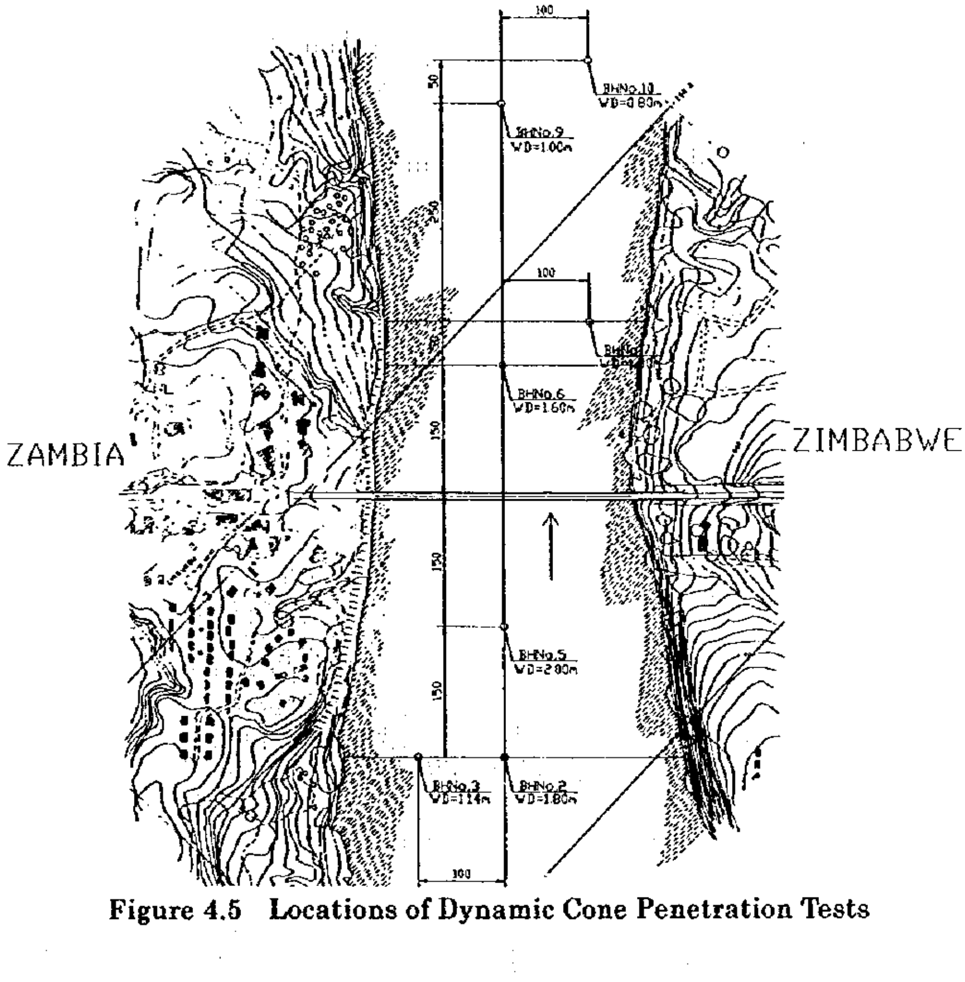


Figure 4.5 Locations of Dynamic Cone Penetration Tests

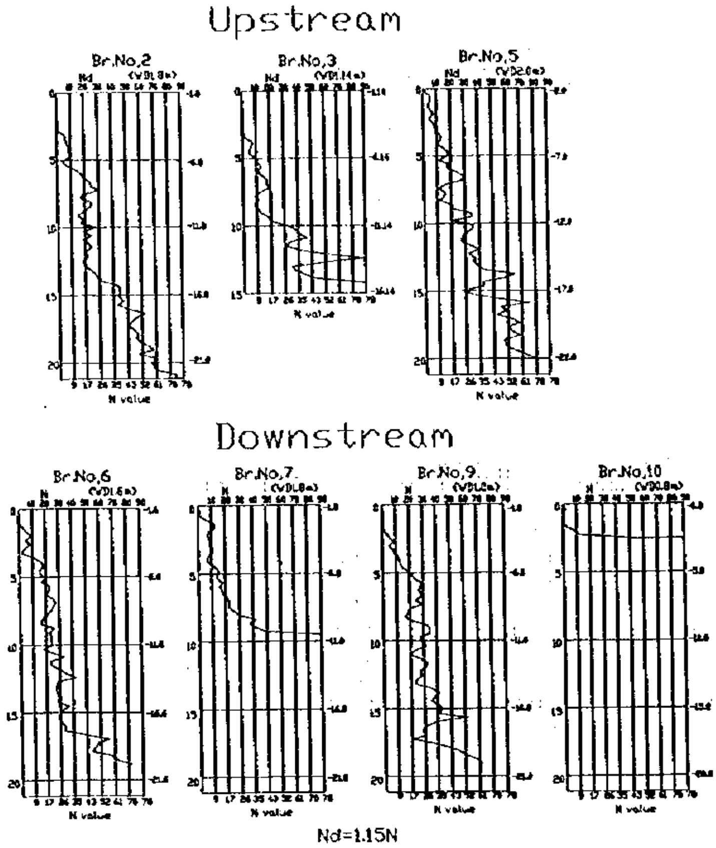


Figure 4.6 Dynamic Cone Penetration Test Results

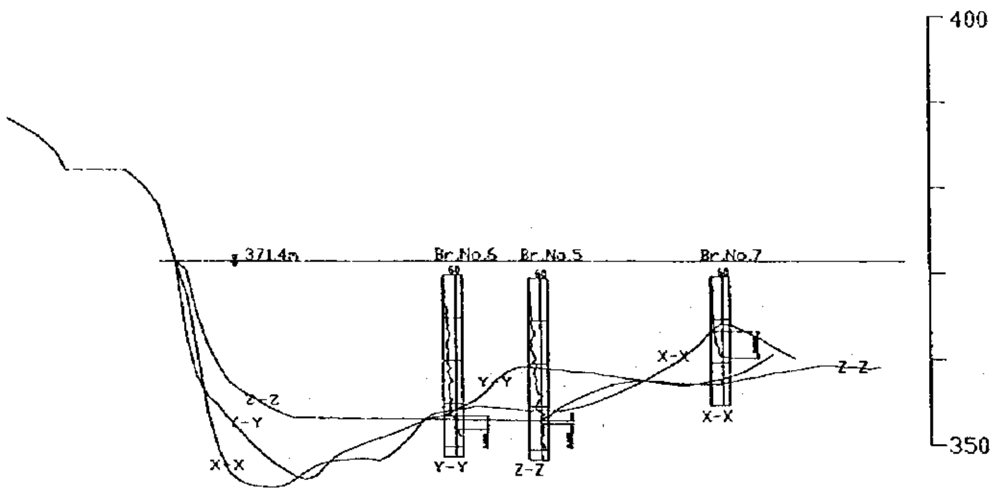
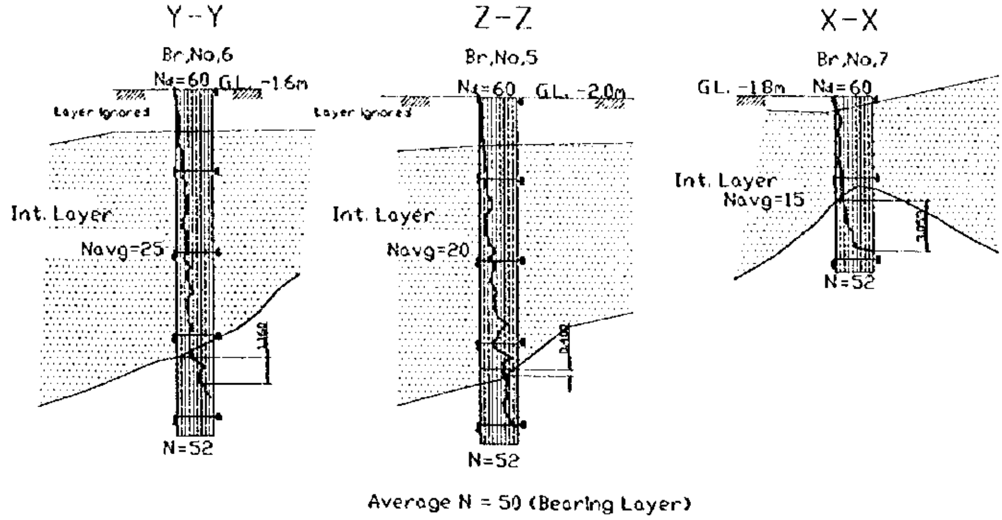


Figure 4.7 Comparison of Soil Boundaries by Sonic Prospecting and Dynamic Cone Penetration Test Results



200m downstream **150m downstream** **150m upstream**

Figure 4.8 Nd Values and Bearing Strata

(3) Borehole Test

Borehole tests were carried out at 4 locations on Route A (100 m upstream of the existing bridge), two (2) in river banks and two (2) in the river bed.

1) River Banks

Stiff weathered rock is located under the thin surface soil in both banks (refer to Figure 6.1). These weathered rock layers descend toward south-west at Zambia side and north-east at Zimbabwe side, respectively.

2) River Bed

Under the loose sand of 1 to 3 meters thickness, there exist medium dense to dense sand layer of some 2 meters and below 5 meters very dense sand and pebble layer. Standard penetration test shows 25 to 50 blows for these lower 2 soil layers. Below these dense sand and pebble layers, very stiff clayey silt and gravel layers are located. SPT of these layers show more than 40. Figure 4.9 indicates the soil conditions by borehole tests in the river bed on the line 100 meters upstream from existing bridge.

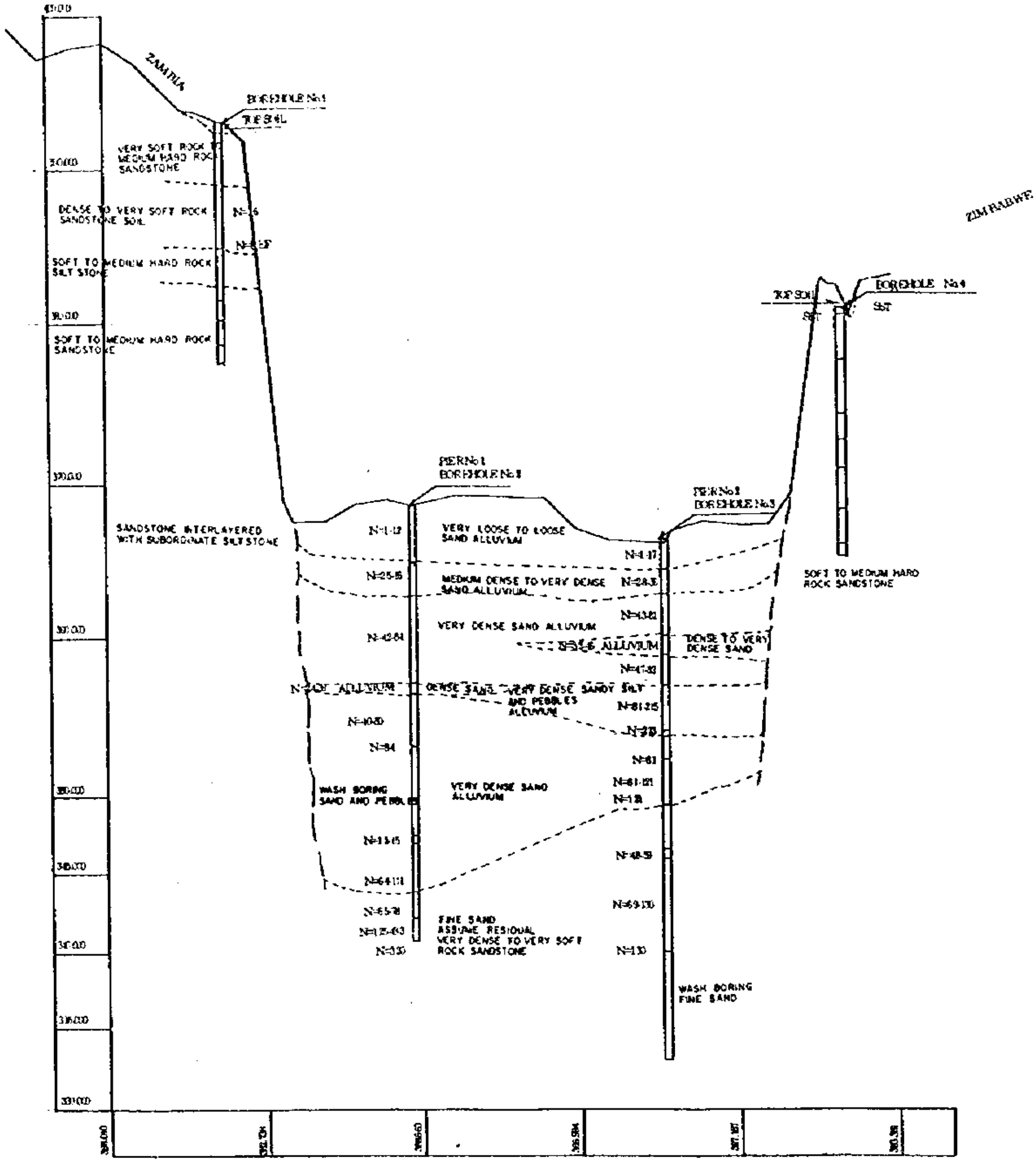


Figure 4.9 Borehole Test

5 BRIDGE ALTERNATIVE STUDY

5 BRIDGE ALTERNATIVE STUDY

5.1. Existing Bridge Condition

5.1.1. Loading Capacity

(1) Visual Inspection

The Study Team carried out the detailed investigation on the existing bridge structural condition during July 7 to July 12, 1997 mainly by visual inspection. Concrete strengths of the structural members were confirmed by Schmidt hammer testing. From these works, it is concluded that the existing Otto Beit Bridge has no structural problem regarding its loading capacity at the present and under the present condition of traffic control (one vehicle on the bridge at a time and 55 ton vehicle weight limit). It will continue to be serviceable for the traffic if good maintenance works are provided. The followings is a brief description of the existing bridge components as determined from the inspection.

1) Main Cables and Hanger Cables

Deterioration of painting in all parts and partial loss of painting was observed. Deterioration of painting of main cable was noticed, but some of hanger cables are rusted even after maintenance works. Deformation and/or slips of clamps were not observed.

2) Stiffening Girder and Cross Frame

Generally good condition was observed. However, in some parts of lower chords of the stiffening girder, deterioration of painting and rusting were observed.

3) Floor Slab and Stringer Girder

Generally good condition was observed. However, some 10 by 15 cm concrete scaling and exposure of re-bars at bottom surface of concrete deck slab were observed. Concrete strength shows an average of 54 Mpa by Schmidt hammer testing.

4) Main Tower

Tower columns on both Zambian and Zimbabwean sides are in good condition in shape as well as painting. Many small deformations by gun bullets are observed in web plates of Zambian tower columns. The cable saddles at tower tops were not observed as to their deformation and slippage.

5) Anchorage

No movement or settlement were observed in anchorage structures on both sides. There are also no excessive cracks in concrete structures. As for the conditions of bent tower, spray saddle and cable anchorage, all parts are maintained in good conditions without painting deterioration and rusting. Concrete strength by Schmidt hammer testing shows an average of 46 Mpa in Zimbabwean side and 39 Mpa in Zambian side.

6) Main Tower Foundation

There is no movement or settlement in tower foundation at both sides. However, some cracks (about 0.2 mm wide lateral crack at about 60 cm below the top surface of foundation) at tower base were noticed, where the anchor bolts seem to be embedded. The concrete strengths show an average of 45 Mpa in Zimbabwean side 40 Mpa in Zambian side by Schmidt hammer testing, respectively.

(2) Stress Condition under Design Loads

Otto Beit Bridge was constructed in 1939 and open to public for more than 60 years. The design load/methodology was not the same as used nowadays. For the purposes of checking the stress condition under normal use without any restriction, major structural members of the bridge were examined by considering present design loads/methodologies as below;

Japanese Standard (live load case B)
South African Standard (NC loading)
British Standard (HA and HB loads)

The yield stresses of the materials were obtained from the design summary of Otto Beit Bridge design. However, the yield stress used in limit state design is assumed due to the uncertainties of stress-strain relationship of the materials used in the Bridge.

The design vehicle loading used in each Standard is shown in Figure 5.1 to Figure 5.3.

Allowable stress design method is adopted from Japanese Standard and British Standard vehicle loadings, and limit state design method is adopted from British and South African standards. Table 5.1 and Table 5.2 show the check results by allowable stress method and Table 5.3 and Table 5.4 show the results by limit state method. The major results are as below;

- Stress of lower chord of No. 90 exceeds the allowable stress under Japanese Standard.
- Stress of all lower/upper chords and part of diagonal members exceed the allowable stress under British Standard (allowable stress design)
- All lower and upper chords are over stressed under the BS loading (limit state design)
- All lower, upper chords and diagonal members are over stressed under the SA loading (limit state design)

From these results it is concluded that without traffic management of load limitation and one way movement, the bridge structure will suffer a damage from vehicle movement.

The members of the bridge where stress checks were conducted are shown in Figure 5.4.

