No. 1

Japan International Cooperation Agency
Ministry of Transport and Energy
Republic of Zimbabwe

# BASIC DESIGN STUDY REPORT ON THE PROJECT FOR REHABILITATION OF RURAL ROADS IN THE REPUBLIC OF ZIMBABWE

November 1993

Nippon Koei Co., Ltd.

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**PREFACE**

In response to a request from the Government of the Republic of Zimbabwe, the Government of Japan decided to conduct a Basic Design Study on the Project for Rehabilitation of Rural Roads and entrusted a study to the Japan International Cooperation Agency (JICA).

JICA sent to Zimbabwe a study team headed by Mr. Takeo Kai, Transport & Land Development Specialist, Institute for International Cooperation, JICA, and constituted by members of Nippon Koei Co., Ltd., two times from February 26 to March 20, 1993 and from May 21 to June 18, 1993.

The team held discussions with the officials concerned of the Government of Zimbabwe, and conducted field surveys at the study areas. After the team returned to Japan, further studies were made and a draft report was prepared. Then, a mission was sent to Zimbabwe in order to discuss a draft report, and the present report was prepared.

I hope that this report will contribute to the promotion of the Project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Zimbabwe for their close cooperation extended to the team.

November 1993

Kensuke Yanagiya

Kensuke YANAGIYA
President
Japan International Cooperation Agency

November, 1993

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for Rehabilitation of Rural Roads in the Republic of Zimbabwe.

This study was conducted by Nippon Koei Co., Ltd., under a contract with JICA, during the period of February 22, 1993 to November 30, 1993. In conducting the study, we have examined the feasibility and rationale of the Project with due consideration to the present situation of Zimbabwe, and formulated the most appropriate basic design for the Project under Japan's Grant Aid scheme.

We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs and the Ministry of Construction. We also wish to express our deep gratitude to the officials concerned of the Department of State Roads, Ministry of Transport and Energy as well as Embassy of Japan in Zimbabwe for their cooperation and assistance during our study.

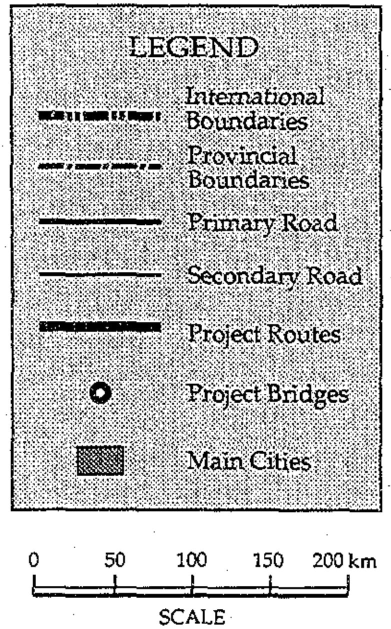
Finally, we hope that this report will contribute to further promotion of the Project.

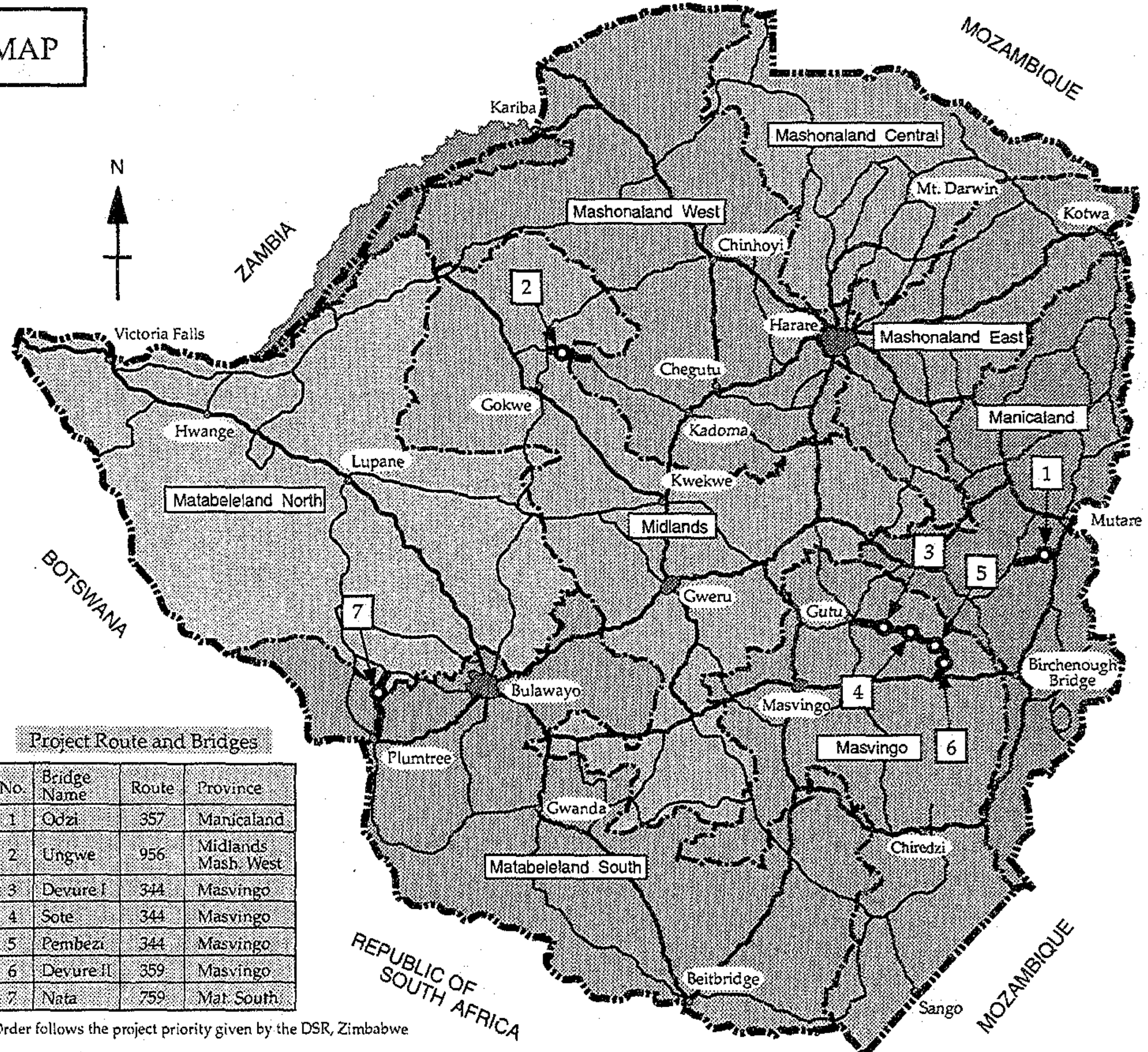
Very truly yours,

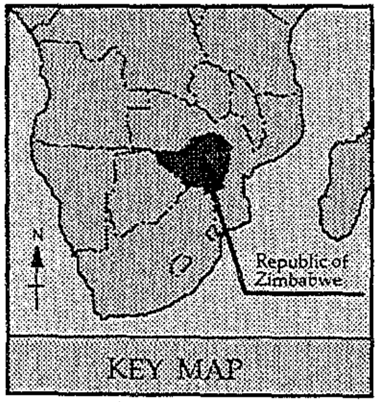
Kazumasa Tada

Kazumasa Tada
Project Leader
Basic Design Study Team on
the Project for Rehabilitation of Rural
Roads in the Republic of Zimbabwe
Nippon Koei Co., Ltd.

# PROJECT LOCATION MAP




Project Route and Bridges

| No. | Bridge Name | Route | Province |
|---|---|---|---|
| 1 | Odzi | 357 | Manicaland |
| 2 | Ungwe | 956 | Midlands Mash. West |
| 3 | Devure I | 344 | Masvingo |
| 4 | Sote | 344 | Masvingo |
| 5 | Pembezi | 344 | Masvingo |
| 6 | Devure II | 359 | Masvingo |
| 7 | Nata | 759 | Mat. South |

Order follows the project priority given by the DSR, Zimbabwe

## Summary

Zimbabwe, a landlocked country, has a transportation system composed of roads, railways and air, and inland water transport facilities. The Government of Britain had paid considerable attention to improving the trunk road network as well as the railway network. At the time of independence, in 1980, the trunk road network which connected major cities had been nearly completed.

Although the Government of Zimbabwe (GOZ) intended to improve and expand rural roads, along with maintenance works on major trunk roads, they could not invest sufficient funds due to lack of financial resources in these road projects.

In 1980 very few large-scale agricultural landowners possessed approximately half of the total agricultural land. At the other end of the scale, an overwhelming majority of poor farmers were living around the communal lands where living standards remained in a poor condition. In order to correct these social and economic imbalances the GOZ has ranked the rural development programme and the resettlement programme as its basic policy. As a consequence of these two basic programmes, improvement of rural roads relating to the communal lands has been planned.

Judging from the present situation, satisfactory progress has not been made as a result of financial problems and a deficiency of foreign currency. Therefore the GOZ requested grant aid in the form of materials and construction equipment from the Government of Japan (GOJ) which were necessary to replace bridges along national rural roads.

In response to the request, the GOJ decided to conduct a preliminary study and the Japan International Cooperation Agency ( JICA ) dispatched a mission to Zimbabwe in 1992 for this purpose. After this study, the mission reported that the priority of bridges and related rural roads be subjected to the results of the basic design study.

At the same time the mission recommended that improvement of not only bridges but also related roads should be considered in order to enhance the effect of Japanese aid. In addition, it was reported that concrete type bridges would be preferable as the type of bridges to replace the existing ones because of their lower construction cost and easiness of maintenance works. Furthermore, recognizing that the GOZ has a relatively high technical capability in relation to road construction compared with other African countries, the force account work by the GOZ for the road improvement was recommended on the premise of the GOJ aid for the necessary equipment and materials. However, the mission concluded that the selection of prospective roads and equipment and materials to be granted should be determined based on the results of the basic design study.

JICA dispatched a basic design mission and executed two field investigations from 26$^{th}$ February to 20$^{th}$ March and from 21$^{st}$ May to 18$^{th}$ June 1993.

During these field investigations, the basic design study mission had discussions with the Zimbabwean officials concerned, confirmed the contents of the request, and examined the background of the Project as well as the evaluation of technical standards in Zimbabwe. The mission executed a geotechnical investigation and topographic survey, discussed with the Zimbabwean counterpart engineers Zimbabwe's standards for road and bridge design, and simultaneously collected required data.

Through a series of discussions with counterparts the following matters were deliberated on:

- fundamental design dimensions of roads
- applicable type and magnitude of bridges (bridge length, proposed height, etc.)

In addition, construction conditions in Zimbabwe were scrutinized for the purpose of gathering indispensable data to be used for the cost estimation.

The mission confirmed the priority order given by the GOZ to the candidate routes at the stage of meeting with the GOZ, and the agreements reached during the discussions about the works to be undertaken by the GOZ.

After returning to Japan, the mission further examined the necessity/effectiveness of the Project based on the results of the field investigations, studied adequate types and magnitude of bridges and reviewed equipment and materials that were requested by the GOZ. After completing the bridge design, the road design, required quantities for construction and the construction scheme, etc. were carried out.

After evaluating the priority order adopted by GOZ and assessing the assistance effect of Japan's Grant Aid, the Project recommended by this basic design study is summarized as follows.

o Recommended scope of works by GOJ

<u>Bridge construction including approach roads to be implemented by the Japanese side</u>

| Bridge Name | Odzi Bridge | Route 357 | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 157.0 m | Effective Width | 7.0 m |
| | Superstructure | 7 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 2, Wall type Pier × 6 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 1,475 m | Right Bank | 2,968 m |

| Bridge Name | Ungwe Bridge Route 956 | | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 49.5 m | Effective Width | 7.0 m |
| | Superstructure | 2 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 2, Wall type Pier × 6 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 123.5 m | Right Bank | 123.5 m |

| Bridge Name | Devure I Bridge Route 344 | | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 107.0 m | Effective Width | 7.0 m |
| | Superstructure | 5 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 1, Buttressed Abutment × 1<br>Wall type Pier x 4 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 1,258 m | Right Bank | 585 m |

| Bridge Name | Sote Bridge Route 344 | | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 74.0 m | Effective Width | 7.0 m |
| | Superstructure | 3 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 2, Wall type Pier × 2 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 328 m | Right Bank | 498 m |

| Bridge Name | Pembezi Bridge Route 344 | | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 49.5 m | Effective Width | 7.0 m |
| | Superstructure | 2 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 2, Wall type Pier × 1 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 3,762 m | Right Bank | 1,158 m |

| Bridge Name | Devure II Bridge Route 359 | | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 173.0 m | Effective Width | 7.0 m |
| | Superstructure | 7 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 2, Wall type Pier × 6 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 951 m | Right Bank | 376 m |

| Bridge Name | Nata Bridge | Route 759 | | |
|---|---|---|---|---|
| Main Bridge | Bridge Length | 74,0 m | Effective Width | 7.0 m |
| | Superstructure | 3 Span PC Simple Post-tensioning Girder | | |
| | Substructure | Invert T-type Abutment × 2, Wall type Pier × 2 | | |
| | Foundation | Spread Foundation | | |
| Approach Road | Left Bank | 1,136 m | Right Bank | 490 m |

Supply of equipment and materials by Japan's Grant Aid

| Descriptions | Quantity |
|---|---|
| A. Earth Moving Equipment<br>Motor grader 130 PS and others | 24 nos. |
| B. Compaction Equipment<br>Tyred roller 8~20t and others | 6 nos. |
| C. Ancillary Equipment for A & B<br>Water tanker 8 $m^3$ and others | 18 nos. |
| D. Asphalt Paving Equipment<br>Asphalt distributor 6 $m^3$ and others | 4 nos. |
| E. Miscellaneous Equipment<br>Concrete Mixer 0.25 $m^3$ and others | 4 nos. |
| Spare parts for the above equipment | 1 set |
| F. Construction Materials<br>1) Galvanized Corrugated Steel pipe<br>2) Straight asphalt | <br>98 t<br>3,650 $m^3$ |

o Recommended scope of works by GOZ

Road rehabilitation to be implemented by the Zimbabwean side

| Route No. | Length (km) | Road rehabilitation to be implemented (km) |
|---|---|---|
| Route 357 | 41.60 | 37.00 |
| Route 956 | 37.80 | 37.50 |
| Route 344 | 86.90 | 79.08 |
| Route 359 | 16.00 | 14.50 |
| Total | 182.30 | 168.08 |

Remark : The project length of Route 956 above equals the initial project length of 38.06 km determined during the site reconnaissance minus the existing Sanyati Bridge length.

The gross construction cost to be borne by the Zimbabwean side is estimated as 57.2 Million Z $.

Since the existing condition of Route 759 was poor, especially in its alignment, compared to the other project routes, the scope of road rehabilitation of this route was excluded from the Project. As for the Nata bridge on this route, it was included in the Project, taking into account the expected benefit to the people in the project area. However, it was finally judged that, compared with the other bridges, the construction of Nata Bridge would not give the expected effect as the Japan's Grant Aid Program, to the project area.

