BASIC DESIGN STUDY
ON
THE PROJECT FOR REHABILITATION
OF
N-N DEMONSTRATION UNIT
IN
THE PEOPLE'S REPUBLIC OF BANGLADESH

MAY, 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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P R E F A C E

In response to the request of the Government of the People's Republic of Bangladesh, the Government of Japan has decided to conduct a basic design study on the Project for Rehabilitation of N - N (Narayanganj - Narsingdi) Demonstration Unit, and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bangladesh a study team headed by Mr. Tokuo Todoroki, Construction Department, Kantoh Agricultural Administration Office, Ministry of Agriculture, Forestry and Fisheries (MAFF) from February 15 to March 30, 1988.

The team had a series of discussions on the Project with the officials concerned of the Government of Bangladesh and conducted a field survey in the project area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

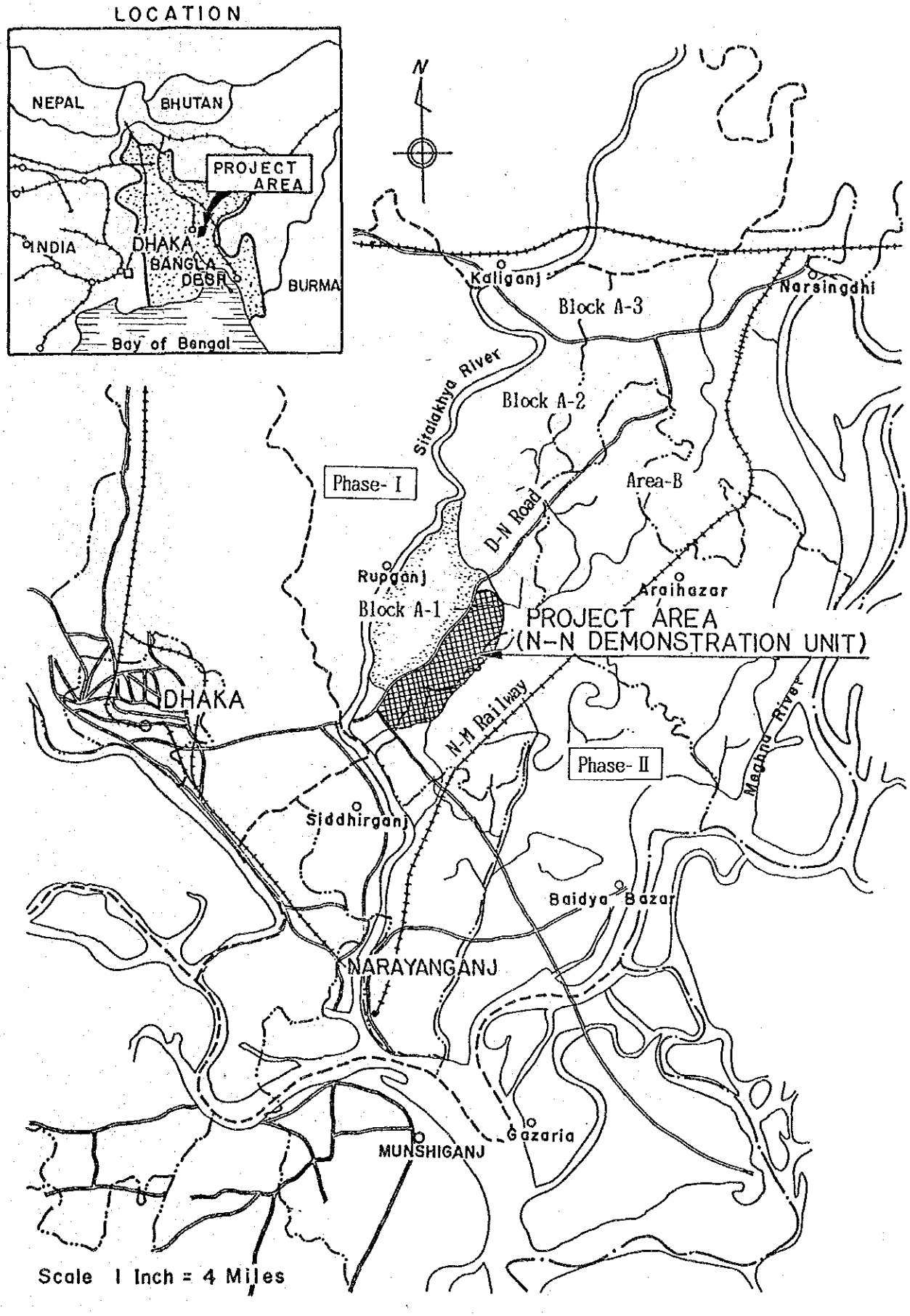
I wish to express my deep appreciation to the officials concerned of the Government of the People's Republic of Bangladesh for their close cooperation extended to the team.