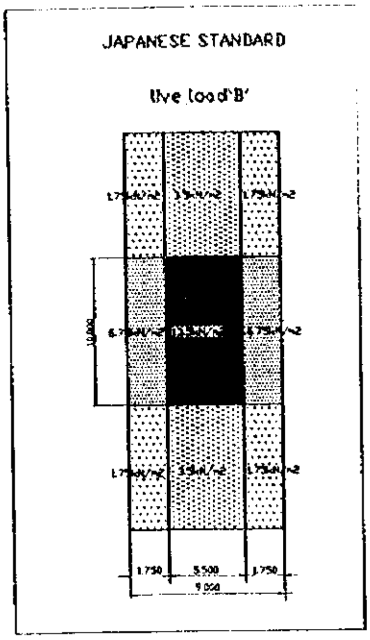


Figure 5.1 Vehicle Loading of Japanese Standard (Live load B)

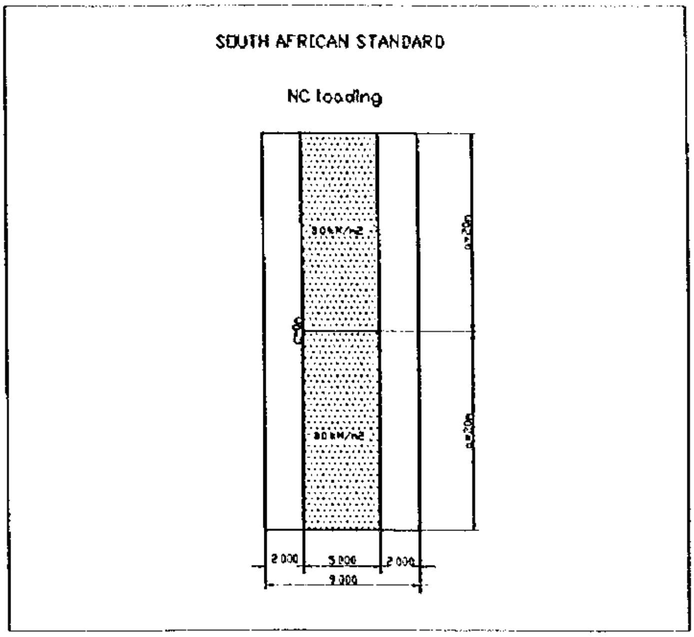


Figure 5.2 Vehicle Loading of South African Standard (NC loading)

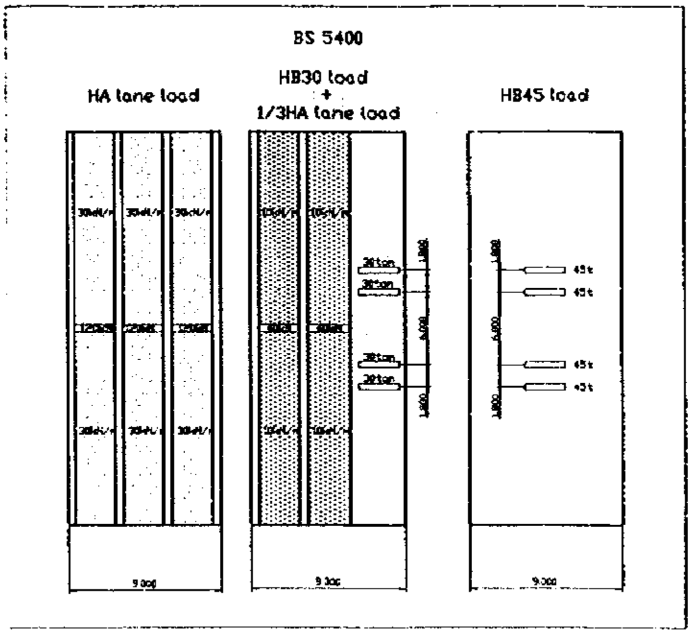


Figure 5.3 Vehicle Loading of British Standard (HA and HB Loading)

Table 5.1 Stress Check Results by Japanese Loading unit (tf)

	No.	D. Load	L. Load	Sidewalk	Temp.	Total	Allowable	Judge
Upper Chord	14	0	-342	-50	-13	-405	-417	ok
	16	0	-347	-50	-14	-411	-434	ok
	19	0	-334	-47	-16	-397	-417	ok
Lower Chord	87	0	344	49	14	407	415	ok
	90	0	325	45	14	385	382	no
	94	0	287	38	15	340	350	ok
Diago-Nal	141	0	85	0	3	88	151	ok
	142	0	-79	0	-3	-82	-84	ok
	147	0	71	0	1	72	127	ok
	148	0	-60	0	-1	-61	-70	ok
Cable	282	869	349	43	8	1269	1307	ok
	283	868	348	43	8	1266	1307	ok
Hanger	355	19	8	1	1	29	120	ok
	371	19	10	1	0	30	120	ok
	389	19	10	1	0	30	120	ok

Table 5.2 Stress Check Results by British Loading unit (tf)

	No.	D. Load	L. Load	Sidewalk	Temp.	Total	Allowable	Judge
Upper Chord	14	0	-473	-50	-13	-536	-417	no
	16	0	-475	-50	-14	-539	-434	no
	19	0	-446	-47	-16	-508	-417	no
Lower Chord	87	0	469	49	14	532	415	no
	90	0	431	45	14	490	382	no
	94	0	364	38	15	417	350	no
Diago-nal	141	0	113	0	3	117	151	ok
	142	0	-113	0	-3	-116	-84	no
	147	0	78	0	1	79	127	ok
	148	0	-78	0	-1	-79	-70	no
Cable	282	869	377	43	8	1297	1307	ok
	283	868	373	43	8	1290	1307	ok
Hanger	355	19	10	1	1	31	120	ok
	371	19	10	1	0	30	120	ok
	389	19	10	1	0	30	120	ok

Table 5.3 Stress Check Results by BS Loading (Serviceability Limit State) unit (tf)

	No.	D. Load	L. Load	Sidewalk	Temp.	Total	Allowable	Judge
Upper Chord	14	0	-615	-65	-7	-686	-531	no
	16	0	-617	-65	-7	-689	-551	no
	19	0	-579	-61	-8	-648	-531	no
Lower Chord	87	0	610	64	7	681	580	no
	90	0	560	59	7	626	559	no
	94	0	474	49	8	530	522	no
Diago-nal	141	0	146	0	2	148	230	ok
	142	0	-146	0	-2	-148	-219	ok
	147	0	101	0	1	102	193	ok
	148	0	-101	0	-1	-102	-183	ok
Cable	282	869	490	55	4	1418	1900	ok
	283	868	484	55	4	1411	1900	ok
Hanger	355	19	13	1	1	33	151	ok
	371	19	13	1	0	33	151	ok
	389	19	13	1	0	33	151	ok

Table 5.4 Stress Check Results by S. African Loading unit (tf)

	No.	D. Load	L. Load	Sidewalk	Temp.	Total	Allowable	Judge
Upper Chord	14	0	-1701	0	-7	-1708	-531	no
	16	0	-1699	0	-7	-1706	-551	no
	19	0	-1609	0	-8	-1617	-531	no
Lower Chord	87	0	1678	0	7	1685	580	no
	90	0	1566	0	7	1573	559	no
	94	0	1410	0	8	1417	522	no
Diago-nal	141	0	439	0	2	441	230	no
	142	0	-391	0	-2	-393	-219	no
	147	0	300	0	1	301	193	no
	148	0	-267	0	-1	-267	-183	no
Cable	282	869	681	0	4	1554	1900	ok
	283	868	672	0	4	1544	1900	ok
Hanger	355	19	17	0	1	37	151	ok
	371	19	27	0	0	46	151	ok
	389	19	30	0	0	49	151	ok

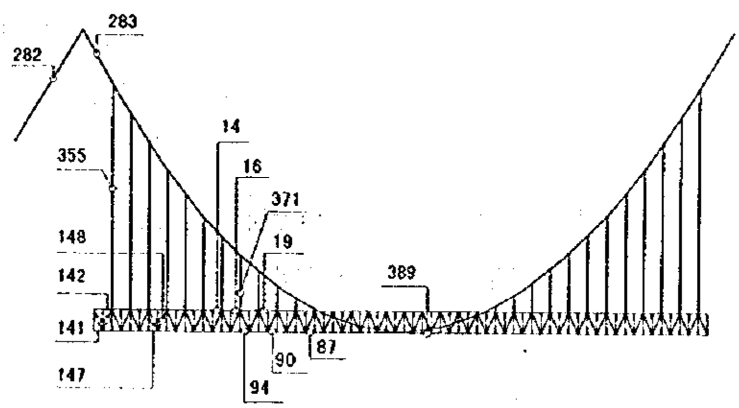


Figure 5.4 Member Diagram for Stress Check

5.1.2. TRAFFIC CAPACITY OF THE BRIDGE

(1) Premises of Calculation

Traffic capacity on the existing bridge is estimated based on the existing traffic control condition, i.e. one way traffic and one vehicle on a bridge at a time. The premises of calculation of traffic capacity are as below;

a) operating speed limited on the bridge is adopted 15 km/h, and average running speed on the bridge also is adopted as 15 km/h,
b) only one vehicle can pass through on the bridge,
c) operation by one way traffic system,
d) vehicles should stop at 100 m behind entry to the bridge on both sides,
e) distance between vehicle stop lines is 500 m (100 + 300 + 100 m).

(2) Traffic Capacity on the Bridge

The capacity of the bridge is estimated according to the following procedure;

a) running time for the distance of 500 m: 2 minutes
b) number of vehicles to pass distance in one hour: 30 veh./h
c) traffic capacity of the Bridge: 30 veh./h
d) traffic capacity on the Bridge when customs and immigration offices are open; 12 hours: 11 hours for vehicle passage at 30 veh./h equals 330 veh. per day

5.1.3. MAINTENANCE CONDITION

(1) Present Maintenance Operation Condition

The maintenance works of the Otto Beit Bridge is under control of MOTE (Zimbabwe) provincial office in Chinhoyi. This office administers an exclusive maintenance crew composed of 3 technicians who are carrying out daily routine maintenance works on the Bridge. Daily work record is reported to the director in provincial office in Chinhoyi. However, there is no maintenance manual or standard for the Bridge maintenance.

Other than these daily maintenance works, weekly report is submitted to the director from the superintendent engineer in Makuti office, who is in charge of the national road network maintenance in Chirundu area. Yearly maintenance program for the Bridge is planned by MOTE provincial office based on the information through daily as well as periodic maintenance inspections, and sent to the Ministry head office for its evaluation and approval. About 80 thousand Zimbabwean dollars is used annually for the daily maintenance works. Technical and important inspection work is usually subcontracted to the relevant consultant in that field. The large maintenance work is carried out by a contractor through open bidding tender.

(2) Maintenance Work Share between Two Countries

The maintenance works of the Bridge were, before 1960, made by the Government of Rhodesia at Harare. During the independence war of Zambia from 1960 to 1964, actual maintenance work was not carried out.

After the end of the war in 1964, the arrangement between two Governments on sharing the property holdings and the maintenance of the Bridge was made as an equal partnership.

However, due to reasons by the Zambian side, the actual maintenance works were carried out only by the Southern Rhodesia/Zimbabwe side efforts. There seems to be some technical difficulties to determine the details of maintenance without any maintenance standard for the Bridge as well as cost differences between two countries. This situation shall be improved by the Ministries' top level agreements.

5.1.4. FUTURE ROLE OF THE EXISTING BRIDGE

As described in section 5.1, the capacity of the existing bridge is insufficient for both loading and traffic volume to cope with today's and future's needs at Chirundu. Nevertheless, the bridge structure itself is still in very sound condition owing to continuous maintenance efforts. Furthermore, this bridge has become a part of natural scenery of the spot, attracting many people with its elegant appearance.

Future role of the existing bridge is, therefore, identified as a bridge serving for pedestrians and in emergency between Zambia and Zimbabwe. This bridge should also be kept as a memorial, of a history of bridge construction, after completion of a new bridge at Chirundu.

5.2. BRIDGE ROUTE ALTERNATIVES

5.2.1. BASIC CONSIDERATION FOR ROUTE LOCATION

The alternative route location study shall be conducted based on the consideration of following technical, economical matters and environmental aspects.

a) Effects of environmental aspects including social environmental aspects.
b) Technical aspects of bridge design, construction method and project cost.
c) Effects of improvement plan on customs clearance facilities.
d) Natural conditions in the study area.
e) Relationship with the future development plans of the region
f) Existing facilities conditions, and
g) Economic aspects.

The Study Team conducted the various field reconnaissance surveys in the Study area and collected data in order to understand the conditions described above related to route location. As a result of analysis of reconnaissance survey and data collection, the following basic policies or guidelines for route location are identified.

a) To preserve the natural environment including social environmental aspects as much as possible.
b) To avoid passing through the existing and future community area as much as possible.
c) To utilize the existing public and private housing or facilities as much as possible.
d) To keep a compatibility with the future development plans such as customs clearance and immigration facilities, housing and tourism.

5.2.2. CONTROL POINTS FOR ROUTE LOCATION IN THE STUDY AREA

As a result of various field reconnaissance surveys and analysis of data collected, the major control points of route location are as follows,

(1) Existing Customs Clearance and Immigration Facilities

Existing customs clearance and immigration facilities are located at the Zambia side and Zimbabwe side about 50 to 100 meters from river edge of Zambezi river bank. In a later section, the improvement plan of these customs clearance and immigration system facilities are examined. Taking into account these planning situations or conditions, alternative routes are examined based on the two (2) cases. One is utilization of the existing customs clearance facilities, and the other is construction of new customs clearance facilities.

(2) Existing Housing Facilities in Zambia Side

There are about 40 houses for officers of the customs clearance and immigration and police station at the southern part of the existing customs area. According to the Zambia Revenue Authority (ZRA) development plan, these houses will be removed to the northern part of the existing Chirundu Township area. The tender of this development plan for construction of 40 houses will be commenced in November 1997. Considering this development situation, these facilities do not control the route location.

On the other hand, there are some houses for officers and private houses at the northern part of the existing customs clearance and immigration area. The construction of housing have been gradually developing to the northern part. When the alternative route will be located in this area, it is very difficult to avoid passing through these houses.

(3) Existing Housing Facilities in Zimbabwe Side

There are some houses for officers of the customs clearance and immigration, police station, and water treatment station at the southern end of the existing customs clearance and immigration facilities. When the alternative route will be located upstream from the existing Otto Beit Bridge, it is very difficult to avoid passing through these houses. Therefore, in this area, the route should be selected to minimise the effects to the existing houses.

(4) Water Supply Pump Station

There are water pumps in the Zimbabwe and Zambia sides approximately 50 meters upstream of the existing Bridge. Water for inhabitants in the Chirundu Border Post is supplied by these water pumps. Taking into account the importance of water supply, the route should be selected to preserve the existing water pumps.

(5) Existing Otto Beit Bridge

As a result of reconnaissance survey and analysis of major components of the existing Otto Beit Bridge, the existing bridge can be operated for transportation of pedestrian, bicycles, and motor cycles.

5.2.3. ROUTE ALTERNATIVE PLAN

Based on the results of reconnaissance survey, various field surveys, physical conditions of the study area and considering the basic route location policies, the alternative route location study is conducted. Taking into account the above mentioned matters, three different crossing points of the Zambezi river for new bridge construction site such as Route-A (upstream of Otto Beit bridge), Route-B (downstream and beside the bridge) and Route-C (downstream of the bridge) are selected as shown in Figure 5.5.

(1) Alternative Route-A

Alternative Route-A is located at about 100 meters upstream of the existing Otto Beit bridge. This route is located to avoid demolishing the existing water pumps located on both sides of the existing Otto Beit bridge, and to avoid passing through the existing houses on both sides of the Zambezi river as much as possible. After completion of the new bridge, the existing customs clearance and immigration facilities located on both sides of the Zambezi river can still be used.

(2) Alternative Route-B

Alternative Route-B is located at the about 50 meters downstream of the existing Otto Beit bridge. This route is located to utilise the existing customs clearance and immigration facilities on both sides of the Zambezi river and to avoid passing through the existing housing areas as much as possible.

(3) Alternative Route-C

Alternative Route-C is located at the about 225 meters downstream of the existing Otto Beit bridge. This route is located to avoid passing through the existing housing areas. However, after completion of new bridge, the existing customs clearance and immigration facilities on both sides of the Zambezi river will not be used, and new facilities will be required.

Dimensions of each of the Alternative Routes are summarised in Table 5.5.

Table 5.5 Dimensions of Each Alternative Route

Items	Route-A	Route-B	Route-C	Remarks
River cross point	upstream about 100 m	downstream about 50 m	downstream about 225 m	
River width (m)	330	300	310	
Bridge length (m)	400	380+100	380	
Road length (m)	Zim=400 Zam=425	Zim=150 Zam=560	Zim=625 Zam=570	
Total length (road +bridge) (m)	1,225	1,190	1,570	
Max. longitudinal grade (%)	3.0	3.0	5.0	
Mini. curvature (m)	55	35	75	
No. of houses to be demolished	25	10	6	
Max. cutting height (m)	15.0	4.0	7.0	
Max. embankment height (m)	4.0	4.0	6.0	
Existing custom facilities	To be used	To be used	difficult	
Excavation volume (m3)	67,000	10,000	23,000	
Embankment volume (m3)	7,000	7,000	42,000	
Pavement volume (m3)	8,200	7,100	12,000	

5.2.4. Evaluation of Alternative Route

The evaluation of alternative routes study is conducted based on the technical matters, environmental aspect and economic aspects. The detailed environmental evaluation and economic aspects are described in later chapters. As a result of various examinations, the Alternative Route -A is selected as the most optimum route of new bridge construction site. The main selection reasons are as follows.

(1) Environmental Viewpoints

a) Since the alternative Route -C is passing through the existing and future housing development area at Zambia side, the Route-C is eliminated.

b) Route -B can not avoid the three houses which are located near the river bank at Zambia side. It is very difficult to acquire the land.

c) The area down stream from the existing bridge at Zimbabwe side should be kept in a good environmental condition as much as possible, in order not to disturb endangered species.

d) From the environmental viewpoint, Alternative Route-A is selected.

