NO.

BASIC DESIGN STUDY
ON
THE PROJECT FOR REHABILITATION
OF
TRUNK ROAD
IN
THE REPUBLIC OF GHANA

FINAL REPORT

DECEMBER 2002

JAPAN INTERNATIONAL COOPERATION AGENCY
KATAHIRA & ENGINEERS INTERNATIONAL

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PREFACE

In response to a request from the Government of the Republic of Ghana, the Government of Japan decided to conduct a basic design study on the Project for Rehabilitation of Trunk Road and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Ghana a study team from May 13 to June 13, 2002.

The team held discussions with the officials concerned of the Government of Ghana, and conducted field studies at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Ghana from September 2 to 8, 2002 in order to discuss a draft basic design, and as this result, the present report was finalized.

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 Ghana for their close cooperation extended to the team.

December, 2002

Takao KAWAKAMI
President
Japan International Cooperation Agency

December, 2002

Letter of Transmittal

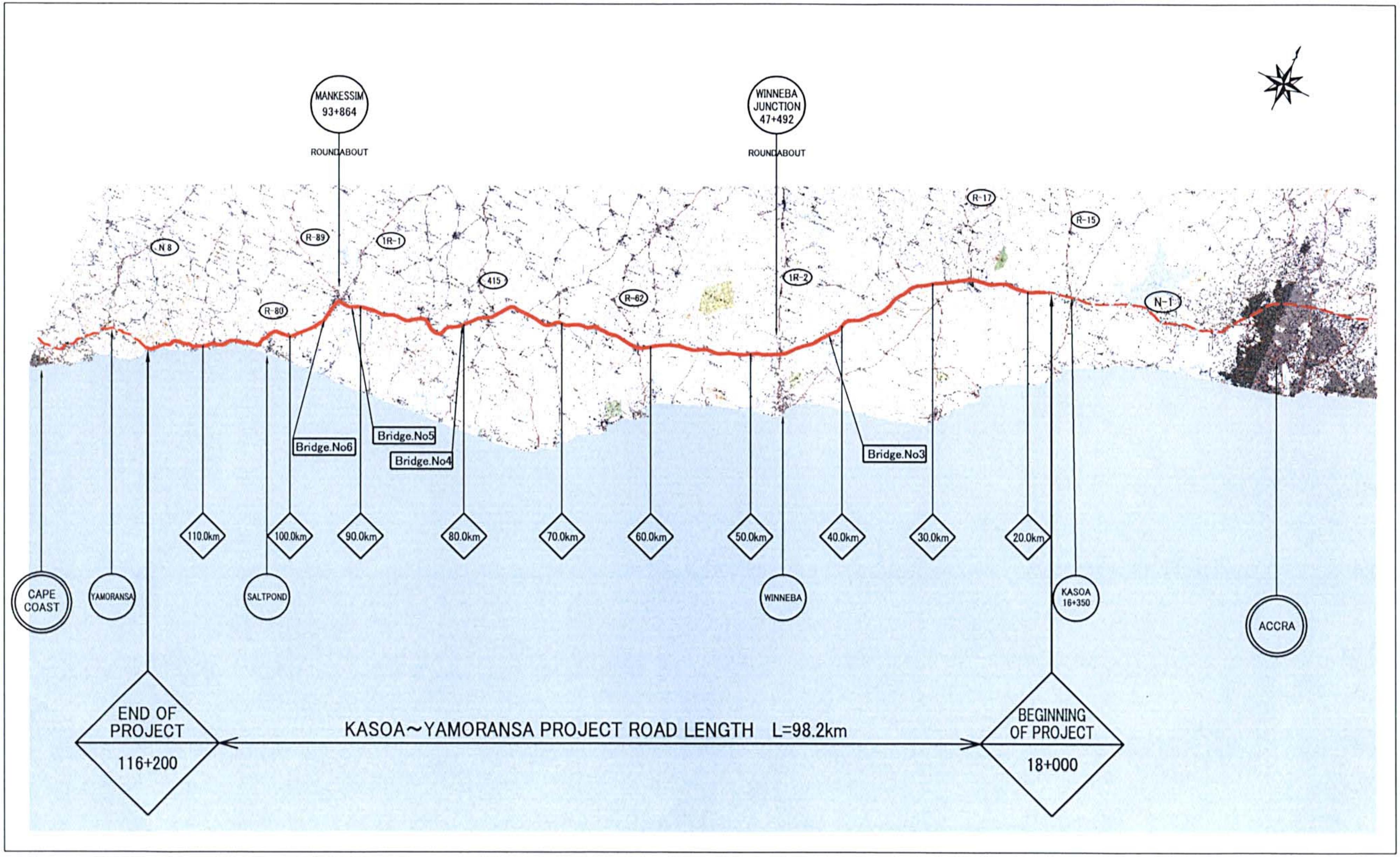
We are pleased to submit to you the basic design study report on the Project for Rehabilitation of Trunk Road in the Republic of Ghana.

This study was conducted by Katahira & Engineers International, under a contract to JICA, during the period from April 24, 2002 to December 20, 2002. In conducting the study, we have examined the feasibility and rationale of the Project, with due consideration to the present situation of Ghana and formulated the most appropriate Basic Design for the Project under Japan's grant aid scheme.

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

Very truly yours,

Minoru MIURA
Project Manager,
Basic Design Study Team on the Project for
Rehabilitation of Trunk Road
Katahira & Engineers International



Location Map of Study Section

PERSPECTIVE

ABBREVIATIONS

ADT	:	Average Daily Traffic
BP	:	Beginning Point
CBR	:	California Bearing Ratio
DBST	:	Double Bituminous Surface Treatment
DFR	:	Department of Feeder Roads
DUR	:	Department of Urban Roads
ECOWAS	:	Economic Community of West African States
EP	:	End Point
ESAL	:	Equivalent Standard Axle Load
GHA	:	Ghana Highway Authority
GDP	:	Gross Domestic Products
HDM	:	Highway Development and Management
HIPC	:	Heavily Indebted Poor Countries
IP	:	Intersection Point
IRI	:	International Roughness Index
JBIC	:	Japan Bank for International Cooperation
JICA	:	Japan International Cooperation Agency
NFRRMP	:	National Feeder Roads Rehabilitation and Maintenance Program
M_R	:	Resilient Modulus (psi)
MRT	:	Ministry of Roads and Transport
R	:	Radius
SN	:	Structure Number
VOC	:	Vehicle Operating Cost
W_{18}	:	Predicted Number of 18-kip Equivalent Single Axle Load Application

SUMMARY

Ghana has a land area of 240,000 square kilometers, which is about 2/3 of the area of Japan, with a population of 19 million inhabitants in 2002. The country has rectangular shape and is located on the coast of the Gulf of Guinea to the south, with Burkina Faso to the north, Ivory Coast to the west and Togo to the east. The project area is located on the southern part of the flat coastal area which is considered as a tropical zone with an average temperature ranging between 25℃ and 30℃. There are two rainy seasons from May to June and from September to October with an annual rainfall of about 900mm.

The economy of Ghana depends mainly on primary products with primary-product-type characteristics. Foreign currencies are obtained through exporting agricultural and mining products, such as cocoa, timber, diamond, gold, etc. Therefore, the economy is deeply dependent on international market prices. Since 1983, the country started to restructure the economy system by launching an Economic Recovery Program and GDP went up 50% in late 1980s to put the country as economically well-restructured compared with other Africa sub-Sahara countries. In recent years, however, the economy is meeting severe difficulties due to sluggish of international economy and low prices of gold, cocoa and other products and high prices of crude oil. The present government of President Kufuor started efforts to recover the bad economic conditions and took the decision to avail itself of the HIPC initiative for dept service relief.

The road sector in Ghana is under the responsibility of the Ministry of Roads and Transport. Under the ministry, there are the three agencies of Ghana Highway Authority, (GHA) Department of Feeder Roads (DFR) and Department of Urban Roads (DUR) that are responsible for roads based on their classifications. The Implementing Agency for this project is GHA that controls 13,277 kilometers of national roads, inter-regional roads and arterial local roads. About half of the roads under GHA are unpaved. The road section under this project is a part of National Highway No. 1 which forms part of Trans-African highway network system that includes Trans-ECOWAS highway network. Sections of National Highway No. 1 are being improved to international standards of arterial highways by other donor countries and international financing institutions. The section of the road under this project does not satisfy also the international standards.

Improvement of this road section will not only improve the living environment of local people but will largely contribute to the movement of people and goods in the country.

This project is to improve a length of 98.2 kilometers of the road between Kasoa and Yamoransa as a grant aid. The works include improvement of road geometry, widening of road shoulders and the provision of pavement and drainage system. The road design will consider not only the standard requirements but also safety and serviceability of the people along the road.

The first request by the Government of Ghana was to improve the road section between Accra and Yamoransa with a length of 116.2 kilometers. However, the 4-lane section between Accra and Kasoa with a length of 18 kilometers, which is required to be implemented in early stages, was awarded to the World Bank for improvement works.

The project road is designed in accordance with GHA Standards with the load limitations of ECOWAS Highway Standards. In some particular cases, however, the standards of Japan Road Structures and the geometric design parameters of AASHTO are applied. The outline of the Improvement Plan for the project road section between Kasoa and Yamoransa is as follows:

Outline of Improvement Plan

Length	98.2 kilometers
Width Configuration	2-Lane highway for the two traffic directions, with a lane width of 3.65m and the total width is ranging between 12.3m and 14.3m
Pavement Structure	Asphalt concrete pavement, mechanically stabilized crushed stone sub-base course, crusher run, and bituminous surface treatment shoulder
Drainage	Earth/stone/concrete side-ditch, box culvert, pipe culvert, improvement of bridge drainage system
Additional Facilities	Guardrail, guide post, road hump, road sign, road marking, bus stop, slope protection, roundabout, approach road

In case of implementing the project under the grant aid program, 5.5 months are required for the detailed design and 45 months for construction works.

The main impact and direct benefit of the project is as follows:

<u>Improving Transport Efficiency</u>

Improving the road will result in great savings in vehicle operating cost and will increase the road capacity for about 1.6 times up to the target year 2010.

In addition, improving the road will generate the following indirect benefits:

Improving Living Standards
The living standards of people in the road influence area will be improved through better accessibility to work, schools and healthcare facilities.

Improving Traffic Safety
The applied standards and safety facilities based on the travel speed, such as adequate horizontal and vertical geometrical alignments, enough sight distance, speed control devices and sign boards at villages, wide shoulders to separate motorized and non-motorized traffic, etc. will provide safer traffic on the road.

Reduction in Transport Cost
Smooth movement of traffic on the improved road will reduce fuel and maintenance costs, which will result in reducing transport cost.

Supporting Agricultural Development
Reducing the transport cost of agricultural products from farm to market with increased frequency, capacity and accessibility due to improved road will support agricultural development activities.

Activation of Regional Development
The increase in accessibility for traffic will result in higher land values and usability, which will lead to attracting new investments and development and will activate the regional economy.