On the condition that Japan's Grant Aid will be asked for the Project, detailed design of this Project will be commenced after the signing of the Exchange of Note between the GOJ and the GOZ. It will take about 3 months for the preparation of bid documents and tendering. After the evaluation of bids, the construction contract will be concluded and then the construction works will be commenced. The total construction period is estimated to be approximately 28 months.

Based on the basic design study, this Project has been justified as follows

- o Substantial direct benefit is expected to accrue from the implementation of the Project

- o Rural roads along the communal lands will be improved so that they will become available also in the rainy season. As the bridges related to these roads will be replaced, the bottlenecks on these routes will disappear.

- o As a result, access to hospitals in the communal lands, where the living standards are poor at present, should be improved so that basic human needs in these lands can be secured. Since transport to major rural cities will be possible in any weather condition, economic activities in the communal lands are expected to be activated and job opportunities can be increased.

- o The Project will generate a considerable effect on the Zimbabwean national policy—to raise the living standards of the people, and to increase equity in distribution of income and wealth—by the realisation of all-weather type rural roads which will accelerate the process of resettlement and facilitate the development of the communal areas, which are emphasised in the Second Five Year National Development Plan of Zimbabwe.

- o In terms of the technology transfer, the Project is expected to transfer the construction technology of PC post-tensioned girder type bridge which was proposed in the Project—first introduction to Zimbabwe. This will surely strengthen the Zimbabwean bridge construction technology and widen the range of bridge type selection. It is anticipated that Zimbabwe will construct PC bridges by themselves in future.

# BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION OF RURAL ROADS IN THE REPUBLIC OF ZIMBABWE

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# *Chapter 1 Introduction*

# Chapter 1 Introduction

The Republic of Zimbabwe has a fairly well developed transport system that has been mainly concentrated in the commercial, agricultural, mining and industrial areas. However communal farmers do not reap the full benefits of the financial sector since they have difficulties in transporting inputs and outputs from/to the main economic centres of the country. During the rainy seasons, some sections of the communal lands are cut off due to the flooding of low elevation bridges. Some transporters have refused to go to certain areas because of the poor road conditions, therefore communal farmers have had no way of marketing their products.

The Department of State Roads (DSR), Ministry of Transport and Energy (MOTE), concentrates its efforts on the construction and maintenance of the road network in the rural areas due to the increasing role of the rural roads. Special emphasis is placed on the provision of all year accessibility of rural markets and services. In order to increase the rate of bridge construction in the less developed rural areas, and to provide improved access to communal farms and resettlement areas, GOZ made a request to the GOJ on May 1992 for the supply of vehicles, equipment, materials, finance, and experts for the construction of 10 bridges under the Grant Aid Cooperation.

GOJ decided to conduct a preliminary study, and entrusted the study to JICA. JICA despatched a preliminary study team headed by Mr. Itaru Minami, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, from 27 September to 10 October 1992. The preliminary study team studied the propriety of the request, and recommended that 1) the construction of concrete bridges will be appropriate, 2) rehabilitation of related roads will enhance the effect of the Japanese Grant Aid programme by promoting rural development—the national policy of Zimbabwe , and 3) the implementation of the supply of materials and equipment for the road rehabilitation by the Zimbabwean side should be further studied in the next basic design study phase.

GOJ proceeded to the next step with the implementation of the basic design study. JICA formed the basic design study team headed by Mr. Takeo Kai, Transport and Land Development Specialist, Institute for International Cooperation, JICA, and despatched the team twice to carry out the field investigation. The first field investigation was carried out from 26th February to 20th March 1993, and the second field investigation from 21st May to 18th June 1993.

The basic design study team conducted a reconnaissance of the project sites, topographic and geological survey, unit cost/market price survey, and inventory of available construction equipment and materials. Several meetings were held between the team and DSR staff regarding design criteria for the Project or scope of the Project.

Based upon the above results, the basic design study team exchanged the minutes of discussions, annexed in this report, with GOZ. On returning to Japan, the team carried out further assessment on the adequacy of the road rehabilitation/bridge construction, prepared basic designs of roads and bridges, and estimates of work quantities, studied the construction schedule, estimated the project cost and finally evaluated the Project. In accordance with the above mentioned basic design study, the team prepared a draft report of the Project.

JICA despatched a mission headed by Mr. Takeo Kai to Zimbabwe to discuss a draft report, from 17$^{th}$ September to 30$^{th}$ September 1993. After the perusal of the report and discussion, GOZ agreed and accepted the components of the report. The mission exchanged the minutes of discussions with GOZ to confirm the main items agreed between the both parties, as annexed in this report.

This report contains the results of the basic design study. The list of study team members, activities of the team in Zimbabwe, list of people met in Zimbabwe, and the minutes of discussions are attached in the appendices. Boring logs of the geological survey are attached as well.

# *Chapter 2 Background of the Project*

# Chapter 2 Background of the Project

## 2.1 Background of the Project

Zimbabwe is mostly a highland country, and is classified roughly into the High Veld (EL. 1,200~1,500 m), Middle Veld (EL. 900~1,200 m), Low Veld (lower than EL. 900 m), and Eastern Highlands (EL. 1,800~2,600 m). Most of Zimbabwe is located in the highlands, higher than El. 1,000 m, and the climate is that of the subtropical zone of savanna. The climate is classified roughly into three seasons, which are the dry winter (April~August), summer (September~November) and rainy season (November~March). The precipitation in the northeastern area and mountainous area is 1,400 mm/year and that in the southern area is 400 mm/year. The population of Zimbabwe consists of African races (97%) such as the Shonas and the Ndeberes, and others which are European and Asian races. The population in 1992 was supposed to reach 9,910,000.

The gross domestic product (GDP) in Zimbabwe is evaluated to have had comparatively favorable development compared with other neighbouring countries since independence in 1980. Zimbabwe maintains an average 2.8% growth rate of GDP, and, at present, the GNP per capita is US$ 640.

Zimbabwe has ample mineral resources, comparatively high productive agriculture and developed manufacturing industries. Also Zimbabwe has a good social infrastructure including the trunk transportation system and the electric facilities that support the above industries. Zimbabwe has its own non-petroleum energy supply which is composed of ample hydroelectric resources and abundant coal, and is self-sufficient in energy supply.

GOZ has placed importance on the resettlement plan and rural development plan in order to realise the equitable distribution of benefits from the ample mineral resources and agricultural products, and to improve the communal lands which presently show inferior resident environments.

Zimbabwe is now carrying out the Second Five Year National Development Plan (SFYNDP) since 1991. In this SFYNDP, Zimbabwe has transferred the priority for investment from the social and economic infrastructures, to the manufacturing sector infrastructure. The public investment programme of SFYNDP is shown in Table 2-1. The basic strategy of development in SFYNDP is as follows:

(1) Increasing the rate of savings and channelling these into productive investment;

(2) achieving expansion in trade; and

(3) encouraging the operation of market forces

Table 2-1 Five-Year Public Sector Investment Programme by Industrial Sector 1991/92-1995/96

Unit : $\times 10^6$ Z$

| Sector | Five-Year Plan Budget Allocations | | | | | 1991/92 to | Share |
|---|---|---|---|---|---|---|---|
| | 1991/92 | 1992/93 | 1993/94 | 1994/95 | 1995/96 | 1995/96 | in % |
| 1. Agriculture | 427 | 475 | 525 | 600 | 675 | 2,702 | 22.1 |
| 2. Mining | 10 | 15 | 20 | 25 | 30 | 100 | 0.8 |
| 3. Manufacturing | 10 | 30 | 50 | 75 | 100 | 265 | 2.0 |
| 4. Energy and Water | 405 | 450 | 440 | 480 | 580 | 2,355 | 19.2 |
| 5. *Transport & Communication* | *634* | *600* | *650* | *700* | *710* | *3,294* | *26.9* |
| 6. Housing and Urban Dev. | 368 | 270 | 255 | 230 | 210 | 1,333 | 10.8 |
| 7. Education | 100 | 130 | 165 | 180 | 215 | 790 | 6.4 |
| 8. Health | 48 | 65 | 85 | 100 | 120 | 418 | 3.4 |
| 9. Public Administration | 90 | 65 | 50 | 40 | 20 | 265 | 2.2 |
| 10. Defence | 178 | 80 | 60 | 40 | 20 | 378 | 3.1 |
| 11. Other Sectors | 182 | 70 | 50 | 30 | 20 | 352 | 2.9 |
| Total | 2,452 | 2,250 | 2,350 | 2,500 | 2,700 | 12,252 | 100.0 |

Investment in the transportation sector is deemed as the first priority in order to accelerate the development of remote areas. In the past, budgetary allocations were supplied to the construction of Primary Roads prior to that of Secondary/Feeder Roads. But now, the policy has changed to accelerate the construction of Secondary/Feeder Roads, and to extend the road network length.

On the other hand, the Central Mechanical Equipment Department (CMED), MOTE, currently suffers from difficulty in pursuing road maintenance work with worn-out construction equipment and plant which now accounts for more than 50% of its property, and, consequently, results from uneconomical operation. Shortage of spare parts has also caused unfavourable interruptions in routine maintenance. The SFYNDP intends to reinforce the maintenance work units by updating construction equipment and plant.

In Zimbabwe, various road authorities are responsible for the construction and maintenance of road infrastructure, while the Ministry of Transport and Energy is the overall authority responsible for setting limits, standards, and specifications for the various classes of roads. Table 2-2 shows the inventory of roads by each authority in 1991.

Table 2-2 Zimbabwean Road Inventory - 1991

Unit : km

| Road Type | Road Authority | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | State | Rural Council | District Council | Urban Council | Lands | Parks | |
| Earth/Track | 3,728 | 0 | 13,823 | 0 | 3,407 | 0 | 20,958 |
| *Gravel* | *6,445* | *19,786* | *16,993* | *1,153* | *2,593* | *9,000* | *55,970* |
| Single Lane Surfaced | 1,720 | 1,615 | 0 | 738 | 0 | 0 | 4,073 |
| Two Lanes with Gravel Shoulders | 5,575 | 140 | 0 | 3,326 | 0 | 0 | 9,041 |
| 2 or more Lanes Surfaced Shoulders | 966 | 0 | 0 | 70 | 0 | 0 | 1,036 |
| Total | 18,434 | 21,541 | 30,816 | 5,287 | 6,000 | 9,000 | 91,078 |

Source : Department of State Roads

DSR, Ministry of Transport and Energy, is responsible for the national roads which are classified into three categories—Primary Roads, Secondary Roads and Feeder Roads. The total length of Primary and Secondary Roads is judged as enough to form a sufficient road network. However adequate maintenance work has not been carried out for financial reasons, and several routes are obstructing traffic. The District Roads and other roads, which are considered as second trunk roads or lower, are not long enough to form an appropriate road network to contribute to rural development, and remain in poor condition without appropriate maintenance.

SFYNDP places a high priority on road transport as the most effective measure in benefiting the rural farms through economic development, and incorporating rural areas in national economic development. SFYNDP also emphasizes that the improvement of roads is the most direct/effective means in accelerating the rural area's self-development. Therefore, in SFYNDP, the investment in roads is aimed firstly at development of rural areas, and the priority of road improvement itself is given to road rehabilitation and upgrading of its service level. Currently the investment in roads by the SFYNDP gives priority to the Primary Roads under construction and, then, to the Secondary Roads and Feeder Roads in the rural areas.

## 2.2 Outline of the Request

Taking into account the Project background mentioned in Section 2.1, GOZ requested GOJ to provide construction equipment and materials for replacement of 10 bridges along the Secondary/Feeder roads in rural areas through the cooperation of the Japan's Grant Aid Program. Tables 2-3 and 2-4 show the list of bridges for replacement, and requested construction materials and equipment.

In response to the request of GOZ, GOJ decided to conduct a preliminary study and entrusted it to JICA. Accordingly, JICA dispatched a preliminary study team headed by Mr. Itaru Minami to Zimbabwe in order to examine the scope of the Project.

Table 2-3 List of Bridges for Replacement

| Bridge Name | Province | Route No. | Route |
|---|---|---|---|
| 1 Odzi | MAN | 357 | Bazeley~Marange |
| 2 Devure | MSV | 359 | Moodies Pass~Mushongwe |
| 3 Pembezi | MSV | 344 | Chirumhanzu~Kurai |
| 4 Sote | MSV | 344 | Chirumhanzu~Kurai |
| 5 Devure | MSV | 344 | Chirumhanzu~Kurai |
| 6 Chavezi | MTS | 659 | Gwanda~Blanket Mine |
| 7 Ungwe | MID | 956 | Nemangwe~Sanyati |
| 8 Nata | MTN | 759 | Plumtree~Tsholotsho |
| 9 Dora | MSW | 183 | Guruve~Raffingora |
| 10 Musitwi | MSW | 131 | Guruve~Raffingora |

Table 2-4 List of Requested Equipment and Materials

| | Description | Quantity | Remark |
|---|---|---|---|
| (a) | Structural weathering steel beams of the "corten" type for bridge girder | 280 pcs | 18 m in length |
| (b) | Ancillary material like nuts, bolts, shear connector studs, paint, stiffeners and permanent (lost) shutters | 1 lot | |
| (c) | Crane | 1 nos. | 30 tonne capacity |
| (d) | Guard rail material complete with nuts and bolts | 6,000 m | |
| (e) | Neoprene compression seal | 500 m | |
| (f) | Concrete mixer | 10 nos. | 400/300 litre capacity |
| (g) | Concrete poker vibrators complete with drive units | 15 nos. | 50 to 75 mm diameter |
| (h) | Truck | 10 nos. | 5 tonne capacity |
| (i) | Tipper truck | 5 nos. | 8 tonne capacity |
| (j) | Mobile welding plant complete with electrode | 5 nos. | (towable) |
| (k) | Diesel powered electricity generating set | 2 nos. | (towable) |
| (l) | 4WD truck | 12 nos. | 1 tonne capacity |
| (m) | Water pump centrifugal | 10 nos. | 150 mm |
| (n) | Batcher | 5 nos. | 1.5 tonne capacity |

Based on the preliminary study results, the following were recommended to GOJ:

i) It is understood that rehabilitation of the 10 bridges is required to dissolve the bottlenecks on the roads running through the communal lands. However, it was recommended that replacement of only 7 bridges including rehabilitation of the related roads be implemented on a priority basis in Zimbabwe.

ii) A part of the above works would be implemented on a force account basis with construction equipment and materials to be provided by Japan's Grant Aid Program

iii) The final scope of the Project such as project routes and their total length, the number of project bridges, and type of equipment to be supplied, will be finalized after completion of the basic design study.