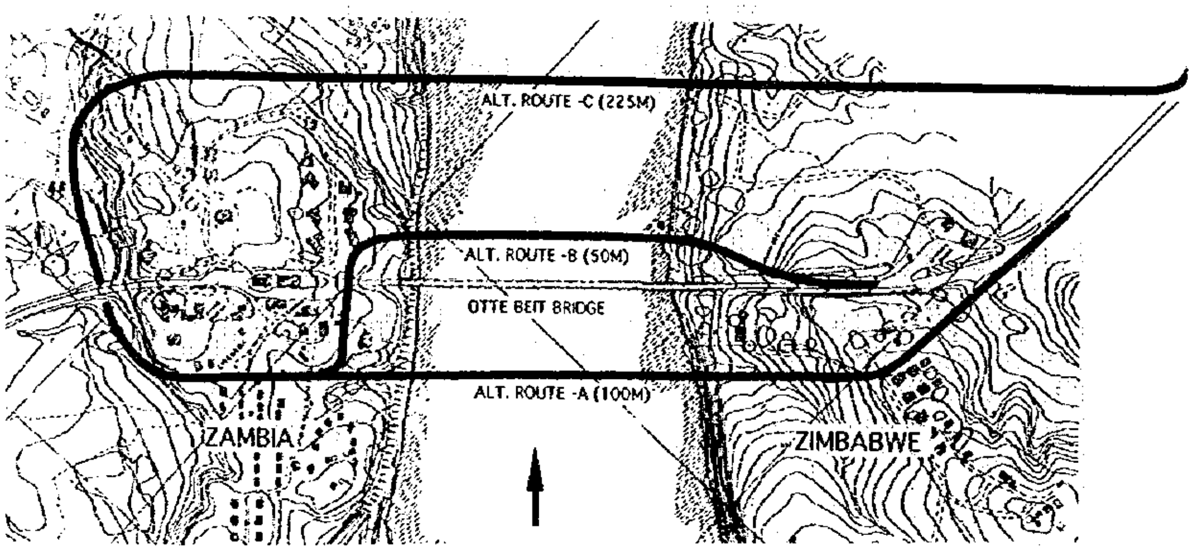


Figure 5.5 Alternative Route Location Map

(2) Technical Viewpoints

a) Route -C makes it very difficult to use the existing customs facilities. It also makes it very difficult to construct new customs facilities due to the limited space available for its construction.

b) Route -B can make use of existing customs facilities, however, the horizontal alignment is very small making it difficult for many large trucks to pass through the bridge.

c) From technical viewpoints, Alternative Route -A is selected.

(3) Economic Viewpoints

a) The direct cost of construction of bridge and access roads for route A, B and C is US$ 13.3, 13.2 and 13.5 million respectively.

b) The direct costs of all alternatives are almost equal.

c) From economic viewpoints, Alternative Route -A is selected.

5.3. BRIDGE ALTERNATIVES

5.3.1. DESIGN CRITERIA

(1) Road Geometry

The road geometry for the preliminary design study is determined by referring to the standards of trunk roads of both countries. (Refer to Figure 5.6)

Number of traffic lane:	2 lanes
Lane width:	3.5 meters
Shoulder width:	2 x 1 meters
Maintenance walk width:	2 x 0.75 meter
Design speed:	80 km/h

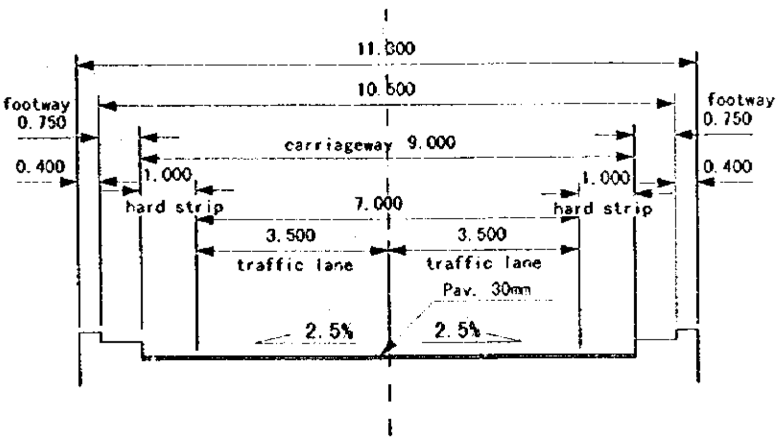


Figure 5.6 Road Geometry

(2) Span Length

The HH-Flood discharge of the Zambezi River is estimated to be 11,585 m^3/s excluding discharge from Kariba Dam for the current power generation (about 4,100 to 7,500 m^3/s). Depending upon the Guideline of Japanese River Structure Construction, the minimum span length of the bridge shall not be less than the length estimated by the formula below;

$L \geqq 0.005Q + 20 \leqq 70$
where L : span length (m)
Q : Flood discharge (m^3/s)

Therefore, in Chirundu case,

$L = 0.005 \times (11,585 + 5,800) + 20 = 107$ m → 70 m

Minimum span length shall be more than 70 m, which means maximum possible number of piers inside the river bed is 3.

(3) Top Elevation of Pile Cap inside the River

Zambezi river is natural river without any river training. Therefore, top elevation of pile cap shall be determined considering the scouring depth. The hydrological investigation estimates the scouring depth to be 3 to 5 meters, which takes into consideration the sedimentation layer of fine sand covering the shallow water depth area from middle to right side part of the river. The soil condition by bore hole test indicates that very dense sand and pebble layer is located some 5 meters below the river bed. This layer could be considered less vulnerable to scouring.

(4) Design Loads

1) Vehicle Load

Japanese vehicle load is applied for the design work of this Feasibility Study. For designing main bridge members, uniform main loading of 13.5 kN/m2 (10+3.5) of 10 meter length and uniform sub loading of 3.5 kN/m2 applied on the carriageway surface of 5.5 meters width. In addition to those, half of these loadings are applied on the rest of the carriageway surface (refer to Figure 5.1).

In addition to this vehicle loading, impact load is applied based on the formula given below;

$i = 20 / (50 + L)$ for steel structure
$i = 7 / (20 + L)$ for concrete structure
where, i represents impact factor,
L represents loading length on the member considered.

2) Temperature Change

Based on the temperature change indicated in Zimbabwe Bridge Design Code, average 31 Celsius degrees in maximum and 14 Celsius degrees in minimum are recorded at Kariba area. Using these data and considering structural characteristics, the following temperature changes are considered for design work;

a) concrete structure: for whole structure : 15 to 35 degrees
difference between members : 5 degrees

b) steel structure for whole structure : 10 to 40 degrees
difference between members : 10 degrees

3) Creep and Shrinkage of the Concrete

Creep and shrinkage of the concrete depend on the member size, age of concrete at loading, relative humidity around the member, etc. However, for this design work, the following factors are adopted (based on Japanese Code) (refer to Table 5.6).

Table 5.6 Creep and Shrinkage of Concrete

Concrete Age at Permanent Loading	4-7 days	14 days	28 days	90 days	365 days
Creep Coefficient	2.6	2.3	2.0	1.7	1.2
Shrinkage Coefficient	20 E-5	--	14 E-5	16 E-5	12 E-5

4) Seismic Load

The area of Kariba dam is one of the nest of earthquake in the region. Seismic records regarding epicentre and magnitude in this region are available from 1967 for the last 30 years. Based on this data, the maximum accelerations of the ground at Chirundu site are estimated for each seismic data using empirical formula developed in Japan. By assuming the occurrence of the seismic phenomena as Poisson distribution, the expected maximum acceleration of the ground is forecasted for return period of 200 years (bridge life is 100 years). The diagram of this analysis is shown in Figure 5.7. From these analyses, horizontal acceleration of 0.1 g is employed for the design work. (See Appendix 3 for more reference)

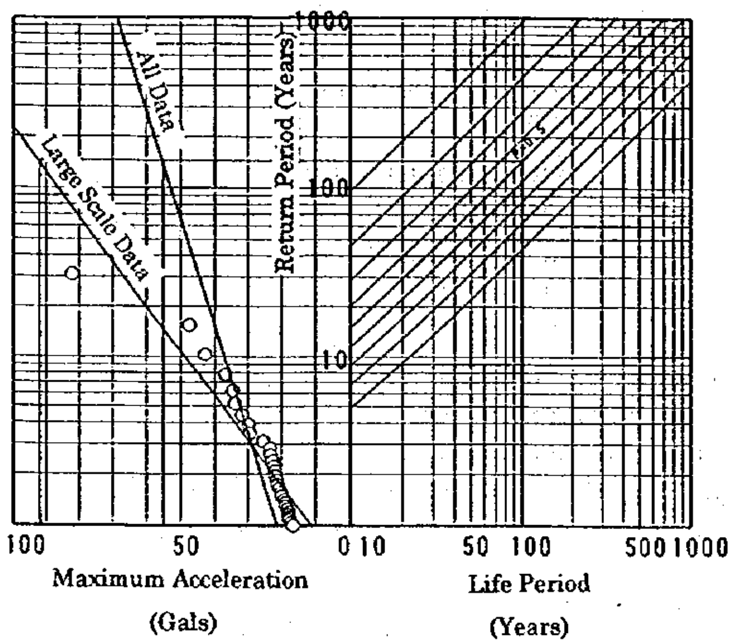


Figure 5.7 Seismic Effect Analysis Diagram

(5) Materials

1) Concrete

Three (3) different strengths of concrete are used as shown in Table 5.7.

Table 5.7 Concrete Type

Design Strength (Mpa)	Members to be used for	Remarks
40	concrete superstructure	
30	top portion of the pier	
24	substructure	
18	levelling	

2) Reinforcing Bar

SD295 (JIS code): yield strength more than 306 Mpa
tensile strength 449 to 612 Mpa

3) Steel Plate

SS400(JIS) yield strength more than 245 Mpa
SM490Y(JIS) yield strength more than 367 Mpa

4) Prestressing Tendon

SWPR7B(JIS) yield strength more than 1630 Mpa
(12T15.2 mm strand cable)

5.3.2. Selection of Bridge Alternartives

(1) Bridge Type

Principal materials of superstructure for span length up to some 400 m are both steel and concrete in general. Their characteristics are as follows;

A) Concrete

- local procurement of the aggregates
- less maintenance works
- necessity of sufficient quality control at site
- longer construction period at site

B) Steel

- high quality control by fabrication yard
- shorter construction period at site
- procurement from third countries
- repainting need for maintenance
- less contribution to local economy

For the sake of local material utilization and less maintenance works, concrete structure is adopted for the super structure of the bridge.

The following bridge types are considered in general for the span length over 100 meters;

- suspension bridge with concrete stiffening girder,
- cable stayed prestressed concrete bridge,
- concrete arch bridge,
- continuous prestressed concrete box girder bridge.

In the case of a concrete arch bridge, there is need for large scale construction equipment and temporary construction facilities. Therefore the other three (3) types of bridges were considered further for the comparison.

The comparison of the alternatives are summarised in Table 5.8. The characteristics of each bridge alternative are as described below;

a) Suspension bridge
   - There is no pier inside the river.
   - Suspension bridge with concrete stiffening girder has its own limitations. The girder weight is much heavier than steel girder and therefore, a large section cable would be required.
   - Anchorages for main cables shall be constructed on both sides of the bridge.
   - Temporary facility is not required because construction of girder is carried out using hanger cables from main cables.

b) Cable stayed bridge
   - The most popular type of bridge adopted for span length of 150 to 300 meters.
   - Cantilever erection from main tower is combined with stay cable erection.
   - Temporary bridge is required until main tower inside the river is completed. This temporary bridge shall be maintained until completion of superstructure, and used for the transportation of materials and equipment.

c) Prestressed concrete girder bridge
   - Two (2) piers shall be constructed inside the river.
   - This type of bridge structure is appropriated for span lengths of 70 to 150 meters.
   - Balanced cantilever erection from piers in the river can be carried out.
   - Temporary bridge is required.

It is concluded that prestressed concrete girder bridge is the most economical option among the four alternatives.

5.3.3. COMPARISON OF BRIDGE ALTERNATIVES

Table 5.9 shows the appraisal of the bridge alternatives from view points of construction cost, construction difficulties, environmental impact to the site, aesthetic aspect, maintenance and local economy contribution.

Suspension type is the most expensive option, and seems to be very difficult to adopt for this project. Cable stayed types with one and two piers inside the river have almost same characteristics, but alternative plan of one pier would be less costly. PC girder plan is the least costly alternative, but has some drawbacks of construction difficulty and aesthetic aspects.

As a total evaluation, prestressed concrete girder alternative is selected for the next preliminary design work, mainly for reasons of less construction and maintenance costs, and greater contribution to local economy.

Table 5.8 Comparison of Bridge Alternative (1)

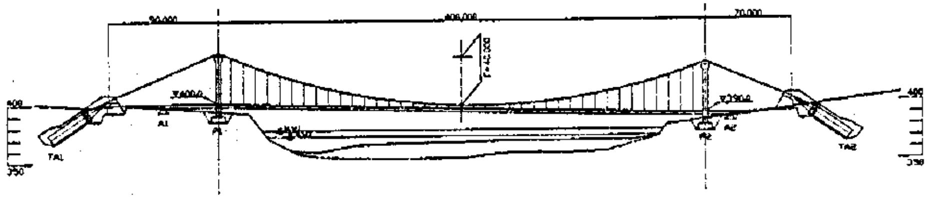
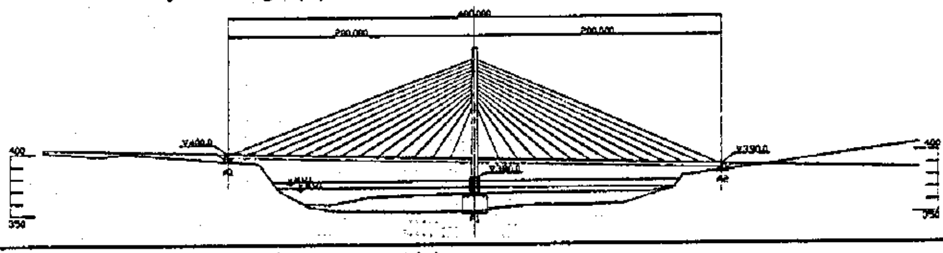
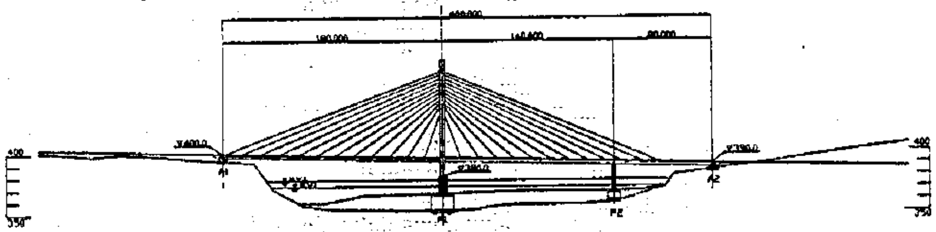
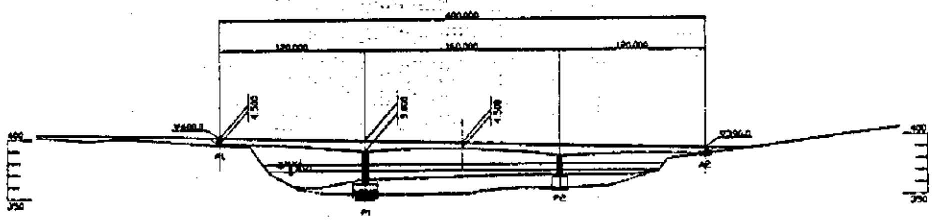
General View	Characteristics	Cost		Remarks
Alt. 1. Suspension Bridge 	• Single span suspension bridge with PC box girder • No foundation in the river, no interference with water flow • Foundation work in dry condition • Anchorage is divided into two parts beside the road • Dead load of PC girder is larger than that of steel girder. Therefore, cable cross section and the anchorage become bigger. • Same type as Otto-Beit Bridge, scenic impression is limited.	supers.	14.2	direct construction cost in million US$
		subs.	6.3	
		total	20.5	
Alt. 2. Cable Stayed Bridge (Symmetric) 	• Main girder is PC box • Main tower is RC solid section • Cable is multi-fan type of 2 planes • Main girder around the main tower is floating type. No vertical shoe is placed. • Construction is cantilever erection from the tower • Main tower is 2.5 times taller than that of existing bridge • Very impressive, and modern	supers.	8.5	direct construction cost in million US$
		subs.	4.4	
		total	12.9	
Alt.3 Cable stayed bridge (not symmetric) 	• Main tower is closer to Zambia than alt.2. Auxiliary pier is placed at Zimbabwean side • Tower and cable type is same as alt. 2 • Further study needed to assess pier. (cost and benefit) • Construction period is shorter than alt. 2 • Very symbolic	supers.	7.7	direct construction cost in million US$
		subs.	5.3	
		total	13.0	
Alt.4 Three spans continuous PC box girder 	• 3 spans continuous girder with varying depth • Cantilever erection from middle piers using four erection platforms. • Not very impressive • Foundation at Zambian side is close to the main flow, thus scouring is anticipated. Foundation is embedded deep into the bearing layer which results in larger coffer dam and concrete amount	supers.	5.7	direct construction cost in million US$
		subs.	5.5	
		total	11.2	

Table 5.9 Comparison of Bridge Alternative (2)

Route			Route "A" (100 m upstream from existing bridge); In Zimbabwe side, relocation of houses for police officials is required. High cut of hill also is needed. Existing border facilities are used. Formation level of bridge : 395 to 400 (from Zimbabwe side)							
Bridge Type			Suspension Bridge		Cable Stayed Bridge		Cable Stayed Bridge		PC Girder bridge	
General Description			400 m single span bridge, concrete girder, without pier in the river. Main cable anchored in the ground, no local experience with concrete girder.		Symmetrical type with 2 x 200 m spans, one pier in the river, 105 m high pylons in the middle of bridge, concrete girder, sufficient experience available.		Non symmetrical type with max. 180 m span two piers in the river, some 95 m high pylons, concrete girder, sufficient experience available.		3 spans symmetrical PC girder with max.160 m span, two piers in the river, one of which is very near to current flow, sufficient experience available.	
Evaluation	Construction cost (bridge / access)		32.9 million US$	X	21.1 million US$	△	21.3 million US$	△	18.5 million US$	◎
Evaluation	Construction	Bridge Structure	Careful attention must be paid for girder construction	△	Balanced cantilever-out construction, pier located on shallow river bed	○	Balanced cantilever-out construction, pier located on shallow river bed	○	Two piers construction in the river, near current flow	○
Evaluation	Construction	River Control	No problem	◎	Temporary bridge Near river center, easy	○	Temporary bridge near river center, easy	○	Temporary bridge near flow center, difficult	△
Evaluation	Environment	Natural Factors	No serious problem	○	Polluting river water anticipated	△	Polluting river water anticipated	△	Polluting river water anticipated	△
Evaluation	Environment	Social Factors	Relocation of officials' houses	△	Relocation of officials' houses	△	Relocation of officials' houses	△	Relocation of officials' houses	△
Evaluation	Aesthetic aspect		Harmonizes with existing bridge	◎	Very impressive	○	Impressive	○	Not impressive	△
Evaluation	Maintenance		Cable maintenance required	△	Cable maintenance required	△	Cable maintenance required	△	Less maintenance works	◎
Evaluation	Local economy contribution		Less than other alternatives	△	Local materials and labor used	○	Local materials and labor used	○	Mostly local materials / labor used	◎
Evaluation	IRR(%)								6.99	
Evaluation	Total evaluation		△		○		△		◎	
Recommendation			No		Second		No		First	

6 PRELIMINARY DESIGN OF THE BEST ALTERNATIVE

6 PRELIMINARY DESIGN OF THE BEST ALTERNATIVE

6.1. BRIDGE DESIGN

6.1.1. FOUNDATION

(1) Bearing Strata for Foundation

The results of borehole test on both banks show the existence of weathered rock layer just under the surface soil (refer to Figure 6.1). Therefore, spread footings for the abutments are planned to be located on the weathered rock layer on both banks.