Promotion of Tourism Activities
The road will improve traffic accessibility from the capital city of Accra to tourism and resort areas at Cape Coast.

Improving this important road will promote development not only on national level but it will generate direct benefits to local people along the road as well, as it will activate and contribute to regional and local economy and improve living standards of local inhabitants. Therefore this project is evaluated as appropriate to be implemented under Japan's Grant Aid. The Government of Ghana, however, has to carry out the land acquisition procedures and secure the required land in accordance with the implementation schedule.

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BACKGROUND OF THE PROJECT

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BACKGROUND OF THE PROJECT

National Road No.1 is a major trunk coastal road with a total length of 533 km in Ghana. The road connects the Great Accra Metropolitan Area with the borders of Ivory Coast in the west and Togo in the east.

The road section between the Capital City “Accra” and the city of Yamoransa was planned to be financed under Japan’s Yen loan but this financing scheme became later unavailable after the decision of Ghana to avail herself of HIPC initiative. Then, the Government of Ghana requested the Japanese Government to implement this road project under its Grant Aid Program.

In response to the request of the Government of Ghana, the Government of Japan decided to conduct a basic design study on the Project for Rehabilitation of Trunk Road in Ghana, and entrusted the Study to Japan International Cooperation Agency (JICA).

JICA dispatched the Preparatory Study Team on November 2001, which explained to the Government of Ghana the differences between the Grant Aid Scheme and Yen Loan Scheme and the review results of the project components.

At the beginning of the field survey by the Basic Design Study Team on May 2002, MRT withdrew the four-lane section from Accra to Kasoa from the previously requested road project for the Grant Aid. The section from Accra to Kasoa was advertised for the pre-qualification of consultants and contractors on May, 2002 under the World Bank financing. Therefore, this study for the Grant Aid Scheme is only covering the road section from Kasoa to Yamoransa, with a total length of 98.2 km.

Next, the Basic Design Study Team, dispatched to Ghana on May 2002, discussed with Ghanaian side on the agreement between the Preparatory Study Team and the Government of Ghana, confirmed the background, objectives and contents of the Project, collected relevant data, surveyed the project site and reviewed results of the project design and components under the Grant Aid Scheme and considerations on the road improvement level requested by the Ghanaian side.

After returning to Japan, the Study Team evaluated the Project based on the necessity, socioeconomic impact, appropriateness and other relevant factors and the basic design plans were drown up.

Members of the Study Team visited Ghana during July -August 2002 for the purpose of confirming procedures and tasks toward securing the land acquisition required for road improvement works.

As a result, the Draft Basic Design for the improvement of the road section, with a length of 98.2 kilometers between Kasoa and Yamoransa was proposed and explained by the Study Team to Ghanian side on September 2002. In addition, a member of the Study Team visited Ghana again on October 2002 to provide technical assistance in the site for the task of land acquisition. After explanations and consultations on the Draft Basic Design with concerned agencies, the Basic Design of the Project was developed as presented in this Final Report.

CHAPTER 2

CONTENTS OF THE PROJECT

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2.1 Basic Concept of the Project

The Project Road forms the southern leg of the Trans-Coastal ECOWAS Highway located within the Central Region of Ghana, where the extent of poverty is obvious. The project was previously planned to be financed under a loan extended by the Japan Bank for International Cooperation (JBIC). In view of the decision of Ghana to avail herself of the HIPC initiative, discussions between the two governments of Ghana and Japan concluded that Ghana would not have access to financing through the usual Yen loan for the implementation of this project. It has been noted, however, that the Japanese Government financing could take the form of a grant aid scheme, as the project will support the basic human needs of people, improve the daily life for inhabitants, support poverty reduction efforts and promote development of social and economic activities in the region.

Ghana has made efforts in reducing poverty since the early 1990s, particularly in urban regions and where exports such as cocoa, gold and timber are produced. As a result, the overall poverty rate fell from 51.7% in 1991/92 to 39.5% in 1998/99. However, poverty remains a systematic problem in Ghana, particularly in regions where it is closely linked to low access to basic transport infrastructure, health services and education. With a per capita of about US$300 in 2001, Ghana's income level remains below the average of sub-Saharan African Countries.

The project will promote agricultural and industrial development in the Central Region and other parts of southern Ghana with expected high increasing rate in productivity of the two sectors. This region has also the potential for enhancing other economic activities such as trade and commerce, tourism small-scale industries with the ultimate objective of reducing the levels of poverty.

2.2 Basic Design of the Requested Japanese Assistance

2.2.1 Design Policy

1) Basic Condition

a. System of Implementation of Road Improvement:

The road length to be improved under this project is 98.2 km located between 18+000 KM and 116+200 KM. The design standard applied for the improvement works of the road elements are those of ECOWAS Highway Standards in addition to Ghana Highway Authority Standards for Primary Roads its pavement manual of "Manual for the Design of Pavements, 1998".

The road has two lanes and the existing horizontal and vertical alignments will be utilized as long as they meet the standard limits and safety is provided. Sections that do not geometrically meet the applied standards will be improved and locations of frequent flooding will be raised. The existing pavement will be utilized as a sub-base and surface course with binder and base course, which are designed based on the forecasted future traffic volumes for 15 years after completion and results of CBR tests, will be applied. Bridges will be subject to repair works as their condition is still good and drainage facilities will be extended or replaced when necessary. Necessary traffic control and safety devices will be installed and other road facilities will be provided. All of the tasks of detailed engineering design and construction supervision will be carried out under adequate consulting services.

b. Construction under Japan's Grant Aid Scheme:

The road improvement activities and works to be implemented by the Japanese side are subject to the regulations of Japan's Grant Aid Schemes, in which a Japanese contractor will carry out the construction works under the supervision of a Japanese consulting firm. Construction equipment that will be imported by the Japanese contractor for the project will be taken out of the country after work completion. For local activities related to the project, local suppliers and contractors will be utilized and locally available materials will be used. A soft component for traffic safety and technology transfer activities including in-the-job training will be performed during the project implementation.

c. Existing Condition of the Project Road:
The road handles high traffic volumes and its condition in general is bad with high rates of traffic accidents. Market days provide more traffic volumes and congestion due to considerable decrease in road capacity.

The horizontal alignment of the road is acceptable in general as it meets the design speed criteria of GHA Standards. The project road will follow the existing alignment as much as possible and improvements at few locations will be carried out to assure safety on the road. The project area has both flat and rolling characteristics and the vertical alignment generally meets the design standard in accordance with the designated design speeds. However, some low sections that are subject to flooding require raising the road level. In addition, few sections of the road require improvement to increase the sight distance in order to assure traffic safety.

The existing pavement shows different types of deficiencies and deteriorations, including potholes, depressions, transversal/longitudinal cracks, localized failure sections, etc. Results of field surveys show that the existing pavement consists of 3 cm of DBST and a base course of approximately 15 cm in average.

The existing drainage facilities include a total of 267 pipe and box culverts. Some of the culverts with inadequate drainage capacity and will require complete replacement. Other culverts that have good condition and adequate drainage capacity will be subject to extension works to meet the new width of the road.

Other road facilities, such as the signing system and markings are not enough to provide safe driving conditions and required information for road users. Off-road bus stops will be provided to improve road capacity and increase safety levels.

2) Design Policy

The project road forms part of the Trans-African Highway Network System that includes Trans-ECOWAS highway network, as a section of the coastal highway that connects Ivory Coast and countries west of Ghana to Togo and countries east of Ghana, linking all countries along the coast of West Africa. Basically, the design policy for the project road is to apply ECOWAS Standard that is related to the design load and GHA Standards for the design of all other elements.

Based on the above-mentioned findings and different field surveys, the design policy is established to provide optimum utilization of a grant aid scheme that maximizes the project's socioeconomic impact and traffic safety.

Traffic Volume:

Traffic surveys were conducted on different sections of the project road to obtain the Average Daily Traffic (ADT) volumes. Next, a forecast procedure was applied to get the future growth rate and future traffic volumes of the target year 2020. At present, results of the traffic surveys show that the road handles daily traffic volumes ranging between about 4,000 to 9,000 vehicles.

Design Speed:

The applied design speeds are those of GHA Design Standards for 3 different areas as follows:

(Kph)

Area	Speed
Flat	100
Rolling	80
Populated	50

Road Width:

Based on the present traffic volume and future traffic volume forecast as well as the implementation under Japan's grant Aid scheme, the road width is designed for two lanes with a width of 3.65m for each lane. The shoulder width is 2.5m in rural areas and 3.5m in populated areas. The width of lanes and shoulders is based on the GHA Design Standards.

Pavement Structure:

As an international coastal highway, the project road is subject to high traffic volumes of both passenger and freight vehicles. It handles also heavy trucks that are transporting goods from ports and between neighboring ECOWAS countries. The pavement structure is designed to be composed of the following layers:

1. Asphalt Concrete Surface Course
2. Asphalt Concrete Binder Course
3. Base Course
4. Sub-base Course

The existing pavement of DBST (3 cm) and Base Course (15 cm) will be utilized as the sub-base course in the new pavement structure. ESAL is estimated based on the accumulative axle loads for 15 years (2006 – 2020) of future average daily traffic volumes with an annual growth rate of 6%. From Kasoa to Winneba ESAL is 16.64 million while between Winneba and Mankessim ESAL is 8.42 million.

Culverts and Drainage:
Drainage facilities that do not have adequate drainage capacity or in bad condition will be replaced. Other good condition culverts with adequate drainage capacity will be extended to meet the new width of the road.

Bridges:
There are 4 RC T-section type bridges along the project road, which are:

Bridge	Length	Location
Ayensu	38.4m	42+190 KM
Nakwa	36.9m	80+270 KM
Amisa	62.0m	92+424 KM
Mankessim	19.6m	94+061 KM

The main structures of the four bridges are generally in good condition, however, there is a need only for some rehabilitation and repair works to assure traffic safety on the road, in addition to pavement overlay that will be implemented also under this project. Other repairing works will include the pitching of the river sides at bridge locations.

2.2.1.1 Basic Policy

The basic policy for project implementation is established based on the following factors:

Role in Road Network:

The project road forms part of the Trans-African Highway Network System that includes Trans-ECOWAS highway network, as a section of the coastal highway that connects Ivory Coast and countries west of Ghana to Togo and countries east of Ghana, linking all countries along the coast of West Africa. In addition, the road connects also Accra to the port of Takoradi and plays an important role in the daily life of people in southern areas. It is the main coastal road in the country where both population density and concentration of socioeconomic activities are high.

Traffic Demand:

To determine the present traffic volumes on the project road, traffic count surveys for 24 hours of two successive working days were conducted at the different road sections. Then, counted volumes were calibrated by applying daily variation and monthly fluctuation factors to estimate the average daily traffic volumes of the year 2002. To estimate future traffic volumes on the road, the past trend of traffic growth was investigated, and growth factors and forecast approaches applied on other sections of the road were reviewed. In addition, growths in social and economic parameters that affect traffic growth were taken into consideration with expected shifted and induced traffic due to road improvement. The present and forecasted future traffic demands on the road, divided into three sections, are presented in Table 2.2.1-1 for the two years of 2002 and 2020.