The preliminary study team recommended the scope of the basic design study to include the road sections and bridges as tabulated below:

Table 2-5 Scope of the Basic Design Study recommended by the Preliminary Study

| | Province | Route No. | Road Section (From/To) | Length (km) | Bridge Name |
|---|---|---|---|---|---|
| 1 | Masvingo | 344 | Chirumanzu–Gutu–Kurai | 89 | Devure I, Pembezi, Sote Bridge |
| | | 359 | Mushongwe–Moodies Pass | 16 | Devure II Bridge |
| 2 | Manicaland | 357 | Odzi Bridge–Marange | 41.6 | Odzi Bridge |
| 3 | Matabeleland South | 759 | Plumtree–Samenani | 55.6 | Nata Bridge |
| 4 | Midlands and Mashonaland West | 956 | Kuwirirana–Nemangwe | 39.0 | Ungwe Bridge |

During the second field investigation by the basic design study team, GOZ requested that the following materials and equipment listed in Table 2-6 be supplied for the related road rehabilitation which would be implemented by Zimbabwean side.

Table 2-6 List of Requested Equipment and Materials

| Machine | Power/Capacity | Remark |
|---|---|---|
| A Earth equipment | | |
| Road grader | 100~150 kW | with engine |
| Bull-dozer (tracked tractor) | 200~250 kW | |
| Bull-dozer (tracked tractor) | 130~150 kW | |
| Bull-dozer (tracked tractor) | 50~60 kW | |
| Excavator | 25~50 tonnes | with engine |
| Tipper (dumper) | 3~5 $m^3$ | with engine |
| Front-end-loader (tractor shovel) | 100~150 kW | with engine |
| B Compaction equipment | | |
| Pneumatic tyred roller | 8~15 tonnes | with engine |
| Pneumatic tyred roller | 5~10 tonnes | without engine |
| Steel wheeled flat roller | 8~12 tonnes | with engine |
| Grid roller | 5~19 tonnes | without engine |
| C Ancillary equipment for (A) & (B) | | |
| Water tanker (bowser) | 5~15 $m^3$ | with engine |
| Water tanker (bowser) | 3~5 $m^3$ | without engine |
| Pneumatic tyred tractor | 60~115 kW | |
| Disc harrow | 5 furrow | Towed |
| Water pump (150 mm) | | |
| D Surfacing equipment | | |
| Bitumen distributor | 5,000~10,000 litres | with engine |
| Stone chip spreader | 3.0 m wide | with engine |
| Drag Broom | 3.0 m wide | with engine |
| E Sundries | | |
| Telescopic loader | 7~10 tonnes | with engine |
| Concrete mixer | 175~300 litres | Towed |
| F Materials | | |
| Steel corrugated pipes for culverts | | |
| Bitumen | | |

## 2.3 Location and Condition of the Project Sites

### 2.3.1 Road Condition

The Project sites are widely scattered in the five Provinces of Zimbabwe, including the Provinces of Manicaland, Midlands, Mashonaland West, Masvingo, and Matabeleland South. The road condition of each proposed route is summarized as follows. Each route passes through the communal lands.

(1) Route 357

Route 357, classified as a Secondary Road and having a total length of 41.6 km, is situated in the Manicaland Province and connects Chinyauhwera and Marange. This route has ranked as the highest priority roads to be improved as this road serves the Muromo, Chinyauhwera, and Marange Communal Lands. This road is narrow and is an unpaved earth road with a width of 6 m. Some parts of this route have poor geometry and uneven surface, so realignment is required in the rehabilitation work to upgrade it to a secondary national road. The Odzi Bridge is located on this route, which is a R.C. simply supported girder bridge of 146 m in total length. This bridge frequently causes traffic interruption during peak flood periods.

(2) Route 956

Route 956 is a Secondary Road of 158 km in total length, passing through the Midlands and Mashonaland West Provinces, and connecting Golden Valley and Nemangwe. This route, linking Kadoma and Gokwe Communal Lands via Sanyati, is a vital road for transportation of agricultural products, including cotton produced in the hinterlands. The proposed project section, totaling 38 km from Kuwirirana toward Golden Valley, was once upgraded to a gravel road, 8 m in width, and realigned. Then, the rehabilitation (surfacing) of the section is required as a high priority now. The section from the said gravel road end to Golden Valley is surfaced, but only a one-lane-width in the centre of the road.

On this route the Ungwe bridge is located, which is a submersible R.C. slab bridge with a bridge opening of 3.1 m wide × 1.6 m high. This bridge is also a bottleneck during the rainy season.

(3) Route 344 and 359

Routes 344 and 359 are situated in the Masvingo Province. Route 344 links Gutu and Kurai (89.1 km), while Route 359 connects Kurai and Moodies Pass (26 km). These two routes are presently classified as Feeder Roads in the rural area. These routes are very important roads for the regional economy as they connect Gutu and Bikita that contain communal lands and the government's grain deposit center, respectively. These towns are centers of the distribution industry and regional activity. Furthermore, these routes are also important for generating traffic in the communal lands. Upgrading of the project roads will enhance the accessibility to such major towns as Gutu, Mutare, and Masvingo for the said generated traffic. The function of these routes—to strengthen the socioeconomic interdependence among these cities—is extremely important.

Route 344, on which the Devure I, Sote, and Pembezi Bridges are proposed, is an unpaved road with a width of approximately 5 m and realignment will be required to meet the specified geometric design criteria for a Secondary Road. Route 359 which was recently constructed is a gravel road with a width of 8 m and includes the proposed Devure II Bridge on the Devure River near Kurai. All of these bridges are vented causeways, in varying length from 53 to 170 m and in width from 3 to 6 m. These bridges cause traffic interruption during peak flood periods.

(4) Route 759

Route 759 is a Feeder Road in Matabeleland South Province. This road is 44.5 km long and links Plumtree to Tsholotsho Communal Land in Samenani. The improvement of this route is expected to greatly enhance the socioeconomic interdependence of the Communal Lands along the route between Plumtree and Bulawayo.

The route is a gravel road with a width of 5~8 m and has a winding alignment in many places. The Nata Bridge is located on this route. Though this route has the least traffic volume, the Nata bridge, a drift of about 100 m long, is a considerable bottleneck during the flood season. The priority for road improvement of this route was set as the lowest among the above-mentioned road rehabilitation project by the GOZ.

### 2.3.2 Traffic condition

Table 2-7 shows the Annual Average Daily Traffic (AADT) in 1992 on the five routes. Locations of traffic count point are given as circled numbers in Figures 2-1 (1) and (2).

In the framework of the basic design study, a traffic survey was carried out at the seven bridges, during April to May 1993, according to the following conditions:

| | | |
|---|---|---|
| Survey period | : | 3 days |
| Survey time | : | 14 hours (6 a.m.~8 p.m.) |
| Classification | : | bus, truck, small vehicle (including pick-up) and pedestrian |

Table 2-8 shows the results of the traffic survey. The survey result will be summarised as follows:

- The vehicle traffic volume was about 10~50 vehicles/14 hours.
- The pedestrian volume was about 100~200 persons/14 hours except at the Sote and Pembezi Bridge sites
- The heavy vehicles ratio was about 40~60 % and at the Ungwe Bridge site where the rate was very high at 73 %.

### 2.3.3 Traffic Accidents

The number of traffic accidents and casualties in 1992 on the five routes are listed in Table 2-9. According to the table, the number of accidents on Route 344 was very high compared to the other routes.

Table 2-7 Annual Average Daily Traffic in 1992

| Location No. | Route | Kilopost | Heavy vehicle | Bus | Others | Total | Heavy vehicle ratio | Bus ratio |
|---|---|---|---|---|---|---|---|---|
| 1 | 357 | 0.5 | 51 | 31 | 88 | 170 | 48% | 18% |
| 2 | | 39.5 | 21 | 5 | 39 | 65 | 40% | 8% |
| 3 | 956 | 0.5 | 42 | 30 | 0 | 72 | 100% | 42% |
| 4 | | 41.5 | 61 | 26 | 49 | 136 | 64% | 15% |
| 5 | | 42.0 | 57 | 26 | 50 | 133 | 62% | 20% |
| 6 | | 63.0 | 63 | 26 | 78 | 167 | 53% | 16% |
| 7 | | 65.0 | 78 | 34 | 70 | 182 | 62% | 19% |
| 8 | | 71.5 | 58 | 23 | 27 | 108 | 75% | 21% |
| 9 | | 72.0 | 76 | 31 | 98 | 205 | 52% | 15% |
| 10 | | 101.5 | 38 | 23 | 11 | 72 | 84% | 32% |
| 11 | | 102.0 | 42 | 25 | 3 | 70 | 96% | 36% |
| 12 | | 113.0 | 42 | 21 | 8 | 71 | 89% | 30% |
| 13 | | 113.5 | 5 | 2 | 1 | 8 | 89% | 25% |
| 14 | | 157.5 | 2 | 0 | 1 | 3 | 67% | 0% |
| 15 | 344 | 0.5 | 37 | 16 | 61 | 114 | 46% | 14% |
| 16 | | 21.5 | 51 | 18 | 101 | 170 | 41% | 11% |
| 17 | | 22.5 | 40 | 19 | 96 | 155 | 38% | 11% |
| 18 | | 43.0 | 178 | 27 | 702 | 907 | 23% | 3% |
| 19 | | 44.5 | 352 | 101 | 1,078 | 1,531 | 30% | 7% |
| 20 | | 45.4 | 9 | 1 | 38 | 48 | 21% | 2% |
| 21 | | 123.0 | 10 | 4 | 10 | 24 | 58% | 17% |
| 22 | 359 | 0.9 | 7 | 2 | 32 | 41 | 22% | 5% |
| 23 | | 26.0 | 11 | 1 | 26 | 38 | 32% | 3% |
| 24 | | 26.5 | 8 | 4 | 10 | 22 | 55% | 18% |
| 25 | 759 | 0.5 | 6 | 0 | 24 | 30 | 20% | 0% |
| 26 | | 43.5 | 3 | 2 | 0 | 5 | 100% | 40% |

Table 2-8 Traffic Survey Results of April and May 1993

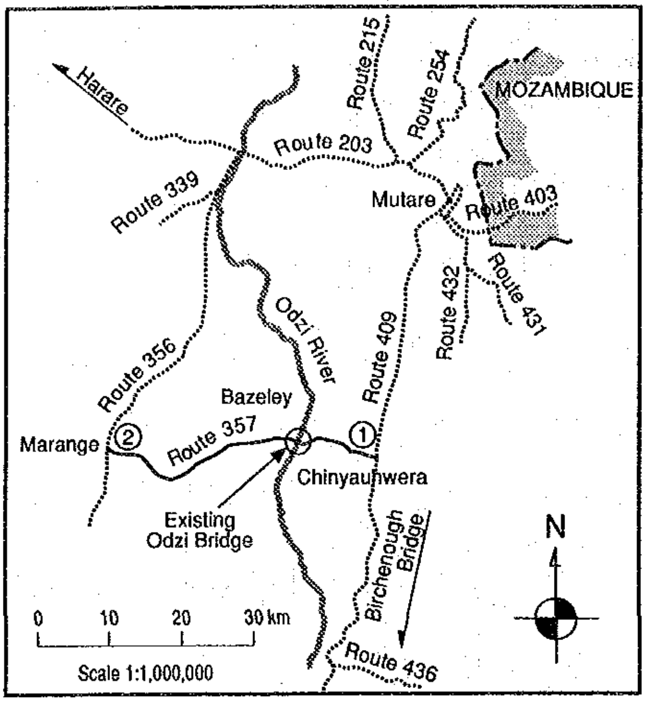
Unit : Vehicles or Persons/14 hours

| Bridge Name | Route | Bus | Truck | Passenger car | Total | Pedestrian |
|---|---|---|---|---|---|---|
| Odzi | 357 | 8 | 6 | 19 | 33 (42%) | 196 |
| Ungwe | 956 | 22 | 13 | 14 | 48 (73%) | 100 |
| Devure I | 344 | 10 | 10 | 31 | 51 (39%) | 231 |
| Sote | 344 | 4 | 1 | 4 | 9 (56%) | 25 |
| Pembezi | 344 | 4 | 1 | 4 | 9 (56%) | 25 |
| Devure II | 359 | 1 | 3 | 4 | 8 (50%) | 68 |
| Nata | 759 | 4 | 3 | 9 | 16 (44%) | 68 |

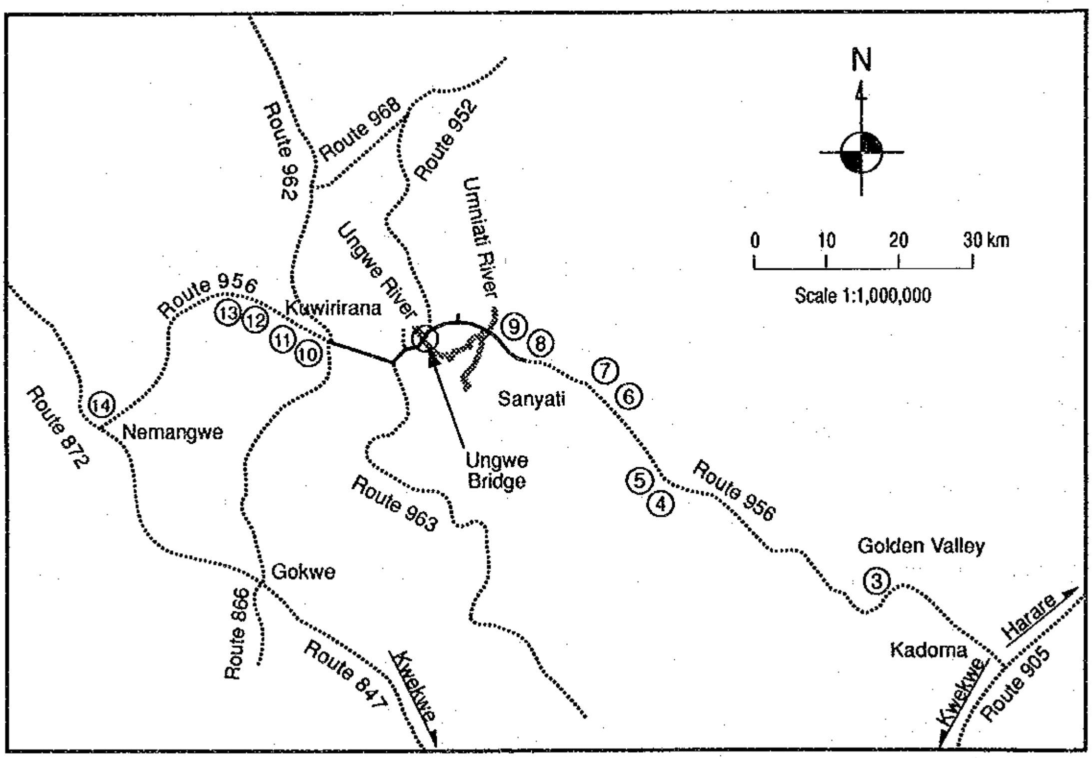
Note : Values in () shows the ratio of heavy vehicles

