社会開発調査部報告書

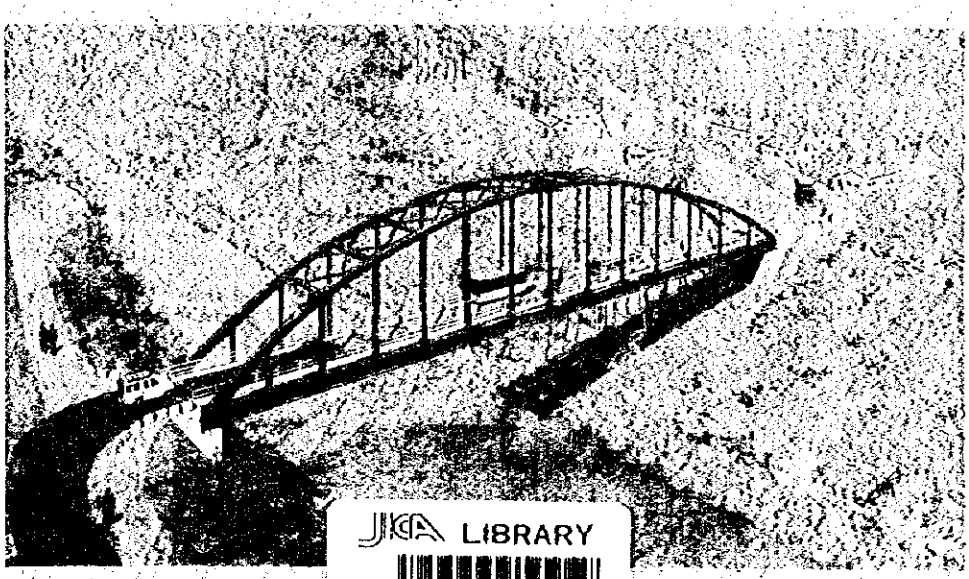
No. 2

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF COMMUNICATIONS,
THE ROYAL GOVERNMENT OF BHUTAN

THE STUDY
ON
NATIONAL HIGHWAY BRIDGE CONSTRUCTION
IN
THE KINGDOM OF BHUTAN

FINAL REPORT
VOLUME 1
SUMMARY



JULY 1998

PACIFIC CONSULTANTS INTERNATIONAL
HOKKAIDO ENGINEERING CONSULTANTS Co., Ltd.

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NOTE

The following exchange rate was adopted through this report.

US$ 1.00 = Nu. 38.6 (March 1998)

PREFACE

In response to a request from the Government of Bhutan the Government of Japan decided to conduct a Study, and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team to Bhutan between August 1997 and June 1998. The study team was headed by Mr. Hiroyuki ENDO and composed of members of Pacific Consultants International and Hokkaido Engineering Consultants Co., Ltd.

The team held discussions with the officials concerned of the Royal Government of Bhutan, and conducted field surveys at the study area. After the team returned to Japan, further studies were made 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 Royal Government of Bhutan for their close cooperation extended to the team.

July 1998

Kimio Fujita
President
Japan International Cooperation Agency

July 1998

Mr. Kimio FUJITA
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

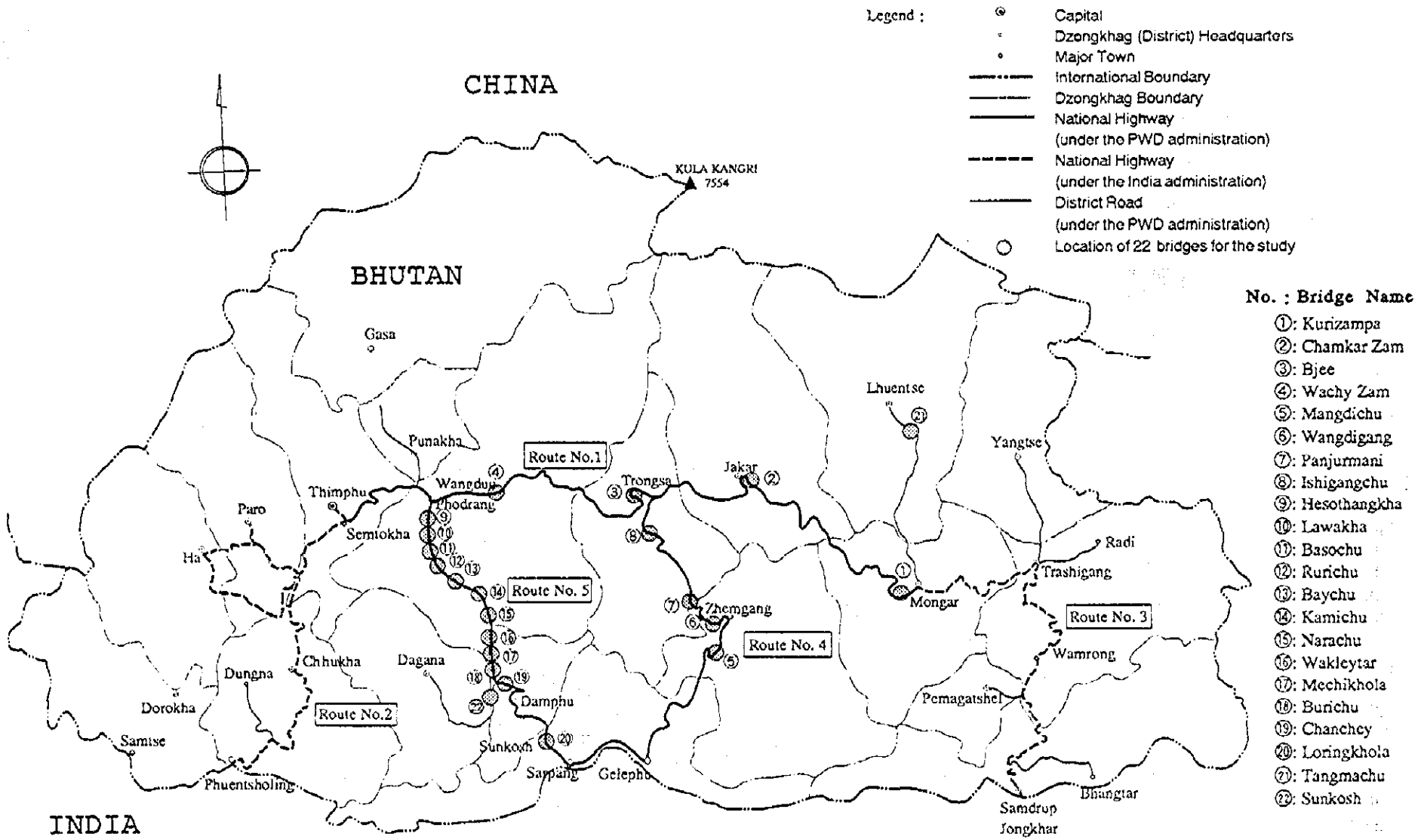
We are pleased to submit to you the report on the Study. The report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency as well as the comments made by the Ministry of Communications, Public Works Division and the authorities concerned in Bhutan. The report consists of three volumes; a Summary, a Main Text, and an Appendix. This report presents the Study on National Highway Bridge in the Kingdom of Bhutan.

We believe that this project will contribute greatly to upgrade the transport system in Bhutan.