Table 2.2.1-1 Present and Future Average Daily Traffic (ADT) of Project Road

Year	Average Daily Traffic (ADT)			Growth Rate (2002)
	Kasoa ~ Winneba	Winneba ~ Mankessim	Mankessim ~ Yamoransa	
2002	8,948	4,943	4,123	1.00
2007	11,974	6,615	5,518	1.34
2010	14,262	7,878	6,571	1.59
2015	19,085	10,543	8,794	2.13
2020	25,541	14,109	11,768	2.85

Socioeconomic Impact:

The improvement of the Project Road is expected to contribute to the socioeconomic development in the whole country especially in the southern areas and Central Region. Providing an efficient road for commodity flow and movement of people will promote economic activities such as agricultural and industrial sectors. It will enhance and the free flow of goods and people to foster socioeconomic integration of Ghana with neighboring countries. As a good condition road with required safety facilities, it will reduce both traffic accidents and travel cost and provide comfort to the traveling public.

The whole population of the country will benefit from the project indirectly, but the population that will benefit directly is that of southern areas especially the districts in the Central Region where the Project Road is located. Table 2.2.1-2 presents the expected beneficiary population in the future through the implementation of the project.

Table 2.2.1-2 Beneficiary Population ('000)

Population		2000	2010	2020
Ghana		18,740	23,944	30,048
Greater Accra Region		2,429	3,104	3,895
Central Region		1,532	1,958	2,457
Districts of the Project Road	Ewutu Efutu Senya	120	153	192
	Gomoa	181	231	290
	Mfantseman	182	232	292
	Abora Aseibu Kwamankese	82	105	132
	Cape Coast	115	146	184

2.2.1.2 Natural Conditions

Most of Ghana is made up of wooded hill ranges, wide valleys and low-lying coastal plains, though the northern third of the country is thick with rainforests. The country consists mostly of low-lying savannah regions, with a central belt of forest. A fair chunk of central Ghana was swallowed by Lake Volta in 1964, when the Volta River was dammed and the lake swelled to become one of the largest in Africa.

While Ghana's average temperatures show little variety - floating generally between 25°C and 29°C with extreme values that may reach 20°C and 33°C - it's the thick humidity that you'll remember. There are three rainfall zones. Along the coast, including Accra, the rainfall is light and the rainy season lasts from April until June with a short spell in October. In the interior forests, the rains are heavier and last longer. In the north, the weather becomes drier, with only one rainy season, which lasts from May to September.

At the area traversed by the Project Road, the geological characteristics at many places show old formations with Precambrian sediments of slate and granite outcrops. The dominated soils of the area consist mostly of red-brown clays and sand. Four major rivers running southward are traversing the road. Topographically, the project road runs through rolling and flat areas.

The climate in the project area is tropical with a very limited rainfall. The coastal savannas near Accra are the most arid parts of the country. The average rainfall increases westwards along the Project Road from about 850 mm in Accra to 1100 mm at the west. The mean temperature ranges 20 – 33°C along the Project Road.

2.2.1.3 Socioeconomic Conditions

Ghana is one of the most densely populated countries in West Africa. According to the 2000 population census, Ghana has a population of about 18.74 million inhabitants, which shows an increase of about 50% when compared with 1984 census population of 12.3 million inhabitants, which means an average annual growth rate of about 2.55%. The World Bank projections show that growth will slow till 2.3% during the next 15 years to reach about 24 million in 2010.

Economy of the country depends mainly on agriculture, which accounts for about 39% of GDP in 1999. Cocoa is the mainstay of Ghanaian economy contributing 26% of export earnings. In 1999 the economy of Ghana faced difficult situations due to the low prices of exported cocoa and gold with increase in prices of imported oil. That caused depreciation in the exchange rates and increase in inflation.

The project road passes through the central region south of the country with high population density and concentration of socioeconomic activities. The main economic activities of the project area are agriculture, fishing and tourism. Other activities that contribute to traffic on the road include trade and transport of passengers and goods, such as timber logs and cocoa from adjacent areas, as well as cargo from and to the seaports of Tema and Takoradi.

2.2.1.4 Construction and Procurement Conditions

Implemented projects under foreign assistance can import to the country required construction equipment on project-basis to be exclusively used for that particular project or funding agency projects.

As many of the required construction equipment are not locally available, such equipment will be imported to be used only for this project. In principal, all the locally available necessary equipment, materials, facilities and labors for different activities of construction will be utilized in the project. Items which are not available from local resources are planned to be procured from a third country.

2.2.1.5 Practical Use of Local Enterprises

A Japanese contractor will carry out the construction works of the project; however, all locally available resources will be utilized. Local contractors may participate in different related activities and local suppliers can provide required materials and facilities either locally produced or imported. In case of unavailability of some required items, such as guardrails that are not manufactured or locally available in Ghana, they will be imported from a third country.

2.2.1.6 Management and Maintenance Ability of Implementing Agency

After completion of the construction works, maintenance of the improved road will be managed by GHA. GHA will be fully responsible for all the required works of inspection, repair, maintenance, rehabilitation and management to keep the project road in a good condition for safe and efficient use.

After improving the road, durable pavement will reduce the time and cost for maintenance that could save considerable budget of state authorities. However, routine maintenance of the road and related facilities will be required and maintenance crews under GHA will be set up. In case of detecting significant defects or damages during routine maintenance, special maintenance procedures should be formulated based upon detailed field inspections.

There are some constraints, either budgetary or technical, that should be overcome as they may affect the performance of management and maintenance activities by GHA. GHA has reduced the number of employees from 8,500 in 1985 to 3,300 in 2000. The authority has been in the course of transiting from a labor intensive institution to a more cost effective and efficient management and engineering institution through a shift of its maintenance and construction works from “force account” to “contracting out” practice.

2.2.1.7 Establishment of Facility Grade

Basically, the road improvement measures are established so that the road elements meet with ECOWAS Highway Standards and GHA Standards. The Project Road is a link in ECOWAS Highway Network that connects 15 ECOWAS countries. Other links and sections of the network are improved by different donors and different financial systems. However, all the sections are basically improved to have the same standards and design characteristics in order to provide a homogeneous and safe transport network in the region.

2.2.1.8 Construction and Procurement Method and Schedule

Road construction techniques and methods that result in high quality roads will be applied. A Japanese contractor will carry out the construction works based on organized arrangements for all contractual, management and quality aspects of construction. For quality assurance in construction, all plans and specifications will stipulate many requirements to be met by test of materials and construction procedures. During construction, the safety of road users and workers will be carefully considered in addition to environmental consequences.

As for the procurement method for requirements of the project, all the locally available resources for necessary equipment, materials, facilities and labors for different activities of construction will be utilized in the project. Such items may be locally produced items or items imported from abroad. Items which are not available through local resources will be procured from a third country.

The implementation schedule is planned to give the optimum utilization of available funds and resources to complete the construction works and related activities in the shortest available period.

2.2.2 Basic Plan

The original length of the Project Road was 116.2 km, from Malam Intersection to Yamoransa, as requested by the Government of Ghana. However, the length of 18.0 km from Malam Intersection to Kasoa was decided to be implemented by I.D.A. and Ministry of Roads and Transport (MRT) of the Government of Ghana has withdrawn that particular section. Therefore, the actual study length is 98.2 km, from Kasoa to Yamoransa. For this reason, the initial plan to consider four lanes for heavy traffic sections was excluded because it would be applied for Malam Intersection～Kasoa section. Furthermore, Mankessim by-pass was excluded at the preliminary study stage as it does not meet the objectives of this grant scheme, and after discussions with MRT, excluding the bypass was reconfirmed.

Consequently, based on inventory data of the study section (98.2km), the results of environmental requirements and traffic volume survey, the basic plan was established to meet GHA Design Standards.

The National Highway No. 1 which includes the study section is specified as a link in the Trans-ECOWAS Highway Network, and other donors also took part in improving other sections of the highway. For this reason, meetings were held with the Implementing Agency of the Government of Ghana as much as possible, to discuss ways of coordination with other donors and standardization of the road.

2.2.2.1 Overall Plan

Table 2.2.2-1 shows a summary of the basic plan for the total section (98.2 km), which follows the design standard of GHA:

Table 2.2.2-1 Summary of Basic Plan

Items	Description
Classification of Road	Primary Trunk Road (Flat Terrain, Rolling Terrain, Populated Area)
Daily Traffic Volume - 2002/2020 (divided into three sections)	8,948/25,541 - 4,943/14,109 - 4,123/11,768
Design Speed	100kph (Flat Terrain), 80kph (Rolling Terrain), 50kph (Populated Area)
Number of Lanes / Lane Width	2-lane Road / 3.65m
Shoulder Width	2.5m (Rural area), 3.5m (Densely Populated Area)
Min. Horizontal Curve Radius	435m (Flat Terrain), 250m (Rolling Terrain)
Max. Vertical Gradient	6.0% Limited (Section Length)
Cross Fall (Carriageway)	2.5% / Max. Superelevation 6.0%
Cross Fall (Shoulder)	2.5%

Note: The value for 'Daily Traffic Volume 2002' is estimated based on actual survey records.

2.2.2.2 Road Alignment

In view of the function of the existing road, the alignment was designed to follow the existing center line as closely as possible and will be taken towards the environmental and cost factors of construction.

(1) Horizontal Alignment

The minimum horizontal curve radii in the existing road is located at small sections of rolling terrains or in the villages is within standard of designed speeds respectively.

- The Standard of GHA for the minimum horizontal curve radii is as follow:

Topography	Design Speed	Minimum Curve Radii (Superelevation 6%)
Flat Terrain	100 kph	435 m
Rolling Terrain	80 kph	250 m
Village	50 kph	90 m

- There are 19 sections with small horizontal curve radii (R is below 450m, 19 locations) as presented in Table 2.2.2-2.

Table 2.2.2-2 Sections below 450m of Horizontal Curve Radii

No.	IP No.	Point (STA No.)	Topography	Designed Speed (kph)	Horizontal Curve Radii (m)	Regulated Min. Curve Radii (m)
1	IP-89	101+449	Rolling Terrain	80	350	250
2	IP-91	102+657	Village	50	300	90
3	IP-92	102+973	Village	50	350	90
4	IP-93	103+704	Village	50	310	90
5	IP-98	106+577	Village	50	440	90
6	IP-100	107+171	Village	50	250	90
7	IP-101	107+322	Village	50	320	90
8	IP-102	107+966	Village	50	380	90
9	IP-103	108+286	Village	50	340	90
10	IP-106	110+408	Village	50	320	90
11	IP-108	111+355	Village	50	340	90
12	IP-109	112+271	Rolling Terrain	80	350	250
13	IP-110	112+865	Rolling Terrain	80	350	250
14	IP-111	113+481	Rolling Terrain	80	400	250
15	IP-112	114+457	Village	50	380	90
16	IP-113	114+565	Village	50	350	90
17	IP-114	114+955	Village	50	340	90
18	IP-115	115+555	Flat Terrain	100	450	435

As shown in Table 2.2.2-2, some relatively small horizontal curve radius are found intermittently towards the end, but they all satisfy the design standard. Moreover, verification of the sight distance and the curve length were carried out, and it was found that they meet the values in the design standard.