May, 1988

Kensuke Yanagiya

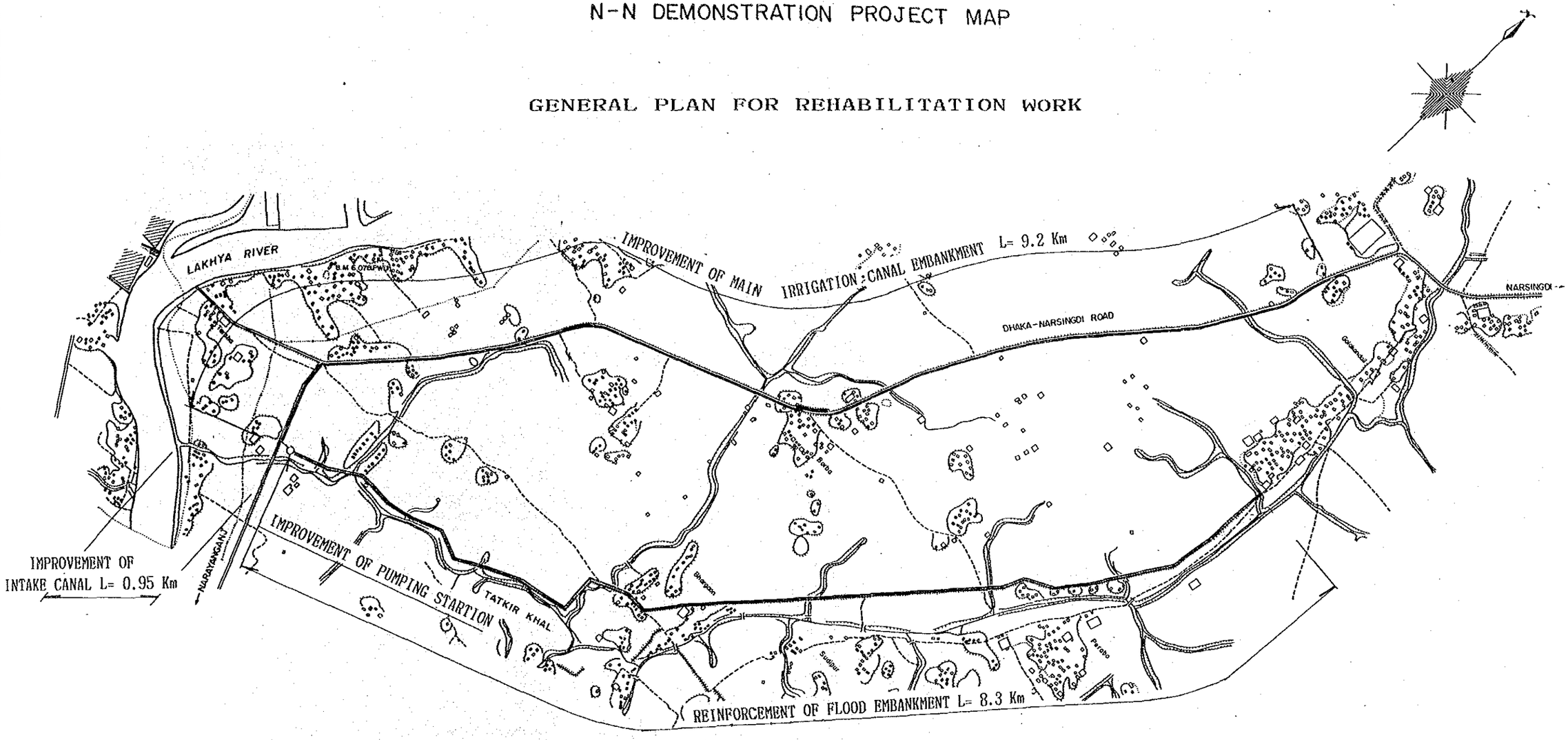
Kensuke Yanagiya
President
Japan International Cooperation Agency