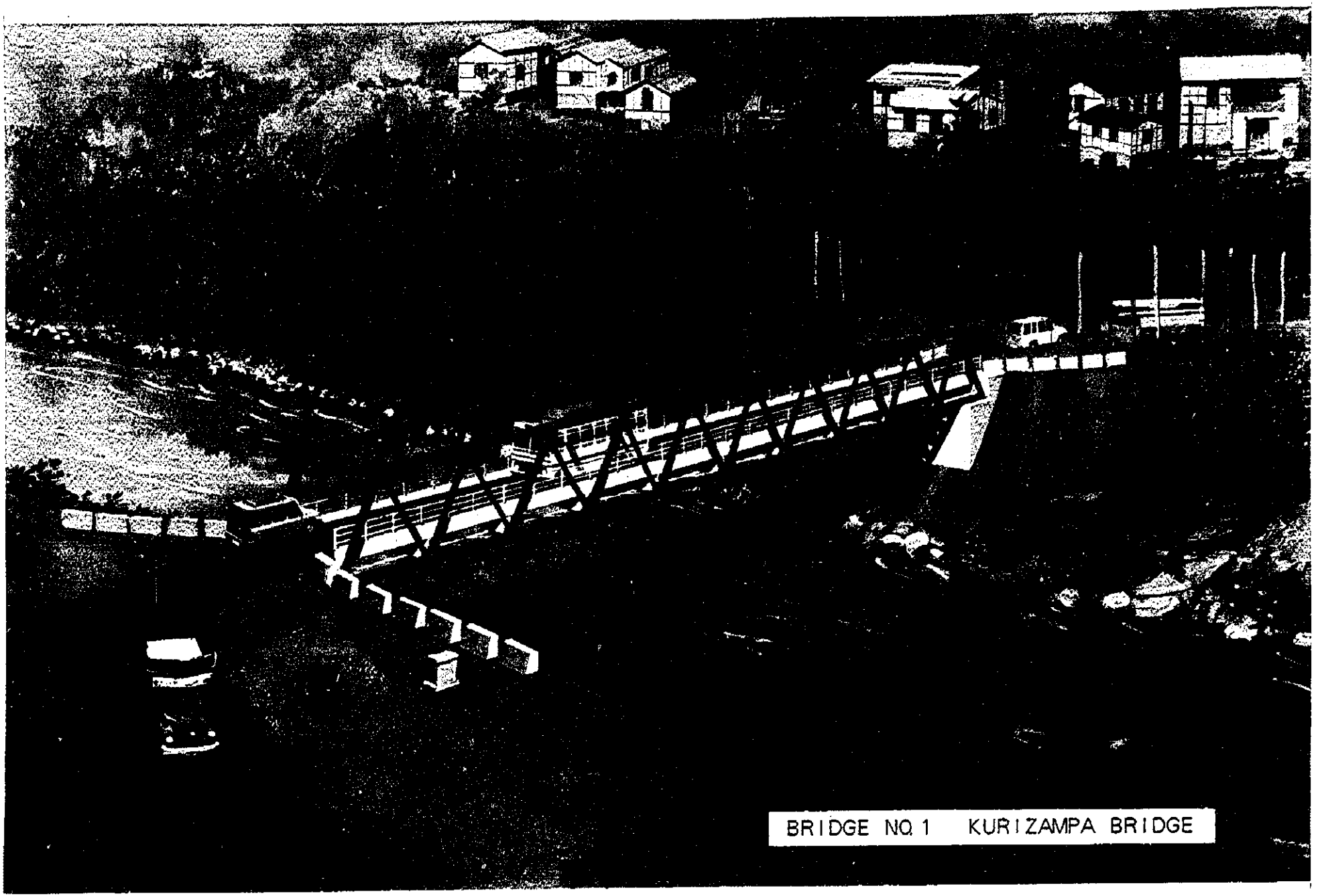
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Construction. We also wish to express our deep gratitude to the Ministry of Communications and the Governmental Agencies concerned in Bhutan, the Japanese Embassy in India for the close cooperation and assistance extended to us during our study. We hope this report will contribute to construct bridges.