Figure 2.2.2-1(1)～(3) show a rough sketch of the horizontal alignment elements in relation to the adopted design speed.

(2) Vertical Alignment

The vertical alignment of the Project Road is also in a good condition and it is possible to maintain most of the present alignment. In some areas, the vertical gradient is greater than the standard gradient, but it still satisfies the limitation length under the design standards.

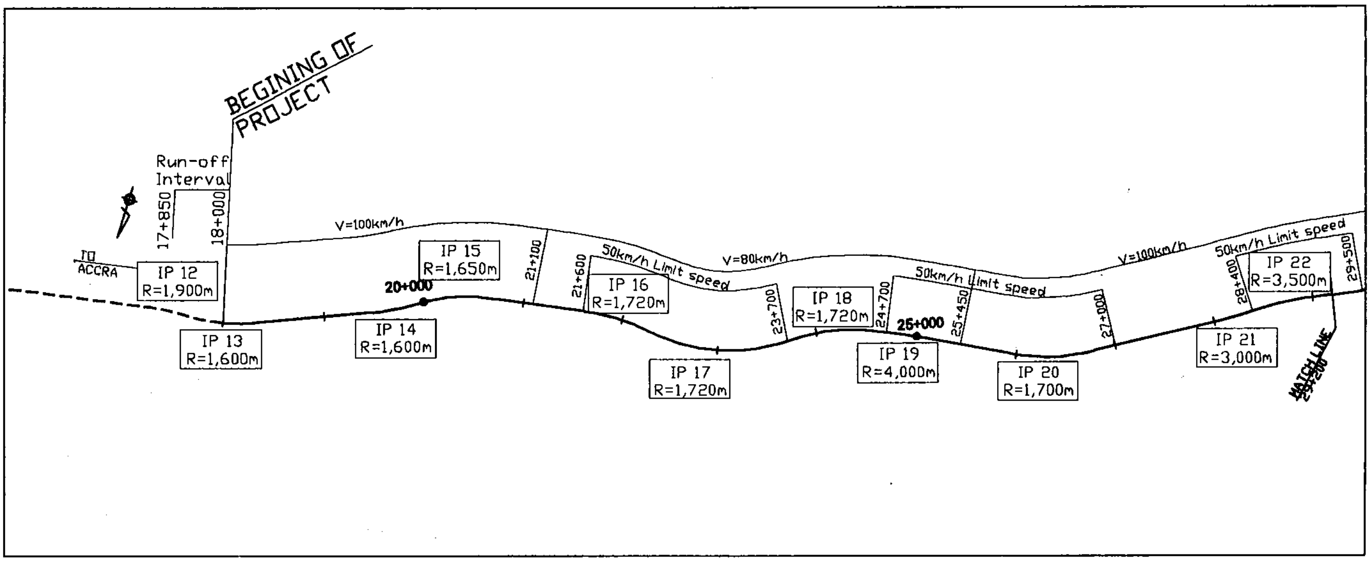
- GHA Standards for vertical alignment is as follows:

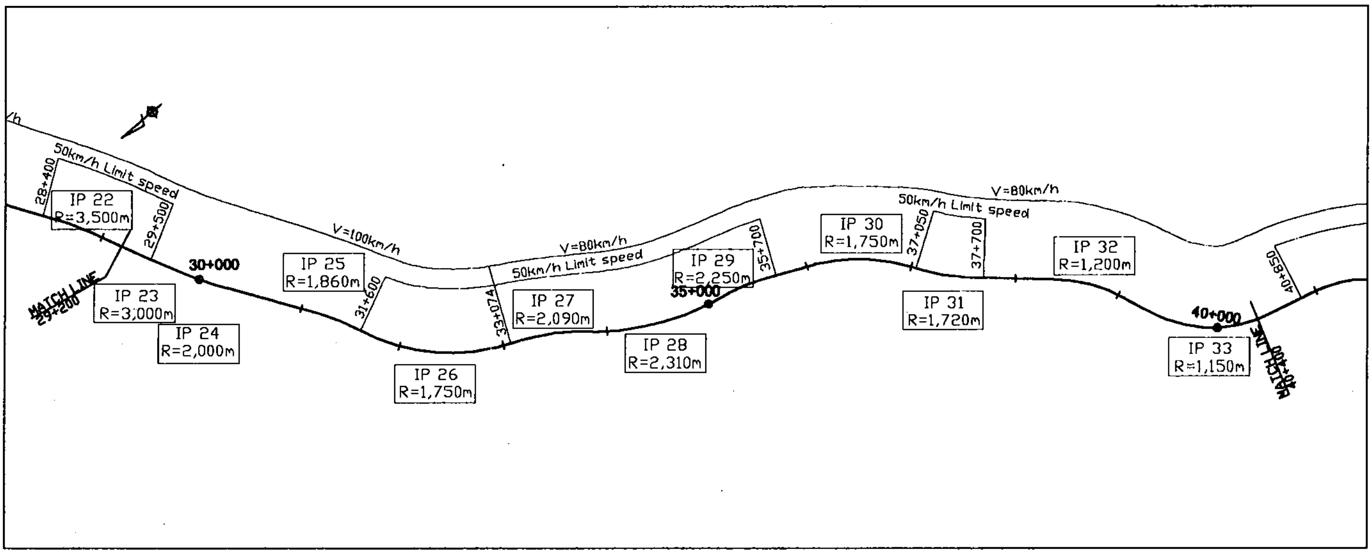
Design Speed	Standard Gradient	Exemption Value	
		Gradient	Max. Distance
100 kph	3%	4% 5% 6%	700m 500m 400m
80 kph	4%	5% 6% 7%	600 500 400
50 kph	6%	7% 8% 9%	500 400 300

There are 34 areas where the vertical gradient exceeds 3% as shown in Figure 2.2.2-1 (2) and Table 2.2.2-3.

- The vertical alignments (2.0%～3.0%) are found intermittently towards the end of the Project Road near Yamoransa, but they all satisfy the GHA Standard. Moreover, verification of the sight distance and the curve length were carried out, and it was found that they meet the values in the design standard.

- Flood Section Measures
  As there are 11 sections subject to flooding, for which measures are taken, such as raising the plan elevation higher than the existing road level, providing cross culverts and drainages. The flood sections are shown in Figure 2.2.2-1 (2) and Table 2.2.2-4.





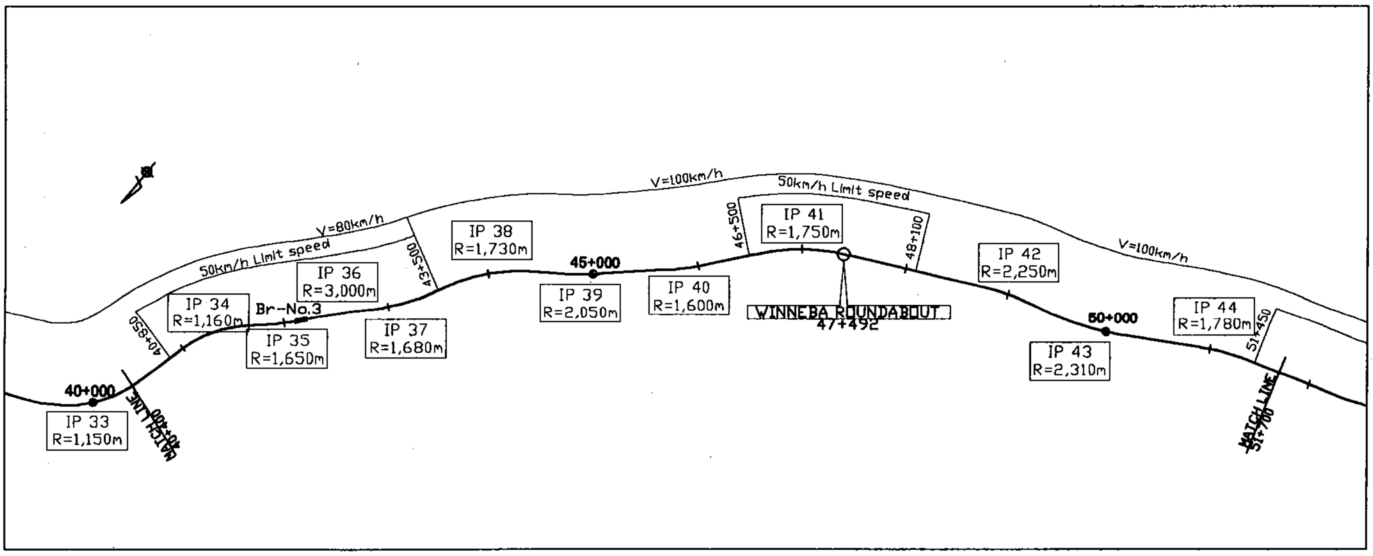


Figure 2.2.2-1 HORIZONTAL ALIGNMENT AND DESIGN SPEED (1)