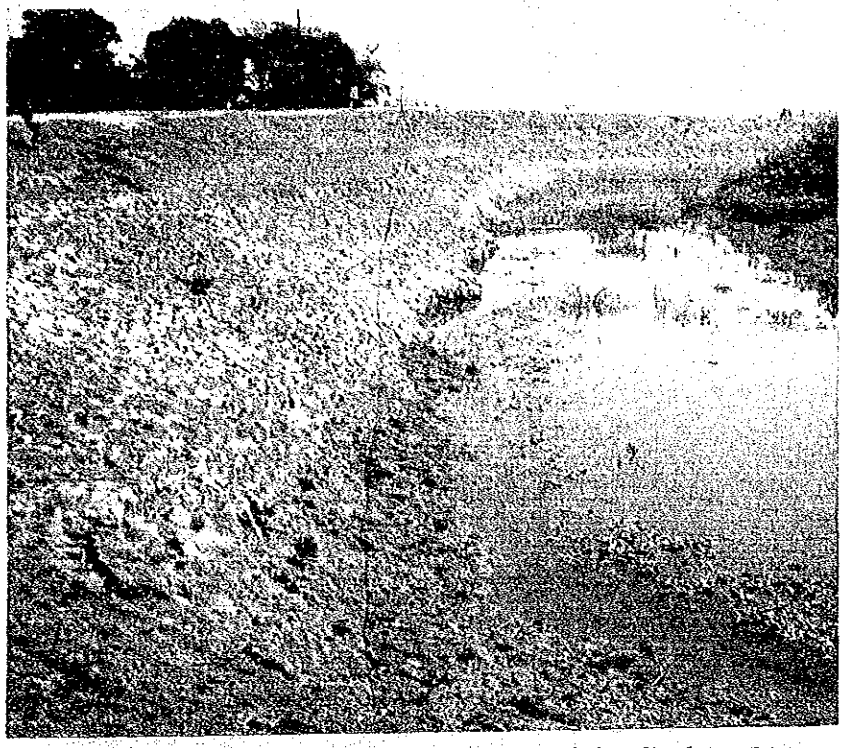
LOCATION MAP



N-N DEMONSTRATION PROJECT MAP

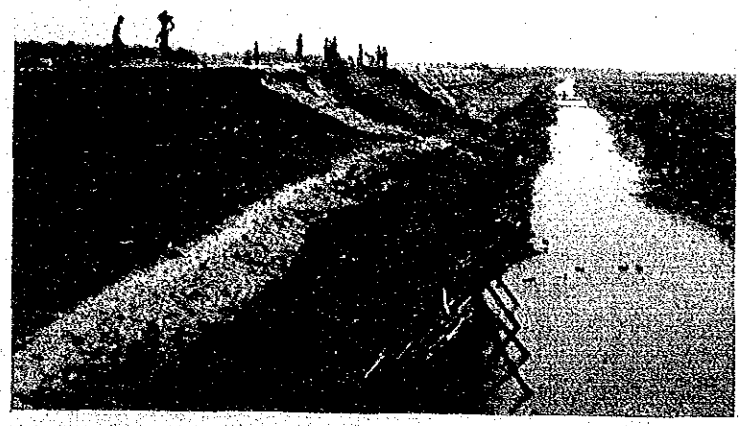
GENERAL PLAN FOR REHABILITATION WORK



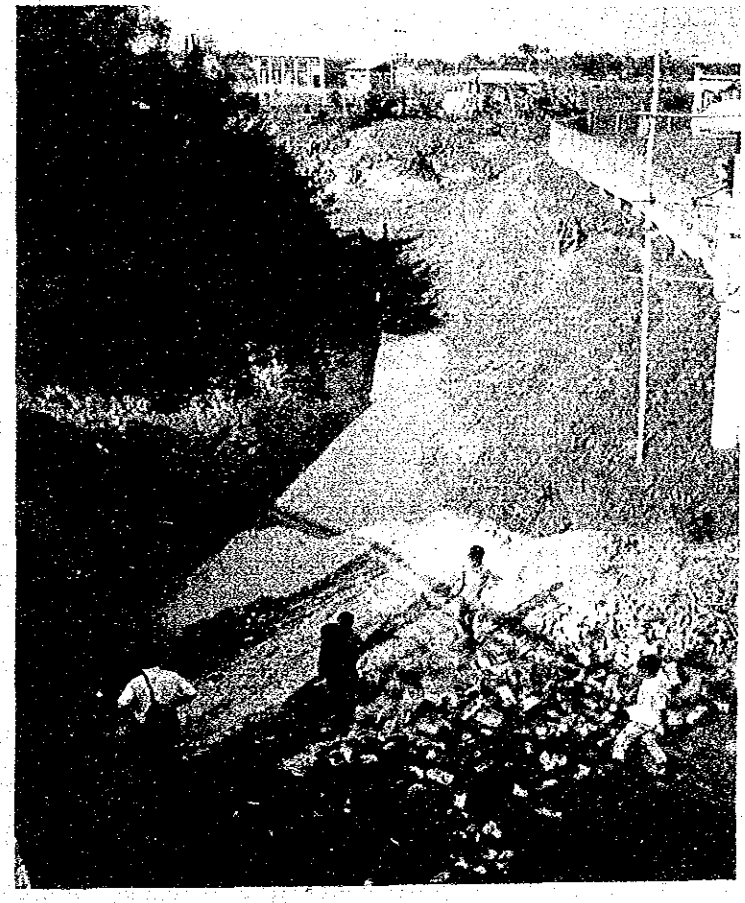


A part of Flood Embankment scoured by Tatkir River (about 0.40km away from Pumping Station)

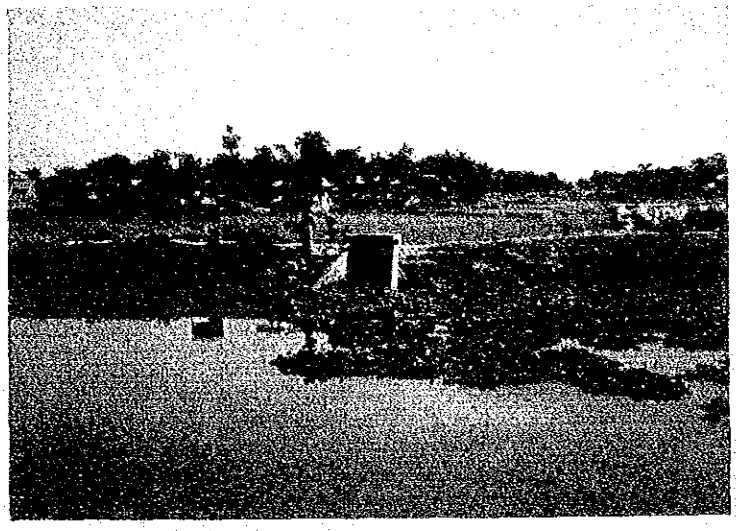