The borehole tests in the river do not show such weathered rock layer within 20 to 30 meters below the river bed surface (refer to Figure 6.2). However, dense to very dense sand/pebble layer or very dense clayey silt/gravel layer are confirmed 5 to 10 meters below the river bed surface. This layer is sufficiently stiff for the foundation of the bridge (SPT more than 30). Therefore, such layers are planned as the bearing strata for the pier foundation.

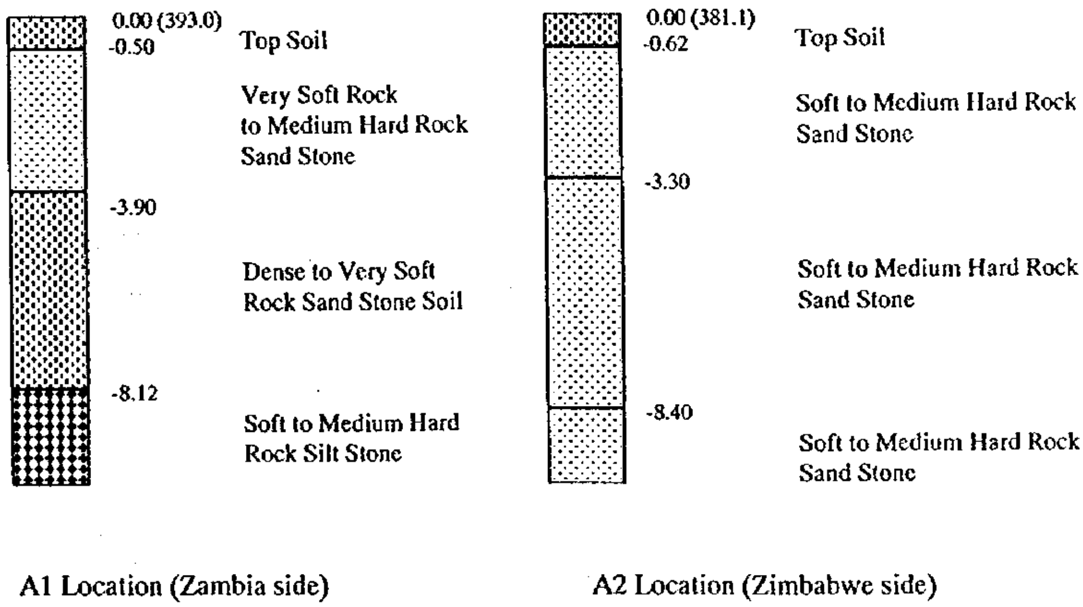


Figure 6.1 Borehole Test Results on Both Banks

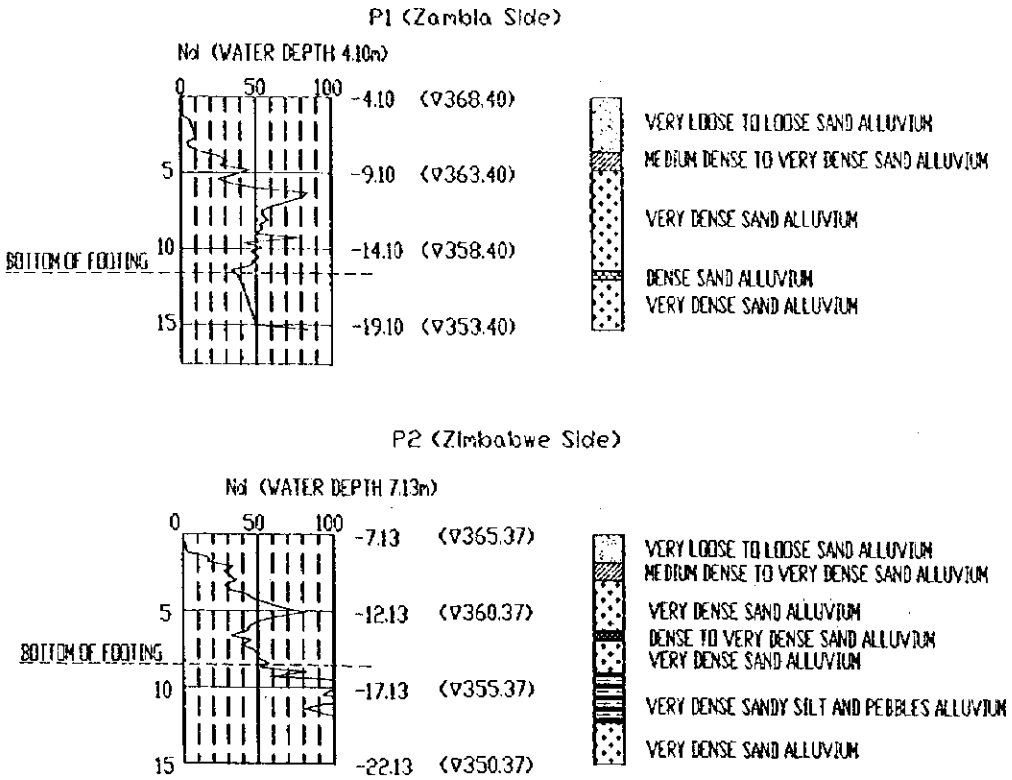


Figure 6.2 Borehole Test Results inside River

(2) Foundation for Piers

Taking into account the scouring of upper loose sand layer as well as footing thickness, bedding elevation of the pier foundations are to be constructed 10 m below the river bed surface at P1 (Zambia side) and 6 m at P2 (Zimbabwe side). Spread footing type foundations are planned for the piers inside the river, although temporary coffer dam is required for excavation of the soil and concreting the foundation.

6.1.2. SUBSTRUCTURE

(1) Abutment

Depending on the height of the abutment, the following types of structure are designed;

A1: height = 8 m	semi-gravity type abutment
A2: height = 14 m	wall type abutment

(2) Pier

Total heights of the piers are more the 30 meters. The shape of pier shaft is designed to be round type to reduce the resistance to water current. In order to minimize a footing size and to improve construction safety, temporary coffer dam constructed of steel pipe sheet pile is planned, which functions as temporary coffer dam during the construction period and is cut at footing top elevation after the completion of pier construction.

6.1.3. SUPERSTRUCTURE

Three (3) spans continuous prestressed concrete girder bridge is designed for the superstructure. The length of each span is 120 m, 160 m and 120 m. Side span length of 120 m was adopted considering the need to leave green space (animal path) in front of an abutment (approximately 20 m) and space between pier and water current for both Zambia and Zimbabwe sides.

The depths of the girder varies from pier to abutment and also to bridge centre, 9 m at pier and 4.5 m at bridge centre or abutment. Construction of the girder is planned to be carried out by cantilevering out from each pier. Therefore this stress condition during construction is taken into consideration in the design process of the superstructure.

After completing the design by Japanese Design Code, safety factor for ultimate state condition is checked by BS5400 Code for major sections. The result is indicated in Table 6.1.

Table 6.1 Safety Factor for Major Sections of Superstructure by Check Loadings

	Side Span (1)	Pier (2)	Center Span (3)
Dead Load (D)	18,529	-71,325	15,574
Live Load (L)			
L1 : HA	5,899	-10,086	3,737
L2 : HB 30 + 1/3 HA	6,345	-9,396	4,686
L3 : HB 45	3,645	-3,663	3,403
L4* NC	6,039	-6,206	5,629
Dx1.15 + L1x1.5	**30,157**	**-97,153**	23,516
Dx1.15 + L2x1.3	29,557	-94,239	24,002
Dx1.15 + L3x1.3	26,047	-86,786	22,334
Dx1.15 + L4x1.3	29,159	-90,092	**25,228**
Resisting Design Moment (γ_m=1.20)	42,434	-150,471	36,362
Safety Factor	1.41	1.55	1.44

Note: (1) Middle of side span
(2) Section at pier support
(3) Middle of centre span

Based on the Zimbabwean Bridge Design Code, the load factor and material/structure safety factor are defined as below.

Dead Load : $\gamma_{fL} = 1.2$

Vehicle Load : $\gamma_{fL} = 1.6$ (HA), 1.3 (HB)

material / structure safety factor : $\gamma_m = 1.20$

Using above factors for the loads in Table 6.1, safety factor of each section is to be as follows:

Side span (1) : Bending Moment = 31,673 t·m, safety factor = 1.34

Pier (2) : Bending Moment = -101,728 t·m, safety factor = 1.48

Center Span (3) : Bending Moment = 26,007 t·m, safety factor = 1.40

The results for safety factor are still more than 1.3.

6.1.4. MAJOR MATERIALS LIST

In Table 6.2 and Table 6.3, major material lists are summarised for the bridge structures.

Table 6.2 Major Material List of Bridge Superstructure

Item	Specification	Unit	Quantity	Remarks
Concrete	40 Mpa	m^3	4,690	Main girder
	24 Mpa	m^3	344	Curb
	18 Mpa	m^3	202	Leveling
Form work	Plywood	m^2	17,346	
Reinforcing bars	SD 295	ton	520	
Prestressing Tendon	12T 15.2mm	ton	276	Girder
	12ϕ7	ton	32	Floor
	ϕ32	ton	22	Shear
Pavement	Asphalt	m^2	3,590	Carriageway

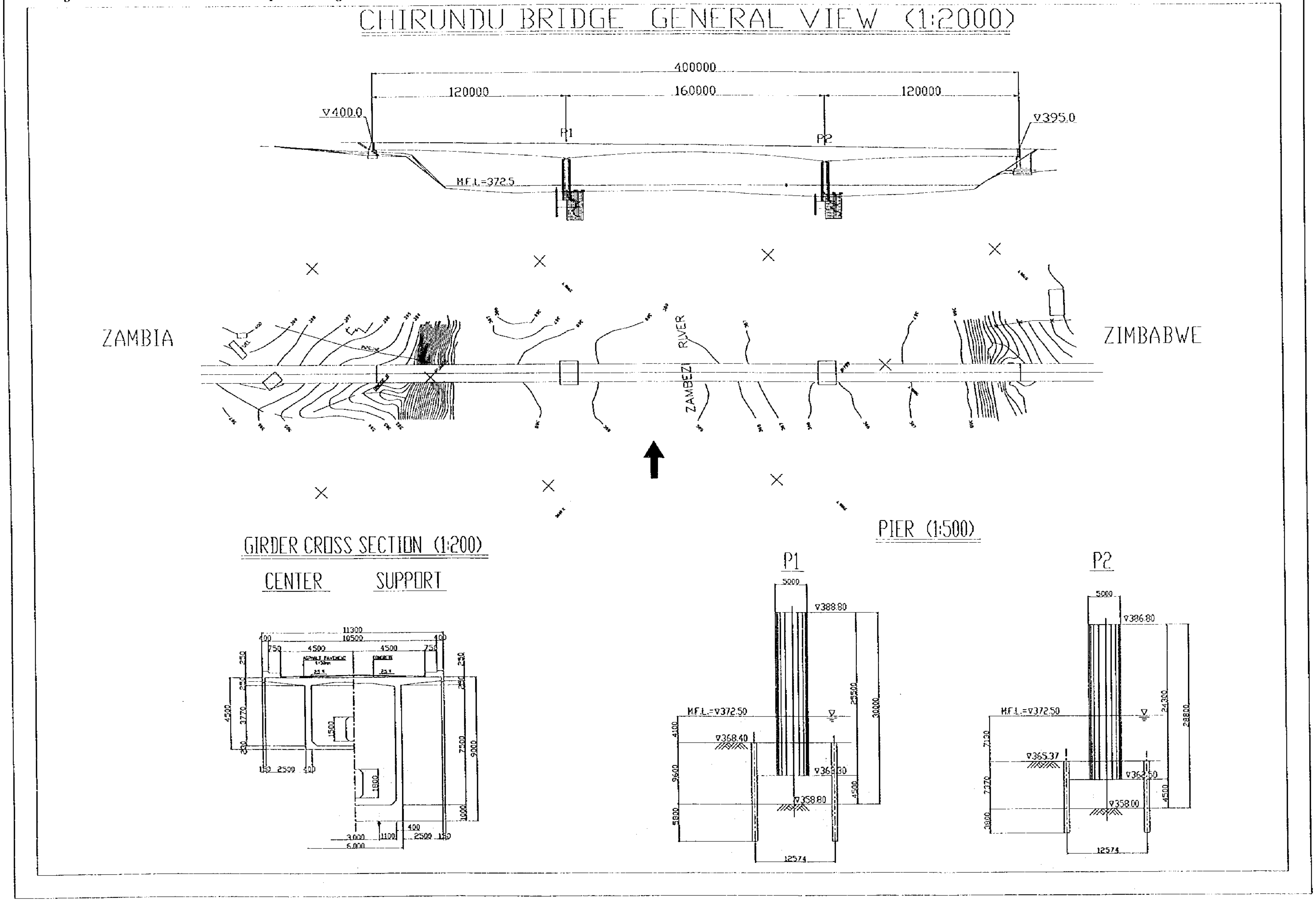
Table 6.3 Major material list of Bridge Substructure and Foundation

Section	Item	unit	A1	P1	P2	A2	Remarks
foundation	Concrete	m3	--	825	825	1,104	30/24 MPa
	re-bar	ton	--	62.3	62.3	9.7	
	Formwork	m2	--	--	--	88	
	Excavation	m3	296	2,121	1,628	289	rock exv. for abut
pier/abutment	Concrete	m3	312	779	733	460	
	re-bar	ton	12.4	76.9	73.8	46.3	
	Formwork	m2	331	598	564	694	
	Scaffolding	m2	495	771	734	1,194	
	Staging	m3	87	--	--	130	for wing constr.
	Fill	m3	193	935	526	775	

note: Materials of abutment foundation are included in body.

Legend: A1 – Abutment on Zambia side
P1 – Pier
P2 – Pier
A2 – Abutment on Zimbabwe side

Figure 6.3 General View of the Proposed Bridge



6.2. Preliminary Design for Road Section

6.2.1. Horizontal Alignment Design

The horizontal alignment study is conducted for the Alternative Route-A. The new bridge will be constructed at about 100 meters up-stream from the existing Otto Beit Bridge parallel to the bridge.

The starting point of horizontal alignment is located at the existing Beira Corridor about 600 meters from the existing bridge in Zambia side, and the ending point of route is located at the existing Beira corridor about 220 meters from the existing bridge in Zimbabwe side, that is in front of the existing customs office.

6.2.2. Vertical Alignment Design

The vertical alignment is examined taking into account balancing of earthwork, geometric design standards, and geographic conditions along the route. The maximum longitudinal grade is adopted as 4.0 % considering vehicle conditions. The vertical alignment is presented on the Drawings.

6.2.3. Cross Section Design

The cross section design is conducted considering the vehicle conditions, road characteristics, and geographic conditions along the route.

(1) Carriageway Width

About 67 % of total traffic volume is represented by truck vehicles. Considering the truck occupancy rate, and road design standards, 3.50 meter carriageway width is adopted for this project.

(2) Shoulder Width

Taking into account the traffic characteristics on the roads, and design standards of roads in Zimbabwe, 1.5 meters shoulder width on both sides was adopted for this project.

(3) Shoulder Protected Width

For protection of pavement structure, and to establish a traffic signal and sign, shoulder protection widths are needed. 1.0 meter shoulder protected areas are provided on both road sides.

The typical cross section is presented in Figure 6.4.

6.2.4. PAVEMENT DESIGN

(1) Type of Pavement to be adopted

There are two kinds of pavement types, i.e., cement concrete pavement and asphalt concrete pavement. When deciding the type of pavement for the project, the following matters should be examined.

i) climate
ii) soil conditions
iii) condition of project area
iv) past experience in the country
v) construction cost and maintenance cost
vi) possibility of procurement of pavement materials

Asphalt concrete pavement is adopted for this project taking into account the above mentioned considerations. The main reasons for the selection are as follows,

a) asphalt concrete pavement is cheaper than cement concrete pavement
b) there is sufficient local experience in construction of asphalt concrete pavement
c) there are no adverse effects to the natural conditions in the study area when asphalt concrete pavement is used.

(2) Pavement Structure

Pavement thickness is calculated depending upon the future traffic volume, material of pavement, and CBR of sub-grade of road. The future traffic volume in 2010 is estimated as 504 vehicle per day, and the number of trucks is estimated at 341 truck per day. CBR of sub-grade is assumed at 8 %. As a result of pavement thickness calculation, the following depth for each course is identified.

i) surface course = 50 mm
ii) base course = 150 mm
iii) sub-base course = 250 mm

The material of surface is adopted as hot mixed asphalt concrete, the adopted base course is cement stabilised, and sub-base course will be crushed stone.

6.2.5. DRAINAGE DESIGN

Since the roads are located in the open field area, the drainage for roads are often not constructed. However, concrete U-type drainage (W=5.0m, H=1.5m) will be provided at the toe of embankment slope, up-stream of A-2 abutment for protection of embankment slope.

6.2.6. MAJOR CONSTRUCTION QUANTITIES FOR ROADS

The preliminary road design is conducted in accordance with above mentioned matters. The road length of Zambia and Zimbabwe sides are about 620m and 240 m respectively. The major construction quantities for roads are presented in Table 6.4.