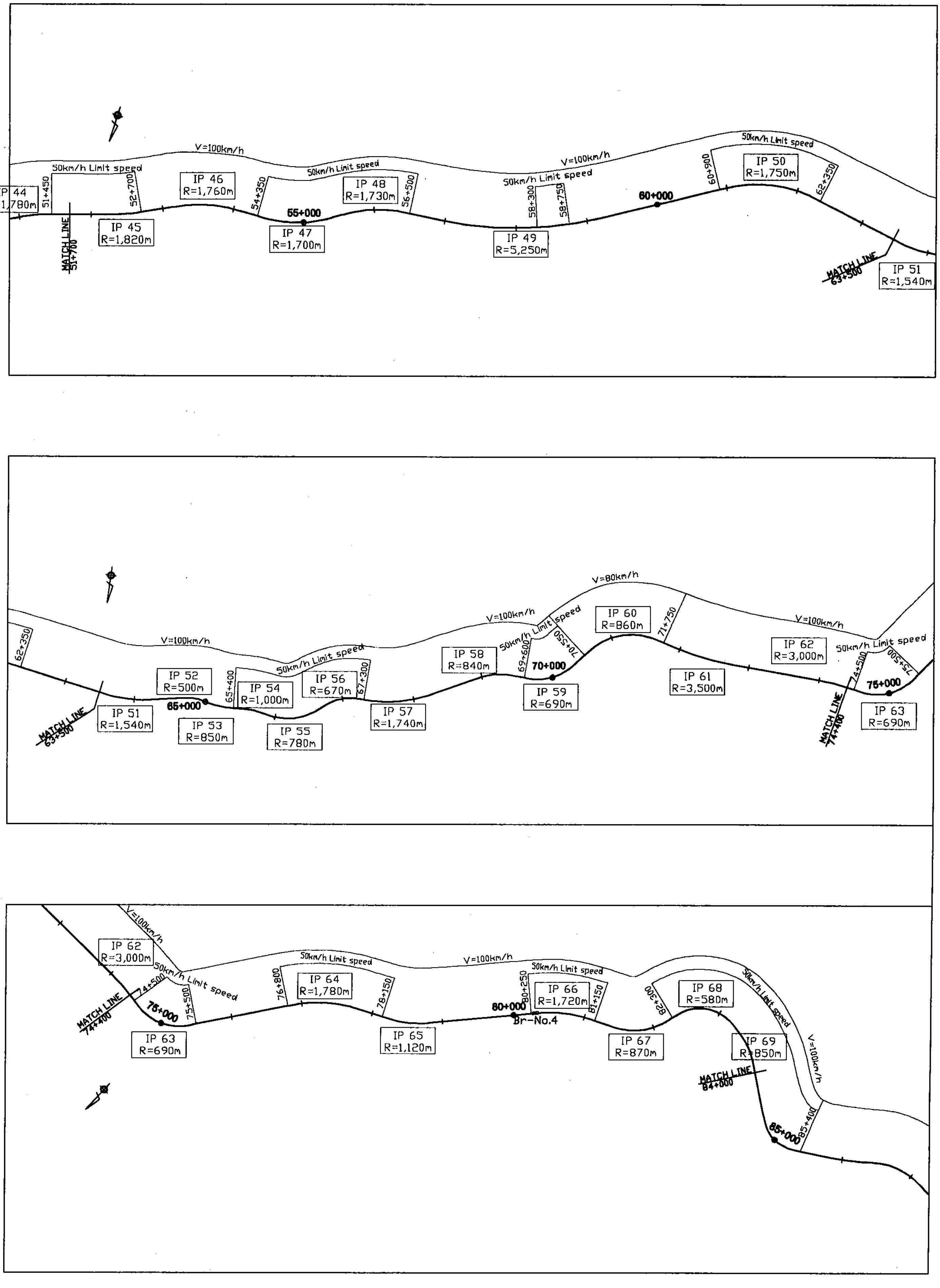


Figure 2.2.2-1 HORIZONTAL ALIGNMENT AND DESIGN SPEED (2)

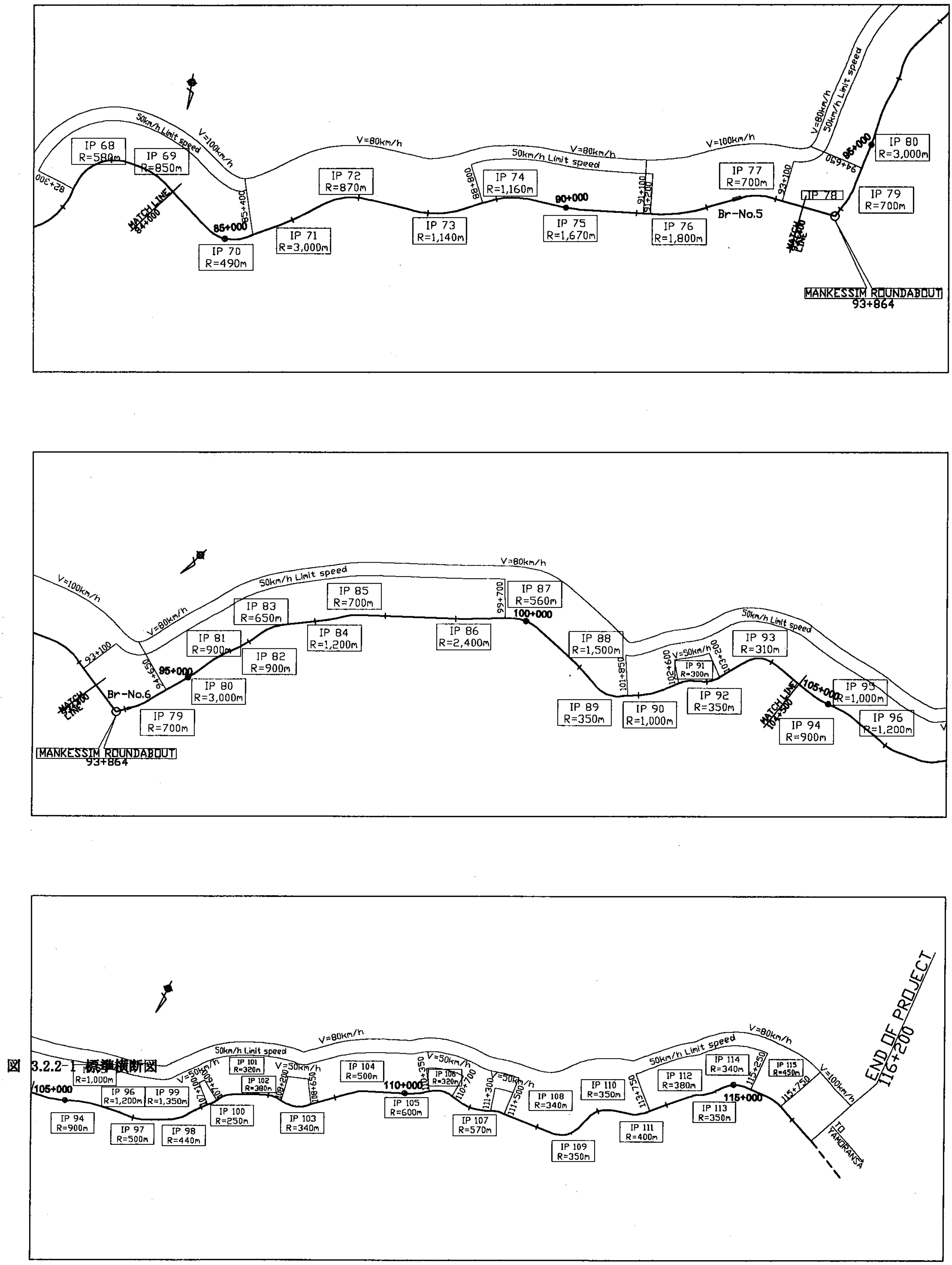


Figure 2.2.2-1 HORIZONTAL ALIGNMENT AND DESIGN SPEED (3)

Table 2.2.2-3 Sections with more than 3% of Vertical Gradient

No.	B P	E P	Up/Down		Distance (m)	Design Speed (km/h)	Vertical Gradient (i= %)	Standard Vertical Gradient by Design Speed (i= %)	Limited Distance by Gradient (m)
1	21+550	21+700	Down		150	50	3.00	6.00	
2	22+250	22+400	Up		150	50	3.74	6.00	
3	24+000	24+250	Down		250	100	3.80	3.00	4% = 700m
4	24+950	25+250	Down		300	50	4.20	6.00	
5	26+150	26+350	Up		200	50	3.00	6.00	
6	33+250	33+500	Up	]	250	50	4.42	6.00	
7	33+700	34+000	Down		300	50	4.54	6.00	
8	34+900	35+200	Up	]	300	50	4.94	6.00	
9	35+400	35+650	Down		250	50	4.36	6.00	
10	36+450	36+700	Up	]	250	80	3.28	4.00	
11	36+950	37+050	Down		100	80	4.68	4.00	5% = 600m
12	38+100	38+550	Down		450	80	4.88	4.00	5% = 600m
13	38+700	38+900	Up		200	80	3.94	4.00	
14	39+300	39+500	Up		200	80	4.37	4.00	5% = 600m
15	40+850	41+050	Down		200	50	4.20	6.00	
16	41+350	41+550	Down		200	50	4.62	6.00	
17	43+250	43+400	Down		150	50	4.85	6.00	
Winneba Rotary (47 + 492)									
18	65+500	65+900	Up	]	400	50	4.61	6.00	
19	66+150	66+250	Down		100	50	3.01	6.00	
20	71+350	71+525	Down		175	100	3.58	3.00	4% = 700m
21	85+900	86+250	Up	]	350	80	5.30	4.00	6% = 500m
22	86+500	86+850	Down		350	80	5.06	4.00	6% = 500m
23	89+700	89+950	Up	]	250	50	4.06	6.00	
24	90+150	90+300	Down		150	50	3.70	6.00	
25	90+800	90+900	Down		100	50	3.22	6.00	
Mankessim Rotary (93 + 864)									
26	100+450	100+750	Up		300	80	4.30	4.00	5% = 600m
27	101+250	101+500	Down		250	80	5.06	4.00	6% = 500m
28	102+300	102+400	Down		100	50	3.22	6.00	
29	107+050	107+200	Up		150	50	4.18	6.00	
30	108+100	108+250	Down		150	50	4.92	6.00	
31	109+275	109+425	Down		150	50	3.06	6.00	
32	111+550	111+675	Down		125	80	3.02	4.00	
33	112+050	112+250	Down		200	80	3.51	4.00	
34	113+975	114+250	Up		275	50	3.01	6.00	

Table 2.2.2-4 Revised Vertical Alignment Sections due to Flooding

No.	Location BP～EP	Distance (m)	Elevated Height	Remarks
1	25+450～26+000	450	0.80	Vertical Sag Point. Close to River
2	27+300～27+500	200	0.90	Vertical Sag Point. Close to River
3	46+900～47+250	350	1.80	Basin in wide. Topography is complicated.
4	48+100～48+400	300	1.20	Surrounding area is flat
5	49+050～49+350	300	0.80	Surrounding area is flat
6	51+000～51+350	350	1.60	Close to River
7	56+500～59+200	2,700	1.20	Surrounding area is flat
8	59+600～60+600	1,000	0.90	Surrounding area is flat
9	63+000～64+000	1,000	0.80	Surrounding area is flat
10	67+950～69+050	1,100	0.70	Surrounding area is flat
11	96+000～96+300	300	0.70	Surrounding area is flat
	Total	8,050		

The above eleven (11) locations and elevated height were determined according to the topography and the information from local peoples on flooding height and frequency.

Even though the vertical alignment of the distance (700m) from 32+700 KM to 33+400 KM, meets the standards, this section does not provide safety for drivers, because of the waved vertical alignment. Therefore smoothed vertical alignment was required by providing cut and fill section of 1.30～1.50m as requested by GHA.

2.2.2.3 Cross Section Composition

(1) Design Speed

Cross section structure and alignment are influenced by the design speed, which follows the GHA Design Standard for Primary Trunk Roads. The standard gives the speed of 100kph for flat terrain, 80kph for rolling terrain, and for populated areas, to secure traffic safety, a speed of 50kph is adopted.

(2) Number of Lanes

The concerned road section under this project is fully 2 lanes for the whole length. The future traffic volumes on the road show that the level of service in 2020 for the section from Kasoa to Winneba will be "Level D", which gives the consideration for a 4-lane road in the future. However, it was decided that 2-lane road covers the requirements up to the target year 2020. Meetings with officials of the Government of Ghana and the concerned agencies also concluded the adoption of 2-lane width for the whole length of the Project Road.