Many holes found in the existing embankment body during the emergency work (made by some kind of insect)



Emergency work under construction and timbering by local inhabitants
(about 5.7km away from Pumping Station)

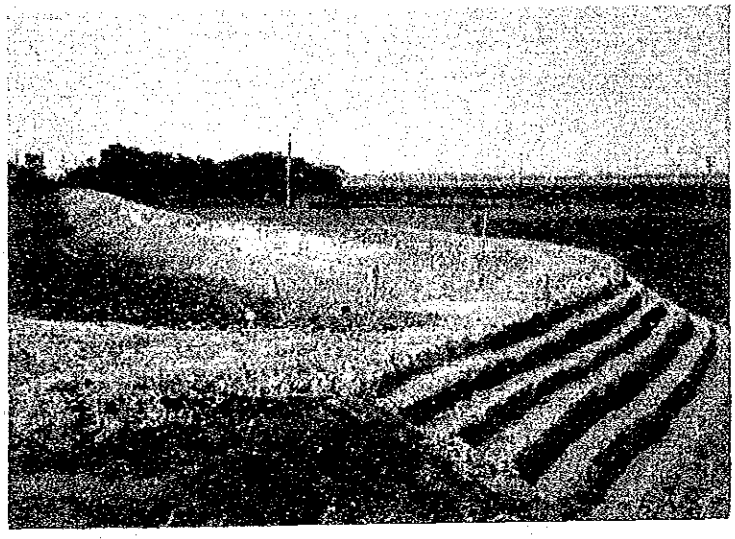


Intake Canal and Pumping Station
(dredging by BWDB)