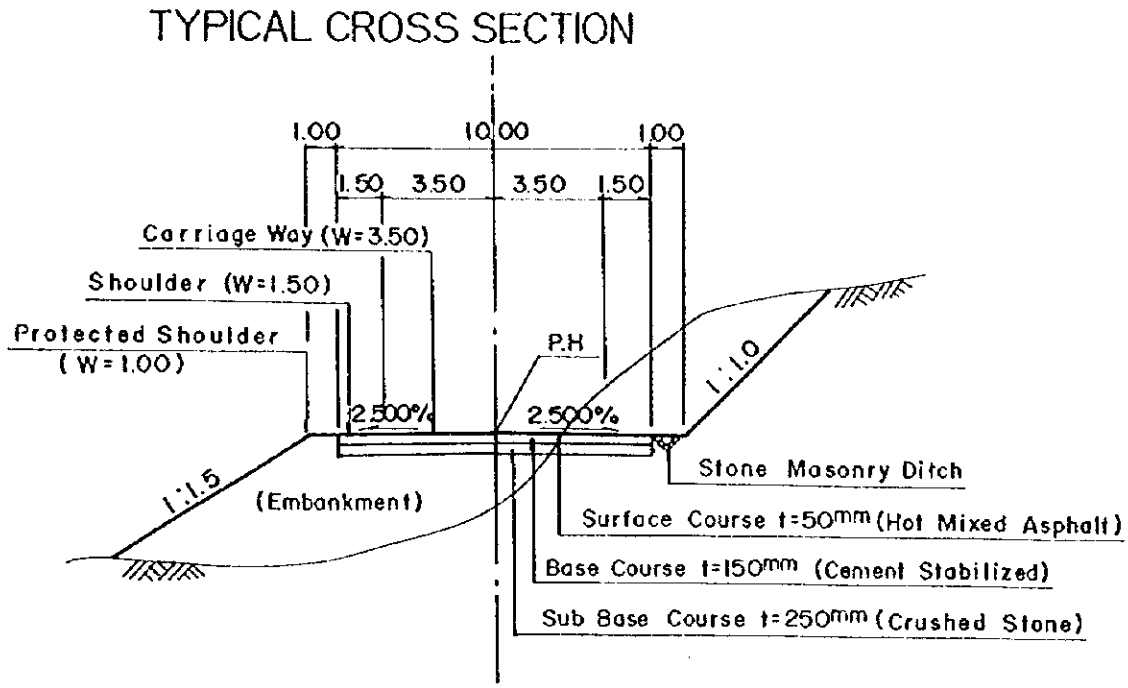


Figure 6.4 Typical Cross Section

Table 6.4 Summary of Construction Quantities for Roads

Working Items	Class	Unit	Quantities Zambia	Quantities Zimbabwe	Total
Site Clearing	Housing Area	m2	7,800	10,800	18,600
	Field	m2	7,200	4,400	11,600
Demolishing	Water Pipe	m	200	200	400
	Water Pond	Vol.	3	0	3
Excavation		m3	14,397	17,765	32,162
Embankment		m3	33,637	20,600	54,237
Borrow Soil		m3	19,240	2,835	22,075
Pavement	Surface T=50	m2	6,200	3,800	10,000
	Base T=150	m2	6,200	3,800	10,000
	Sub-base T=250	m2	6,200	3,800	10,000
Drainage	C-box(2.0×2.0)	m	20	0	20
	C-U (0.5×0.15)	m	0	110	110
Frontage Road	W=4m	m	0	360	360

7 BORDER FACILITY ALTERNATIVE STUDY

7 BORDER FACILITY ALTERNATIVE STUDY

7.1. EXISTING BORDER FACILITY AND IMMIGRATION/CUSTOMS PROCEDURE

7.1.1. CAPACITY OF EXISTING BORDER POST

The capacity of a border post is measured in terms of the facilities available to process the various traffic throughout (freight, passenger and pedestrian) and "turn around" level which conform to regional and international standards. The critical facilities which affect the levels of capacity of any border are:

available parking space and room to manoeuvre for motor vehicle of various categories and people,

available physical infrastructure and handling facilities (arrival/departure halls and associated administration offices, searching facilities, storage facilities, public amenities and support services),

customs, immigration and other clearing systems in place along with adequate trained staff to implement the systems.

If the above facilities are available in adequate measure then the capacity of border post can be said to be sufficient to be able to comfort and cope with the levels of acceptable international "turn around " time standards.

Table 7.1 International Standard Turn Around Time

Type of Traffic	Trucks	Buses (up to 60 pas)	Saloon Cars	Pedestrian
Turn Around Time	3 - 5 hours	1.30 - 2 hours	30 minutes	15 minutes

(1) Zambia Side

1) Staff

Zambian Government through the Zambia Revenue Authority has in the past three (3) years embarked on a refurbishment and expansion programme of the major border posts (Chirundu, Kariba, Livingstone, Victoria Falls and Kazungula).

In respect of Chirundu the programme involves a complete refurbishment of existing border post. The creation of a complete new freight terminal complex capable of handling up to 100 trucks either way per day along with temporary border post which is being used to handle all the traffic whilst the refurbishment programme is proceeding.

The refurbishment to the border post was completed by the middle of November, 1997 and works to the freight terminal has been temporarily suspended pending decision of the proposed new bridge and the associated proposed facilities under the JICA study. It was decided to use the refurbished border post for purposes of handling light passenger, buses and pedestrian traffic and to handle all truck and freight traffic through the temporary border post by December, 1997. Until such time as a formal freight terminal will be ready and available.

Additionally the Zambia Revenue Authority has immediate plans to introduce a computer programme called ASYCUDA along with the use of a single administrative document for clearing all freight. The improvement programme includes 40 new staff houses.

Table 7.2 Current Staff Establishment (6:00 to 18:00)

Customs

Location	Asst. Comm.	Snr. Collector	Collector	Exam. Officers	Customs Officers	Asst. Cos. Officers	Support Staff	Total
Combined All Staff	1	1	3	4	10	2	9	29

Immigration

Location	Pri. Officer	Snr. Officer	Officers	Asst. Officers	Assistants	Support Staff	Total
Combined All Staff	-	1	4	5	7	2	19

2) Traffic Demand

Statistics available to date reveal the following traffic going through the border post daily thus;

- buses (10 either way)
- trucks (100 coming into Zambia and 80 going out of Zambia)
- small vehicles (90 coming into Zambia and 70 going out of Zambia)
- altogether a combined average of 1,000 person enter Zambia and 900 leave Zambia daily through buses, trucks, passenger vehicles and pedestrian means.

3) Existing Parking Area (refurbished border post and temporary freight terminal)

The existing parking area is not adequate to cope with the current requirements which is for a 12 hours border opening time. It is estimated that the facilities are only 35 % adequate in respect of the present demand load for passenger vehicles and 15 % for trucks.

4) Existing Building (refurbished border post and temporary freight terminal)

The existing border post which will handle passenger and pedestrian traffic is only 60 % adequate. There is need to expand on the arrival and departure halls even at current demand load. The existing temporary freight terminal which will handle all freight is only 10 % adequate even at current demand load. There is serious shortfalls in storage capacity, inspection facilities, office accommodation and public amenities.

5) Customs and Immigration Systems

The current customs system for freight clearing involves the filling 16 forms which must be checked manually. The system is cumbersome and time consuming and often mistakes are made in completing the forms which leads to delays in processing the freight. There are moves to introduce a single administrative document which will be a regional system based on computer application. Immigration uses a single form which records the particulars of the traveller and is relatively simpler to administer. It is estimated that the adequacy of the current systems are 20 % for customs and 60 % for immigration.

6) Clearing Agents

There are enough clearing agents but they lack adequate facilities of offices, machines and equipment to do the job.

7) Trained Staff (Customs, immigration, Police and Others)

There are serious staff shortfalls in all departments and the current figures fall far below the current requirements to run the border even at the level of 12 hours border opening time. The main cause of staff shortages is the lack of housing.

(2) Zimbabwe Side

1) Staff

Current staff at Zimbabwe border post is as below;

Table 7.3 Current Staff Establishment (6:00 to 18:00)

Customs

Location	Snr. Collector	Collector	Examiners	Support Staff	Total
Combined All Staff	-	1	15	6xGuards 2xClerks 1xReceptiont 1xOrderly	26

Immigration

Location	Principal Officer	Snr. Officer	Officers	Assistant Officers	Assistants	Support Staff	Total
Combined All Staff	1	1	4	4	2	1	13

2) Traffic Demand

Same as the traffic demand indicated in previous section in Zambia.

3) Existing Parking Area and Border Post Building

The existing parking is not adequate to cope with the current requirements which is for a 12 hours border post opening time. Space is particularly critical for articulated lorries and freight trucks which sometimes have to park in a single file along the main road for up to 3 kilometers inland from border post. The border post are is often very congested.

The border post buildings comprise mainly of one block which houses the arrival and departure halls and ancillary offices and one covered shed used for inspection. There is a weight bridge some 2 kilometers inland from border post which belongs to the Ministry of Transport and Energy. It is estimated that the facilities are only 30 % adequate in respect of passenger and pedestrian demand and 10 % adequate in respect of freight demand load.

4) Custom and Immigration System

The Zimbabwean customs have implemented and are using the ASYCUDA computer system at Chirundu. It is believed that the system is now well understood and has contributed and improved the efficiency of handling and processing freight. Immigration uses a single form which records the particulars of a traveller and is relatively simpler to user and administer. It is estimated that the adequacy of the current systems are 50 % for customs and 60 % for immigration.

5) Trained Staff (Customs, Immigration, Police and Others)

All the various departments have confirmed that they are terribly understaffed and are operating with staff far below their requirements to run the border post even at the current level of 12 hours opening time. Although training and equipment plays some part by far the single most important impediment to adequate staffing at the border post is the non availability of appropriate housing and other related amenities.

7.1.2. Immigration and Customs Procedure

(1) Immigration

Immigration procedure entails that a person report to the immigration counter and present a passport. The immigration officer will check the following.

1) The validity of the passport

Depending on the country of origin if a visa is needed.
Depending on the length of stay if the necessary permits are issued and valid.
The passport information are then transferred into a ledger which is the official record.

These procedures can be expedited if the system is computerised with a central data base. The immigration officer will then read a bar code into the computer which immediately will give him the exact status of person. This will ensure far greater control and speed in handling passengers.

Further improvement will be to separate residents which make up the greater volumes of people crossing the border with foreigners, residents need only to be checked to have a valid passport and no recording procedure is necessary. This will expedite procedures considerably.

(2) Customs Clearance

1) Passenger

A improvement will be to separate residents which make up the greater volumes of people crossing the border with foreigners, residents will have to be checked more thoroughly because of the goods they buy across the border and have to pay duties on, while foreigners are mainly tourist and it is not always necessary to do inspections of goods.

2) Freight

The current system used by Zambia for clearance documents is the multi form system as well as the ASYCUDA one form system. They are in the process to switch over to only the one form system. The current system used by Zimbabwe for clearance documents is the ASYCUDA one form system.

The objective of all the SADC countries are to standardise to the ASYCUDA one form system. This in itself will contribute a great deal to expedite clearance of goods as only one set of documents is needed for goods in transit across several countries as well as address the confusion of transporters and clearing agents related to all the different documentation needed by the different countries. Currently the clearance times can vary from 2 hours up to several days. The reasons for these delays are as follow;

Lack of staff to handle the necessary traffic volumes
Staff to be increased in relation to traffic volumes that must be
Staff to be adequately trained to high level of efficiency.
Staff to be provided with the necessary equipment and facilities to do their work efficiently.

Another serious point of delay is where the necessary documents presented by the transporter or his clearing agent are completed incorrectly or are not adequate. This can cause delays for several days and are a major factor of congestion in the parking areas. This problem can be addressed by standardising to the one form system to simplify the system. Penalties in the way of fines can imposed on transporters and clearing agents for incorrect documentation. A average of 5 hours are a acceptable international standard for the clearing of freight including a full inspection of goods.

(3) Conclusion

Due to various levels of the lack of facilities, equipment, security and personnel these border post cannot function with the necessary control and speed of handling of passengers and goods that is required.

Housing and infrastructure services have to be addressed as a integral part of the border post facilities to ensure the working thereof.

Current passing time through Chirundu border post is less than that of international standard time due to the lack of facilities and staff. This phenomena is not a favourable condition but a disadvantageous one from view point of the country's economy. The insufficient function of the border post allow the flow of illegal goods and persons across the border, which give damage to the industrial development of domestic market.

The purpose of improving the Chirundu border post facilities as well as procedures are summarised as below.

- to check the freight goods based on the documents and by sight,
- to levy correct custom duties on imported goods, and therefore, to protect domestic industries from smuggled goods,
- to prevent trafficking of illegal drug,
- to shorten customs clearing time,
- to simplify and shorten the immigration/ customs procedures for passengers.

7.2. Border Facility Site and Landuse Analyses

7.2.1. Zambian Side

A established town area of medium to low density development to a master plan by the Local Authority which allows for future expansion (refer to Figure 7.1). The area west of the existing Border Post consists of government housing which is condemned and to be replaced with new housing on the east side of town. Other facilities on the west side are a police station; informal market; clearing agents; garage and a shop. The area east of the existing Border Post consists of a much larger build up town area and all future expansion is planned in this area. In close proximity of the Border Post there are a garage; bar/restaurant; informal traders and temporary facilities for clearing agents. The area further away consists mainly of medium density housing and other facilities like a motel and hospital.

Meetings with the Siavonga Town Council made it clear that the area west of the road and existing Border Post is the softer option for development and that land can be made available for the development of new facilities at a much lower cost for expropriation and social interference within the existing town planning structure and fabric. Any options to construct the new bridge and Border Post facilities downstream will have a major impact on the east side of the town and is not to be recommended.

7.2.2. Zimbabwean Side

The Chinhoyi Regional Department of Physical Planning has confirmed that the township's layout is a final approved one (refer to Figure 7.2). This area consists of two groups of housing on the top of the higher ground to the west of the existing border post. These houses are mainly government housing with a few private houses in the furthest area. To the south there are tourism development on the river bank that consists of a fishing club with all their facilities where national tournaments are held at a regular basis; a fishing and safari lodge adjacent to that. Further back south along the main road there are a Vehicle Inspection Depot of the Dept. of Transport, a motel and garage.

The border post and other facilities mentioned above fall within a greater nature conservation area and are therefor very sensitive to development. The area of land starting at the existing border post and south along the main road up to the motel and garage are the suitable for the border post development and will have the least impact on the area. To the west the topography is of such that a development there will mean major excavations which is costly and very damaging to the natural environment. To the east any development will interfere with tourism potential of the area as well as the sensitive nature conservation area.