Table 2-9 Traffic Accidents (1992)

| Route No. | No. of Accidents | No. of Persons Killed | No. of Persons Injured |
|---|---|---|---|
| 357 | 0 | 0 | 0 |
| 956 | 5 | 0 | 2 |
| 344 | 37 | 2 | 34 |
| 359 | 0 | 0 | 0 |
| 759 | 7 | 0 | 2 |

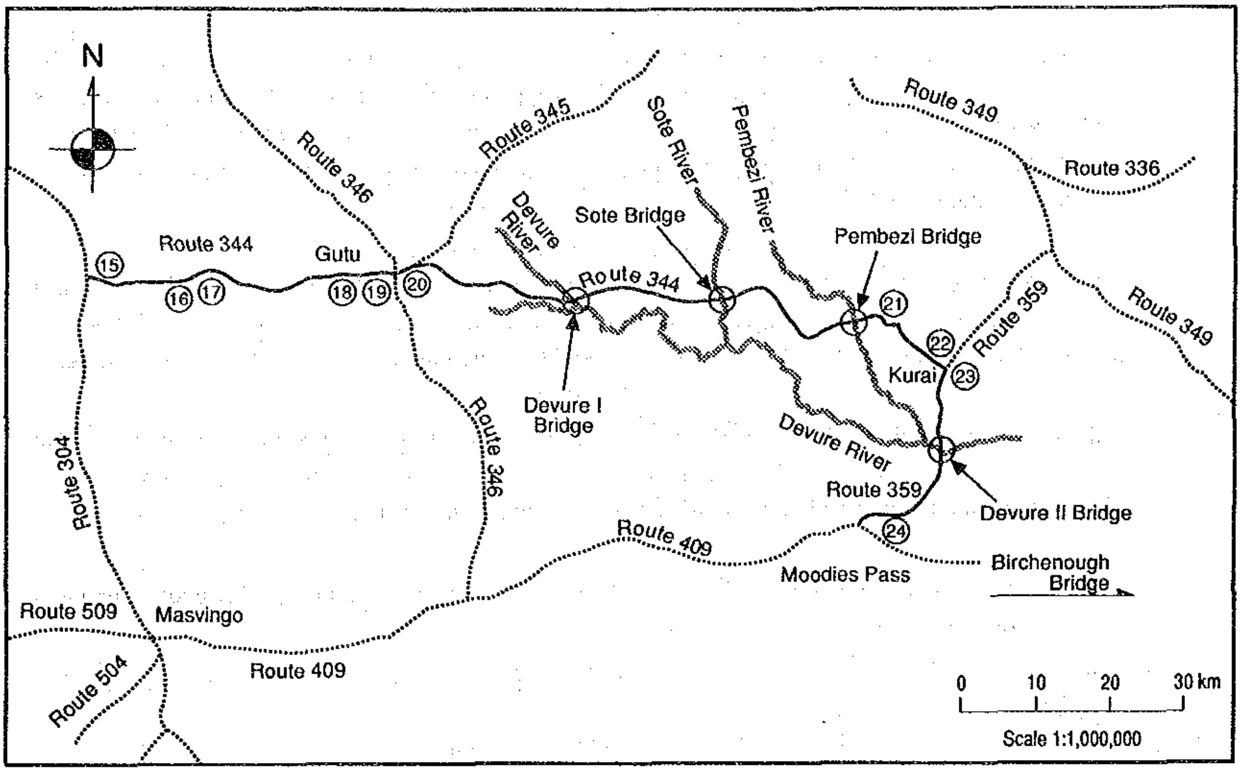



(a) Route 357

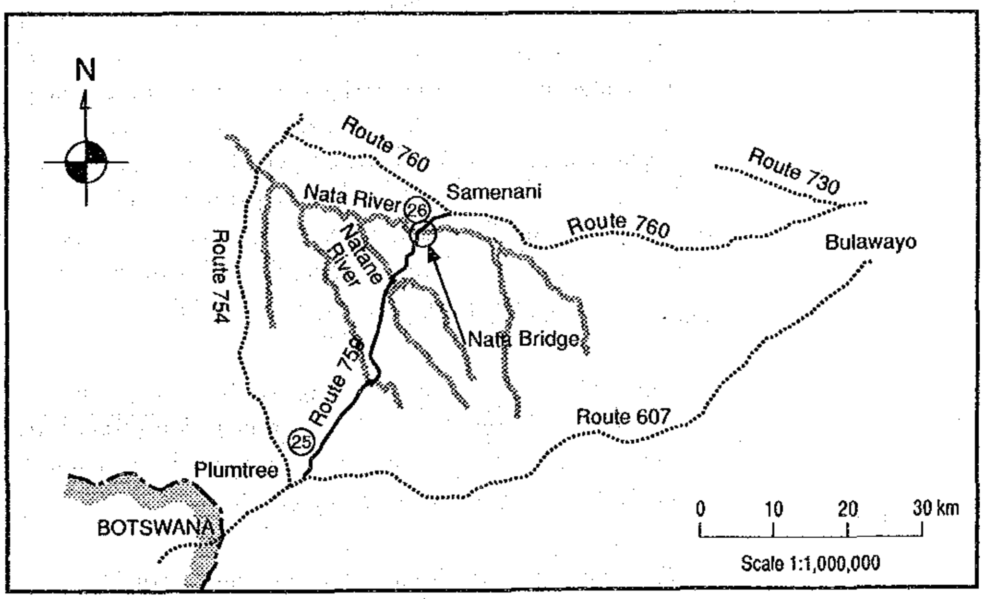



(b) Route 956

Fig. 2-1 (1) Location Map of Traffic Count Points




(c) Route 344 and Route 359




(d) Route 759

Fig. 2-1 (2) Location Map of Traffic Count Points

### 2.3.4 Geological Features

According to the Provisional Geological Map of Zimbabwe, Geological Survey, 1991, the geological condition of the country is as follows. The northwest area of Zimbabwe contains small areas of Precambrian granite, but is composed mainly of younger rocks. The east area of Zimbabwe consists mainly of granite and gneiss with relatively small, irregularly shaped inclusions of other rocks.

In the basic design study, geological investigation was carried out at five (5) bridge sites apart from the Odzi and Ungwe Bridges The drilling work was carried out on the site of each abutment and on the riverbed, thus a total of 3 drill holes per bridge site were made.

In general the bedrock is Precambrian Granite (2.65 billion years old) which is intruded by Dolerite dykes. The unconfined compressive strength of the slightly weathered or fresh bedrock is between 35 MPa and 61 MPa which indicates a medium hard rock.

The geological condition of each site is detailed below and the geological profile of each bridge site is shown in Figures 2-2 (1)~(5).

(1) Devure I Bridge (Route 344)

<u>Gutu Side</u>

The superficial deposit on this bank is composed of a loose light greyish brown homogeneous silty sand with pockets of organic plant remains. In certain areas this silty sand overlies a layer of compact, well graded slightly gravelly sand. The gravelly sand is underlain by the predominant overburden stratum across the site, composed of a stiff, dark grey and brown mottled, intact gravelly clay, with some subangular cobbles of quartz, feldspar, granite, and dolerite. Directly underneath the clay stratum is a dense dark grey silty sand, which yields some water. This deposit, in turn is underlain by a sound dolerite bedrock which was encountered at a depth of 6.4 m below the existing ground surface. The bedrock is composed of a greenish grey, slightly weathered dolerite which is very strong. It is in a fractured condition. The unconfined compressive strength of this rock is 42.4 MPa.

The dolerite is in the form of an intrusive sheet dyke and is relatively unaltered. The dyke extends along the centreline for an estimated 30 m towards the channel where it makes intrusive contact with the country granitic rock.

Groundwater exists 3.0 m below the ground surface.

<u>Channel</u>

The superficial deposit across the channel is composed of loose reddish-brown homogeneous coarse sand overlying a granitic bedrock in various stages of weathering which was encountered at a depth of 1.0 m below the existing ground surface. The unconfined compressive strength of this rock is 52.2 MPa.

Groundwater exists 2.6 m below the riverbed.

<u>Kurai side</u>

The surface of this bank is covered by a compact, greyish-brown silty sand. The silty sand is underlain by a very stiff sandy clay. Directly underlying the clay stratum is a yellowish brown coarse grained, moderately weathered granitic bedrock, which was encountered at a depth of 7.5 m below the existing ground surface. The bedrock is composed of a pinkish grey coarse grained, slightly weathered granite, which is very strong at a depth of 11.0 m below the existing ground surface.

Groundwater exists 3.2 m below the ground surface.

(2) Sote Bridge (Route 344)

<u>Gutu side</u>

This bank comprises a shallow reddish-brown completely weathered granite overlying a sound granitic bedrock whose weathering state varies from moderately weathered to slightly weathered. The upper 4.2 m of the bedrock is fractured and moderately weathered gneissic granite. The lower bedrock below 4.8 m is light brownish grey coarse grained, slightly weathered gneissic granite, which is very strong.

Groundwater exists 2.0 m below the ground surface.

<u>Channel</u>

Across the width of the channel the bedrock is covered by a coarse grained alluvial sand. The bedrock is just below the existing channel.

The unconfined compressive strength of this rock is 53 MPa.

Groundwater exists 0.8 m below the riverbed.

<u>Kurai side</u>

The superficial deposit on this bank is composed of an estimated 1.8 m thickness of compact dark brown, well graded silty sand. This deposit is underlain by a sound gneissic granite which is coarse grained, fresh, and very strong. The unconfined compressive strength of this rock is 50 MPa.

Groundwater exists 1.5 m below the ground surface.

(3) Pembezi Bridge (Route 344)

Gutu side

The superficial deposit on this bank is composed of an estimated 0.8 m of compact well graded silty sand. The slightly plastic granular deposit overlies a loose dark-brown, coarse sand. Directly underlying the coarse sand is a very stiff to hard silty clay with some cobbles and traces of gravel. This deposit, in turn, is underlain by a sound granitic bedrock which was encountered at a depth of 3.2 m below the existing ground surface. The bedrock comprises a pinkish grey, coarse grained slightly weathered granite. It is very strong with closely spaced joints. The unconfined compressive strength of this rock is 60.3 MPa.

Groundwater exists 3.0 m below the ground surface.

Channel

Across the channel the bedrock is overlain by an estimated 3.0 m of loose alluvial sand. The bedrock is pinkish grey, coarse grained, highly to slightly weathered granite.

Groundwater exists 2.8 m below the riverbed.

Kurai side

The surface of this bank is covered with an estimated 0.5 m of light grey, compact silty sand. The granular deposit is underlain by 4.5 m of pinkish brown, coarse grained, highly weathered granite. The highly weathered granite is underlain by a slightly weathered granite, the same as is on the Gutu bank.

The unconfined compressive strength of this rock is 50.5 MPa.

Groundwater exists 3.5 m below the ground surface.

(4) Devure II Bridge (Route 359)

Moodies Pass side

The superficial deposit on this bank is composed of an estimated 1.0 m of compact sandy gravel fill. The fill is underlain by a stratum of alluvial coarse sand. Directly underlying the alluvial sand is moderately weathered granite with very closely spaced joints at a depth of 4.0 m. Fresh granitic bedrock was encountered at a depth of 5.4 m below the existing ground surface. This bedrock is composed of dark pinkish-grey, coarse grained fresh granite, which is massive with widely spaced joints. The bedrock is of high strength with an unconfined compressive strength of 61.1 MPa.

Channel

Across the channel the bedrock is overlain by a loose pinkish brown, homogeneous subangular coarse sand with traces of gravel.

The bedrock is light pinkish grey coarse grained, fresh granite, which is very strong and massive with widely spaced joints and fissures.

The unconfined compressive strength of this bedrock is 35.1 MPa.

Groundwater exists 3.5 m below the riverbed.

Kurai side

The surface of the bank is covered with a layer of very dense, yellowish grey homogeneous silty sand, with occasional pebbles. Occasional granitic boulders were encountered throughout. The superficial deposit is underlain by very dense, light yellowish-brown, angular well graded sandy gravel, with occasional rounded quartz and dolerite pebbles. The thickness of this stratum is approximately 2.3 m. The bedrock was encountered at a depth of 6.3 m below the existing ground surface. The upper 4.5 m of this bedrock is in a fractured and moderately weathered condition. The lower bedrock is composed of dark grey, medium grained fresh dolerite, which is very strong and massive, with widely spaced joints and fissures. The unconfined compressive strength of this fresh dolerite is 47.3 MPa. The dolerite dyke extends an estimated 5 m, from borehole No. 4 along the centreline towards the channel where it makes intrusive contact with the granitic country rock.

(5) Nata Bridge (Route 759)

Bulawayo side

This bank is covered with loose, grey, homogeneous, medium grained granitic sand which is 0.4 m thick. The sand is underlain by fresh granite boulder which overlies a greenish white completely weathered granite. The bedrock was encountered at a depth of 1.3 m below the existing ground surface. The bedrock is composed of greenish grey, coarse grained fresh granite. It is of high strength with an unconfined compressive strength of 88.1 MPa.

Channel

Across the channel the bedrock is overlain by loose, brown, coarse grained sand. The bedrock was encountered at a depth of 2.7 m below the existing ground surface. The bedrock is massive and slightly to faintly weathered granite below 3.94 m, but it is traversed by fractures which are filled in by greenish white material.

The unconfined compressive strength of this rock is 54.6 MPa.

Groundwater exists 0.1 m below the riverbed.

Plumtree side

The surface of the bank is covered with a layer of loose, grey, homogenous granitic sand. The layer is 0.65 m thick. The superficial deposit is underlain by firm, greenish grey, coarse grained sandy clay with a thickness of 1.85 m. Below the sandy clay, at 2.5 m below the surface, dense medium grained, sand was encountered, with occasional quartz cobbles. Overlying the granitic bedrock is a 0.9 m thick layer of greenish white, coarse grained, completely weathered granite, with a total stratum thickness of 2.3 m. The bedrock was encountered at a depth of 5.7 m below the surface. The bedrock is composed of reddish pink, moderately weathered, fractured granite with a thickness of 1.75 m. The bedrock has a very high frequency of tight fractures which show oxidation surface staining and some are infilled by a fine greenish white material. 7.45 m below the surface the bedrock encountered was whitish pink, slightly weathered, coarse grained granite with a high strength giving an unconfined compressive strength of 19.6 MPa.