Very truly yours,

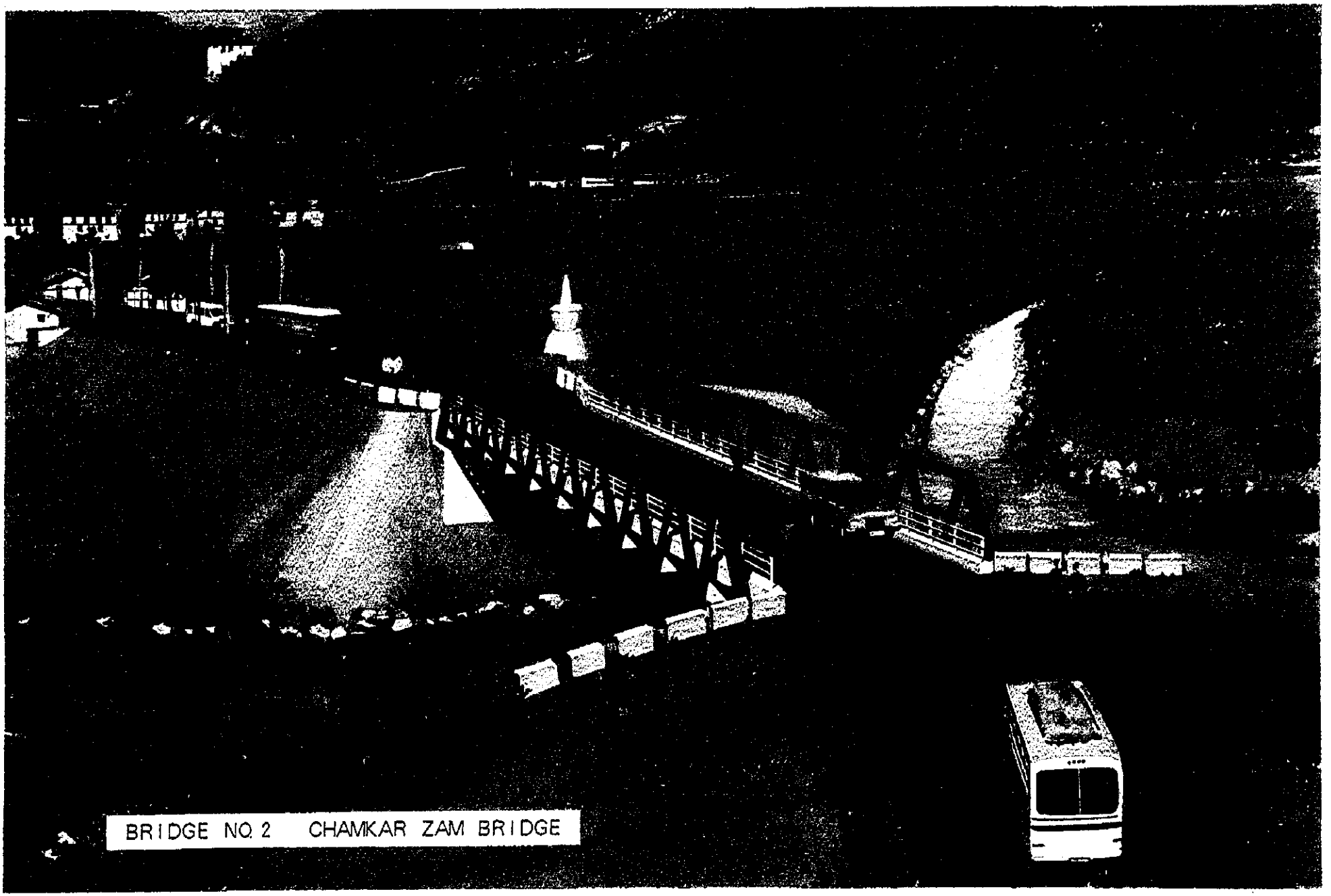
Mr. Hiroyuki Endo
Team Leader

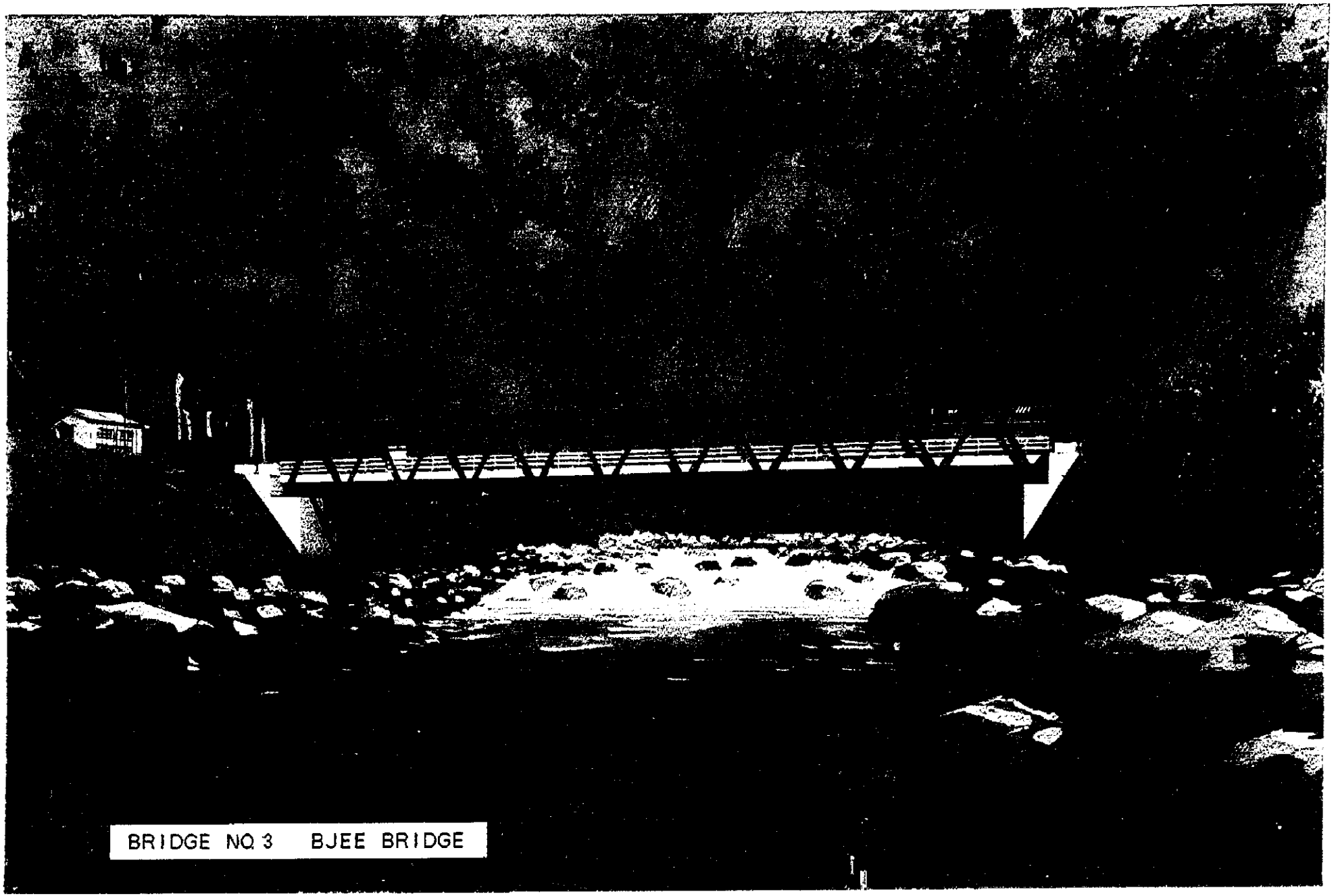


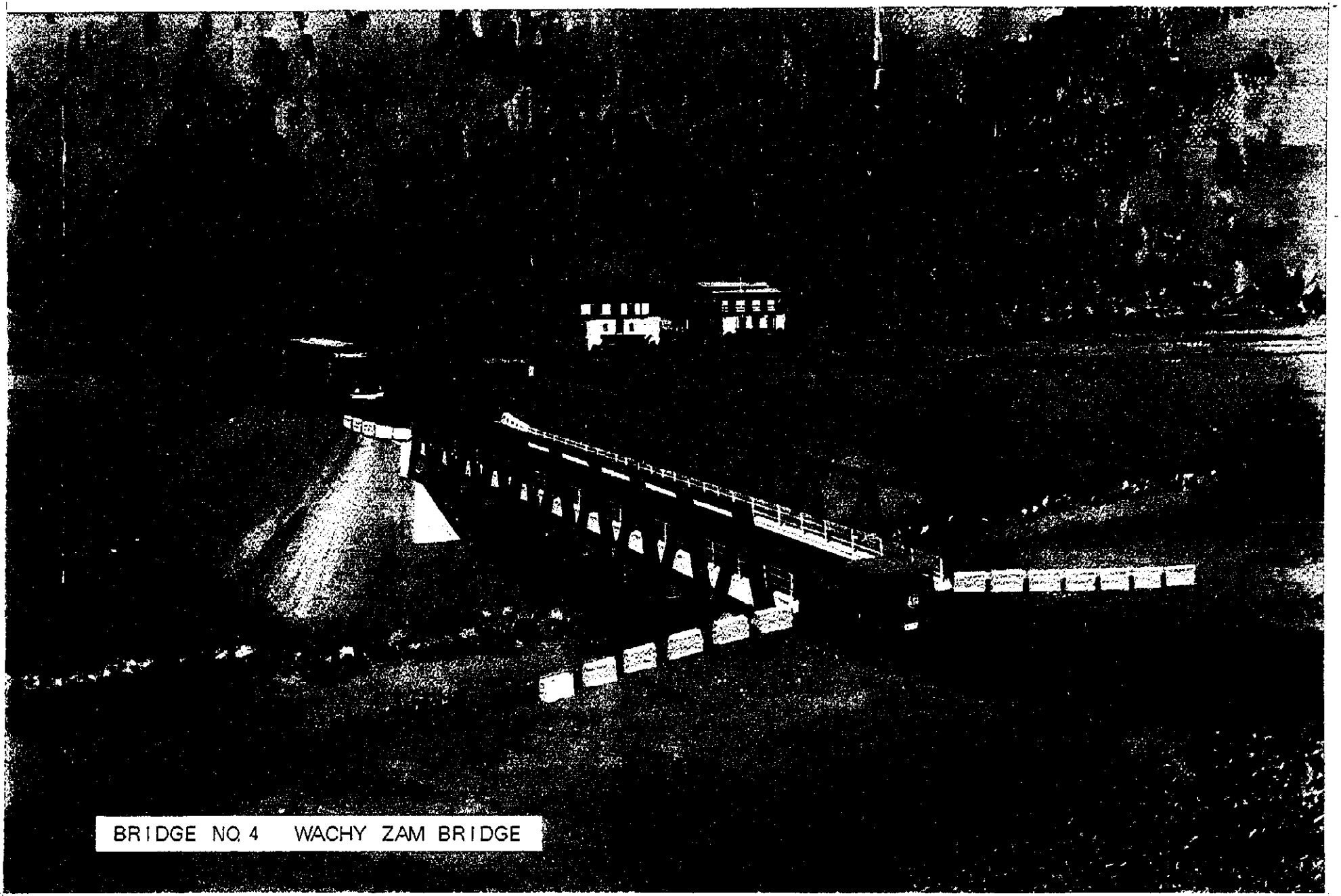
Location Map of Bridges for the Study



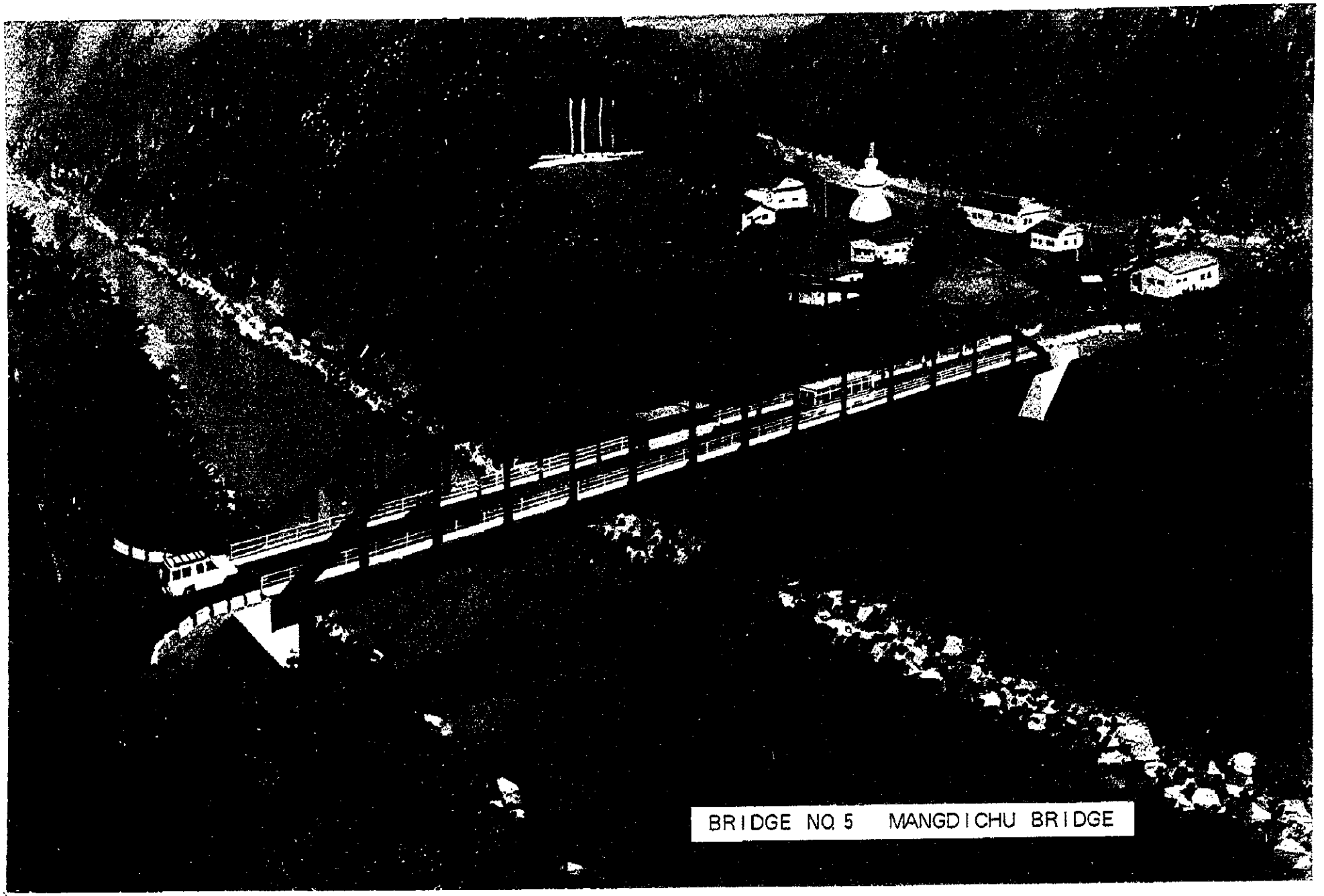
BRIDGE NO. 1 KURIZAMPA BRIDGE


BRIDGE NO. 2 CHAMKAR ZAM BRIDGE


BRIDGE NO 3 BJEE BRIDGE



BRIDGE NO. 4 WACHY ZAM BRIDGE



BRIDGE NO. 5 MANGDICHU BRIDGE

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1 Outline of the Study Recommendations

Bridge No.	Bridge Name	Highway No.	Results of the Study				Approach Road L (m)
			L (m)	B (m)	Type	Substructure	
No. 1	Kurizampa	No. 1	54	5.5	Steel Truss	Abutment Deep Well	70
No. 2	Chamkar Zam	No. 1	43	7.5	Steel Truss	Abutment	160
No. 3	Bjee	No. 1	50	5.5	Steel Truss	Abutment Deep Well	70
No. 4	Wachy Zam	No. 1	43	5.5	Steel Truss	Abutment Deep Well	109
No. 5	Mangdichu	No. 4	100	5.5	Steel Lohse	Abutment Deep Well	242

2 Background and Objectives of the Study

(1) Background

Bhutan is a land-locked country, and its socioeconomic development depends largely on an efficient and reliable road network. However, the lack of a well-developed transport network has been identified as one of the major constraints to the development of more remote areas of the country. Road infrastructure development has therefore been given priority in all the past five year plans.

The national highway network in Bhutan provides links between districts (Dzongkhags) and the capital, and between the district capitals. Some of the national highways carry international traffic to India, such as National Highway No. 2 (Thimphu-Phuentsholing) and National Highway No. 3 (Tashigang-Samdrup Jongkhar). These highways are narrow with winding horizontal alignments with many hairpin bends, and are prone to landslides and subsidence.

The construction and maintenance of the roads in Bhutan is technically difficult due to the fragility of the ground and the risk of landslides during the monsoon period. The terrain in which the roads are located require that they are aligned along the sides of mountainous valleys and cut into hillside, making road construction more demanding in terms of technology and finance and therefore costlier than those located in the plains.

Most of the bridges along the national highways were built as temporary structures (Bailey bridges with stone masonry substructures) and have passed their design life. Due to such conditions, the restrictions on vehicle loads become tighter each year. Within a few years they will not be passable by any form of transport, much less heavy vehicles. Therefore, it is absolutely necessary to replace them with permanent bridges in order to maintain normal road transportation.