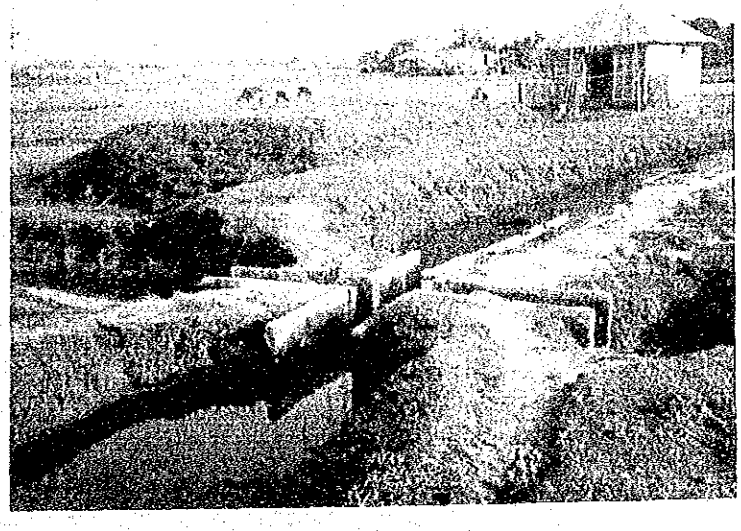


Turnout No. 1 from Main to Secondary Irrigation Canal

Irregularly-shaped canal embankment



Main Irrigation Canal Embankment nearby Barba Village (under reinforcement work by BWDB)



Turnout from Secondary Irrigation Canal No. 2 to Tertiary Irrigation Canal No. 3

SUMMARY

The People's Republic of Bangladesh has been developed, centering on the Bengal Delta formed by the great Ganges Padma and Brahmaputra Jamuna Rivers which traverse Bangladesh and flow into the Bay of Bengal. With a total land area of 144,000 km^2 and a population of some 140 million (1986), Bangladesh is one of the most dense populated countries in the world. 90% of the total land is categorized as lowland, of which two-thirds is farmland. 90% of the total population lives in the countryside and two-thirds of the total working population is engaged predominantly in paddy cultivation.

While year-round paddy cultivation is possible with the adequate water control, over 60% of the arable land is flooded during the rainy season (June - October) due to heavy rainfall and the large inflow of river water from upstream countries. In comparison, little rainfall in the dry season (November - February) causes droughts.

The country suffers from such basic problems as chronic food shortage and poverty due to harsh natural conditions and rapid population increase. The National Development Plan proposes specific targets with the emphasis that no development of Bangladesh can be achieved unless the three crucial problems of poverty, population increase and food shortage are firstly solved. In particular, the Plan places the highest priority on the development programmes in the agricultural sector which aims at self-sufficiency in food production. To attain the self-sufficient food production, solutions shall be firstly provided to such harsh natural conditions as floods and droughts. The provision of flood control embankment and irrigation and drainage facilities, therefore, is the only ways to overcome severe natural constraints on agriculture in Bangladesh.

According to this background, the Government of Bangladesh submitted to the Government of Japan in 1976 a request for the provision of assistance for an irrigation, drainage and flood control project for some 45,000 ha of land in the Narayanganj - Narsingdi (N-N) area which is

located 20 km east of Dhaka, the capital of Bangladesh, spreading both northerly and easterly. As the Location Map shows, the project area lies in an agricultural zone in the vicinity of the capital area and is bordered by Lakhya and Meghna Rivers.

In response to this request, the Government of Japan entrusted the Japan International Cooperation Agency (JICA) to conduct the Feasibility Study between 1977 and 1978 for the western part of the project area (Phase I, 29,000 ha), which is bounded by the N-M railway running through the project area. As a result, the N-N Irrigation Project was found technically feasible and economically viable through this Feasibility Study.