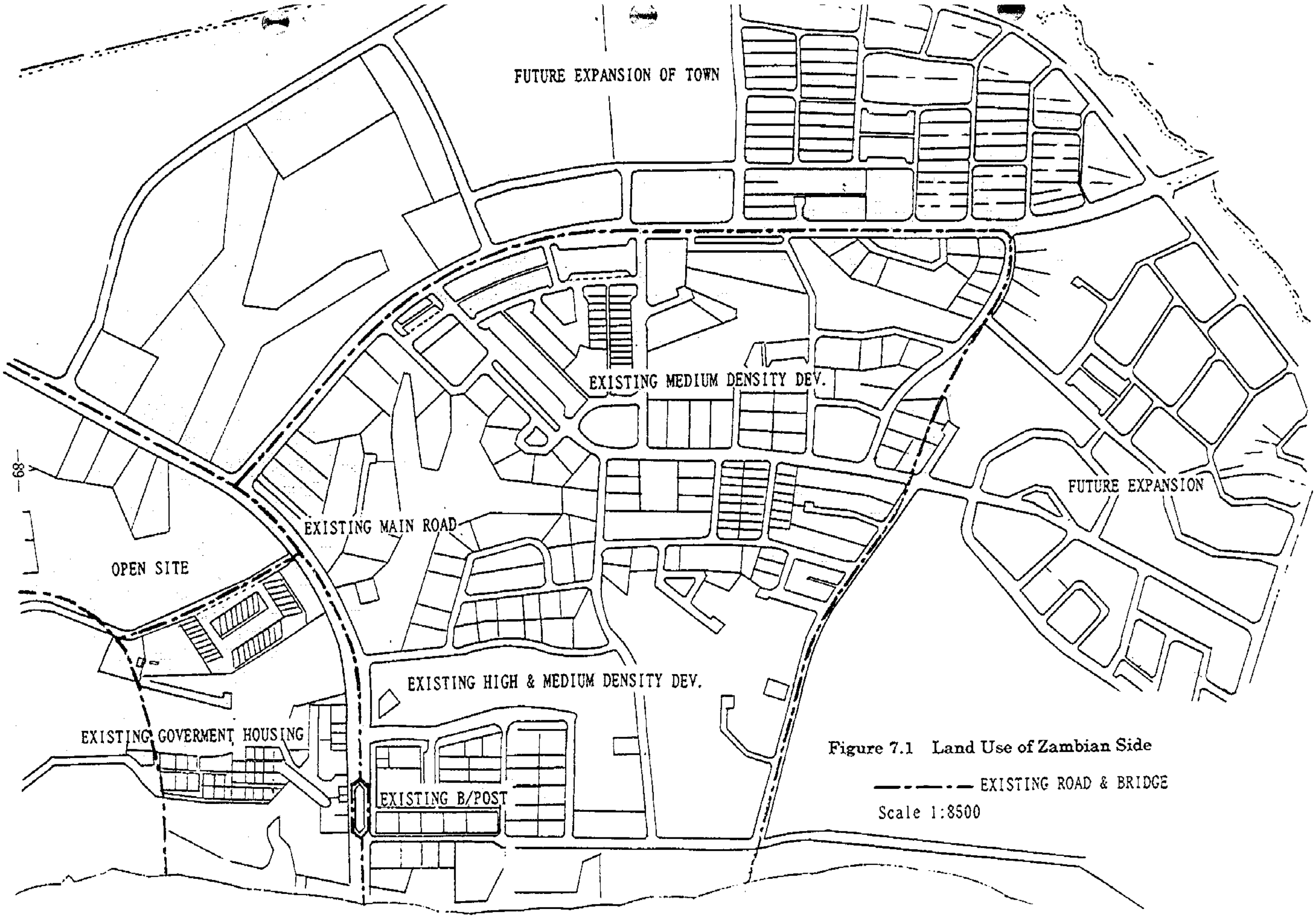


Figure 7.1 Land Use of Zambian Side

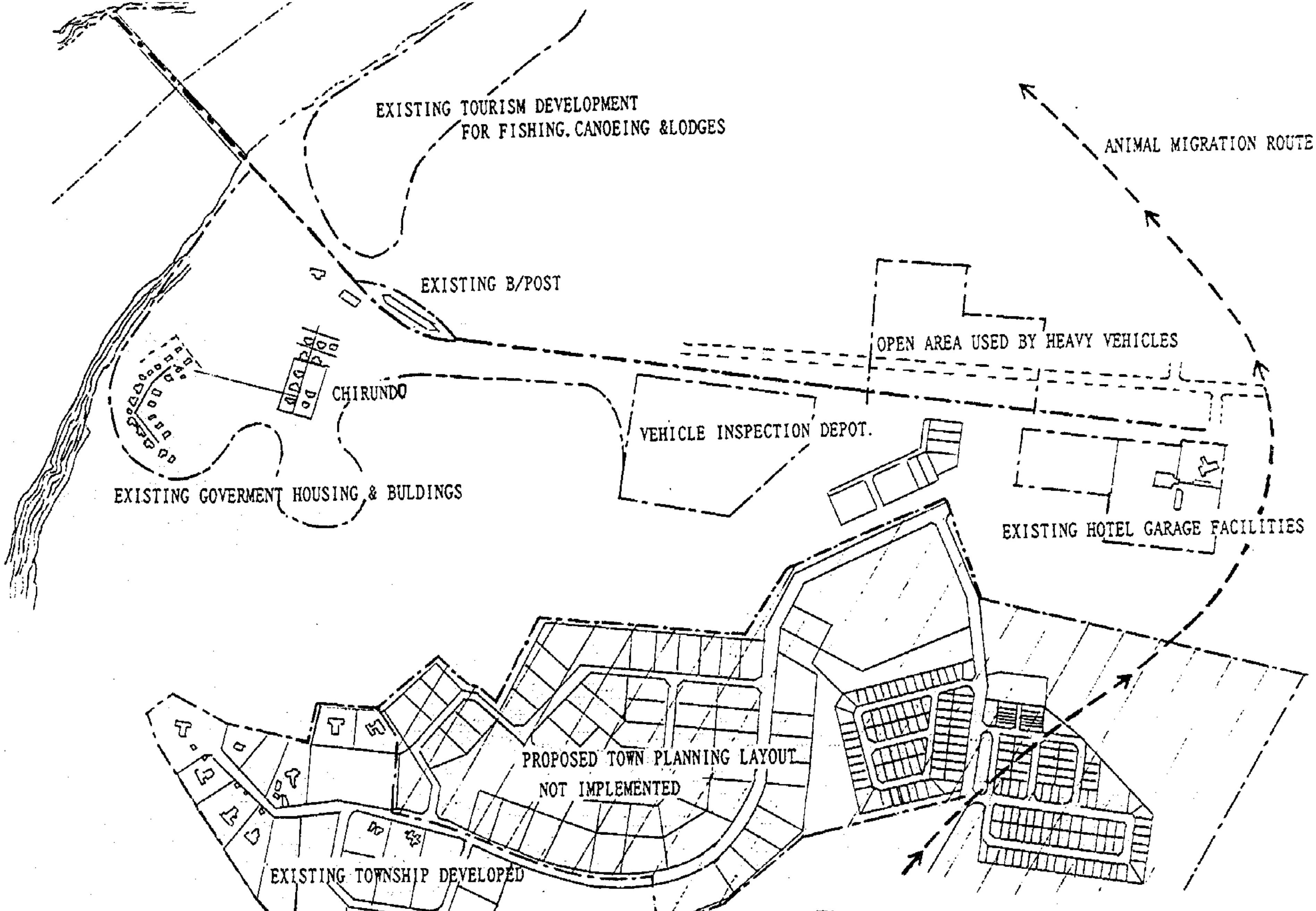


Figure 7.2 Land Use, Zimbabwe side

—·—·— EXISTING ROAD & BRIDGE

7.3. PRINCIPAL SCENARIO FOR IMPROVEMENT OF THE FACILITIES

7.3.1. TYPE OF NEW BORDER POST FACILITIES

There are considered three types of border facility layout depend on their functions and locations.

(1) One Stop Border Facility

With research background and meetings with all the stake holders and various User Departments, it is clear that a combined one stop border facility will be the most efficient and effective. The one stop facility will be constructed either in Zambia or Zimbabwe. The Zimbabwean side is more sensitive to a development of this scale because it falls within a nature conservation area.

(2) Separate Function One Stop Border Facility

Combined separate one stop facilities that function either as the freight handling or the light vehicle and passenger traffic handling can be accommodated at either side of the border. This alternative has an advantage to be smaller size of the area for border post facility than one stop alternative.

(3) Separate Border Post

Separate full functioned facilities are to be constructed for each country on each side of the border. This alternative is the same as present border post ones and the user should accept lesser efficiency than alternatives before described.

(4) Selection of the Type

The comments from the relevant Authorities of both Governments on type of border facility suggested that the combined and function combined types are very difficult to realise due to the political difficulties. It seems that there need a long time to settle this issue and very difficult to obtain a complete conclusion within the Study period. Therefore, in this Study separate type of border post facility is considered.

7.3.2. BASIC ASSUMPTION FOR IMPROVEMENT PLANNING

(1) Traffic Flow

Existing traffic flow shows the figures an average as below;
heavy vehicles 70 per day,
passenger vehicles 28 per day, and
busses 10 per day, moving through the border post in one direction.
Future traffic flow forecasted shows the figures an average as below;
heavy vehicles 174 per day,
passenger vehicles 68 per day, and
buses 15 per day, moving through the border post in one direction.

(2) Accommodation and Personnel

The following analysis and proposed requirements are made on the basis that separate facilities shall be provided for each government. Thus each government will have similar accommodation to handle the same amount of traffic and the passenger handling facilities on the Zambian side currently being refurbished is in use and the temporary facilities will be used for heavy vehicles.

1) Existing Facilities (Zimbabwe and Zambia)

Heavy vehicles

The facilities in both countries for the handling of heavy vehicles are totally inadequate because of lack of facilities to do any inspections. This is essential if any proper control of goods and the relevant duties to be levied be exercised. New heavy vehicle / cargo clearance and handling facilities, properly equipped to efficiently inspect and clear goods for import or export, must be erected. This is essential as it provides a major contribution to the revenue of two countries.

Passenger vehicles and busses.

The existing facilities are inadequate because of lack of office and public space. There is not enough parking space to avoid congestion and covered areas are needed for waiting passengers and inspections.

If the above issues can be addressed at the existing facilities it is possible to re-use these facilities with upgrading and extensions. This will have a cost saving benefit.

Personnel / staff establishment

The current staff establishment at the border post is inadequate to handle existing traffic flow due to the lack of housing and office space at the border post. This has the effect of congestion at peak hours as well as the lack of control and inspection of goods of both passengers and heavy vehicles.

(3) Improvement Process

The improvement of the border post facilities and staff requirement shall be made depending on the demand increase. However, some amount of investment shall be prepared immediately for improving the existing capacity of the facilities as well as improving the amenity conditions of the staffs of border post.

Following steps of investment are tentatively assumed for the improvement of the border facilities, taking into consideration tight financial situation of both countries.

initial investment during 3 years of construction : 40 % of total investment
complementary investment until 2010: 60 % of total investment

7.4. IMPROVEMENT PLAN

7.4.1. FUTURE ACCOMMODATION REQUIREMENTS

The following accommodation requirements were established by using the estimated future traffic forecast and coordinating with the various user departments of both countries of what their needs would be to operate a functional and efficient operation with the necessary control required.

(1) Customs

1) Zambia side

(Unit: m²)

No.	ELEMENT	Year 2002	Year 2006	Year 2010	Total
1	FREIGHT TERMINAL				
	Freight Terminal Bldg.	2,135	915		3,050
	Docking Bay	3,045	1,305	3,150	7,500
	Roads and Parking Area	24,540	19,945	13,260	57,745
2	PASSENGAER CONTROL BUILDING				
	Main Building		1,150		1,150
	Vehicle Theft Unit		305		305
	Car Inspection Unit		84		84
	Extension to Main Bldg.			200	200
	Roads and Parking Area		11,780	437	12,217
3	PEDESTRIAN CONTROL BUILDING				
	Refurbish Existing Bldg.		400		400
	External Works		625		625
4	DRUG ENFORCEMENT COMMISSION				
	Building	178			178
	Car Park and Others	750			750
5	VEHICLE INSPECTION UNIT AND WEIGH BRIDE				
	Building	84			84
6	KIOSK AND FAST FOOD OUTLET				
	Building		375		375
	External Works				
7	PERIMETER FENCING AND GUARDHOUSES				
	Perimeter Fencing	1,680			1,680
	Guard Houses	105			105
	Total	32,517	36,884	17,047	86,448

2) Zimbabwe side

(Unit: m^2)

No.	ELEMENT	Year 2002	Year 2006	Year 2010	Total
1	FREIGHT TERMINAL				
	Freight Terminal Bldg.	2,135	915		3,050
	Docking Bays	3,045	2,305	2,150	7,500
	Roads and Parking Area	20,200	18,433	17,360	55,993
2	PASSENGER CONTROL BUILDING				
	Main Building		310		310
	Alteration to Existing		770		770
	Vehicle Theft Unit		108		108
	Car Inspection Unit		360		360
	Extensions to Main Bldg.			200	200
	Roads and Parking Area		13,078	1,398	14,476
3	PEDESTRIAN CONTROL BUILDING				
	New Building		240		240
	External Work				
4	DRUG ENFORCEMENT COMMISSION				
	Building	209			209
	Car Park	560			560
5	POLICE STATION				
	Building	820			820
	External Works				
6	VEHICLE INSPECTION UNIT AND WEIGH BRIDGE				
	Building	116			116
7	KIOSK AND FOOD OUTLET				
	Building		375		375
8	PERIMETER FENCING AND GURD HOUSES				
	Perimeter fencing	2,061			2,061
	Guard Hoses	120			120
	Total	29,266	36,894	21,108	87,268

7.4.2. Personnel and Housing Requirements

Based on the optimum staff for a 8 hour shift, on the basis that the border post will be open for 12 to 14 hours and that housing for personnel have to be provided to accommodate two (2) shifts.

For final calculation of the housing figures one has to establish the amount of existing government housing available and take into account that some of the personnel will be local people that are already accommodated in their own housing (more relevant on the Zambian side).

(1) Customs

1) Zambia Side - Optimum Staff Requirement for 8 Hours Shift

LOCATION	ASST. COMM	SNR COLLE CTOR	COLLEC TOR	EXAM. OFFICERS	CUSTOMS OFFICERS	ASST OFFICE R	SUPPORT STAFF	TOTALS
Freight	1	1	1	4	6	4	7	24
Passenger	-	1	1	2	2	2	5	13
Pedestrian	-		1	2	2	2	5	12
TOTALS	1	2	3	8	10	8	17	49

2) Zimbabwe side - Optimum Staff Requirement for 8 hours Shift

LOCATION	SNR COLLECTOR	COLLECTOR	EXAMINING OFFICERS	SUPPORT STAFF	TOTALS
Passenger	Shared with Freight	1	3	3	7
Pedestrian	Shared with Freight	Shared with Passenger	5	2	7
Freight	1	1	10	5	17
TOTALS	1	2	18	10	31

(2) Immigration

1) Zambia Side - Optimum Staff Requirement for 8 Hours Shift

LOCATION	PRINCIPLE OFFICER	SNR IMM. OFFICER	OFFICE RS	ASST. IMM. OFFICERS	IMM. ASSISTANTS	SUPPORT STAFF	TOTALS
Freight	-	-	1	1	1	1	4
Passenger	1	1	2	2	2	1	9
Pedestrian	-	1	1	1	1	1	5
TOTALS	1	2	4	4	4	3	18

2) Zimbabwe Side - Optimum Staff Requirement for 8 Hours Shift

LOCATION	PRINCIPLE IMM. OFFICER	SNR IMM. OFFICER	IMM. OFFICERS	IMM. ASSIST.	SUPPORT STAFF	TOTALS
Passenger	1	1	10	1	1	14
Pedestrian	shared with passenger	1	4	1	1	7
Freight	Shared with passenger	1	2	1	1	5
TOTALS	1	3	16	3	3	26

(3) Staff Housing

1) Zambia side

HOUSING

Customs

	1x 160m² House	160 m²			160 m²
	6x 140m² House	840 m²			840 m²
	9x 120m² House	1,080 m²			1,080 m²
	24x 110m² House	2,640 m²			2,640 m²
	30x 100m² House	3,000 m²			3,000 m²
	24x 75m² House	1,800 m²			1,800 m²
	34x 65m² House	2,210 m²			2,210 m²
	2x 140m² House			280 m²	280 m²
	3x 120m² House			360 m²	360 m²
	8x 110m² House			880 m²	880 m²
	10x 100m² House			1,000 m²	1,000 m²
	8x 75m² House			600 m²	600 m²
	17x 65m² House			1,105 m²	1,105 m²
					15,955 m²

Immigration

	1x 140m² House	140 m²			140 m²
	6x 120m² House	720 m²			720 m²
	12x 100m² House	1,200 m²			1,200 m²
	12x 75m² House	900 m²			900 m²
	12x 65m² House	780 m²			780 m²
	6x 50m² House	300 m²			300 m²
	2x 120m² House			240 m²	240 m²
	4x 100m² House			400 m²	400 m²
	4x 75m² House			300 m²	300 m²
	4x 65m² House			260 m²	260 m²
	3x 50m² House			150 m²	150 m²
					5,390 m²

Drug Enforcement Commission, Veterinary and agriculture

	3x 120m² House	360 m²			360 m²
	18x 100m² House	1,800 m²			1,800 m²
	9x 75m² House	675 m²			675 m²
	3x 50m² House	150 m²			150 m²
	6x 100m² House			600 m²	600 m²
	3x 75m² House			225 m²	225 m²
	3x 50m² House			150 m²	150 m²
					3,960 m²
	Total for housing	18,755 m²	0 m²	6,550 m²	25,305 m²

2) Zimbabwe side

HOUSING

Customs

1x 160m² House	160 m²			160 m²
6x 140m² House	840 m²			840 m²
9x 120m² House	1,080 m²			1,080 m²
24x 110m² House	2,640 m²			2,640 m²
30x 100m² House	3,000 m²			3,000 m²
24x 75m² House	1,800 m²			1,800 m²
34x 65m² House	2,210 m²			2,210 m²
2x 140m² House			280 m²	280 m²
3x 120m² House			360 m²	360 m²
8x 110m² House			880 m²	880 m²
10x 100m² House			1,000 m²	1,000 m²
8x 75m² House			600 m²	600 m²
17x 65m² House			1,105 m²	1,105 m²
				15,955 m²

Immigration

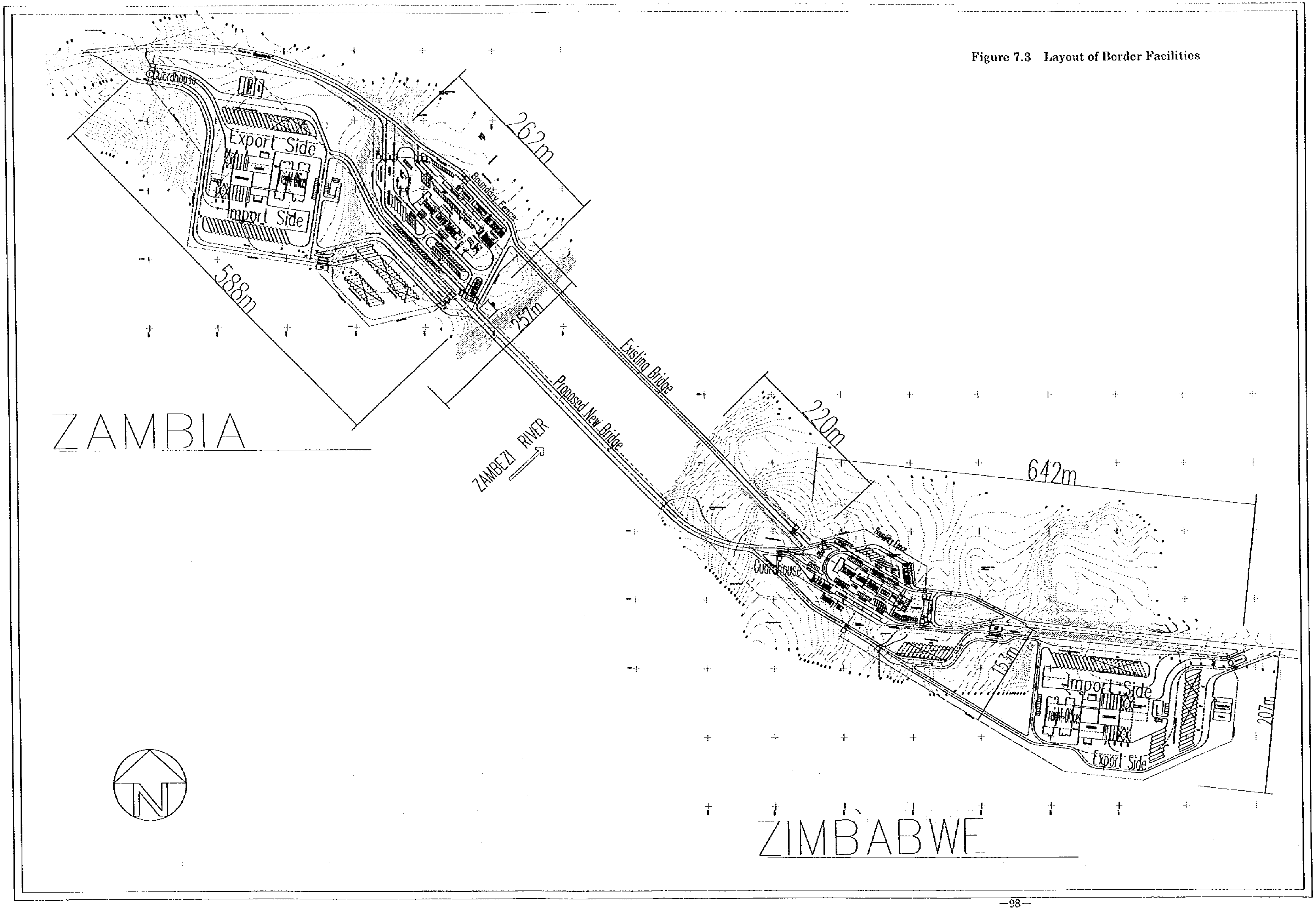
1x 140m² House	140 m²			140 m²
6x 120m² House	720 m²			720 m²
12x 100m² House	1,200 m²			1,200 m²
12x 75m² House	900 m²			900 m²
12x 65m² House	780 m²			780 m²
6x 50m² House	300 m²			300 m²
2x 120m² House			240 m²	240 m²
4x 100m² House			400 m²	400 m²
4x 75m² House			300 m²	300 m²
4x 65m² House			260 m²	260 m²
3x 50m² House			150 m²	150 m²
				5,390 m²

Drug Enforcement Commission, Veterinary and agriculture

3x 120m² House	360 m²			360 m²
18x 100m² House	1,800 m²			1,800 m²
9x 75m² House	675 m²			675 m²
3x 50m² House	150 m²			150 m²
6x 100m² House			600 m²	600 m²
3x 75m² House			225 m²	225 m²
3x 50m² House			150 m²	150 m²
				3,960 m²
Total for housing	18,755 m²	0 m²	6,550 m²	25,305 m²

Draft layouts of t he border post facilities is shown in Figure 7.3

Figure 7.3 Layout of Border Facilities



8 ENVIRONMENTAL IMPACT ASSESSMENT

8 ENVIRONMENTAL IMPACT ASSESSMENT

8.1. METHODOLOGY

8.1.1. INTRODUCTION

In considering the effects of the proposed bridge alignment and border facility options, it is necessary to recognise the potential environmental impacts, both positive and negative, on the surrounding area during construction, operation and maintenance.