Recently, the road network has been developed under the Seventh Five-Year Plan (1991-1996). Its objective was to construct and maintain the road network and bridges in order to facilitate efficient movement of cargo and passengers. An adequate road network in Bhutan is a prerequisite for the socioeconomic development of the country. In the Eighth Five-Year Plan (1997-2002) the programs for highway improvements and permanent bridge construction are again given high priority.

National Highway Route No. 1 is the only a trunk highway which connects the west of the country with the east, and has an important role in maintaining the well-balanced development of the country.

In taking account of these conditions, the Royal Government of Bhutan through the Public Works Division, intends to implement a Study on National Highway Bridge Replacement Project with the assistance of the Government of Japan.

(2) Objective and Scope of Study

Objective of the Study is to carry out a feasibility study for the reconstruction of selected bridges on national highways in order to facilitate the efficient movement of cargo and passengers in the country. Scope of the Study includes:

1) Preliminary survey of 22 candidate bridges:
2) Identification of bridges which need replacement, selection of priority projects (up to five) among these bridges and implementation of a feasibility study for the priority projects
3) Technology transfer on bridge construction planning through the Study

(3) Study Area

The study area comprises 22 bridge sites, as shown in the Location Map of Bridges for the Study.

Four (4) bridges are on National Highway Route 1 (Semtokha-Tashigang, 546 km), four (4) bridges on National Highway Route 4 (Trongsa-Geylephug-Sarpang, 244 km), twelve (12) bridges on National Highway Route 5 (Wangdue-Sarpang, 187 km), one (1) bridge on district highway between Mongar-Lhuntshi, 64 km and one (1) bridge on district highway between Sunkosh and Daga, 87 km.

3 Implementation of the Study

(1) Implementation Schedule

This study is divided into four phases:

Phase 1 : Preliminary Bridges Survey, Identification of Bridges for Urgent Replacement
Phase 2 : Selection of Bridges for the Feasibility Study
Phase 3 : Detailed Survey of the Selected Bridges
Phase 4 : Alternatives Study and Feasibility Study

The flow chart is shown in Figure 1. The chart gives the various work items of the Study, the submission of reports and their scheduled timing.