Following the Feasibility Study, the Narayanganj - Narsingdi (N-N) Terminal Irrigation Facilities Construction Project, which covers an area of some 1,300 ha in the southern part of the N-N Irrigation Project area, was initiated with the grant aid cooperation of the Government of Japan in Fiscal 1981 and was completed in March, 1984 as the Demonstration Unit. As a model area being equipped with modern irrigation and drainage facilities, this Demonstration Unit has effectively demonstrated the positive effects of the Project by means of improved agricultural productivity and brought a great deal of benefits to local inhabitants, enjoying an excellent reputation in Bangladesh.

In July and August, 1987, nevertheless, Bangladesh experienced unusually-heavy rainfall and the resultant extraordinary flooding. Due to this flooding, the flood embankment, which protects the Demonstration Unit from flooding, was partly breached on August 14 and crops in the Unit were entirely damaged. As a result, repair of the flood embankment including rehabilitation of the breached section was necessitated before the next rainy season (June, 1988). Therefore, the Government of Bangladesh submitted a request for the grant aid cooperation to the Government of Japan in the following November, 1987.

In response to this request, the Government of Japan entrusted JICA to send a follow-up study team to Bangladesh in December to prepare emergency measures for the rehabilitation of the damaged flood embankment through investigations on the actual damage to the embankment. The N-N Terminal Irrigation Facilities Rehabilitation Project was subsequently initiated. In succession of this follow-up study, the Government of Japan further decided to conduct a basic design study for the full-scale rehabilitation of the flood embankment, and JICA subsequently sent the Basic Design Study Team to Bangladesh for the period between February 15 and March 30, 1988 to determine the necessary and most appropriate work contents and size of the rehabilitation project which are eligible for a grant aid cooperation project of the Government of Japan.

In the course of the field study, the Study Team examined the background of the rehabilitation project, the requested contents and possible project implementation and maintenance systems, etc. and also conducted technical surveys on the possible causes of the breaching of the embankment and the current conditions of the damaged facilities in view of preparing a rehabilitation plan which would be best suited for Japanese grant aid cooperation. In addition, it was pointed out by the Study Team that the Government of Bangladesh is responsible for the necessary regular checking and the operation and maintenance work of the flood embankment.

On its return to Japan, the Study Team carried out a home office work by taking into consideration the results of the field study, and its results are summarized in this Report.

The objective of the Project is to rehabilitate the N-N Irrigation Project's Demonstration Unit, which was damaged by flooding in 1987, to restore the original functions of the irrigation and drainage facilities. To achieve this objective, a rehabilitation and improvement work will be conducted on the flood embankment, intake canal, pumping station and main irrigation canal with Japanese grant aid cooperation. The contents of the Project are outlined as below:

① Reinforcement of the entire flood embankment by means of widening the width of it within the ready acquired land;

② Improvement of the intake canal to prevent the collapse of its slopes and improvement of the pumping station facilities, in detail, lowering the inlet apron in its location; and

③ Improvement of the main irrigation canal embankment by means of increasing both its height and width.

The responsible organization for the implementation of the Project is the Bangladesh Water Development Board (BWDB) under the administration of the Ministry of Irrigation, Water Development and Flood Control. It is responsible not only for the implementation of such projects as flood control, water resources development and large-scale irrigation, but for the operation and maintenance of the facilities constructed under these projects.

Following the signing of the Exchange of Notes between the Bangladesh and Japanese Governments, the BWDB will implement the Project pursuant to the procedure of the Japanese grant aid system. The completion of the Project will require 2 dry seasons (12 months in total) and 1 rainy season (5 months) totalling to 17 months, and the Government of Bangladesh will, at her own expense, implement the work for which it is responsible, including the necessary legal procedures, in conformity with the implementation schedule.

The operation and maintenance of the facilities constructed under water resources development projects in Bangladesh are entirely conducted by the BWDB and the Demonstration Unit is not exceptional in this sense. This operation and maintenance system will remain unchanged after the completion of the Project. Since a uniform operation and maintenance system has been planned for the entire N-N Irrigation Project, the Maintenance Department (including civil engineering and mechanical sections) will eventually have some 30 employees on the completion of the neighbouring Block A-1 Project. As several years are still required for

the completion of the Block A-1 Project, however, the Department will firstly be run by some 17 employees who are responsible for the entire N-N area, centering on the Demonstration Unit.