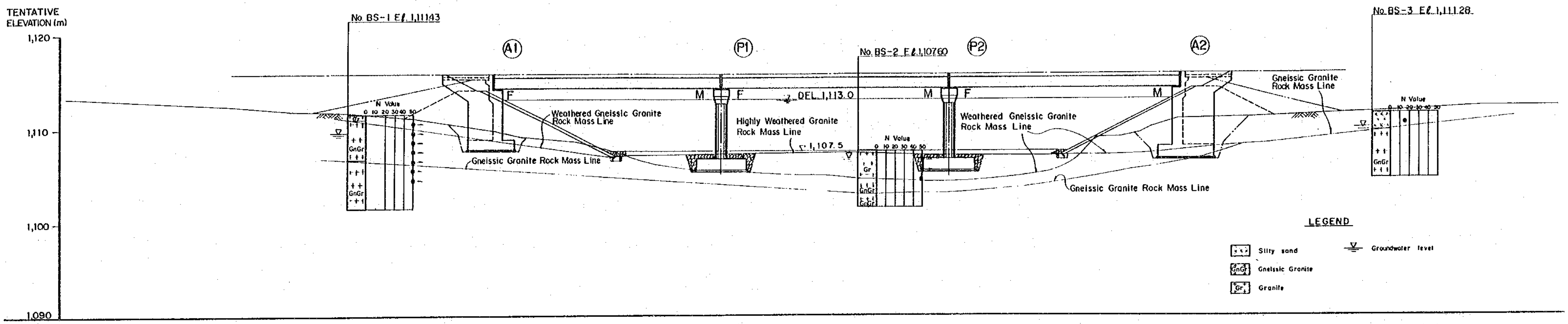
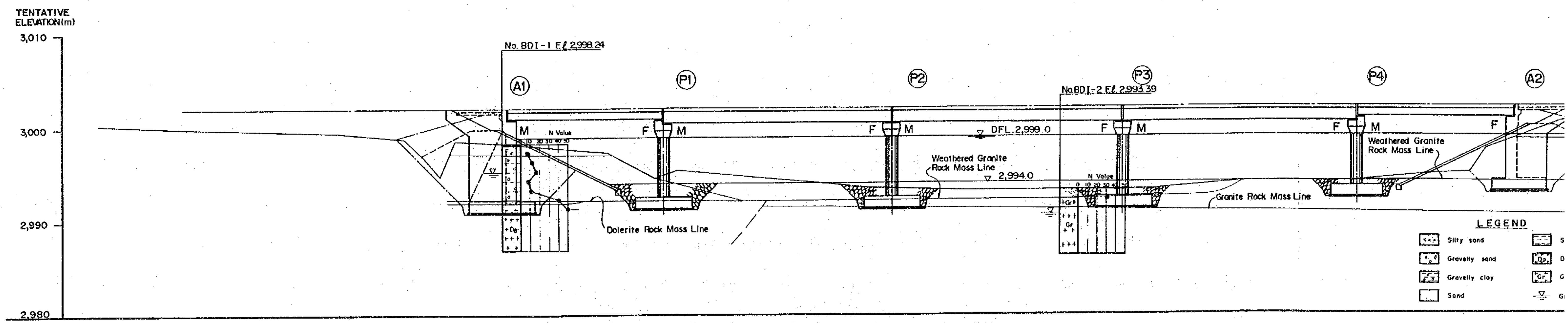



Fig. 2-2 (2) Geological Profile
Sote Bridge (Route 344) s= 1:400

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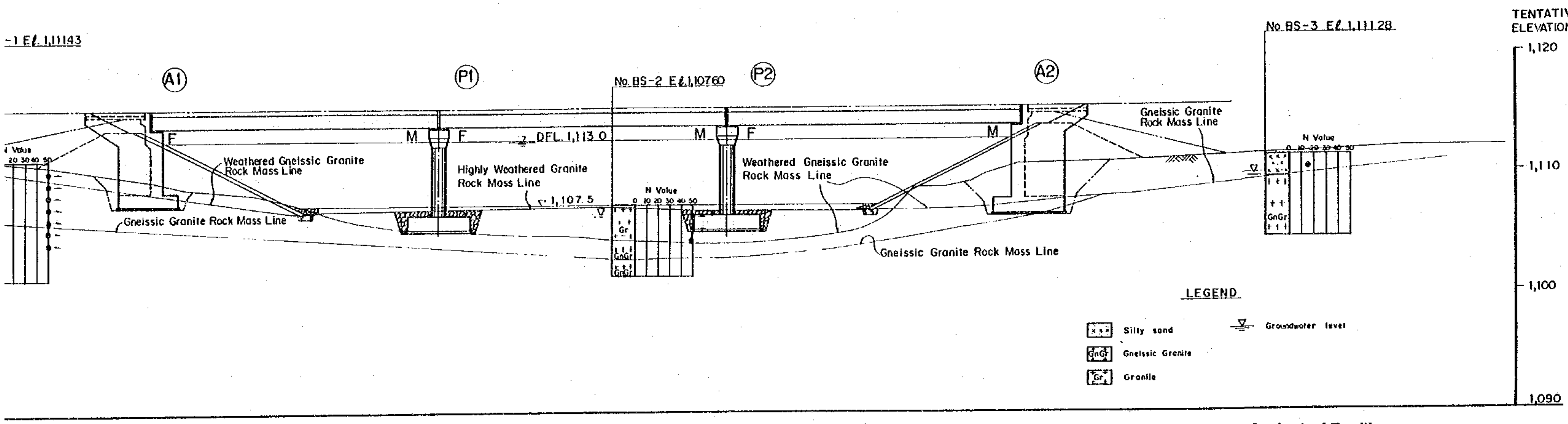



Fig. 2-2 (2) Geological Profile
Sote Bridge (Route 344) s= 1:400

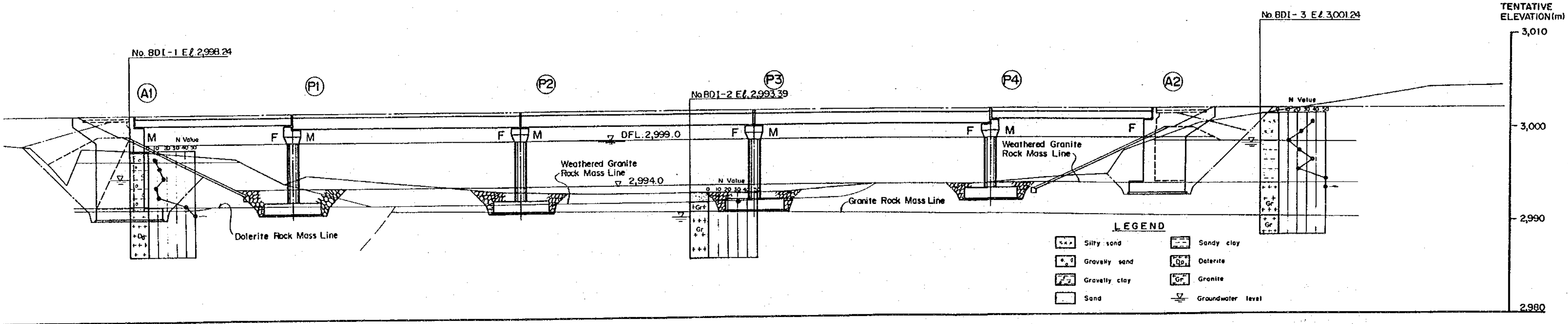
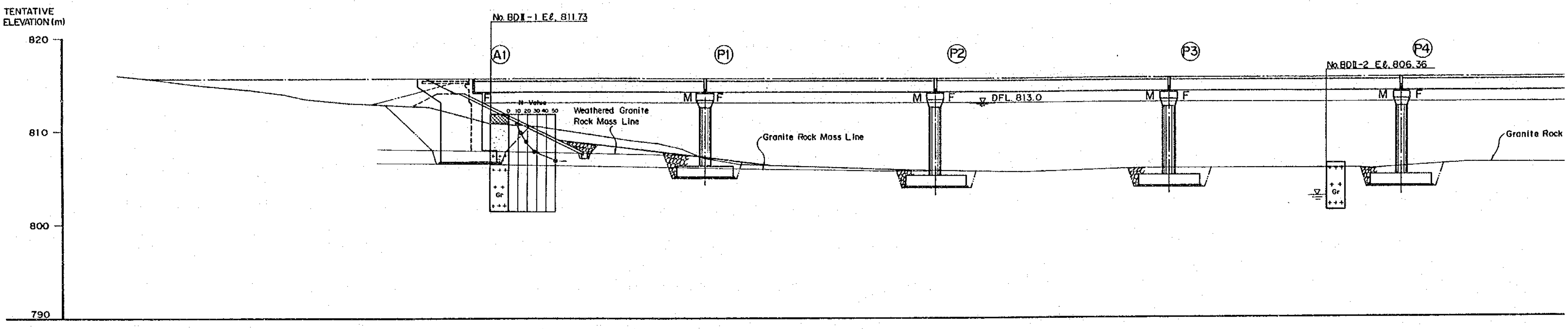
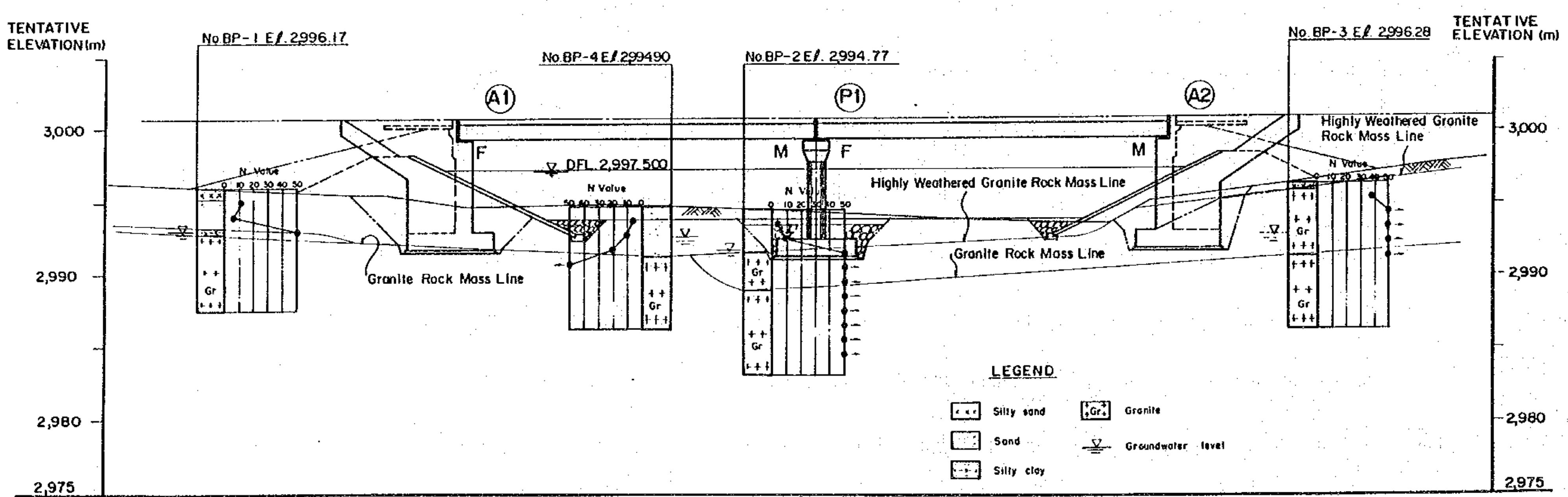



Fig. 2-2 (1) Geological Profile
Devure I Bridge (Route 344) s= 1:400



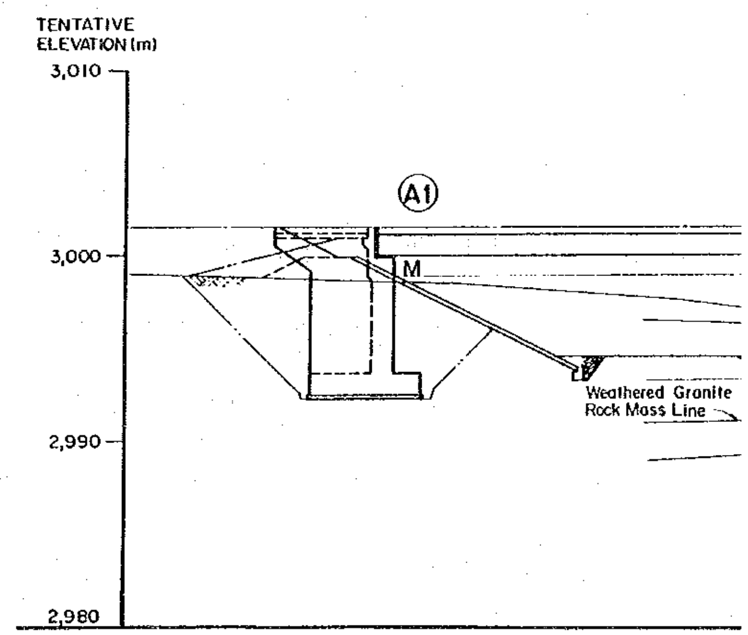




Fig. 2-2 (3) Geological Profile
Pembezi Bridge (Route 344) s= 1:400

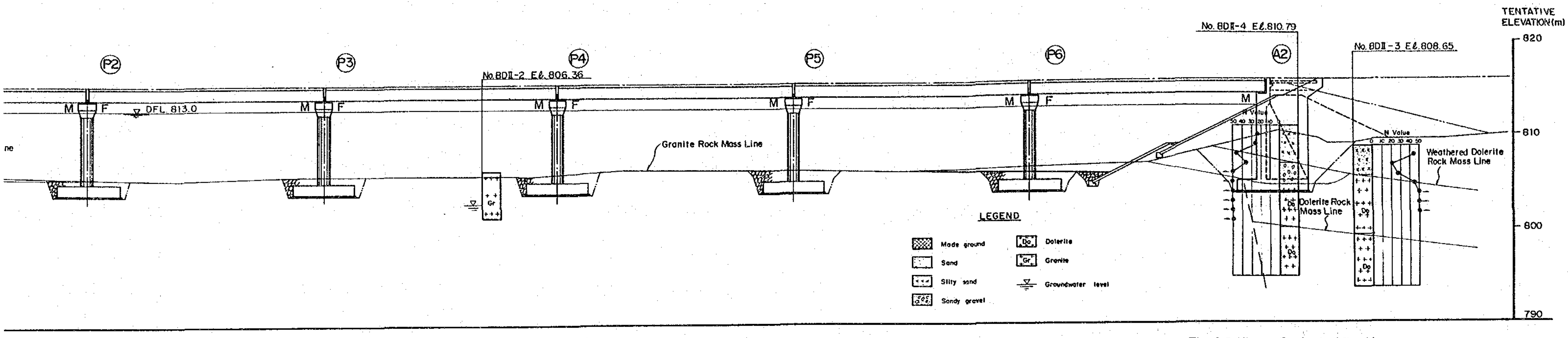
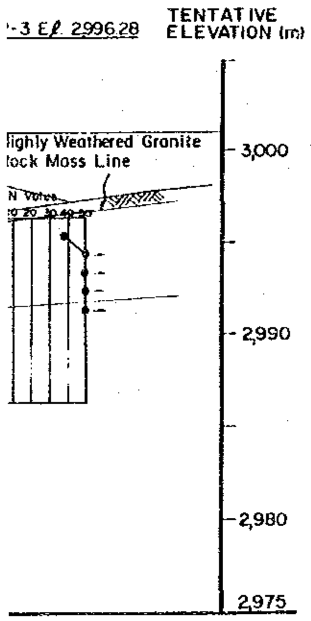