(3) Road Structure Width

Widths for the road structure (carriageway width and shoulder width) are based on the GHA Standard, to consider the coordination with other related projects under "the Project for Rehabilitation of National Highway No. 1".

- The carriageway width was adopted as 3.65m because the main road in this project is on flat and rolling terrain, which means that the design speed is more than 80kph. The other concerned projects on other sections of the road are applying the same width.

- The standard shoulder width is adopted basically as 2.50m, but the concerned site experiences a lot of traffic accidents. Therefore, the shoulder width for densely populated areas and roadside market area is adopted as 3.5m to segregate the passing vehicles and roadside activities. There are 36 village zones that form a community, in which 24 zones of densely populated areas require a shoulder width of 3.5m.

- The regulated section for design speed of 50kph and for shoulder width widening sections were determined based on the following items:

  [50kph rules]

  1) 36 areas where villages are found along the road side are regulated to be 50kph.
  2) When the 50kph-regulated section coincides with a horizontal curve, the regulated section is extended until the end of curvature.
  3) When the interval between a regulated section and the next regulated section is less than 1,000m, 50kph regulation is to be continued, considering the design efficiency.

  [Shoulder-width widening section]

  1) Width widening sections are applied in villages where housing or market activities are near the project road.
  2) Width widening sections are only applied in villages where the central part experiences a lot of pedestrian crossings, and segregation of passing vehicles and roadside activities is required.

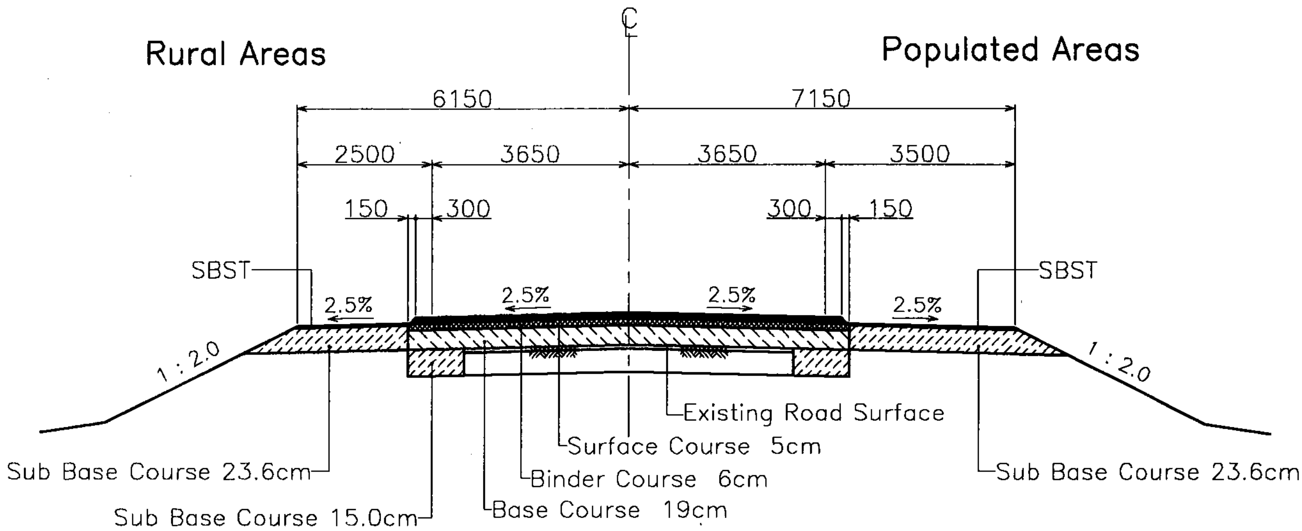
  The above mentioned results are presented in Table 2.2.2-5.

Table 2.2.2-5 50kph Regulated Sections and Shoulder Widening Sections

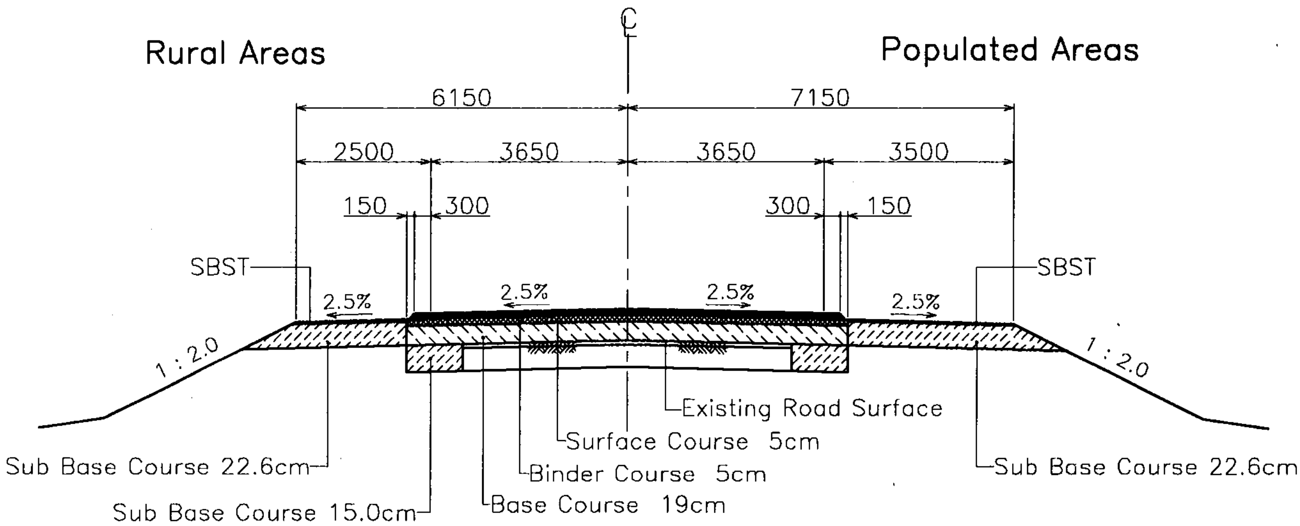
No.	Village	50kph Regulated Section			Shoulder Widening Section		
		BP	EP	Distance (m)	BP	EP	Distance (m)
	Kasoa						
1	Buduburam	21+600	23+700	2,100	22+050	22+750	700
2	Fete Kakrabo	24+700	carried on forward	2,300	24+800	25+050	250
3	Awutu Bereku	continue from above	27+000		26+300	26+750	450
4	Akoti Jct.	28+400	29+500	1,100	29+150	29+250	100
5	Dabanyin	31+600	carried on forward	4,100	33+050	33+150	100
6	Ohiamaadwen	continue from above	carried on forward		34+400	34+500	100
7	Gomoa Nyamebekyere	continue from above	35+700				
8	Potsen Nkwanta	37+055	37+700	645	37+350	37+550	200
9	Adukrom	40+850	carried on forward	2,650			
10	Atokrom	continue from above	43+500		42+350	42+600	250
11	Winneba Jct.	46+500	48+100	1,600	47+100	48+100	1,000
12	New Bewadze	51+450	carried on forward	1,250			
13	Gomoa Amanfi	continue from above	52+700				
14	Otsew Dwokwaa	54+350	56+500	2,150	54+900	55+550	650
15	New Mprumamu	58+300	58+750	450			
16	Ankamu	60+900	62+350	1,450	61+100	62+000	900
17	Gomoa Assin	65+400	67+300	1,900	65+850	66+500	650
18	Kyiren Nkwanta	69+600	70+550	950	70+200	70+550	350
19	Gomoa Anntseadze	74+500	75+500	1,000			
20	Esuehyia Jct.	76+800	78+150	1,350	77+450	78+050	600
21	Ekotsi	80+250	81+150	900			
22	Ekumfi Dunkwa	82+300	carried on forward	3,100			
23	Abontsen	continue from above	carried on forward		83+500	83+750	250
24	Eyisam	continue from above	85+400		84+550	84+850	300
25	Edukuma	88+800	carried on forward	2,400			
26	Ekumfi Swedru	continue from above	91+200		90+600	91+200	600
27	Mankessim	93+100	carried on forward	6,600	93+150	94+750	1,600
28	Abonku	continue from above	carried on forward		96+900	97+400	500
29	Anokye	continue from above	99+700				
30	Afrangwa Jct.	101+850	carried on forward		102+350	102+550	200
31	Saltpond	continue from above	carried on forward				

One section between 32+550 and 32+650 (L=100m), where the foundation is very weak to be replaced with suitable material, takes the depth of 1.0 m from designed road level.

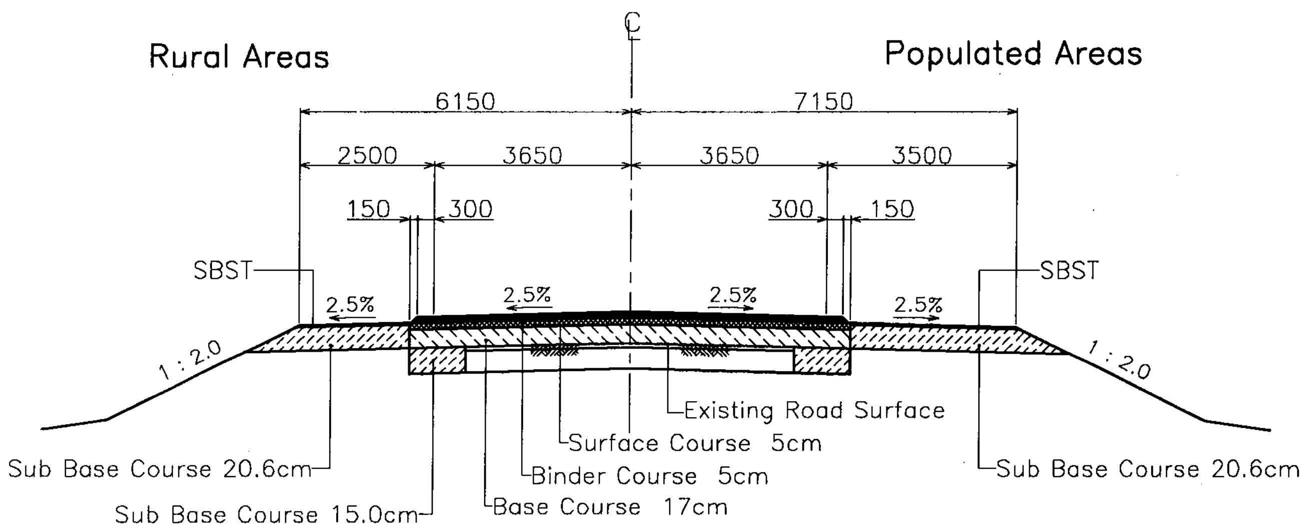
Figure 2.2.2-2 presents the typical cross section in both rural and populated areas.



TYPE- 1 18+000~48+000



TYPE- 2 48+000~94+060



TYPE- 3 94+060~116+200

Figure 2.2.2-2 TYPICAL CROSS SECTION

2.2.2.4 Pavement Structures

The existing pavement condition of the National Highway No. 1 including portions of this project is DBST pavement except some improved sections.