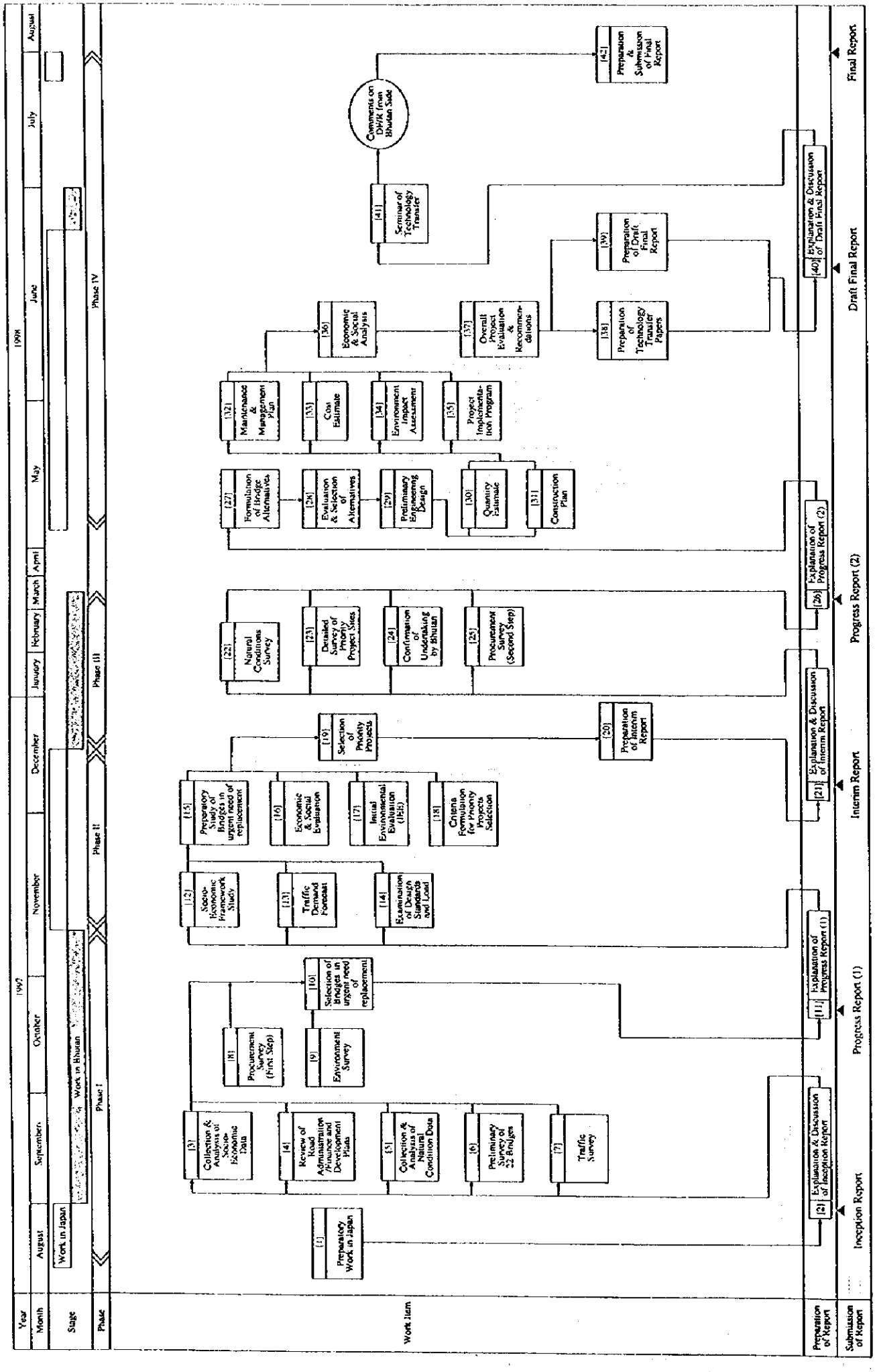

Figure 1 General Work Diagram

(2) Reporting

The Study was conducted in Japan and Bhutan from August 1997 to July 1998. Several reports have been submitted on the progress of the study.

September	1997	Inception Report
October	1997	Progress Report (1)
December	1997	Interim Report
March	1998	Progress Report (2)
June	1998	Draft Final Report
August	1998	Final Report

4 Study Results

(1) Preliminary Bridge Survey and Identification of Bridges which need Urgent Replacement

The first stage in selecting the priority projects for the feasibility study was made from preliminary bridge surveys of the 22 candidate bridges for urgent replacement.

The following points were evaluated:

1) Present capacity of bridges in relation to the design live load
2) Age of bridges
3) Bridge damage rating
4) Relation between sag and span length for unloaded bridge
5) Socioeconomic conditions around bridge sites

The results of the evaluation are shown in Table 1.

In conclusion, the following 12 bridges were identified as those in need replacement. These were studied further in order to select the priority projects for a feasibility study.

Table 1 Results of Evaluation

Br.No.	Br.Name	NHRt.No.	Br.Type	Br.Length (m)	Br.Width (m)	Load Capacity (t)	Age (Year)	Damage Rating	Sag/Span	S.E. Point
1	Kurizampa	1	Bailey TSR	42.7	3.36	5	26	3.0	1/250	O
2	Chamkar Zam	1	Bailey DS	33.7	3.22	5	24	3.3	1/279	O
3	Bjee	1	Bailey TSR	42.7	3.36	9	28	4.0	1/250	O
4	Wachy Zam	1	Bailey DSR	33.7	3.15	18	28	4.0	1/209	O
5	Mangdichu	4	Bailey Susp	97.4	3.2	4	32	3.7	*	O
6	Wangdigang	4	Bailey DS	30.5	3.35	15	28	4.0	1/189	
7	Panjurmani	4	Steel Beam	9.0	4.00	7	2	–	N	
8	Ishigangchu	4	Bailey DS	36.6	3.34	15	5	3.0	1/135	O
9	Hesothangkha	5	Bailey SS	9.2	3.34	18	12	1.3	N	
10	Lawakha	5	Bailey DSR	30.5	3.37	18	9	3.3	N	
11	Basochu	5	Bailey SS	18.3	3.34	15	12	1.3	N	
12	Rurichu	5	Bailey SS	15.3	3.34	18	10	1.6	N	
13	Baychu	5	Bailey SS	15.3	3.34	17	12	1.6	N	
14	Kamichu	5	Bailey SS	18.3	3.34	15	11	1.6	N	
15	Narachu	5	Bailey DS	30.5	3.31	24	6	1.2	1/253	
16	Wakleytar	5	Bailey Susp	73.2	3.37	12	10	2.0	*	
17	Mechikhola	5	Timber Truss	18.0	3.69	8	7	1.2	N	
18	Burichu	5	Bailey DS	27.5	3.37	18	12	1.3	1/273	
19	Chanchy	5	Bailey TS	39.7	3.31	18	11	1.0	1/247	
20	Loringkhola	5	Bailey DDR	48.8	3.30	18	5	3.0	1/286	
21	Tangmachu	Mon/Lhue	Bailey Susp	85.2	3.30	12	15	2.4	*	O
22	Sunkosh	Tsil/Sun	Bailey Susp	85.2	3.30	12	15	2.4	*	

Note: S.E.Point: Socioeconomic Point
N: Negligible
*: Suspension Bridge
Bold figures: Major factors in selecting

The selected bridges are:

Bridge No.	Bridge Name
1	Kurizampa
2	Chamkar Zam
3	Bjee
4	Wachy Zam
5	Mangdichu
6	Wangdigang
8	Ishigangchu
10	Lawakha
16	Wakleytar
17	Mechikhola
21	Tangmachu
22	Sunkosh

(2) Traffic Survey and Traffic Forecast

The purpose of the traffic survey was to analyze the present road traffic conditions in Bhutan, and to provide a future traffic forecast based on the traffic survey for fundamental data for use in bridge planning and for the feasibility study.

The traffic surveys which were carried out in the Study comprised (1) roadside O-D survey, (2) traffic count survey and (3) travel speed survey.

The O-D table for all vehicles shows the results of the traffic survey. This indicates that Thimphu is the focus of the present pattern of intercity trip distribution in Bhutan. Moreover, the intercity traffic demand along National Highway Route No. 1 as an East-West highway is increasing.

The future O-D matrix forecast based on the traffic survey result was examined by the analysis of relations between present O-D and socioeconomic data by zone which is represented by population data. Future traffic volumes along the national highway sections were estimated by traffic assignment calculations which is a procedure of assigning future O-D matrix to the highway network. The assignment method applied is called "the all-or-nothing method".

In accordance with the traffic assignment in 2020 as shown in Figure 2, the assigned traffic volumes passing each of the 12 candidate Project Bridges are:

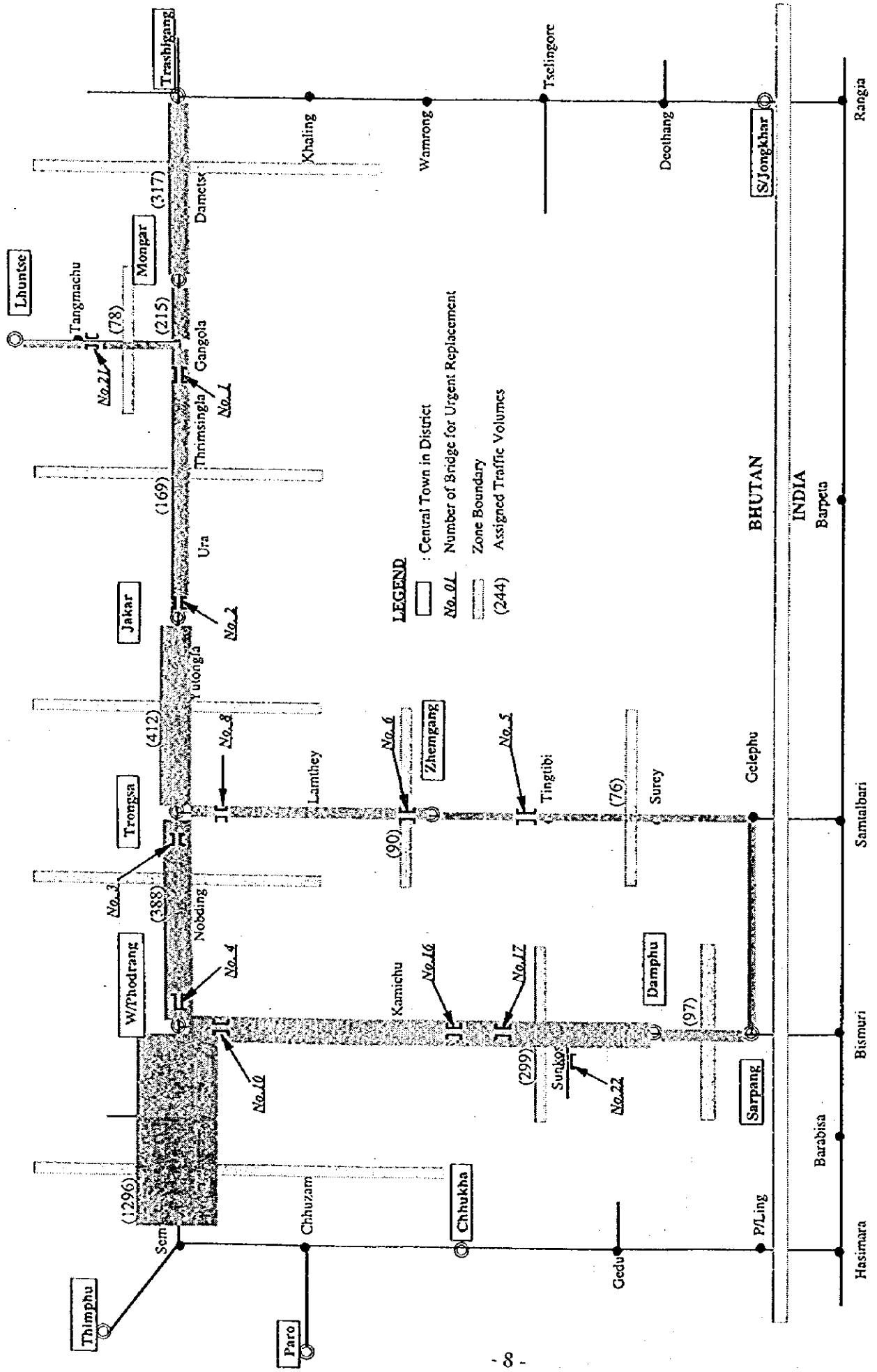

Figure 2 Assigned Traffic Volumes in 2020

No. 1	Kurizampa	169	No. 2	Chamkar Zam	169
No. 3	Bjee	388	No. 4	Wachy Zam	388
No. 5	Mangdichu	76	No. 6	Wangdigang	90
No. 8	Ishigangchu	90	No.10	Lawakha	299
No.16	Wakleytar	299	No.17	Mechikhola	299
No.21	Tangmachu	78			
No.22	Sunkosh	117	(multiplied traffic count data by growth rate of traffic generation for Dagana)		

The actual future traffic volumes passing each bridge, especially Chamkar Zam and Bjee bridges, will be more than these assigned traffic volumes, because of the demand for transportation from the nearby urban areas.

(3) Environment Study

Initially, an IEE for each of 22 bridges was carried out. Based on these IEEs, further assessments for potential impacts on the natural and social environment were conducted at the five bridge sites which were selected as priority projects.

Recommendations include:

New constructed slopes along the access roads should be secured by masonry retaining walls or gabions to prevent soil erosion. For all bridge sites, no environmental problems are anticipated except during construction activities.

According to the construction plan silty water will not be generated at any stage to disturb the riverbed. However, as a precaution, environmental monitoring of the construction site will be performed by photographic survey.

Concerning noise generated during construction, local residents will be informed in advance of the construction schedule, and the nature of the construction will be explained, in order that they may more easily adapt to and tolerate this temporary inconvenience.

(4) Selection of Bridges for the Feasibility Study

In the course of selecting the priority bridges for urgent replacement from the twelve candidate bridges, the following selection criteria were employed:

1) Importance of the bridge within the national highway network plan of Bhutan
2) Future traffic volume for the year 2020
3) Population benefiting from replacement of the bridge

4) Preliminary economic evaluation of the bridge replacement
5) Present condition of the bridge
6) Engineering/Technological difficulty in the bridge construction

The results of the evaluation are shown in Table 2. The following bridges have been selected as priority projects.

Bridge No. 1 Kurizampa
Bridge No. 2 Chamkar Zam
Bridge No. 3 Bjee
Bridge No. 4 Wachy Zam
Bridge No. 5 Mangdichu

(5) Detailed Survey of the Selected Bridge Sites

A topographic survey was conducted for the preliminary engineering design by a survey team from the PWD at the priority bridge sites. Bore holes were drilled and examined to confirm the bearing stratum and capacity. Detailed survey of each bridge site in the winter season was conducted also.

(6) Study of Design Alternatives

Prior to the establishment of design standards and criteria, existing standards, specifications and relevant studies on bridges were reviewed, and recommendations were established.

1) Live load

Bhutanese Class A Loading was adopted for the design.

2) Consideration of bridge width

Based on the forecast traffic volumes and existing conditions of national highways and bridges, the road widths adopted in the design are:

- Width for bridge length less than 50 meters
  One-lane bridge ---- 4.5 meters
  Two-lane bridge ---- 7.5 meters

- Width for bridge length over 50 meters
  One-lane bridge ----- 5.5 meters
  Two-lane bridge ----- 7.5 meters

Table 2 Score Sheet for Priority Projects Selection

Bridge No.	Bridge Name	Importance in NH Network		Forecast Traffic Volume		Population to Receive Benefit & SE Point	Economic Evaluation (Cost Benefit Ratio)		Present Conditions				Eng'ing Techno Difficulty	Total
									Load Capacity	Age	Damage Rating	Sag/Span		
		Rank	Score	Vh/day	Score	10 Thousand	CBR	Score	Score	Score	Score	Score	Score	
1	Kurizampa	A	4	169	2	4.0	1.01	4	1.0	1	1	0.5	2	19.5
2	Chamkar Zam	A	4	169	2	2.5	1.24	4	1.0	1	1	0.5	2	18.0
3	Bjee	A	4	388	4	2.5	1.70	4	1.0	1	1	0.5	2	20.0
4	Wachy Zam	A	4	388	4	3.0	2.08	4	0.5	1	1	0.5	2	20.0
5	Mangdichu	B	2	76	1	2.5	0.40	1	1.0	1	1	0.0	4	13.5
6	Wangdigang	B	2	90	1	0.5	0.44	1	0.5	1	1	1.0	2	10.0
8	Ishigangchu	B	2	90	1	3.0	0.44	1	0.5	0	1	1.0	2	11.5
10	Lawakha	B	2	299	3	1.0	0.71	2	0.5	0	1	0.0	2	11.5
16	Wakleytar	B	2	299	3	1.0	0.56	2	0.5	0	0	0.0	4	12.5
17	Mechikhola	B	2	299	3	1.0	2.08	4	1.0	0	0	0.0	0	11.0
21	Tangmachu	C	1	78	1	3.0	-	0	0.5	0	0	0.0	4	9.5
22	Sunkosh	C	1	117	2	2.0	-	0	0.5	0	0	0.0	4	9.5
Score			Max. 4		Max. 4	Max. 4		Max. 4	Max. 1	Max. 1	Max. 1	Max. 1	Max. 4	Max. 24

3) Alternative Bridge Types

- Span arrangement

For all of the five priority projects, the velocity of water is very high, especially in the rainy season, when high water flows transport large and heavy boulders it is costly and dangerous to construct piers in the river. Therefore for all bridges a simple span design was adopted.

- Bridge length

Basically the proposed bridge lengths will be longer than existing for all five bridges, since the abutments of the existing bridges are located at an unfavorable position for reuse, and new locations must be used.

Proposed bridge lengths are:

Bridge No.	Bridge length
1	54 m
2	43 m
3	50 m
4	43 m
5	100 m

- Comparison between steel and concrete bridge designs

Considering the spaces available for construction, concrete strengths obtainable at present in Bhutan, restrictions on erection and transportation cost and construction period, steel bridges have been recommended.