Fig. 2-2 (4) Geological Profile
Devure II Bridge (Route 359) s= 1:400




e 344) s= 1:400

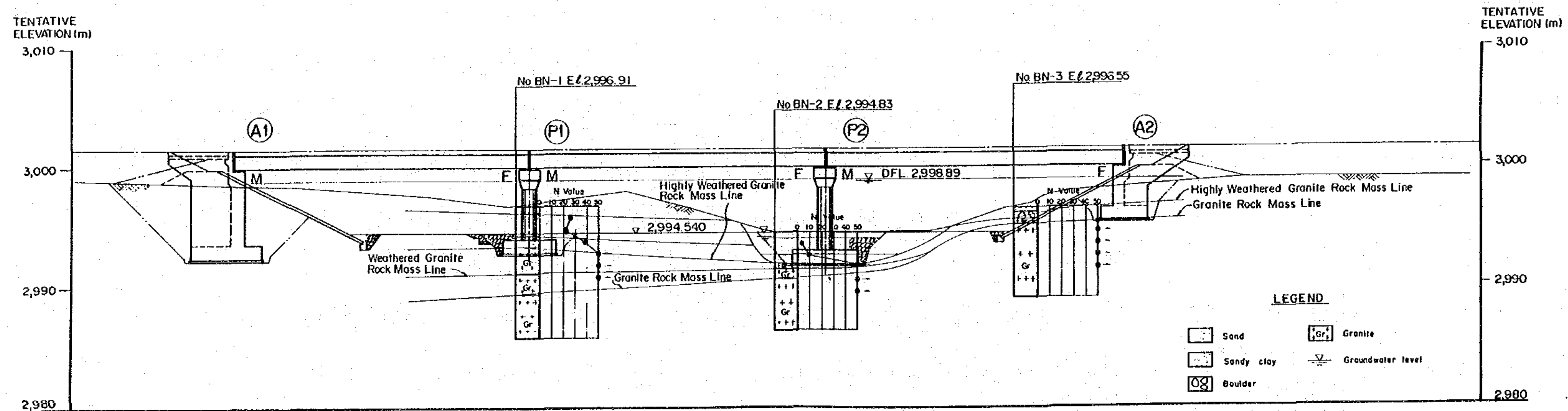



Fig. 2-2 (5) Geological Profile
Nata Bridge (Route 759) s= 1:400

# *Chapter 3 Outline of the Project*

# Chapter 3 Outline of the Project

## 3.1 Objective

Regional development in rural areas of Zimbabwe is one of the major targets set forth in SFYNDP (1991~1995).

The communal lands where living conditions are inferior, are widespread in the rural areas of Zimbabwe. The project areas, mainly in the communal lands, have been the main targets for regional development since independence of the nation, as these areas are vital for agriculture, and are densely populated areas. Though the road network is the fundamental infrastructure for supporting regional development, road network development is slow and faces many difficulties due to, mainly, shortage of funds.

The objective of the Project is to improve and rehabilitate the existing road facilities in the project areas, which are prone to inundation or malfunction in the rainy season, to all-weather type roads.

## 3.2 Study and Examination of the Request

JICA's basic design study team has studied and examined the request on each route concerning people's welfare in the communal lands, economic aspects, traffic conditions, and assistance to other development plans. Table 3-1 summarises the expected benefits by the implementation of the Project.

Table 3-1 Summary of the Expected Benefits by the implementation of the Project (1/2)

| Route 357 | Route 956 | Route 344 and 359 | Route 759 |
|---|---|---|---|
| • This route is the highest priority route which supports the communal lands of Chiromo, Chinyauhwera, and Marange. The route has some stretches where heavy vehicles have access difficulties because of the poor road conditions. The improvement of this route is expected to contribute greatly to the enhancement of the transport efficiency by bringing goods/products to/from the communal lands. | • This route connects Kadoma city, through Sanyati, and Gokwe Communal Lands and is an important route for the transport of farm materials. | • These routes connect Communal Lands in Gutu and Bikita, and are very important routes for transporting farm products and living materials. The government's grain deposit centers are located in these towns. The improvement of these routes is expected to effectively contribute to transport services for farm products and living materials. | • Along this road, 55.6 km long, there is only one school and one hospital. The improvement of the road is expected to contribute to the use of these institutions by the people in the communal land.<br>• The improvement of this route is also expected to contribute to the accessibility of the communal lands to Plumtree and Bulawayo. |

contd.......

Table 3-1 Summary of the Expected Benefits by the implementation of the Project (2/2)

| Route 357 | Route 956 | Route 344 and 359 | Route 759 |
|---|---|---|---|
| • The road width of approximately 6 m is narrow and this can be dangerous when large vehicles pass each other. In the rainy season sometimes the existing Odzi Bridge is flooded and unpassable. The improvement of this route is expected to contribute to securing stable life in the communal lands such as supporting transport and rescue activities in an emergency, securing school roads, securing medical services, and the stable provision of living materials.<br><br>• The area benefited by the improvement of the route is Bazeley town and other three towns. This area is a communal farming area mainly cultivating wheat, maize, and cotton. It is expected that the improvement of the road will greatly contribute to the regional economy. | • The area which will benefit most by the improvement of the route contains Goredema town and 8 other towns. The main economic activity of the area is agriculture, cultivating mainly cotton and maize. The improvement is expected to contribute to the stabilization of the transport of produce from farms, and accelerate regional development in the agricultural sector.<br><br>• The road improvement is also expected to contribute to securing commuter and school roads, securing medical services and the stable provision of living materials required in the communal lands. | • In the proposed area there are schools almost every 7 km along the road and six hospitals. The improvement of the routes is expected to contribute to the emergent medical activity.<br><br>• The main economic activity of the area which will be affected by the road improvement is agriculture. The improvement of these routes is expected to effectively contribute to the stabilization of transport for farm products and development. | • The main economic activity in this area, where the road rehabilitation will directly benefit, is agriculture including dairy farming. The improvement of the route is expected to effectively contribute to the stabilization of transport for farm products and support for future development plans. |

Regarding the equipment and materials which were requested by GOZ, as listed in Table 2-6, JICA's basic design study team has studied and examined as follows. As mentioned in Section 3.3.3, the total length of related road rehabilitation was estimated as 168 km.

(1) Equipment

Based upon the requested list, the basic design study team held several meetings with DSR staff concerned to clarify the required number and usage of equipment for the Project. The following were cleared through these meetings.

- Among the requested equipment, DSR gave priority to a motor grader, and a water tanker.
- Bulldozer with a large capacity such as 27 t is not necessary.
- A hand broom can substitute for a drag broom.
- A telescopic loader can be substituted by other equipment such as a wheel loader.

Some equipment such as a tyred roller without engine, a grid roller, and a water tanker without engine, were outdated, and not manufactured in Japan. Therefore these equipment were excluded from the list. On the other hand, equipment for the compaction work is essential for the road construction. So a vibration roller which is the most suitable equipment for the compaction of fill and pavement work, was added to the list. In order to execute smoothly the water related construction such as the drainage work, water pumps to divert the water flow will be required more numbers than DSR expected. The list of equipment and its numbers which will be supplied by GOJ, were finalised taking into consideration of above mentioned conditions.

During the construction, supporting equipment such as a truck (4 t class), a fuel bowser (around 2 $m^3$), or a pickup truck (1 t class) will be required to maintain, and utilise effectively the supplied equipment. The basic design study recommends GOZ to provide such supporting equipment in order to secure the smooth operation of the Project.

(2) Materials

Requested materials to be supplied by GOJ were steel corrugated pipes for culverts, and bitumen (asphalt) as shown in Table 2-6. Quantities of asphalt was estimated to cover the surfacing of 168 km in length and 8 m in width. The applied binder application rate was 2.72 litre/$m^2$. This rate was judged as appropriate, compared to the rate of approximately 3.0 litre/$m^2$ for the similar type of road in Japan, and considering the required service level of the project road.

Regarding the steel corrugated pipes, the basic design study team assessed the required number of pipes during the site reconnaissance of Route 357. Between the section from the existing Odzi Bridge to Marange, 25 km in length, 8~9 locations require pipe culverts of the following dimension and numbers:

Dimension : $\phi$1200 mm × 12 m, 2.0 mm thick (76 kg/m)
Number : 2 nos./location

When the above quantities was applied as average required ones of pipe culverts, the required quantities for the Project was estimated as follows:

$$76\ \text{kg/m} \times 12\ \text{m} \times 2\ \text{nos.} \times \frac{8\ \text{locations}}{25\ \text{km}} \times 168\ \text{km} = 98\ \text{t}$$

The basic design study recommends GOJ to supply 98 t of galvanized corrugated steel pipes for the related road rehabilitation.

## 3.3 Project Description

### 3.3.1 Executing Agency and Operational Structure

DSR of MOTE serves as the main implementing agency for carrying out road and bridge projects in the whole country. Its organization is depicted in Figure 3-1. The budget of MOTE, and the budget allocation of DSR to the construction and maintenance works, in the recent 3 years, were as listed in Table 3-2. The fiscal year in Zimbabwe is from July 1st to June 30th.

Table 3-2 MOTE and DSR Budget of Recent 3 Years

Unit:$\times 10^3$ Z$

| Fiscal Year | MOTE | DSR | | |
|---|---|---|---|---|
| | | Construction | | Maintenance |
| | | Road | Bridge | Road & Bridge |
| 1992/93 | 437,490 | 110,200 | 8,120 | 120,000 |
| 1991/92 | 459,477 | 97,900 | 4,500 | 75,000 |
| 1990/91 | 535,722 | 114,280 | 9,570 | 65,725 |

DSR is responsible for planning, construction, operation and maintenance of the national roads totaling 18,000 km including bridges. The Department has about 6,500 staff including labourers for the force account work. DSR headquarters has about 500 staff which are roughly classified into Engineers, Technicians, and Assistants. The engineers have graduated from universities, engineering training center, and others. DSR is comprised of three sections: planning, design, and operations under the director and each division is controlled by the deputy director.

The Planning Division is in charge of the cost/effectiveness analysis of the project, decisions on priority, collecting of necessary information for design, and obtaining funds from the Ministry of Finance. This Division contains the planning and transportation branch, the computer branch, and the engineering training center. The Design Division is in charge of designing roads and bridges based on the collection, analysis, and examination of necessary information and materials for the projects to be carried out with the least cost and maximum effect. The Design Division contains the testing and research branch, the road design branch, and the bridge design branch. The Operations Division is in charge of mainly construction, maintenance, and control for roads and bridges. The Operations Division contains the construction branch, maintenance branch, and eight Provincial Road Engineer Offices in the eight provinces.

The Provincial Road Engineer controls the Provincial Road Office which is in charge of construction and maintenance of roads and bridges in that province. The typical provincial organization is shown in Figure 3-2. Each Provincial Road Office consists of about 40 staff including 3~5 Engineers and 4 Technicians. The Provincial Road Engineer is assisted by four parties: personnel, accounts, road maintenance, and construction. Under the construction party in the office, construction units within the Province are also organized, if required, depending on the construction requirement. One construction unit has about 150- 200 staff in general. However, due to the recent budget restriction, half of the staff are available on a temporary contract basis.

After independence, most of the road construction works were implemented on a force account basis, but recently the works have also been carried out on a contract basis. Based on the field inspection at several job sites being carried out on a force account basis, it can be concluded that the quality of the work is good and acceptable.