The pavement structures of this project road is designed as asphalt concrete pavement structure, the same as the other relevant projects based on the Guidelines of Pavement Structures Design of AASHTO and GHA.

The pavement structures of this road are designed for the 98.2km road by dividing it into three sections according to the daily traffic volumes.

(1) Design Criteria

The criteria for the structure design of pavement is established as presented in Table 2.2.2-6.

Table 2.2.2-6 Criteria for Structure Design of Pavement

Category		Value	Description
1	Design Variable		
1.1	Time Constraints		
	• Performance Period	15 years	Life of Initial Pavement Structure
	• Annual Traffic Growth Rate	6%	
1.2	Traffic	$8.42 \sim 16.64 \times 10^6$	W18, Predicated Number of ESAL
1.3	Reliability	R=80%	Main road : 75～95%
	• Standard Normal Deviate	Z_r= -0.841	
	• Combined Standard Error	So=0.45	Main road : 0.4～0.5
2	Performance Criteria		
2.1	Serviceability	P_o=4.2	Initial Design Serviceability Index
		P_t=2.5	Design Serviceability Index
2.2	Serviceability Difference	Po - P_t=1.7	Differrence between Initial and Design Serviceability Index
3	Material Property		
3.1	Effective Roadbed Soil Resident Modules	M_R=16,500～18,000	M_R=1,500×CBR(11～12)
3.2	Pavement Layer Material Characteristic		Layer Coefficient
	• AC Surface Course		0.40
	• AC Binder Course		0.38
	• Mechanical Stabilized Base Course	CBR=80	0.14
	• Mechanical Stabilized Subbase Course	CBR=30	0.12
4	Pavement Structual Characteristic		
4.1	Drainage		
	• Mechanical Stabilized Base Course	m=1.1	
	• Mechanical Stabilized Subbase Course	m=1.0	

Note: Reliability＝(Pavement design – Performance process)
It is the probability that a pavement designed under this process fulfills its function under conditions of designed life period and environment.

Concerning the performance period, Ghana authorities strongly requested high durability pavement for a target period of 15 years. Therefore, this project adopts 15 years of the performance period in order to avoid the problem of progressive damages due to differences in pavement.

(2) Future Traffic Volume Forecast

The annual average growth rate of 6 % is adopted and applied on the calibrated traffic count survey results which conducted at the different four sections. The basis and methodology of calculation for the forecast of future traffic volume are presented in Appendix 8.

(3) 18-kip ESAL Prediction

The number of 18-kip equivalent single load application (18kph ESAL application) was calculated based on ECOWAS Highway standard that the maximum axle load of 11.5 ton. Table 2.2.2-7 presents the ESAL values for the three sections of the road.

(4) Sub-base Material and Sub-grade Strength (CBR)

The existing pavement of the road is designed to be utilized as sub-base for this project. For design calculation, the average values for all sections based on actual site surveys are applied.

Table 2.2.2-6 CUMULATIVE NUMBER OF STANDARD AXLES (1/3)

Section－1 （ Kasoa～Winneba ）

YEARS				1	2	3	4	5	6	7	8	9	10	11	12	Total
			Vehicle code	1	2	3	4	5	6	7	8	9	10	11	12	
			Vehicle Type	CARS	VANS	WAGONS	S. BUSES	L. BUSES	LT BUSES	TRUCKS (M)	TRUCKS (H)	SEMI TR(R)	SEMI TR(M)	SEMI TR(H)	OTHERS	
			Truck Factor (Central Region)	0.0001	0.0001	0.0906	0.0068	0.8612	0.1019	2.1694	4.2488	3.4809	4.6203	5.0503	2.9697	
			2002 ADT	3,958	872	1,121	1,675	113	246	429	218	21	77	101	24	
			Growth Rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
0	2002			0.40	0.09	101.56	11.39	97.32	25.07	930.67	926.24	73.10	355.76	510.08	71.27	
1	2003			0.42	0.09	107.66	12.07	103.15	26.57	986.51	981.81	77.48	377.11	540.69	75.55	
2	2004			0.44	0.10	114.12	12.80	109.34	28.17	1045.70	1040.72	82.13	399.74	573.13	80.08	
3	2005			0.47	0.10	120.96	13.57	115.90	29.86	1108.45	1103.16	87.06	423.72	607.51	84.89	
4	2006	1		0.50	0.11	128.22	14.38	122.86	31.65	1174.95	1169.35	92.29	449.14	643.96	89.98	
5	2007	2		0.53	0.12	135.91	15.24	130.23	33.55	1245.45	1239.52	97.82	476.09	682.60	95.38	
6	2008	3		0.56	0.12	144.07	16.16	138.04	35.56	1320.18	1313.89	103.69	504.66	723.56	101.10	
7	2009	4		0.60	0.13	152.71	17.13	146.33	37.69	1399.39	1392.72	109.91	534.94	766.97	107.17	
8	2010	5		0.63	0.14	161.88	18.15	155.11	39.95	1483.35	1476.28	116.51	567.03	812.99	113.60	
9	2011	6		0.67	0.15	171.59	19.24	164.41	42.35	1572.35	1564.86	123.50	601.05	861.77	120.41	
10	2012	7		0.71	0.16	181.88	20.40	174.28	44.89	1666.69	1658.75	130.91	637.12	913.48	127.64	
11	2013	8		0.75	0.17	192.80	21.62	184.73	47.59	1766.69	1758.28	138.76	675.34	968.28	135.30	
12	2014	9		0.80	0.18	204.36	22.92	195.82	50.44	1872.70	1863.77	147.09	715.87	1026.38	143.41	
13	2015	10		0.84	0.19	216.63	24.29	207.57	53.47	1985.06	1975.60	155.91	758.82	1087.96	152.02	
14	2016	11		0.89	0.20	229.62	25.75	220.02	56.67	2104.16	2094.14	165.27	804.35	1153.24	161.14	
15	2017	12		0.95	0.21	243.40	27.30	233.22	60.08	2230.41	2219.78	175.19	852.61	1222.44	170.81	
16	2018	13		1.01	0.22	258.00	28.93	247.22	63.68	2364.24	2352.97	185.70	903.76	1295.78	181.06	
17	2019	14		1.07	0.23	273.49	30.67	262.05	67.50	2506.09	2494.15	196.84	957.99	1373.53	191.92	
18	2020	15		1.13	0.25	289.89	32.51	277.77	71.55	2656.46	2643.80	208.65	1015.47	1455.94	203.44	
19	2021															
20	2022															
15 Years 2006 to 2020			(Total ESAL)	11.6	2.6	2984.5	334.7	2859.7	736.6	27348.2	27217.9	2148.0	10454.2	14988.9	2094.4	91181.2

Day	Commulative	91,181	(ESAL)
Year		33,281,136	(ESAL)
Year	Per Lane	16,640,568	(ESAL)

Table 2.2.2-6 CUMULATIVE NUMBER OF STANDARD AXLES (2/3)

Section－2 （ Winneba～Mankessim ）

YEARS			Vehicle code	1	2	3	4	5	6	7	8	9	10	11	12	Total
			Vehicle Type	CARS	VANS	WAGONS	S. BUSES	L. BUSES	LT BUSES	TRUCKS (M)	TRUCKS (H)	SEMI TR(R)	SEMI TR(M)	SEMI TR(H)	OTHERS	
			Truck Factor (Central Region)	0.0001	1E-04	0.0906	0.0068	0.8612	0.1019	2.1694	4.2488	3.4809	4.6203	5.0503	2.97	
			2002 ADT	1,930	595	388	1,229	82	113	164	131	17	35	58	6	
			Growth Rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
0	2002			0.19	0.06	35.15	8.36	70.62	11.51	355.78	556.59	59.18	161.71	292.92	17.82	
1	2003			0.20	0.06	37.26	8.86	74.86	12.21	377.13	589.99	62.73	171.41	310.49	18.89	
2	2004			0.22	0.07	39.50	9.39	79.35	12.94	399.76	625.39	66.49	181.70	329.12	20.02	
3	2005			0.23	0.07	41.87	9.95	84.11	13.71	423.74	662.91	70.48	192.60	348.87	21.22	
4	2006	1		0.24	0.08	44.38	10.55	89.15	14.54	449.17	702.69	74.71	204.16	369.80	22.50	
5	2007	2		0.26	0.08	47.04	11.18	94.50	15.41	476.12	744.85	79.19	216.41	391.99	23.84	
6	2008	3		0.27	0.08	49.86	11.85	100.17	16.33	504.68	789.54	83.94	229.39	415.51	25.28	
7	2009	4		0.29	0.09	52.86	12.57	106.18	17.31	534.96	836.91	88.98	243.15	440.44	26.79	
8	2010	5		0.31	0.09	56.03	13.32	112.56	18.35	567.06	887.12	94.32	257.74	466.87	28.40	
9	2011	6		0.33	0.10	59.39	14.12	119.31	19.45	601.09	940.35	99.98	273.21	494.88	30.10	
10	2012	7		0.35	0.11	62.95	14.97	126.47	20.62	637.15	996.77	105.97	289.60	524.57	31.91	
11	2013	8		0.37	0.11	66.73	15.86	134.05	21.86	675.38	1056.58	112.33	306.97	556.04	33.82	
12	2014	9		0.39	0.12	70.73	16.82	142.10	23.17	715.90	1119.97	119.07	325.39	589.41	35.85	
13	2015	10		0.41	0.13	74.98	17.83	150.62	24.56	758.86	1187.17	126.22	344.92	624.77	38.00	
14	2016	11		0.44	0.13	79.48	18.89	159.66	26.03	804.39	1258.40	133.79	365.61	662.26	40.29	
15	2017	12		0.46	0.14	84.25	20.03	169.24	27.60	852.65	1333.91	141.82	387.55	701.99	42.70	
16	2018	13		0.49	0.15	89.30	21.23	179.40	29.25	903.81	1413.94	150.33	410.80	744.11	45.26	
17	2019	14		0.52	0.16	94.66	22.50	190.16	31.01	958.04	1498.78	159.35	435.45	788.76	47.98	
18	2020	15		0.55	0.17	100.34	23.85	201.57	32.87	1015.52	1588.70	168.91	461.58	836.09	50.86	
19	2021															
20	2022															
15 Years 2006 to 2020			(Total ESAL)	5.7	1.7	1033.0	245.6	2075.1	338.4	10454.8	16355.7	1738.9	4751.9	8607.5	523.6	46131.8

Day	Commulative	46,132	(ESAL)
Year		16,838,125	(ESAL)
Year	Per Lane	8,419,062	(ESAL)

Table 2.2.2-6 CUMULATIVE NUMBER OF STANDARD AXLES (3/3)