- Bridge Type

As to superstructure, substructure and foundation, different types of structures were compared in transportation and erection of structural members, construction period and construction cost. The final selection is given in the following table:

Br. No.	Bridge Name	Width	Length	Superstructure	Substructure
1	Kurizampa	5.5	54.0	Truss	Abutments with deep wells
2	Chamkar Zam	7.5	43.0	Truss	Abutments
3	Bjee	5.5	50.0	Truss	Abutments with deep wells
4	Wachy Zam	5.5	43.0	Truss	Abutments with deep wells
5	Mangdichu	5.5	100.0	Lohse	Abutments with deep wells

- Alignment alternatives

The proposed bridge alignments were studied, and the most suitable alternatives were selected based on the results of the bridge site survey, topographical survey and geological survey.

(7) Preliminary Design and Project Cost

Geometric design criteria and bridge design criteria were considered and finalized for the preliminary design. In the preliminary design 6.0 meters minimum curve radius was selected, in order to minimize excavation and cutting of the mountain face for economical and safe construction of the approach road. The cut mountain face was designed to be protected by stone pitching.

Bridge site conditions are critical at all bridges except No. 2 due to limited working space, and deep foundation piles adopted in order to minimize the excavation for abutments and to have a space for traffic around abutments. Preliminary design was prepared and major material quantities for cost estimates were obtained.

The project cost of 5 bridges is estimated as follows:

Foreign currency portion : 534.0 Million Nu
Local currency portion : 128.7 Million Nu
Total : 662.7 Million Nu
(1 US$ = 38.6 Nu)

(8) Implementation Plan

Implementation plan for the construction stage by international tendering is shown in Figure 3.

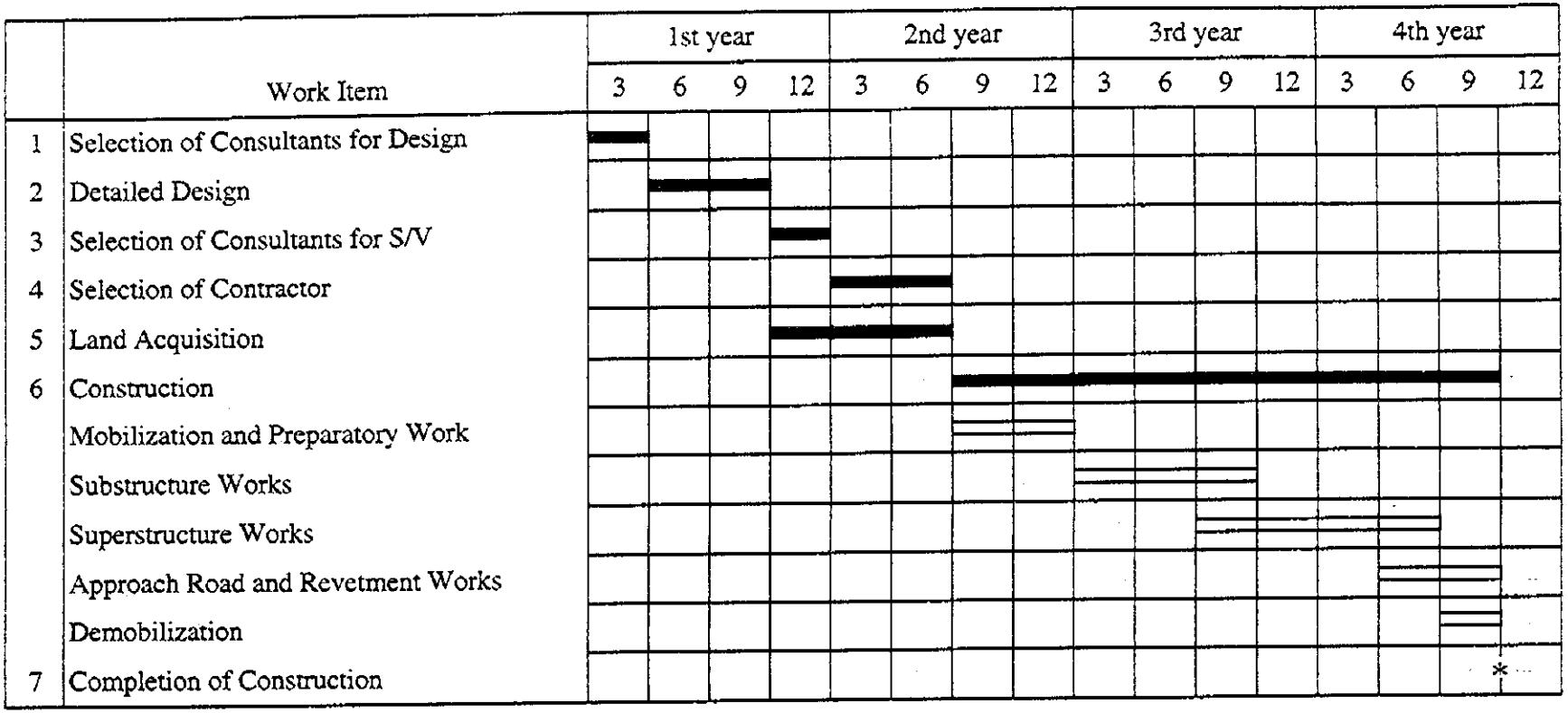

Figure 3 Implementation Schedule (International Competitive Bid Procedure)

5 Evaluation of the Study

(1) Economic Evaluation

Premises for economic analysis are assumed as follows:

- Implementation schedule in the Figure 3 and cost disbursement following Table 3

Table 3 Cost Disbursement

(1000 Nu.)

		1999	2000	2001	2002	Total
No. 1 Kurizampa	Construction	0	54,885	36,590	0	91,475
	D/D	3,132	0	0	0	3,132
	S/V	0	4,293	4,293	954	9,540
	Sub-total	3,132	59,178	40,883	954	104,147
No. 2 Chamkar Zam	Construction	0	50,217	27,040	0	77,257
	D/D	3,132	0	0	0	3,132
	S/V	0	4,293	4,293	954	9,540
	Sub-total	3,132	54,510	31,333	954	89,929
No. 3 Bjee	Construction	0	0	52,670	22,573	75,243
	D/D	3,132	0	0	0	3,132
	S/V	0	4,293	4,293	954	9,540
	Sub-total	3,132	4,293	66,963	23,527	87,915
No. 4 Wachy Zam	Construction	0	0	29,743	44,615	74,358
	D/D	3,132	0	0	0	3,132
	S/V	0	4,293	4,293	954	9,540
	Sub-total	3,132	4,293	34,036	45,569	87,030
No.5 Mangdichu	Construction	0	75,430	113,145	0	188,575
	D/D	8,353	0	0	0	8,353
	S/V	0	4,293	4,293	954	9,540
	Sub-total	8,353	79,723	117,438	954	206,468
Total	Construction	0	180,532	259,188	67,188	506,908
	D/D	20,883	0	0	0	20,883
	S/V	0	21,464	21,464	4,770	47,698
	Sub-total	20,883	201,996	280,652	71,958	575,489

Note 1: Construction --- Construction Cost, D/D --- Detailed Design Cost, S/V --- Supervision Cost
Note 2: The construction cost of No. 4 Wachy Zam Bridge includes the land acquisition cost for paddy field.

- Project life for economic analysis

  Project life of 30 years, after the opening of the project bridges, is assumed.

- Annual increasing rate of benefits

  Annual benefits after the opening of the Project Bridges are assumed as follows:

  until 2020 --- applied annual average growth rate of every five years

  after 2020 --- applied annual average growth rate from 2015 to 2020

  The benefit calculations in this Study are estimated as the comparison between the case "with" the traffic regulation for heavy vehicles as same conditions at present (heavy vehicles will be compelled to make a long detour.) and the case "without"

the traffic regulation for heavy vehicles as a result of construction of the selected five (5) bridges.

Estimated Benefit

(Unit : Million Nu. / Year)

	2000	2005	2010	2015	2020
Case 1 (Kurizampa & Chamkar Zam)	18.91	21.98	28.37	35.67	38.74
Case 2 (Bjee & Wachy Zam)	46.84	55.59	70.26	84.69	95.25
Case 3 (Mangdichu)	11.03	13.25	16.20	19.10	20.61

- Discount rate

  Discount Rate of 15% is assumed corresponding to the present long term interest rate in Bhutan.

The results of three indicators for economic evaluation (IRR, NPV, CBR) are shown in the next table.