This section identifies these potential impacts and associated effects. The following approaches have been adopted as a basis for the assessment.

Identification of Potential Impacts and Effects – For each environmental impact (eg water pollution) there may be a range of environmental effects which need to be considered. For example, land take impacts will result in effects on visual quality, ecology and access.

Identification of Potential Receivers – For many environmental parameters the overall impact will depend on the spatial relationship between the source and receivers. Impacts will also depend on the characteristics of the receivers, as some will be more sensitive to an environmental component than others. As far as possible all potential receivers have been identified for each environmental impact.

Method of Evaluation of Impacts – The assessment of the significance of any impact will be a function of its interaction with potentially sensitive receivers. For example the effect of a noise impact will only be significant if there are receivers which could suffer as a consequence of the noise impact.

Influence on Design and Mitigation – Environmental considerations, identified during the ongoing assessment, should be incorporated in the scheme design from an early stage in its development. The adoption of this iterative approach to design, assessment and mitigation proposals should ensure that the final scheme takes account of all environmental concerns.

8.1.2. IDENTIFICATION OF IMPACTS, RECEIVERS AND ASSESSMENT CRITERIA

The identification of the impacts, receivers and assessment criteria is being carried out through extensive consultation with relevant government departments, local government, planning departments, NGOs, health clinics and schools.

The final assessment report conforms with the standards of the Zambia Environmental Protection and Pollution (Environmental Impact Assessment) Regulations 1997, the Zimbabwe Procedures and Guidelines for Conducting Environmental Impact Assessment of Road Construction Projects (December 1994) and the Zimbabwe Environmental Impact Assessment Guidelines (September 1997).

(1) Visual Amenity and Landscape Character

Impacts on visual amenity and landscape character can arise from:

Views to and from areas of scenic importance, such as the existing Otto Beit Bridge.

Designs, finishes and materials, and their compatibility with surrounding features.

The first stage of the landscape impact evaluation comprised the determination of the baseline landscape character: topography, vegetation, areas of landscape value, historic features, level of open views and material finishes. This was followed by a determination of the overall visibility of the proposed bridge options and the impacts each would have in terms of compatibility with the existing bridge and surrounding landscape features.

(2) Ecology

The proposed bridge options and border facilities could give rise to the following impacts on wildlife and habitats:

Severance of game corridors
Loss of Mopane bush habitat
Disturbance due to noise, construction plant movements and human presence during construction
Pollution incidents during construction

The significance of ecological impacts was determined through evaluation of the importance of the area, its habitats and their associated flora and fauna. Data were derived from consultation, review of literature and site surveys.

(3) Planning and Policies

The impacts on planning and policies can arise from:

Land used in specific planning zones
Promotion of economic/social policies

Current and proposed land use and policies can have implications for the construction of the proposed bridge and border facilities, on both sides of the River Zambezi. It is therefore necessary to examine current and proposed uses of the land and the appropriate policies, aim, strategies and opportunities to identify any areas of potential conflict or confluence with existing plans and policies. The planning context was determined through examination of the documents identified in section 8.2.

(4) Socio-economy

Impacts on the socio-economy can arise during construction and operation of the bridge from the following:

Demand for skilled or unskilled labour from the local workforce.
Influx of labour to the area providing opportunities for entrepreneurs.
Increased demand for prostitutes caused by influx of migrant workers during construction period.
Increased pressure on local medical and school facilities.

The significance of socio-economic impacts was determined through evaluation of the existing socio-economic conditions, job opportunities, facilities etc. Data was collected through extensive consultation and visits to the site.

(5) Traffic and Transport

Impacts associated with traffic and transport will arise from:

Construction traffic movements -- resulting in air pollution, noise and dust, disruption to road users, risk to safety.
Increased traffic after bridge completion
Land take during construction

Potential receivers for impacts associated with traffic and transport are truck drivers and other road users, the communities living in Chirundu on both sides of the river, local ecology and water resources. The assessment of these impacts was based on a consideration of the baseline traffic levels on the roads subject to land take or construction traffic, duration of the impact and the nature of the area in which the project is located.

(6) Amenity and Tourism

Impacts on amenity can arise from:

Land take
Visual intrusion
Severance
Air pollution, noise and dust

Effects arising from visual intrusion, noise and air emissions are discussed in Sections (1) and (9).

The assessment of land take and severance is based on existing land uses and population movement patterns.

(7) Archaeology and Cultural Heritage

For the purposes of this study, Archaeological and Cultural Heritage resources are defined as:

Known and unknown archaeological remains
Upstanding structures of historic significance.

Impacts on these resources can result from:

Disturbance of land, and consequently on archaeological remains, during construction of the proposed works
Covering of known and unknown buried resources
Impacts on the setting of historic features through disturbance of scale, material finishes or relationship with the surrounding environment.

The assessment is based on consultation with relevant bodies and site visits. Archaeologists from both Zambia and Zimbabwe were commissioned to carry out this work as an additional part of the EIA, in order to comply with the legal requirements for both countries.

(8) Hydrology and Water Quality

Potential impacts on water quality could comprise:

Accidental pollution during construction, eg through spillage of diesel or concrete; and
Discharge of water to the River Zambezi.

The assessment is based on consultation with relevant bodies and water sampling from the River Zambezi.

(9) Air Quality, Noise and Dust

These impacts will be mainly confined to the construction phase, although as the numbers of vehicles using the bridge increases, air quality, noise and dust will become more of an issue. The source of impacts will include:

Operation of construction plant

Movement of construction vehicles on site and access roads

Creation of dust through excavation, blasting and vehicle movements.

Potential receivers for air quality impacts are those people living and working close to the site, as well as animals and birds.

8.2. Policy, Legal and Administrative Framework

8.2.1. Introduction

The following section provides an overview of the relevant legislation and policy in Zambia and Zimbabwe.

8.2.2. Legislative Framework and overview – Zambia

(1) Government Organisation

The Constitution of Zambia Act came into force in August, 1991 and was the instrument for the re-introduction of the multiparty system of government under which elections were held in October 1991.

(2) National Legislation

The National Environment Council of Zambia (ECZ), which was established under the Pollution Control Act in 1992, controls environmental management. The ECZ is made up of a Council Board and the Secretariat (executive wing) called the Inspectorate. The Council Board is made up of 28 individuals representing stakeholders from different line ministries, the parastatal sector and the private sector. The Board reports to the Minister of Environment and Natural Resources through the Chairman. The Natural Resources Advisory Board which is no longer in existence has had some of its functions replaced by the Agricultural Lands Committee which became functional in 1993. Parts IV to VIII of the Act set out the role of the ECZ in setting discharge permits/licences for water, and the prohibition of water pollution; setting ambient air quality and emission standards and guidelines; the disposal of waste; and noise emissions standards for construction sites, plants etc. The ECZ has powers to prosecute and jail senior managers and directors who are found to be violating the regulations. The Environmental Protection and Pollution Control Act therefore provides for the protection of the environment through provisions on natural resource management as well as for pollution control under the powers of the Environment Council.

Other Acts and legislation which have an impact on the environment and environmental management are as follows. Many of these are fragmented, sector biased and sometimes contradictory:

The Town Planning Act, CAP 475, which came into force in 1962, provides for the appointment of planning authorities, for the establishment of a Town and Country

Planning Tribunal, for the preparation, approval and revocation of development plans, for the control of development and subdivision of land and for the preparation of payment and assessment of compensation in respect of planning decisions.

The National Parks and Wildlife Act, 1991, which provides for the establishment, control and management of National Parks, conservation and protection of wildlife and objects of interest in national parks, the establishment of Game management Areas; the licensing of hunting; control of possession of trophies; and the control of bush fires.

The Public Health Act, 1930 (CAP 535) Enactment, which has the objectives of preventing and suppressing diseases, and generally to regulate all matters connected with public health in Zambia.

The Natural Resources Conservation Act, Chapter 315, 1970, which amongst other things established the Natural Resources Advisory Borad to exercise general supervision over natural resources and the means of their conservation, use and improvement; and to stimulate public interest in the proper conservation, wise use and improvement of natural resources.

The Fisheries Act (CAP 314) which provides for the development of commercial fishing, the control of fishing and the registration of fishermen and their boats. The Act, however, only regulates commercial fisheries, although non-commercial fishing areas clearly affect fisheries management.

The Zambezi River Authority was enacted in 1987, and repealed the Central African Power Act of 1963. The objective of the Act is to give effect to certain provisions of the interstate agreement relating to the utilisation of the Zambezi River, concluded between the governments of the Republic of Zambia and Zimbabwe. The Act established the Zambezi River Authority (ZRA) to operate, monitor and maintain the Kariba complex, to consult with the Zimbabwe Electricity Supply and ZESCO to investigate the desirability of constructing new dams on the Zambezi River and make recommendations to the Council of Ministers; and also to collect, accumulate and process hydrological and environmental data on the Zambezi River.

The Mines and Minerals Act 32, of 1976 regulates the law relating to mines and minerals. The Act is silent on water, noise and air pollution arising from underground and surface mining, and does not address the dumping of waste sufficiently.

Zambia also has a National Environmental Action Plan (NEAP) which identifies environmental issues, analyses the causes and recommends actions to resolve them. The NEAP aims to integrate environmental and socio-economic issues. The NEAP is implemented through the Environmental Support Programme (ESP), and the Ministry of Environment and Natural Resources is responsible for co-ordination and monitoring of its implementation. The main aim of the NEAP is to identify environmental problems and issues, analyse their causes and recommend actions required to resolve issues.

The NEAP process has identified five major issues which are causing large social costs to Zambia:

water pollution and inadequate sanitation;
soil degradation;
air pollution in the Copperbelt towns;
wildlife depletion (fish and game); and

deforestation.

(3) Requirements for EIA

The Environmental Protection and Pollution Control (Environmental Impact Assessment) Regulations, 1997 set out the requirements for EIA in Zambia. Developers shall not implement projects for which an environmental impact statement is required unless the ECZ has issued a decision regarding the project. The contents of an Environmental Impact Statement (EIS) shall include:

- A description of the project
- A description of the site
- A description of the raw material inputs, technology, processes, and products and by-products
- A description of the site and surrounding environment
- A description of the environmental effects
- A description of the socio-economic impacts
- Impact Management Plan
- An indication of whether the environment of any neighbouring state is likely to be affected.

(4) Local Government

Local Government in Zambia is divided into a number of tiers. The Department of Town and Country Planning is based in Lusaka. Beneath this is Provincial Planning, controlled by the Provincial Planning Authority/Physical Planning. At the district level is the District Planning Office. For Chirundu, the District Planning office is located at Siavonga, and the Provincial Planning Authority is based at Choma.

(5) Local Planning Policy

The first planning proposals for Chirundu are traced back to 1954, when plans were prepared showing a police station, houses, rest huts, trading sites, garage and service station and a motel amongst others. The development of Chirundu was almost brought to a halt when the Federation of Rhodesia and Nyasaland was created. The dismantling of the border post was proposed since the Southern Rhodesia Government was prepared to finance the development of a post on the other side of the river. When the Federation of Rhodesia and Nyasaland was dissolved in 1963 development at Chirundu began again and plans for houses and other uses were made. However, since this period planning and allocation of plots has been on an ad hoc basis.

The Chirundu Layout Plan was prepared by the research unit of the Department of Town and Country Planning, Lusaka, in 1991. The objectives of the layout plan are as follows:

- To provide a guide for development in the township;
- To provide enough land for development for some foreseeable future;
- The promotion of the township as a growth centre with regard to its position as a border town and the second biggest settlement in the district with social facilities capable of serving the township and the surrounding areas;
- Promotion of industries and creation of job opportunities in the township;
- To stimulate agricultural activities in the surrounding areas by promotion of interdependence of agricultural produce and the social services provided by the township.

The plan has been divided into three phases, and a detailed proposal plan showing demarcated land uses has been prepared (Figure 8.1). Phase one of the layout plan comprises existing developments and pockets of undeveloped land, the main business area, all the land enclosed by the powerline, the main road to Kafue and Chiawa roads and a proposed fee paying car park, covering a total area of 126 ha. The second phase consists of the neighbourhood adjacent to the two schools, hospitals, cemetery, industrial areas along Kafue road and residential and institutional areas, covering a total area of 73.5 ha. The third phase consists of the development of the neighbourhood adjacent to Mutendele Mission and below the powerline. The land for the mission could also be planned upon request from the mission authorities, but the Town Planning Act does not cover areas owned by missions.

8.2.3. LEGISLATIVE FRAMEWORK AND OVERVIEW – ZIMBABWE

(1) Government Organisation

The Legislature of Zimbabwe consists of the President and a Unicameral or "Single Chamber" parliament. The President is the Head of State, Head of Government and Commander-in-Chief of the Defence forces. He is elected by voters registered on the common roll and holds office for a period of six years, after which he may by elected for further periods of office.

Parliament consists of 150 members, 120 of whom are elected by voters registered on the common roll for 120 common roll constituencies, eight are Provincial Governors who are ex-officio members of parliament, 10 are traditional chiefs and 12 are appointed by the President.

(2) National Legislation

In order to ensure that environmental management programmes are built into overall development initiatives, the Government of Zimbabwe has established the Ministry of Environment and tourism, which is responsible for most of the environmental regulation in the country. This responsibility encompasses the principal aspects of the natural environment through the following acts of Parliament:

The Natural Resources Act, Chapter 150, which outlines national strategies for conserving and improving natural resources.

The Communal Land Act, which classifies and defines communal lands.

The Communal Land Forest Produce Act, No 20, of 1987, which regulates the use of forest produce in protected areas. This Act, however, is subject to differing interpretations, and is contradictory in parts. For example, the Communal land Forest Produce Act restricts the use of forest produce in communal areas. It lists 60 protected trees, including may of the more important fruit trees, for which any form of exploitation is prohibited without a special licence or permit. At the same time, the Act allows any inhabitant to "exploit any forest produce, including reserved trees, on any land which he is permitted to occupy, in the course of clearing such land for residential purposes or for the purpose of planting crops". The law also enables the council to harvest forest produce in communal areas provided due regard is paid to the interests of the present and future inhabitants of the area.

Rural District Councils Act of 1982, which establishes Rural District Councils in communal lands (merging Rural councils and District Councils).

The Water Act, No 41 of 1976, which creates a system for controlling the use of both surface and underground water.

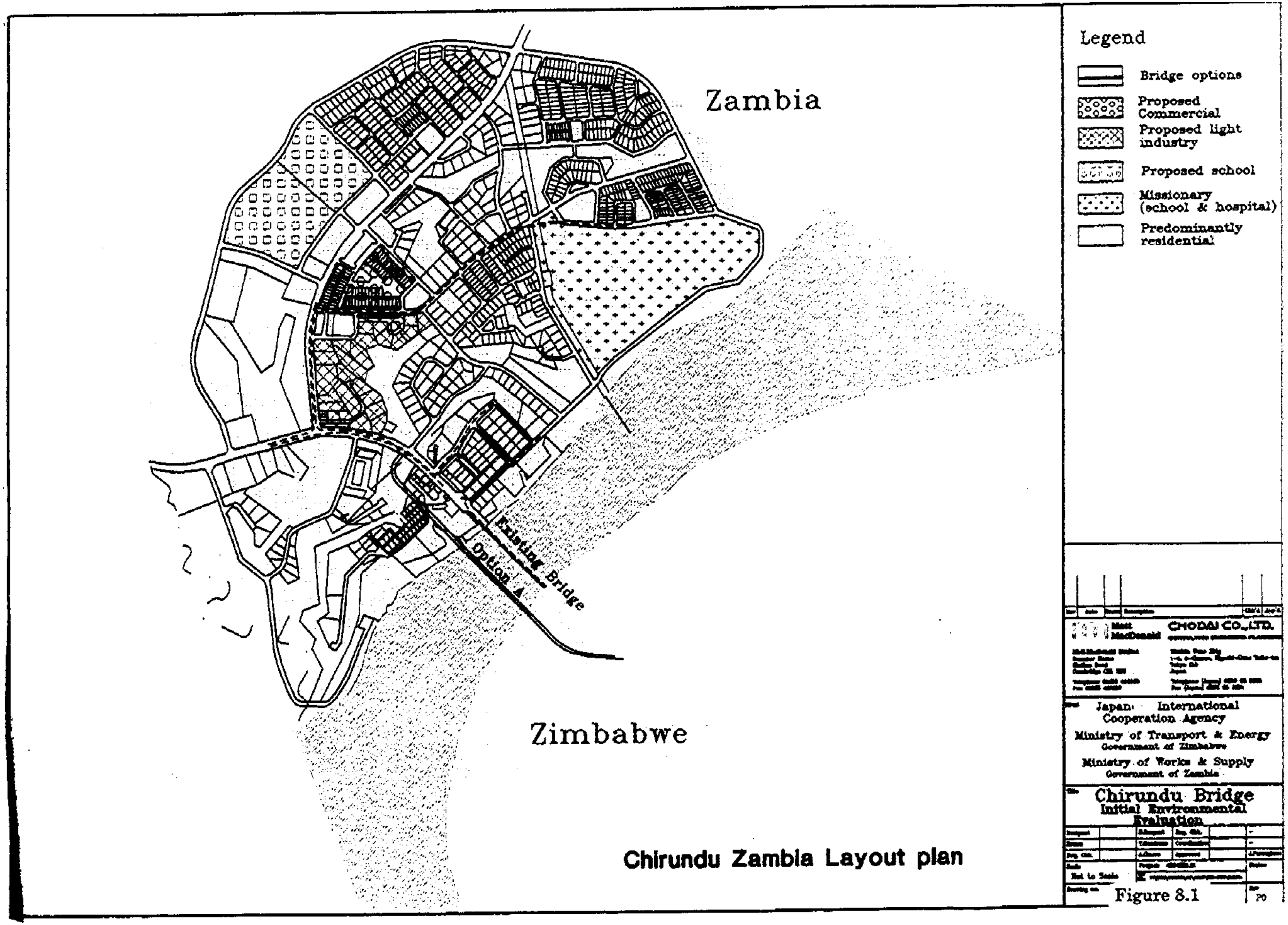

Legend
Bridge options
Proposed Commercial
Proposed light industry
Proposed school
Missionary (school & hospital)
Predominantly residential
Zambia
Zimbabwe
Existing Bridge
Option A
Chirundu Zambia Layout plan
Mott MacDonald
CHODAI CO.,LTD.
Japan International Cooperation Agency
Ministry of Transport & Energy
Government of Zimbabwe
Ministry of Works & Supply
Government of Zambia
Chirundu Bridge
Initial Environmental Evaluation
Not to Scale
P0

Figure 8.1

The Forestry Act, which establishes the Forestry Commission and governs the conservation of timber.