Section－3 （ Mankessim～Yamoransa ）

YEARS				1	2	3	4	5	6	7	8	9	10	11	12	Total
			Vehicle code	1	2	3	4	5	6	7	8	9	10	11	12	
			Vehicle Type	CARS	VANS	WAGONS	S. BUSES	L. BUSES	LT BUSES	TRUCKS (M)	TRUCKS (H)	SEMI TR(R)	SEMI TR(M)	SEMI TR(H)	OTHERS	
			Truck Factor (Central Region)	0.0001	1E-04	0.0906	0.0068	0.8612	0.1019	2.1694	4.2488	3.4809	4.6203	5.0503	2.9697	
			2002 ADT	1,406	419	589	1,038	124	114	201	76	6	49	80	6	
			Growth Rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	
0	2002			0.14	0.04	53.36	7.06	106.79	11.62	436.05	322.91	20.89	226.39	404.02	17.82	
1	2003			0.15	0.04	56.57	7.48	113.20	12.31	462.21	342.28	22.14	239.98	428.27	18.89	
2	2004			0.16	0.05	59.96	7.93	119.99	13.05	489.95	362.82	23.47	254.38	453.96	20.02	
3	2005			0.17	0.05	63.56	8.41	127.19	13.84	519.34	384.59	24.87	269.64	481.20	21.22	
4	2006	1		0.18	0.05	67.37	8.91	134.82	14.67	550.50	407.66	26.37	285.82	510.07	22.50	
5	2007	2		0.19	0.06	71.41	9.45	142.91	15.55	583.53	432.12	27.95	302.97	540.68	23.84	
6	2008	3		0.20	0.06	75.70	10.01	151.48	16.48	618.54	458.05	29.63	321.15	573.12	25.28	
7	2009	4		0.21	0.06	80.24	10.61	160.57	17.47	655.66	485.54	31.40	340.41	607.50	26.79	
8	2010	5		0.22	0.07	85.05	11.25	170.21	18.52	695.00	514.67	33.29	360.84	643.95	28.40	
9	2011	6		0.24	0.07	90.16	11.93	180.42	19.63	736.70	545.55	35.29	382.49	682.59	30.10	
10	2012	7		0.25	0.08	95.57	12.64	191.24	20.80	780.90	578.28	37.40	405.44	723.55	31.91	
11	2013	8		0.27	0.08	101.30	13.40	202.72	22.05	827.75	612.98	39.65	429.76	766.96	33.82	
12	2014	9		0.28	0.08	107.38	14.20	214.88	23.37	877.42	649.76	42.03	455.55	812.98	35.85	
13	2015	10		0.30	0.09	113.82	15.06	227.77	24.78	930.06	688.74	44.55	482.88	861.75	38.00	
14	2016	11		0.32	0.09	120.65	15.96	241.44	26.26	985.87	730.07	47.22	511.86	913.46	40.29	
15	2017	12		0.34	0.10	127.89	16.92	255.93	27.84	1045.02	773.87	50.05	542.57	968.27	42.70	
16	2018	13		0.36	0.11	135.56	17.93	271.28	29.51	1107.72	820.30	53.06	575.12	1026.36	45.26	
17	2019	14		0.38	0.11	143.70	19.01	287.56	31.28	1174.18	869.52	56.24	609.63	1087.94	47.98	
18	2020	15		0.40	0.12	152.32	20.15	304.81	33.16	1244.63	921.69	59.61	646.21	1153.22	50.86	
19	2021															
20	2022															
15 Years 2006 to 2020			（ Total ESAL ）	4.1	1.2	1568.1	207.4	3138.0	341.4	12813.5	9488.8	613.7	6652.7	11872.4	523.6	47224.9

Day	Commulative	47,225	(ESAL)
Year		17,237,106	(ESAL)
Year	Per Lane	8,618,553	(ESAL)

(5) Calculation for Pavement Structure Design

The methodology applied for structural design of pavement is based on the identification of the flexible pavement structure (SN) to withstand the predicted number of axle load traffic (W_{18}). The applied equation and procedure for flexible pavement is as follow.

$$\log_{10}(W_{18}) = Z_R \times S_O + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}[\Delta PSI/(4.2-1.5)]}{0.40 + 1094/(SN+1)^{5.19}}$$

$$+ 2.32 \times \log_{10}(MR) - 8.07 \quad \text{................................(1)}$$

W_{18} : Refer Table 2.2.2-8

Z_R : -0.841

S_O : 0.45

△PSI : 1.7

M_R : Refer Table 2.2.2-9

SN : Required SN presented in Table 2.2.2-10

Calculation results presented in Table 2.2.2-11

Table 2.2.2-8 Figure of W_{18}

	Section 1	Section 2	Section 3
W_{18}	16,640,000	8,420,000	8,620,000

Table 2.2.2-9 Figure of M_R

	Section 1	Section 2	Section 3
CBR (mean)	12.0	11.0	11.0
M_R	18,000	16,500	16,500

Table 2.2.2-10 Figure of SN

	Section 1	Section 2	Section 3
(1) formula left	7.221	6.925	6.936
(1) formula right	7,221	6,925	6,936
SN	3.662	3.386	3.400

Note: Required SN in-put as same as “left side value = right side value” in formula (1).

Calculation of SN for pavement structure design is presented in Tables 2.2.2-11, 2.2.2-12 and 2.2.2-13.

Table 2.2.2-11 Calculation Result of SN in Section-1

1 (inch) = 2.540cm

	Layer Coefficient (a)	Thickness (inch) (D)	Drainage Coefficient (m)	SN = a*D*m	Thickness (cm) (D)
Asphalt Concrete (new)	0.400	1.968	-	0.787	5.0
AC Binder (new)	0.380	2.362	-	0.898	6.0
Wearing Course (new)	0.140	7.480	1.1	1.152	19.0
Base Course (existing)	0.120	7.086	1.0	0.850	18.0 Average (actual)
Total				3.687	OK

Table 2.2.2-12 Calculation Result of SN in Section-2

1 (inch) = 2.540cm

	Layer Coefficient (a)	Thickness (inch) (D)	Drainage Coefficient (m)	SN = a*D*m	Thickness (cm) (D)
Asphalt Concrete (new)	0.400	1.968	-	0.787	5.0
AC Binder (new)	0.380	1.968	-	0.748	5.0
Wearing Course (new)	0.140	7.480	1.1	1.152	19.0
Base Course (existing)	0.120	5.905	1.0	0.709	15.0 Average (actual)
Total				3.396	OK

Table 2.2.2-13 Calculation Result of SN in Section-3

1 (inch) = 2.540cm

	Layer Coefficient (a)	Thickness (inch) (D)	Drainage Coefficient (m)	SN = a*D*m	Thickness (cm) (D)
Asphalt Concrete (new)	0.400	1.968	-	0.787	5.0
AC Binder (new)	0.380	1.968	-	0.748	5.0
Wearing Course (new)	0.140	6.692	1.1	1.031	17.0
Base Course (existing)	0.120	7.086	1.0	0.850	18.0 Average (actual)
Total				3.416	OK

*As SN of all sections is more than required value according to the calculation, the proposed pavement design is applicable.

Figure 2.2.2-3 shows the structural and functional condition of existing pavement, localized failure section, CBR value of existing pavement and proposed improvement methods.

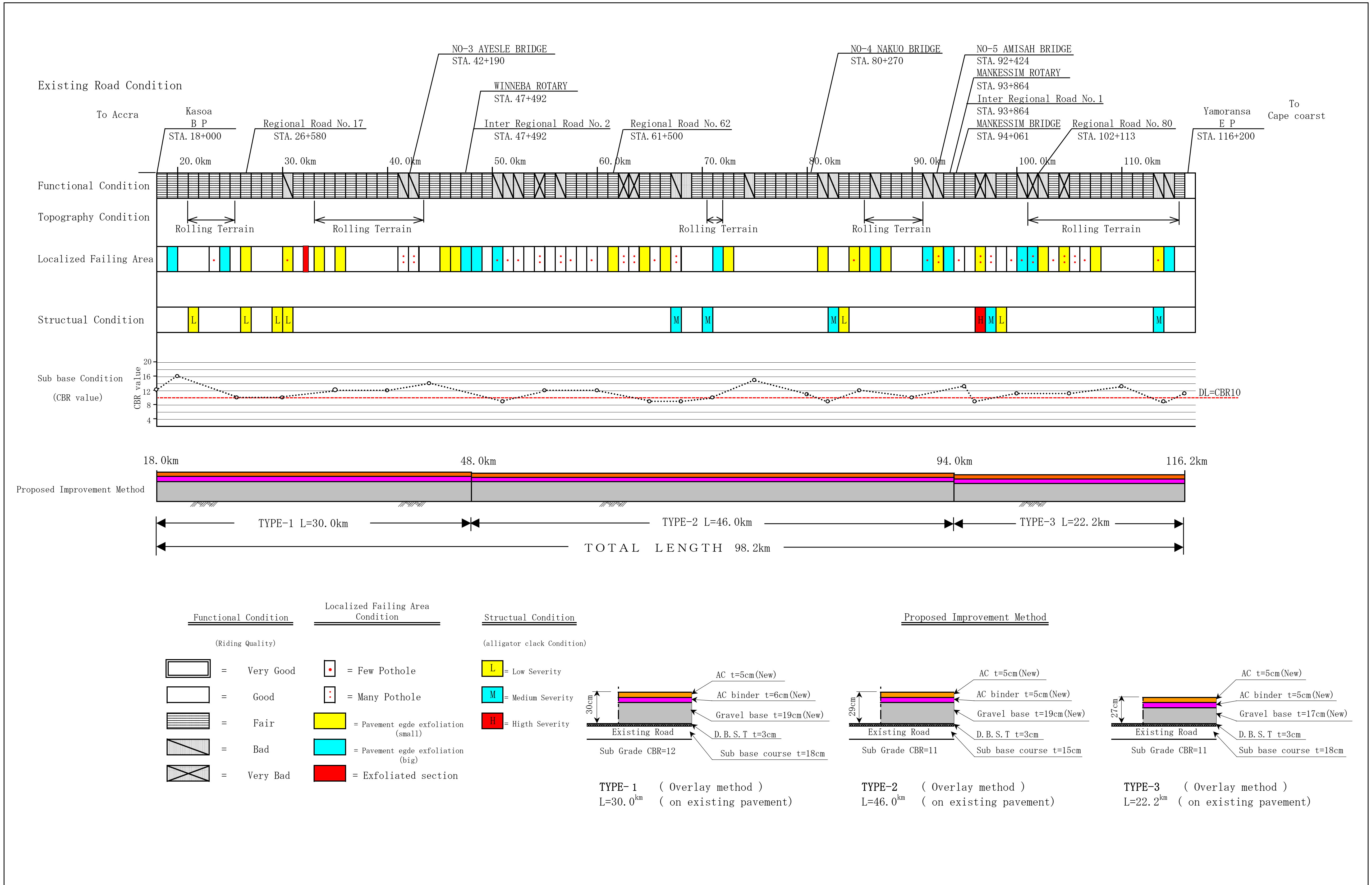


Figure 2.2.2-3 EXISTING PAVEMENT CONDITIONS AND PROPOSED IMPROVEMENT METHODS