Results of Economic Analysis

	IRR (%)	NPV (in Million Nu.)	CBR
Case 1 (Kurizampa & Chamkar Zam)	11.6	- 46.1	0.72
Case 2 (Bjee & Wachy Zam)	28.2	161.9	2.25
Case 3 (Mangdichu)	6.2	- 102.4	0.40

Note : NPV and CBR under discount rate 15%

(Sensitivity Analysis)

In general, the fluctuation factors in sensitivity analysis on highway/bridge development projects are traffic demand, construction costs, maintenance costs and so on. The analysis in the Study was conducted for the conceptual cases in which different levels of benefit and cost were assumed as follows.

(1) Project cost + 10%
(2) Project cost - 10%
(3) Two years delay of timing of the project implementation

The results are shown in the next table.

Results of Sensitivity Analysis

		IRR (%)	NPV (in million Nu.)	CBR
Case 1	Original	11.6	- 46.1	0.72
	Cost - 10%	12.6	- 29.9	0.80
	Cost + 10%	10.7	- 62.2	0.65
	Two years delay	12.3	- 27.9	0.77
Case 2	Original	28.2	161.9	2.25
	Cost - 10%	30.5	174.7	2.50
	Cost + 10%	26.3	149.1	2.05
	Two years delay	28.5	127.2	2.27
Case 3	Original	6.2	- 102.4	0.40
	Cost - 10%	7.0	- 85.7	0.44
	Cost + 10%	5.5	- 119.1	0.36
	Two years delay	6.6	- 74.1	0.42

(Economic Analysis on Combinations of Project Bridge Constructions)
The studied combinations are as follows:

Combination 1 --- All project bridges (No. 1 ~ No. 5)
Combination 2 --- No.1 Kurizampa Bridge, No.2 Chamkar Zam Bridge, No.3 Bjee Bridge and No.4 Wachy Zam Bridge on the National Highway Route No. 1
Combination 3 --- No.1 Kurizampa Bridge, No.2 Chamkar Zam Bridge and No.5 Mangdichu Bridge
Combination 4 --- No.3 Bjee Bridge, No.4 Wachy Zam Bridge and No.5 Mangdichu Bridge

Premises for economic analysis in this section are assumed as follows:

- Benefit estimates
  In case of "without" all project bridges, the above mentioned premise for benefit estimates can not apply, because the detours for the heavy vehicle O-D pairs of zone C (Bumthang), H (Trongsa) and I (Zhemgang) concerned do not exist. Accordingly, the benefit estimates are based on the following premise:

  "In the case "with" priority bridges, the passage of heavily laden vehicles is not regulated. On the other hand, in the case "without" priority bridges, the loads are divided and transported by two (2) heavy vehicles, because fully loaded heavy

vehicles with a load capacity of eight (8) tons, which are generally used in Bhutan, cannot pass on account of the limitation of load capacity on the existing bridges. In this case, the required heavy vehicles for freight transportation are estimated by applying 48.6% (excluding the observation values at the survey stations in highway sections including the Project Bridges) as percentage of heavy laden vehicle traffic volumes on the results of roadside O-D survey. That is to say, in the case "without", the heavy vehicle traffic volumes increase with the result that heavy vehicle operating costs increase."

Estimated Benefit by Combination and Year

(Unit : Million Nu./Year)

	2000	2005	2010	2015	2020
Combination 1	38.78	45.95	58.05	69.75	77.28
Combination 2	24.07	28.65	36.11	43.58	48.65
Combination 3	10.90	12.70	16.25	19.47	21.06
Combination 4	22.14	25.87	33.11	39.48	43.49

- The other premises are same as the above mentioned.

Results of Economic Analysis by Combination

	IRR (%)	NPV (in million Nu.)	CBR
Combination 1	8.4	- 222.5	0.52
Combination 2	8.3	- 143.1	0.51
Combination 3	1.7	- 265.8	0.20
Combination 4	7.0	- 171.1	0.44

Note : NPV and CBR under discount rate 15%

From the results of economic analysis by combination, the indicator IRR and CBR of Combination 1 (implementation of all project bridges) and Combination 2 (implementation of No.1 ~ No.4 bridges) are relatively high. That is to say, from the viewpoint of national economy, the implementation of project bridge construction is very positive.

(2) Impacts on Economic and Social Development

(Transport Service)

Road transport in Bhutan remains the only mode of travelling and freight movement within the country and to the neighboring Indian states. Accordingly, the implementation of the Project will provide adequate and efficient passenger transport service, and ensure the safety, convenience and comfort of passengers. At the same time, it will contribute to speedy and smooth freight movement.

(Education)

The implementation of the Project will contribute to provide the residents for the safe and reliable accessibility to educational facilities in and around the project bridges.

(Health Service)

The ability of health service teams to provide timely service will be improved by the availability of reliable transport. This would be more so when a team must respond to an emergency such as road traffic accidents or when a critically ill patient must be moved to a higher level care center.

(Postal Service)

The Project will contribute to prompt, efficient and economical postal services to all parts of the country through a more effective mail transport network.

(National Development)

Infrastructure is viewed as a prerequisite for starting any development in the country. A well spread and good infrastructure would enhance development by increasing the efficiency of economic activities and the delivery of services.

Development of infrastructure is particularly difficult in Bhutan due to scattered and sparse pattern of human settlement brought about by mountainous and rugged terrain. Moreover, as there are constraints on freight movement and access to markets on account of load capacity limitation of the existing bridges, the economic activities and industrial developments in the whole country are restricted, especially in the central region including Bumthang, Trongsa and Zhemgang Districts. Continued emphasis has been placed on the central region since the launching of planned development in Bhutan.

(Improving Quality of Life for the Residents)

In the objectives of the national development plan, measures to improve the quality of life in Bhutan are directed not only to raise the income-earning capacity of the majority of the

population, but also to improve access to basic services such as education, health and religion as Buddhism has a significant influence on the values of the Bhutanese and has shaped the institutions, organizations and social structure, and facilities such as clean drinking water, sanitation and communications. It is clear that the implementation of the Projects will contribute to providing the residents with safe and reliable access to basic services and facilities.

6 Conclusions and Recommendation

(1) Conclusions

All of the bridges constructed along the major national highways within the Project area are temporary structures already having passed their intended life span. Due to this fact, the loads which these bridges are able to bear decreases each year and tighter load restrictions must be enforced. In particular, four (4) bridges along National Highway Route No. 1, which is the only east-west route connecting the nation's cities and towns; and one (1) bridge along National Highway Route No. 4, which is a major connecting route to India, are more than 25 years old and their function as bridges has considerably diminished. Initially built with a design load of 18 tons, there is now a mere 4-ton load restriction being enforced on these bridges. Each year, despite efforts in maintenance, it becomes more and more difficult to deal with problems such as deformation and sagging, elements which lead to serious damage. In light of this situation, this project is in urgent need of administration, the effects of which are indicated in the following:

1) The present road network is of low density and alternative routes are few. Thus, large vehicles are required to make quite long detours due to load restrictions. By mitigating these detours and time incurred therein, the direct beneficial effects on the national economy alone make it evident that this is a project with high potential.

2) Although it is difficult to calculate the exact economic loss incurred in a situation in which a deteriorated bridge collapses, it is assumed to out-balance the economic gain incurred by the new traffic generated along the detour route.

3) By constructing permanent bridges along National Highway Route No. 1, which connects Thimphu with the second largest city Trashigang, besides alleviating restrictions on transportation and contributing to the efforts of the National Development Plan, the improved route will become a symbol of the balanced national development for which the country is striving, as well as being a safe means of linking the east and the west.

4) Through the mitigation of bridge load restrictions, an enlarged market for agricultural products may be merely one result of the improved quality in transportation. In other words, better access will encourage, growth of industries along the routes, with ripple effects on the overall national economy. In particular, the replacement of Mangdichu Bridge on National Highway Route No. 4 and the mitigation of load restrictions will have considerable impact on the development of industries along the route in the central Bhutan Dzongkhags of Trongsa and Zhemgang.

5) Major social impacts resulting from the construction of permanent bridges include access to educational and medical facilities, which will contribute to the social security of the local residents.

(2) Recommendation

This Project poses no particular technical problems, the positive effects are great, and the concerned agencies are fully capable of administering the Project. Considering the rate of deterioration of the bridges, the Project should be carried out urgently.