The Parks and Wildlife Act (1975), (and 1982 Amendment) which established a Parks and Wildlife Board, mandated to provide for the protection, utilisation and conservation of fish and wildlife; the preservation and propagation of plant life; and the preservation of the natural landscape. The Act also called for the designation of national parks, sanctuaries and safari areas, as well as the national protection of certain animal and plant species. Landholders have rights to use wildlife to their own advantage with minimal interference from government. The Act established some landholders as the "appropriate authority" for wildlife as follows:

The owner or occupiers, on alienated land;

The Forestry Commission, on forest land;

The Department of National Parks and Wild Life Management (DNPWLM) on all other land.

The effect of this legislation was to transfer the proprietorship of wildlife to private landowners and occupiers so that they could use the animals and retain the benefits.

The Mines and Minerals Act, Chapter 165. The Mines and Mineral Act, which is administered by the Ministry of Mines, is an example of legislation which is counteractive in environmental management. It supersedes any other legislation when it comes to mining and mineral prospecting.

The Regional, Town and Country Planning Act, administered by the Ministry of Local Government, Rural and Urban Development.

National Museums and Monuments Act Chapter 313, 1972, which states that:

"an Ancient Monument means any a) building, ruin, or structure or remaining portion of a building, ruin or structure; or b) statue, grave, cave, rock shelter, midden, shell mound or other site or thing of a similar kind; which is known or believed to have been erected, constructed or used in Zimbabwe before 1 January 1890, but does not include an ancient working:

Ancient Working means any shaft, cutting, tunnel or slope which was made for mining purposes before 1 January 1890."

Section 22 states "The discovery of any ancient monument or relic .... Shall be notified in writing to the board without delay"

Section 25 states "No person shall a) without the written consent of the Director, excavate any ancient monument or national monument; or b) contravene or fail to comply with any condition fixed by the Director in giving consent in terms of paragraph c) or any condition prescribed in relation to the excavation of ancient monuments or national monuments."

Section 26 states "No person shall a) without written consent of the Director i) make any alteration to, destroy or damage; or ii) remove from its original site or export from Zimbabwe; any national monument, ancient monument or relic or any part thereof; b) contravene of fail to comply with any conditions fixed by the director in giving consent in terms of paragraph a)."

The Department of National Parks and Wild Life Management has introduced the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE), which gives communal people custody and the responsibility to manage wildlife in their areas.

(3) Requirements for EIA

According to the Procedures and Guidelines for Conducting Environmental Impact Assessment of Road Construction Projects (December 1994) there are at present no legal requirements to conduct Environmental Impact Assessment (EIA) of new projects in Zimbabwe.

However, the government is taking steps to introduce more formal procedures, and in 1992 the Ministry of Environment and Tourism, and the Department of Natural Resources initiated a 5 year programme to upgrade the existing legislation, develop new laws where required, and integrate the nation's overall approach to environmental protection. The Ministry of Environment and Tourism has published a "Prospectus for Environmental Assessment Policy in Zimbabwe: Public Background and Discussion Paper", which was followed by the publication of a draft Interim El Policy for Zimbabwe in March 1994. The Environmental Impact Assessment Guidelines were published in September 1997.

(4) Local Government

Zimbabwe is divided into several administrative districts. Chirundu lies within the district of Hurungwe, Mashonaland West Province. The capital of the province is Chinoyi, located 269 km to the east.

(5) Local Planning Policy

The Regional Town and Country Planning Act (1976) provides for the planning of regions, districts and local areas with the object of conserving and improving the physical environment. In particular it promotes health, safety, amenity, convenience, and general welfare.

A Regional Plan for the whole of the Zambezi valley has not yet been prepared, although feasibility studies have been carried out.

The Regional Town and Country Planning Regulations (1977) identify three types of local plans:

a local subject plan;
a local development plan, which deals with a wide range of issues; and
a local priority plan.

The preparation of the Local Development Plan for Chirundu has been suspended, as a result of the work being carried out by the JICA study team, which will determine the position of the additional bridge across the River Zambezi. The layout of Chirundu is shown in Figure 8.2.

The Local Subject Plan has been prepared within the broad framework of the Zambezi River Basin Regional Plan (although as noted above, this has not been concluded). Three local subject plans have been prepared for Chirundu, one concerned with the development of the river frontage; one concerned with the high density housing area known as Baghdad; and one concerned with the low density housing located on top of the hill above the Baghdad settlement.

A Zambezi Valley Regional Planning Conference, held in February 1993, concluded that:

Due to the fragile nature of the soils and environment, the area is not suitable for agriculture or intensive human settlement. However, the area is subject to increasing development pressures, which are of concern.
An appropriate policy response was required to address the growing tourist industry.
Resources in the Zambezi Valley Region are finite and non-renewable, and Local Authorities therefore need a framework within which to handle development pressures, to prevent irreversible damage being done to the environment.
There is a need for co-ordinated development in the Zambezi Valley.
There is a need to maintain the international perspective of the Zambezi River in planning for the Region.

The Chirundu Local Subject Plan for the river frontage area recommended a strategy of limiting development immediately downstream of the existing bridge, to achieve and maintain a co-ordinated balance between the built and natural environment, and to reduce conflict between human beings and animals, in particular making provision for the game corridors. The Plan also recommended ensuring public access to the river, and the prevention of pollution or degradation of the river.

Policies for achieving these aims include the following:

Developments to be limited to a stretch of land along the shore, measuring 616.7 ha.
Only those developments directly linked to tourist residential and recreational activities to be permitted within the planning area.

Land to be initially allocated on a lease basis with a purchase option, upon which title can be granted after satisfactory completion of developments.

It is a specific planning intention that this area of river frontage should be preserved "as far as possible in a natural state, free from developments".

8.3. ENGINEERING BASELINE AND PROPOSED PROJECT

8.3.1. THE ENGINEERING/ENVIRONMENTAL PROBLEM

At present, the bridge, constructed in 1939, carries only single lane traffic, and more importantly the customs and immigration arrangements at both ends create major delays, with many trucks stopping in Chirundu for between 3 and 7 days. The delays are caused by the bureaucracy involved with the border crossings, with drivers being required to fill in up to 20 different forms.

During the last six months (1997) approximately 50 trucks per day crossed the bridge, although figures range up to 200. There are approximately 12 buses a day in both directions. Food and fuel travels from Zimbabwe to Zambia. Some copper and other goods travel from Zambia to Zimbabwe. The blockages cause delay and inconvenience to travellers and businesses and aggravate pollution and social problems in Chirundu on both sides of the border. As a major trucking stop, Chirundu is severely hit by AIDS.

Truckers sometimes avoid inspection by using the earth roads around the back of the border facilities in Zambia. In addition, any Zimbabwean vehicle over 55 tonnes is forbidden to cross the bridge and, having cleared the paperwork at Chirundu, has to divert to Kariba, via the dangerous hill road, in order to cross the Zambezi over the dam wall. This creates potential conflicts at the tourist resort of Kariba, although the numbers of diverted vehicles are at present relatively small, averaging 6 a month, according to the customs officials at Kariba.

8.3.2. ENGINEERING ALTERNATIVES

3 bridge crossing alternatives were initially under consideration:

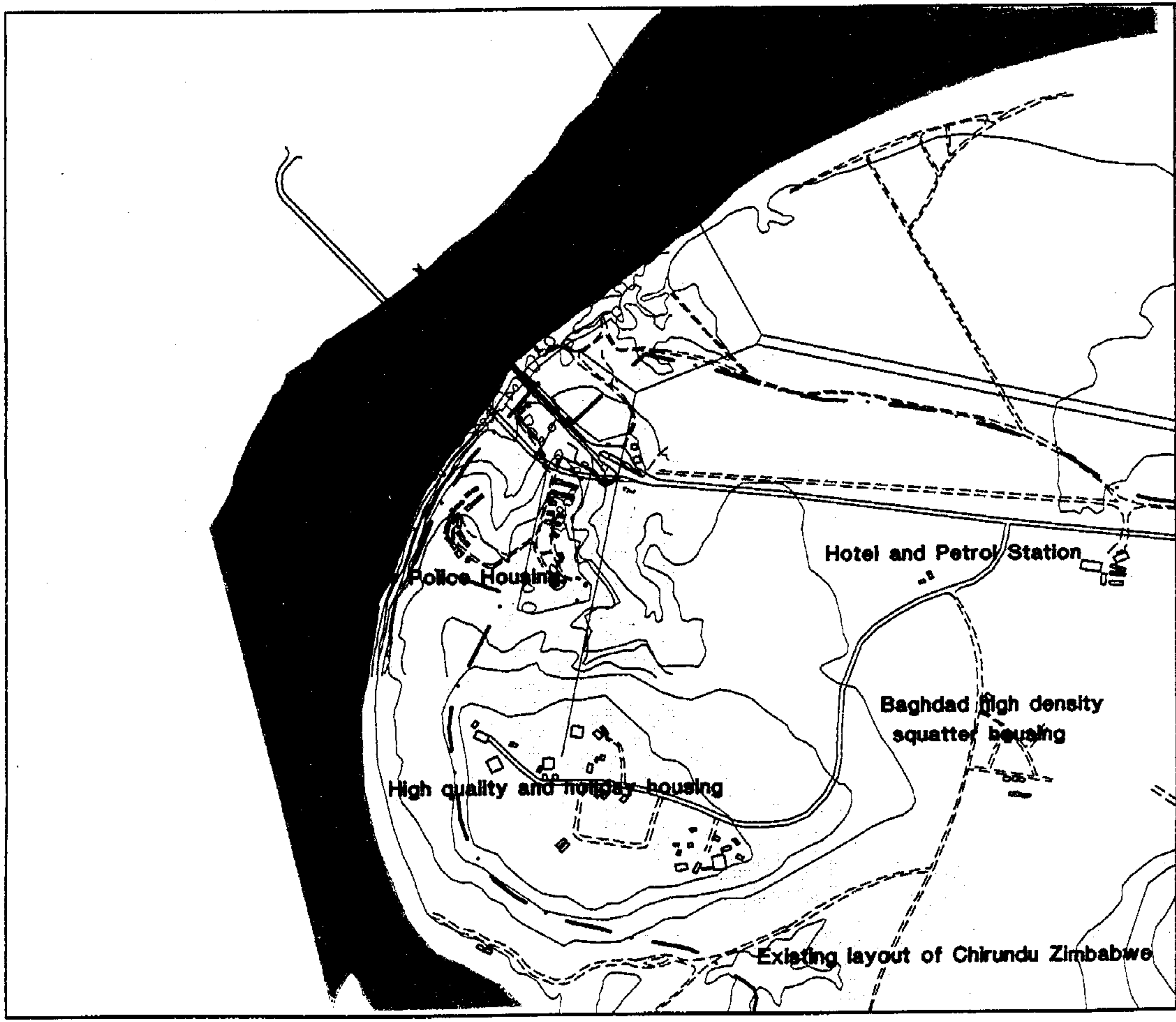
A 100 metres upstream of the existing bridge
B 50 metres downstream
C 225 metres downstream

As a result of the Initial Environmental Evaluation, border post and engineering studies Alternative A was selected as the preferred alternative in September 1997.

The design of the bridge will be a 3 span PC box girder concrete bridge.

8.3.3. BORDER POST FACILITIES

It is understood from discussions with Messrs Smit and Lisulo that the layout is likely to be in the order of 500 m x 100 m, an area of 5 ha. This is necessary to allow the smooth operation of clearing and immigration control.



Mott MacDonald

CHODAI CO., LTD.

Japan International Cooperation Agency

Ministry of Transport & Energy
Government of Zimbabwe

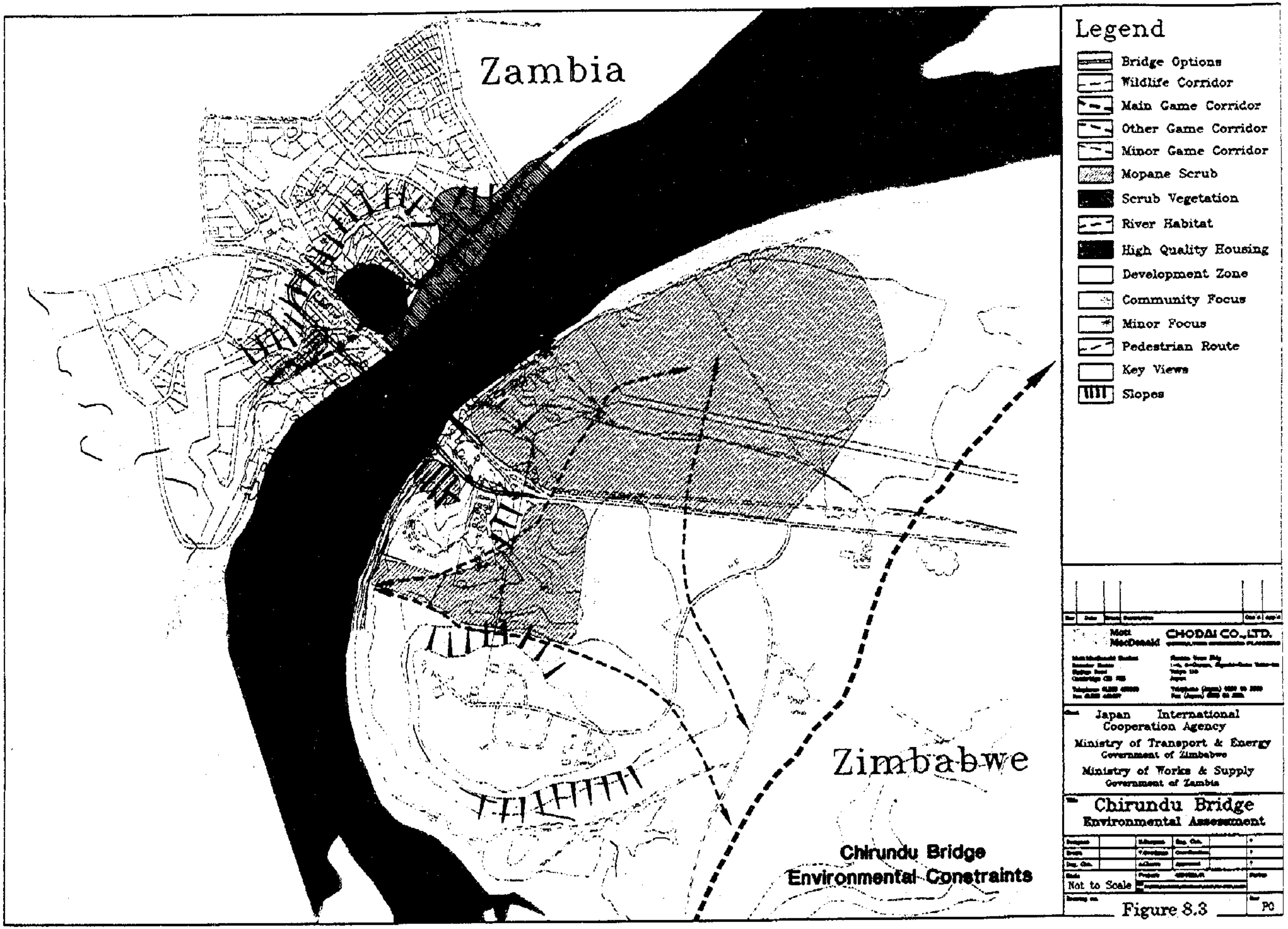
Ministry of Works & Supply
Government of Zambia

Chirundu Bridge
Environmental Assessment

Not to Scale

Figure 8.2

70


Zambia
Zimbabwe
Chirundu Bridge
Environmental Constraints
Legend
Bridge Options
Wildlife Corridor
Main Game Corridor
Other Game Corridor
Minor Game Corridor
Mopane Scrub
Scrub Vegetation
River Habitat
High Quality Housing
Development Zone
Community Focus
Minor Focus
Pedestrian Route
Key Views
Slopes
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Ministry of Transport & Energy
Government of Zimbabwe
Ministry of Works & Supply
Government of Zambia
Chirundu Bridge
Environmental Assessment
Not to Scale
Figure 8.3