The success of the flood embankment project depends on the stability of the embankment itself and, therefore, farmers should be reminded through public relations activities that their properties are protected by the flood embankment and the proper operation and maintenance of the embankment are of crucial importance. In this context, it is necessary to establish farmers' organizations which are provided by such a self-maintenance system as to block rat holes and so forth.

With the completion of the Project, the Demonstration Unit will again be made free from the threat of floods and droughts. In addition, as the functions of the irrigation facilities will be substantially improved compared to those in the past, agricultural productivity can be expected to reach the previous level or more and, thereby, contributing to the achievement of self-sufficiency in food production. Furthermore, the Project will, by its implementation, turn out pivotal socio-economic benefits, such as a restoration of the agricultural income to the previous level through increased agricultural production and stable living conditions. And great contributions are, thus, made to agricultural development which is identical to be the main theme of Bangladesh's current development efforts.

The smooth implementation and eventual success of the Project require the timely implementation of the work to be undertaken by the Government of Bangladesh in conformity with the implementation schedule. After the completion of the Project, farmers' organizations should be established to carry out the operation and maintenance of the flood embankment and irrigation facilities and the management of irrigation water.

BASIC DESIGN STUDY

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TABLE OF CONTENTS

ABBREVIATIONS

GOB	:	Government of Bangladesh
GOJ	:	Government of Japan
MFA	:	Ministry of Foreign Affairs
JICA	:	Japan International Cooperation Agency
BWDB	:	Bangladesh Water Development Board
ERD	:	External Resources Division
MOP	:	Ministry of Planning
K.S.S.	:	Krishak Shamabya Somity (Village Cooperative Society)
S.E.	:	Superintending Engineer
E.E.	:	Executive Engineer
S.D.E.	:	Sub-Divisional Engineer
S.A.E.	:	Sub-Assistant Engineer
W/ASST.	:	Work Assistant
MDC	:	Main Drainage Canal
SDC	:	Secondary Drainage Canal
MIC	:	Main Irrigation Canal
SIC	:	Secondary Irrigation Canal
TIC	:	Tertiary Irrigation Canal
O & M	:	Operation and Maintenance
N-N	:	Narayanganj - Narsingdi
NNDP	:	N-N Demonstration Project
DND	:	Dhaka - Narayanganj - Demra
IDA	:	International Developemnt Association
E/N	:	Exchange of Notes
B/D	:	Basic Design
D/D	:	Detailed Design
T.B.M.	:	Tentative Bench Mark
H.W.L.	:	High Water Level
S.O.B.	:	Survey of Bangladesh
P.W.D.	:	Public Works Department
D-N Road:		Dhaka - Narsingdi Road
D-C Road:		Dhaka - Chittagong Road
T-N Railway:		Tungi - Narsingdi Railway
N-M Railway:		Narsingdi - Madanganj Railway
TK	:	Taka
¥	:	Yen

CONVERSION TABLE

Length

1 foot	= 30.48	cm
1 foot	= 0.305	m
1 inch	= 2.54	cm
1 yard	= 91.44	cm
1 statute mile	= 1.61	km
1 US naut. mile	= 1.85	km
1 Int. naut. mile	= 1.85	km

Area

1 in^2	= 6.45	cm^2
1 ft^2	= 929.03	cm^2
1 yd^2	= 0.835	m^2
1 acre	= 0.405	ha
1 sq. stat. mile	= 2.59	km^2

Volume

1 in^3	= 16.39	cm^3
1 ft^3	= 28316.8	cm^3
1 ft^3	= 28.32	litre (l)
1 gallon (US)	= 3.79	l
1 gallon (Imp.)	= 4.55	l
1 acre foot	= 1233.5	m^3

Temperature

°F = 1.8°C + 32

°C = (°F - 32) 5/9

Velocity

1 knot	= 0.515	m/sec
	= 1.85	km/hr
1 foot/sec	= 0.305	m/sec
	= 1.095	km/hr
1 foot/min	= 0.51	cm/sec
	= 0.18	km/hr
1 mile/min	= 2682	cm/sec
	= 1.61	km/min
1 m/sec (24 hr)	= 86.4	km/day
1 foot/sec (24 hr)	= 26.33	km/day
1 mile/hour (24 hr)	= 38.6	km/day
1 knot (24 hr)	= 44.5	km/day