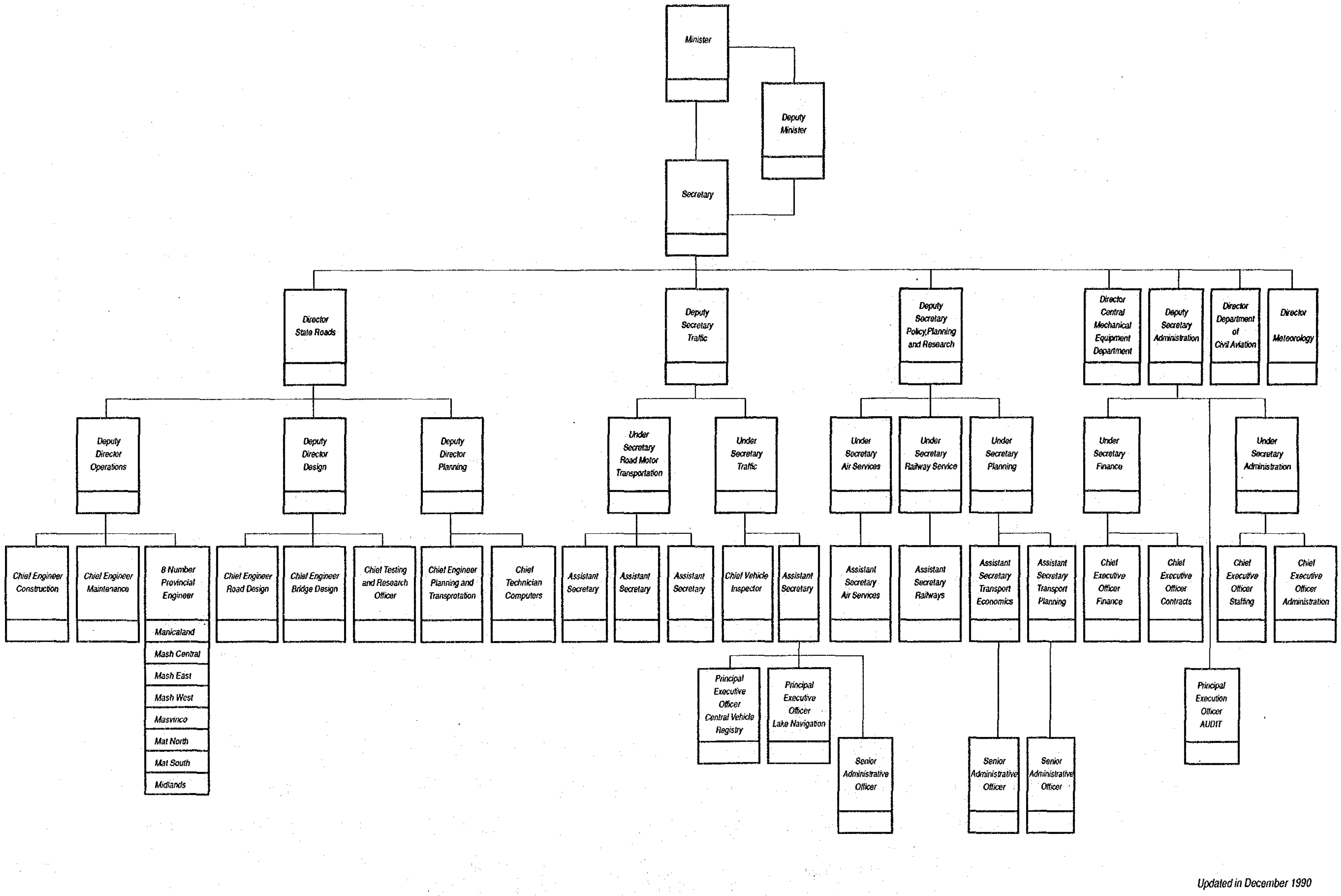



Figure 3-1 Organization of Ministry of Transport and Energy, 1990

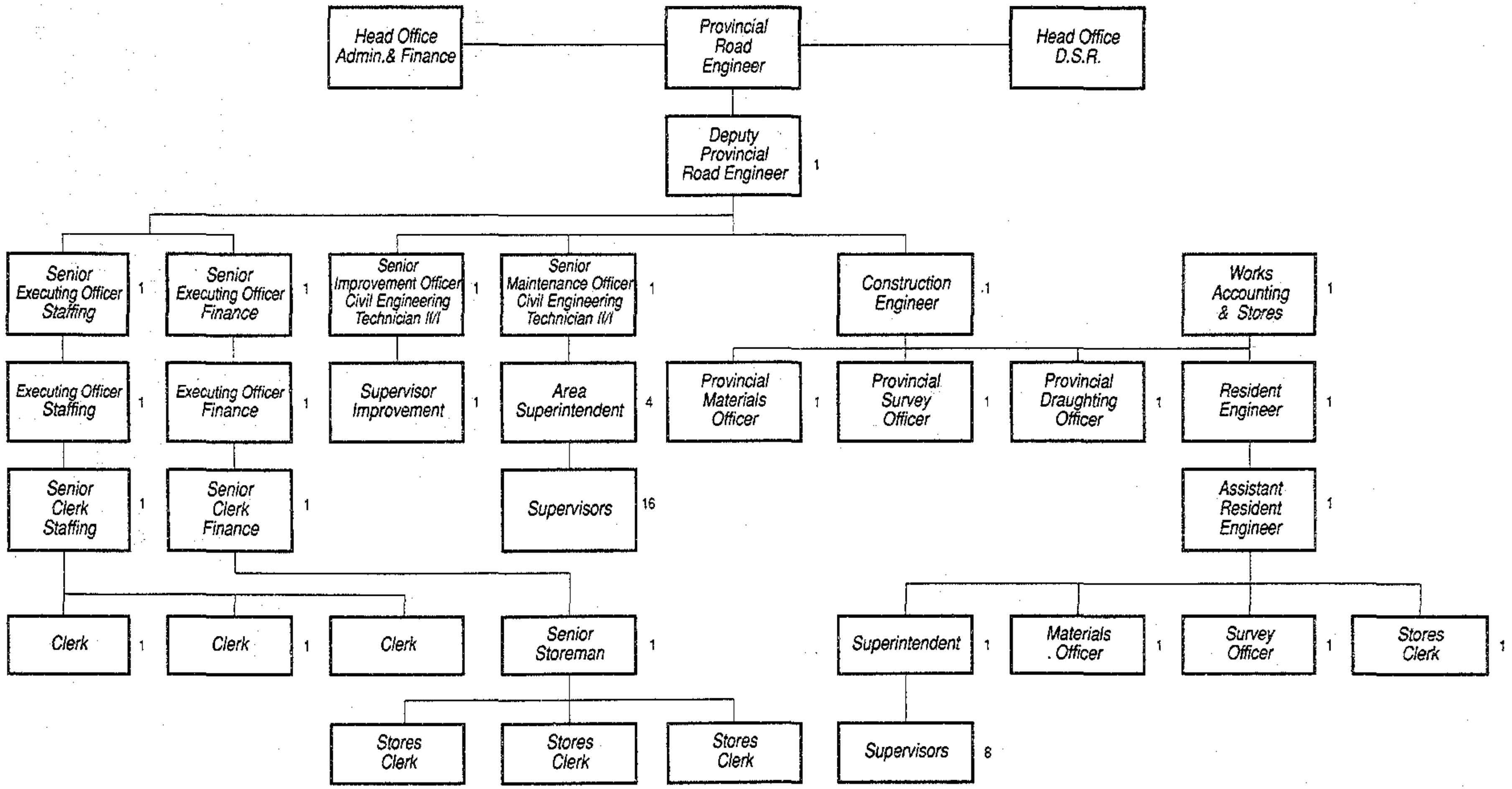



Fig. 3-2 Typical Provincial Organization of Department of State Roads

### 3.3.2 Formulation of the Project

(1) Principles

The following principles were applied to formulate the Project.

i) Objectives of the road rehabilitation will be Route 357, Route 956, Route 344, and Route 359. Regarding Route 759, the rehabilitation of existing road was excluded from the scope of the Project, except for the approach road to the new Nata Bridge, as agreed in the course of discussions with DSR at the second field investigation.

ii) Road alignment will, basically, follow the existing one as much as possible, except for the bridge sites.

iii) The road rehabilitation will be executed by the force account of Zimbabwean side, and the bridge construction will be implemented by Japanese side. Since the location of six bridges, except for Ungwe Bridge, was determined appropriate to shift from the existing bridges, approach roads from existing roads to new bridges shall be constructed. In order to open the new bridges to traffic after the completion as soon as possible, the construction of approach roads should be finished before or at the same time with the completion of the bridges. Therefore it was recommended by the basic design study to implement the approach road construction by Japanese side. The approach roads will be designed to connect the new bridges and existing roads in the shortest length fulfilling the required design criteria.

(1) Outline of the road design

i) Route 357

DSR finished the detailed design for the rehabilitation of this route, from the starting point at Route 409 (Primary Road) to CH. 12+000, and is preparing the design for the stretch from CH. 12+000 to the end point at Marange. The proposed new Odzi Bridge will locate approximately 150 m downstream from the existing one, at around CH. 11+400 on the new alignment. In this basic design study, the design of DSR will be applied except the formation height of the bridge which was raised up from the DSR's design height. the basic design study recommends to rehabilitate the whole section of this route by the Project, in order to realise the expected effect to the project area.

ii) Route 956

DSR finished the detailed design for rehabilitation of this route, dividing into two sections—from Kuwirirana to Nemangwe, and from Kuwirirana to Golden Valley via Sanyati. Based upon the field reconnaissance, the basic design study defined the length to be rehabilitated by the Project as 38.06 km. This section was once upgraded by DSR to a two-lanes gravel road including realignmnet. The purpose of the current DSR's design was the upgrading to the surfaced road. In this basic design study, the design of DSR will be applied except the formation height of Ungwe Bridge which was raised up from the DSR's design height. Since the proposed new alignment was almost same with the existing road's centreline, Ungwe Bridge will locates on the same place of the existing one.

iii) Route 344 and Route 359

The detailed design for upgrading Route 344 was not conducted by DSR yet. However the survey section of DSR carried out the route alternative study on the aerial photographs. Therefore the location of the proposed bridges were determined based on the said alternative study, having the meetings with staff concerned from the survey section. Since the proposed bridges will locate upstream or downstream of the existing ones, the construction of approach roads will be required. The priority of the road rehabilitation will be high at Gutu side, because the population was sparse at Kurai side, or traffic on Route 344 to Masvingo or Harare via Chivhu will use Gutu side more frequently.

The location of new Devure II Bridge on Route 359 was once identified on a aerial photograph. Then the final location of the bridge and approach road alignment were determined by the joint field reconnaissance with DSR staff.

iv) Route 759

The location of Nata Bridge on Route 759 was identified 20 m upstream from the existing structure (piped drift) on a aerial photograph, before the joint field investigation with DSR staff. Then the location of the bridge and approach road alignment were finalised at the project site, confirming any houses or properties will be not affected by the Project.

(2) Outline of the bridge design

Most of the existing bridges were the variations of drift structure such as a drift, piped drift, and arch causeway. During the rainy season, every bridge allows the overflow of flood, and cuts the traffic. In this basic design study, the proposed bridges were designed taking into account the design flood level and an appropriate free board, to secure the all year accessibility. Table 3-3 shows the outline of the bridge design.

Table 3-3 Outline of the Proposed Bridges

| Bridge Name | Route Number | Location | Number of Spans | Bridge Length | Bridge Type |
|---|---|---|---|---|---|
| 1 Odzi | (357) | 11+368 | 7 | 157.0 m | PC post-tensioned |
| 2 Ungwe | (956) | 17+813 | 2 | 49.5 m | PC post-tensioned |
| 3 Devure I | (344) | 68+435 | 5 | 107.0 m | PC post-tensioned |
| 4 Sote | (344) | 88+228 | 3 | 74.0 m | PC post-tensioned |
| 5 Pembezi | (344) | 114+158 | 2 | 49.5 m | PC post-tensioned |
| 6 Devure II | (359) | 15+776 | 7 | 173.0 m | PC post-tensioned |
| 7 Nata | (759) | 1+036 | 3 | 74.0 m | PC post-tensioned |

### 3.3.3 Project Features

On the basis of the basic design study results, it was recommended that this Project be executed by a combination of the following two systems:

(1) Construction of Bridges and Approach Roads

The construction, by the Japanese side, recommended by the basic design study is replacement of the seven bridges, i.e. the Odzi Bridge, Ungwe Bridge, Devure I Bridge, Sote Bridge, Pembezi Bridge, Devure II Bridge and Nata Bridge with a total length of 680 m. The total length of the approach roads of these bridges was estimated as approximately 15.2 km.

Table 3-4 Recommended Construction by GOJ

| Bridge Name | Route No. | Bridge Length (m) | Approach Road Length (m) | |
|---|---|---|---|---|
| | | | Left bank | Right bank |
| Odzi Bridge | 357 | 157.0 | 1,475 | 2,968 |
| Ungwe Bridge | 956 | 49.5 | 123.5 | 123.5 |
| Devure I Bridge | 344 | 107.0 | 1,258 | 585 |
| Sote Bridge | 344 | 74.0 | 328 | 498 |
| Pembezi Bridge | 344 | 49.5 | 3,762 | 1,158 |
| Devure II Bridge | 359 | 173.0 | 951 | 376 |
| Nata Bridge | 759 | 74.0 | 1,136 | 490 |
| Total | | 684.0 | 15,232 | |

(2) Provision of Equipment and Materials

The basic design study recommends that GOJ provides the construction equipment and materials for road rehabilitation of Routes 357, Routes 956, Routes 344, and Routes 359. These road rehabilitation are to be implemented by the force account of Zimbabwean side, by utilising the equipment and materials supplied by GOJ. The total length of theses routes to be rehabilitated was estimated as approximately 168 km, except for the sections which will be implemented by the Japanese side.

Table 3-5 Recommended Road Rehabilitation by GOZ

| Route No. | Length (km) | Road rehabilitation to be implemented (km) |
|---|---|---|
| Route 357 | 41.60 | 37.00 |
| Route 956 | 37.80 | 37.50 |
| Route 344 | 86.90 | 79.08 |
| Route 359 | 16.00 | 14.50 |
| Total | 182.30 | 168.08 |

The basic design study recommends the construction period of 5 years for the construction by Zimbabwean side, mobilising two construction units of DSR. This construction period was judged as appropriate to GOZ, taking into account the budgetary capacity of DSR (refer to Table 3-2), the construction speed/capability of construction units, and economical operation life of construction equipment which will be supplied by GOJ.

The following construction equipment and materials were judged as appropriate to be provided by GOJ, in order to accomplish the work by GOZ, taking into account the mobilisation of two construction units:

Construction Equipment

A Earthwork Equipment (Motor grader, Bulldozer, etc.)
B Compaction Equipment (Tyred roller, etc.)
C Supporting Equipment (Water tanker, Water pump, etc.)
D Pavement Equipment (Asphalt distributor, Chip spreader)
E General Equipment (Concrete mixer)

Materials

| | | |
|---|---|---|
| F | Corrugated steel pipe | 98 t |
| G | Straight asphalt | 3,650 $m^3$ |

### 3.3.4 Operation and Maintenance Plan

It has been estimated that the following type of maintenance work will be required after completion of the Project:

1. Repair and replacement ( about every 5~10 years) of the rubber expansion joints of the bridges
2. Cleaning around the rubber bridge bearings
3. Patching and overlay ( every 5 years) of the bridge surface
4. Repair of damaged river bank protection ( various defects due to local scouring, abnormal flooding)
5. Repair of damaged slope protection around the abutments ( Failure due to flooding)
6. Rehabilitation of the road surface ( about every 5~10 years)
7. Cleaning of the cross drainage structures
8. General road cleaning

It was one of the design policies of the study team to select the type of structures which need less maintenance works after completion. The service level in terms of maintenance to be applied depends on the importance of the links and traffic volume. In any case, however, it is quite important to carry out maintenance work at the earliest possible time in order to prevent aggravation of the deterioration. In view of the above points, it can be said that the maintenance works for items 1, 3, 4, 5, 6 and 7 are the most important out of all the work items.

The annual road maintenance cost per km in Zimbabwe is Z $ 2,000 on average according to the data obtained from DSR. Referring to this cost data and past experiences in similar road/bridge works under Japan's Grant Aid, the maintenance cost required after completion of the Project was estimated as follows;

| | | |
|---|---|---|
| Total maintenance cost during a period of 10 years | : | Z$ 1,750,000.00 (Japanese Yen 32.0 million equivalent) |
| Average annual maintenance cost | : | Z$ 175,000.00 (Japanese Yen 3.2 million equivalent) |

## 3.4 Technical Cooperation

As described in Section 4.2.2 later, it has been proposed in the Project to apply the PC post-tensioned girder type bridge, first introduction to Zimbabwe, instead of the reinforced concrete bridge which is the most popular bridge type in Zimbabwe. In the course of the site reconnaissance, the study team inspected the recently completed Unme Bridge, a reinforced concrete bridge, and found that the construction technique was good and acceptable. It is considered that the construction technique of concrete structures in Zimbabwe is of a fairly high standard compared to other African countries. Therefore, it is expected that the technology transfer of PC bridge construction to the counterparts will be carried out smoothly because they already have fundamental knowledge of concrete bridges. It was judged that technical cooperation such as the despatch of specialists was not necessary. On the other hand, it was recommended that some counterparts be invited to Japan in order to introduce them to Japanese bridge technology through training.

# Chapter 4 Basic Design

# Chapter 4 Basic Design

## 4.1 Basic Design Concepts

The following are the basic design concepts applied in the Study, taking into account the scale of the proposed bridges, experience of bridge construction in Zimbabwe, procurement of materials, accessibility to the project sites, maintenance aspects, etc.:

(1) Concrete bridges will be applied in principle in order to reduce the future maintenance cost after completion.

(2) Taking into account the aspect of technology transfer, the prestressed concrete girder type bridges by the post tensioning system will be applied, which will be their first introduction to Zimbabwe.

(3) Main construction materials for the concrete bridges such as sand, gravel, cement, and re-bars available in Zimbabwe will be utilized in the Project, while the PC tendon will be imported.

(4) To avoid a excessive mobilization of erection equipment, the appropriate girder length will be adopted .

(5) Fabrication of the girders will be carried out beside the project sites to shorten the construction period.

(6) Earthquake resistant design will not be considered in the bridge design, since the occurrence of earthquakes in Zimbabwe is very rare. However it was recommended that an adequate bridge seat width be provided from a bridge safety point of view.

(7) In general, the road network in Zimbabwe has been well developed and both the national and rural roads are well maintained. Accordingly, the basic design of new roads will be carried out in accordance with the road design manual prepared by DSR.

(8) Rehabilitation design for Routes 357 and 956 has been carried out by DSR. In the basic design study, the design results will be utilized as much as possible after careful review.

(9) The road rehabilitation plan for Route 344 is being conducted based on the aerial photos by the Survey Section of DSR. The Department's plan will be adopted within acceptable levels with regard to determination of the bridge site and project scope of the road rehabilitation.

(10) In formulating the rehabilitation plans, it is essential to minimize the relocation of houses and utilities such as power cables and telephone lines, and permanent houses which are located along parts of the project routes.

## 4.2 Study and Examination of the Design Criteria

### 4.2.1 Road Design Criteria

The road design of the Project will follow the "Manual:Part C:Planning" prepared by DSR. The following are the key design criteria for the Project.

- Typical Cross Section : 6/8 (8 metres surfacing)
  3 m of carriageway
  two-way two-lanes
- Design Speed : 80 km/hr
- Normal crossfall : 3 %
- Right-of-Way width : 31.75 m

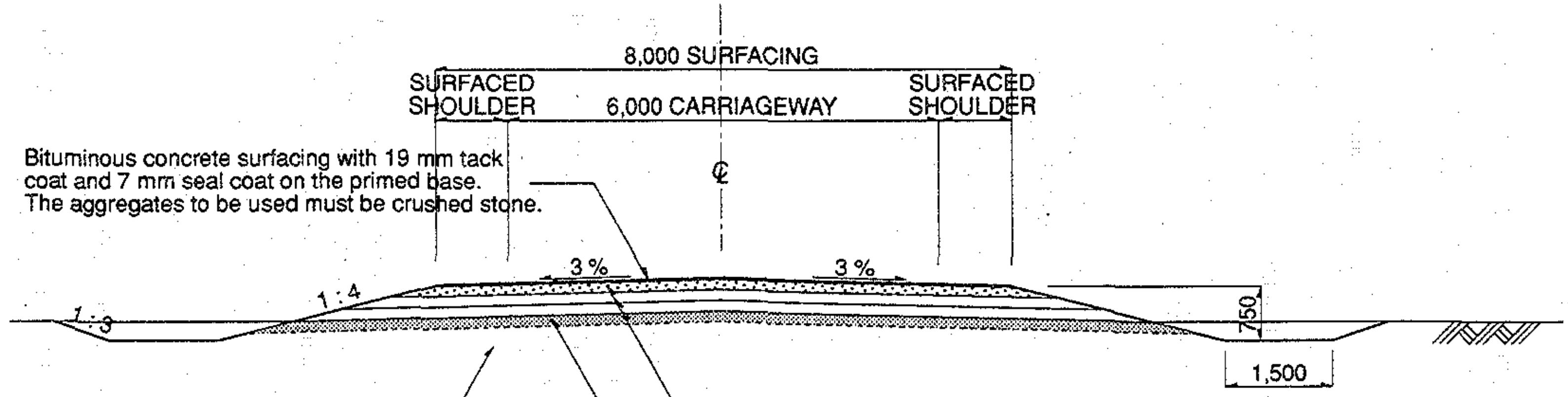
Figure 4-1 shows the typical cross section of the 6/8 road and Table 4-1 shows the major criteria for the geometric design taken from the "Manual : Part C : Planning."

Table 4-1 Major Geometric Design Criteria

| Item | | Recommended | Absolute minimum/maximum |
|---|---|---|---|
| Design Speed | | 80 km/h | |
| Maximum grade | | 5 % | 7 % |
| Minimum curve radius | | 270 m | 180 m |
| Minimum stopping sight distance | | 230 m | 140 m |
| Minimum passing sight distance | | 550 m | |
| Radius of vertical curve | for crest curve | 3000 m | |
| | for sag curve | 3000 m | |

| Superelevation | Radius of curve (m) |
|---|---|
| 3% | 1, 010~ 1, 900 |
| 4% | 720~ 1, 000 |
| 5% | 550~ 710 |
| 6% | 450~ 540 |
| 7% | 380~ 440 |
| 8% | 330~ 370 |
| 9% | 290~ 320 |
| 10% | less than 290 |

As for the pavement design, the minimum pavement layer thickness is defined in accordance with the Pavement Standards as listed in Table 4-2. The top layer of the pavement—Base 1—is to be cement treated.




Roadbed : The roadbed is the part of the ground surface uncovered by clearing the site, completion of the cuts, excavation, and removal of unsuitable material as required, on which the road structure rests.

Base I, II & III : Control compacted selected material in a natural, crushed or stabilised state. The top layer of the Base is generally treated by cement stabilisation.
The thickness and number of Base Layers are determined by the Pavement Standard, and by the design CBR assigned to a subgrade.

Subgrade : The subgrade comprises all materials, up to the underside of the pavement, placed on the roadbed and built into the road structure as specified.
If no such materials have to be placed on the roadbed, the top 150 mm of the roadbed will be referred to as the subgrade.

Fig. 4-1 Typical Cross Section of the 6/8 Secondary Road

Table 4-2 Minimum Layer Thickness

| Pavement Standard | Minimum Base Thickness (mm) | | Minimum Total Pavement Thickness (mm) |
|---|---|---|---|
| | Base 1 | Base 2 | |
| 3 M * | 150 | 150 | 450 |
| 1 M | 150 | 120 | 270 |
| 0.3 M | 120 | 120 | 240 |
| 0.1 M | 120 | 120 | 150 |
| 0.05 M | 120 | 120 | 120 |

* In the case of the Standard 3 M pavement, a minimum of three 150 mm layers of Base are specified.

- The Pavement Standards are based on the Design Traffic—the estimated number of equivalent 80 kN single axles per lane that the pavement is expected to carry during its design life. These Pavement Standards are designated as follows:

| Pavement Standard | Design Traffic [E80] |
|---|---|
| 3 M | 1 to $3\times10^6$ |
| 1 M | 0.3 to $1\times10^6$ |
| 0.3 M | 0.1 to $0.3\times10^6$ |
| 0.1 M | 0.05 to $0.1\times10^6$ |
| 0.05 M | Less than $0.05\times10^6$ |

### 4.2.2 Bridge Design Criteria

(1) Applied Standards

Applied standards for bridge design in the Study were the Specifications For Highway Bridges published by the Japan Road Association and the Design Standard of DSR, Manual Part JD published by MOTE. The former standard was applied to bridge structural design in respect of the loading conditions and analysis, and the latter was applied to bridge geometry and material requirements

(2) Bridge Width

In accordance with Manual Part JD 1.4, bridge width will comply with Type 5 which is 8.8 m in total, consisting of a 6 m double lane carriageway, 0.5 m shoulder, and 0.9 m footway on both sides. The normal crossfall was specified as 2.5 %.

(3) Design Loads

a) Principal Loads

(i) Dead Loads

Dead loads applied in the Study were as follows in accordance with Manual Part JD 3.5.

| | | | |
|---|---|---|---|
| Plain concrete | : 24 KN/m$^3$ | Reinforced concrete | : 25 KN/m$^3$ |
| Prestressed concrete | : 25 KN/m$^3$ | Backfill materials | : 20 KN/m$^3$ |
| Steel | : 78.5 KN/m$^3$ | | |

(ii) Live Loads

The first class loading complied with Specifications for Highway Bridges (SHB) in Japan was applied.

(iii) Impact

For impact effect due to the live load, following formula is adopted in accordance with the SHB.

$$i = \frac{10}{(25+L)}$$ where, L : span length in meters

(iv) Prestress

The initial prestressing force shall be 138.0 $kg/mm^2$

Instantaneous prestressing forces just after prestressing shall be calculated based on the following effects.

Elastic deformation of concrete

| | |
|---|---|
| Young's modulus | $3.1 \times 10^5$ $kgf/cm^2$ (For concrete class C50) |
| | $2.8 \times 10^5$ $kgf/cm^2$ (For concrete class C40) |
| | $2.5 \times 10^5$ $kgf/cm^2$ (For concrete class C30) |
| | $2.0 \times 10^6$ $kgf/cm^2$ (Prestressing tendons) |
| | $2.1 \times 10^6$ $kgf/cm^2$ (Reinforcement bars) |

Friction between prestressing tendons and sheath

$\lambda$=0.004 per a meter, and $\mu$=0.30 per a radian.

Slippage at anchorage

Effective prestressing forces shall be calculated with consideration of the following effects.

| | |
|---|---|
| Creep of concrete | : $\psi$=2.6 |
| Shrinkage of concrete | : $\varepsilon$=$20 \times 10^{-5}$ |
| Relaxation of tendon stress | : 5% |

(v) Earth Pressure

Earth pressure shall be calculated using Coulomb's formula, and surface surcharge and active earth pressure coefficient be 1.0 $t/m^2$ and 0.25 respectively. Shearing resistant angle of soil is $\phi$=35°.

b) Subsidiary Load

Thermal effect shall be considered in bearing design. Coefficient of thermal expansion shall be 10 x $10^{-6}$ per degree centigrade.

c) Particular load

Braking force complied with Design Manual Part JD 7.3.2 is applied as a horizontal force in substructure design.

(4) Material Strength

Material strength except those for PC tendons and the other special materials shall be complied with Manual Part P in principle.

a) Concrete

| Classification | Applicable Members |
|---|---|
| Class C50 (400 kgf/$cm^2$) | Main girders |
| Class C40 (320 kgf/$cm^2$) | Cross beams and deck slabs |
| Class C30 (240 kgf/$cm^2$) | Superstructure except the above members, and wall types of substructure |
| Class C25 (200 kgf/$cm^2$) | All the other reinforced concrete structure except above |
| Class C20 (160 kgf/$cm^2$) | Plain concrete |

Notes: Figures in ( ) shows strength tested using cylinder specimen.

b) Reinforcement Bars : Hot Rolled High Tensile Steel 410 N/$mm^2$
( Rectangular twisted re-bar)

c) PC tendon

- Tensile strength 12Ø7 mm : 155 kgf/$mm^2$ for the main girders
1T-19.3 : 190 kgf/$mm^2$ for the cross beams

### 4.2.3 Selection of Bridge Type

(1) Basic Concepts of Selection

An optimum bridge type was selected considering technology level concerning bridge design and construction in Zimbabwe, construction cost, appropriateness and economy of erection method, shortening overall construction period, river conditions, technology transfer in the Project and etc. Special attention was paid to shortening construction period so as to prepare a realistic and economic construction plan. Furthermore, possibility of usage of prefabricated girders and construction conditions during the rainy season were also taken into account in the bridge type selection.

(2) Bridge Type Selection

a) Preliminary Selection

Generally, bridge types can be divided into two categories, according to the materials they are made from: steel bridges and concrete bridges. For the Project, a concrete bridge is preferable to a steel bridge based on the following reasons:

- Maintenance and construction cost are relatively higher for steel bridges than for concrete bridges.
- Steel members would be fabricated in Japan or a third country in the Project, so there would be little technology transfer.

On the contrary, a concrete bridge offers several advantages that Zimbabwe has already gained experience with constructing concrete bridges, and local materials such as cement and reinforce bars can be used to a maximum extent, and employment opportunities would increase. Hence, a concrete bridge is basically applied in the Study.

Among the concrete bridges consisting of reinforced concrete (R.C.) bridges and prestressed concrete (PC) bridges, R.C. type bridges were discarded in the Study based on the following reasons, although R.C. bridges have been widely applied and well experienced in Zimbabwe.

- Almost no technology transfer through the Project
- Limited span length and consequently increasing the number of piers causes prolongation of construction period
- Inefficient workability during the period of rainy season due to provision of supporting required

Furthermore, a R.C. bridge with prefabrication system was also evaluated but discarded from economical viewpoint, since a large scale of erection equipment will be required in its erection, and from difficulty of the girder transportation during rainy season, in addition to the above reasons.

b) Optimum Bridge Type Selection

Through the above preliminary evaluation of all the conceivable alternatives, a PC bridge was selected as an appropriate bridge type from construction workability, maintenance, construction period, and technology transfer aspects in the Study.

PC bridges are subdivided into two types depending on prestressing system either pretension or post tension. The PC bridges with pretension system complied with BS are being fabricated with a maximum span length of 18 meters in Zimbabwe and applied in a wide extent. Possibility of adopting the pretension PC bridges in the Project was assessed but this type was rejected on the basis of the following reasons:

- Poor accessibility from the PC factories to the bridge sites, i.e. long distance and unpaved surface condition of access roads, especially for difficulty of transporting the beams during the rainy season.
- Less opportunity of technology transfer through the Project
- Limited span length and consequently increasing the number of piers
- Inefficient workability during the period of rainy season
- Lack of reliability of lateral load distribution

Finally, a PC bridge with post-tension system was selected as an optimum type in the Study based on the following reasons.

- Contribution of enhancing bridge construction technology in line with the present situation of that field in Zimbabwe
- Possibility of wide range span arrangement
- Efficient workability during the rainy season which shortens the construction period
- Less maintenance cost compared with that for the other bridge types
- Longer durability and higher reliability

c) Applicable Span Length

The PC post-tension bridge with a 24 m span length was selected as the most suitable bridge type which is applicable to all the bridge sites of the Project, taking into account smoothness of technology transfer, minimal construction cost, adaptability to respective bridge sites and sufficient bridge opening.

The respective aspects mentioned above for determining 24 meter span length are elaborated below:

<u>Smoothness of Technology Transfer</u>

It was judged that to provide the repeated training, concerning the standard methods of PC girder fabrication, prestressing, and erection, would be more effective to ensure acquirement of the technology transfer, than to train various methods. Thus, the same type, the same span length, and standard erection method are applied to all the bridge sites.

Minimal Construction Cost

Considering construction workability at the bridge sites where the water depth is considerably deep during the rainy season and the total cost required, a suitable erection method is by using an erection girder rather than by track cranes. In the erection girder method, the erection cost is governed by a weight of the erection girder, and its rented period. For up to 24 m span girder, a weight of the erection girder is about 21 ton and for the span length more than 24 m, the weight remarkably increases. Hence, it can be concluded that 24 m span length would be the most economical in this aspect.

Adaptability To Respective Bridge Sites

The total bridge length at each site has been determined as follows based on the flood runoff discharge and cross sections of the bridge crossing sites.

| Bridge Name | Approx. Bridge Length |
|---|---|
| Odzi | 160 m |
| Ungwe | 50 m |
| Devure I | 110 m |
| Sote | 75 m |
| Pembezi | 50 m |
| Devure II | 175 m |
| Nata | 75 m |

All the above bridge lengths indicated figures of multiplied by 25 roughly, hence a girder length of about 25 m is commonly applicable to all the sites with a few exceptional cases.

Sufficient Bridge Opening

In general, it is recommended that a minimum span length shall be more than 3~4 times as long as driftwood length. Referring to this empirical recommendation and the fact that the driftwood length measured at the bridge sites was approximately 5~6 m in an average, it is suitable to provide a minimum span length of about 24 m (4 x 6 m) to maintain smooth river flow.