Pressure

1 atmosphere	= 76	cm Hg
1 atm	= 1.013	bar
1 inch Hg	= 0.0334	atm
1 inch H_2O	= 2.49	mbar
1 mbar	= 0.75	mm Hg
1 lb/in^2	= 51.72	mm Hg

Radiation to equivalent depth of evaporation

1 cal/cm^2	= 1/59	mm
1 cal/cm^2 min	= 1	mm/hr
1 mW/cm^2	= 1/70	mm/hr
1 mW/cm^2 (24 hr)	= 0.344	mm/day
1 cal/cm^2 min (24 hr)	= 24	mm/day
1 $Joule/cm^2$ min (24 hr)	= 5.73	mm/day

CHAPTER 1 INTRODUCTION

In 1976, the Government of Japan received a request from the Government of the People's Republic of Bangladesh (hereinafter referred to as the Government of Bangladesh) to conduct a feasibility study for an irrigation, drainage and flood control project covering some 45,000 ha of land in the Narayanganj - Narsingdi (N-N) area which is located at the centre of Bangladesh, that is to say on the outskirts of Dhaka, the capital.

In response to this request, the Government of Japan entrusted the Japan International Cooperation Agency (JICA) to conduct the Feasibility Study between 1977 and 1978 and this Feasibility Study concluded that the N-N Irrigation, Drainage and Flood Control Project was technically feasible and economically viable.

The Government of Bangladesh then selected some 1,300 ha of land (irrigable area: 1,000 ha) in the Rupganj area, located at the centre of the N-N Project Area along Dhaka - Narsingdi (D-N) Road, as the pilot project area and submitted to the Government of Japan a request for the provision of the grant aid cooperation for the construction of the pilot project. The Government of Japan subsequently extended the grant aid cooperation in Fiscal 1981 and the Government of Bangladesh accordingly implemented the Narayanganj - Narsingdi (N-N) Terminal Irrigation Facilities Construction Project between 1982 and 1984. The actual construction work commenced in April, 1982 and was completed in March, 1984 as the Demonstration Unit. As a model area being equipped with modern irrigation and drainage facilities, the Unit has effectively demonstrated the positive effects of the Project and brought a great deal of benefits to the local inhabitants, enjoying an excellent reputation in Bangladesh.

Between July and August, 1987, Bangladesh experienced unusually-heavy rainfall and the resultant extraordinary flooding. Due to this flooding, a part of the Demonstration Unit's flood embankment was breached on

August 14 and crops in the Unit were entirely damaged. As a result, repair of the flood embankment including rehabilitation of the breached section was necessitated before the next rainy season (June, 1988).

In September, the Government of Bangladesh made a request for a preliminary survey on the damaged flood embankment to the JICA Study Team working on the Basic Design Study for the N-N Irrigation Facilities Construction Project (Block A-1) in the Block A-1 area which is located to the immediate northwest of the Demonstration Unit and also submitted a request for the grant aid cooperation to the Government of Japan in November.

In response to this request, the Government of Japan entrusted JICA to send a follow-up study team to Bangladesh to discuss with the Bangladesh side the emergency measures to rehabilitate the damaged flood embankment. The Government of Japan further decided to conduct a basic design study for the full-scale rehabilitation of the flood embankment in succession to this follow-up study. Based on this decision, JICA sent the Basic Design Study Team (hereinafter referred to as the Study Team), headed by Mr. Tokuo Todoroki of the Construction Department, Kantoh Agricultural Administration Office of the Ministry of Agriculture, Forestry and Fisheries, to Bangladesh for the period between February 10 and March 30, 1988 to determine the necessary and most appropriate work contents and size of the rehabilitation project which are eligible for a grant aid cooperation project of the Government of Japan.

In the course of the field study, the Study Team examined the background of the rehabilitation project, the requested contents and possible project implementation and maintenance systems, etc. through consultations with officials concerned of the Government of Bangladesh, on the basis of surveys on the project site and other related facilities. The Study Team also conducted the technical surveys required for the preparation of Basic Design of the project which would be appropriate and suitable for the grant aid cooperation. The scopes of the conveniences to be provided by and the construction work, etc. for which the Government of Bangladesh will be responsible during the implementation

period of the rehabilitation project were confirmed and the minutes of the discussions were concluded.

On its return to Japan, by taking into consideration the results of the field study, the Study Team carried out a home office work comprising study item-wise analyses and examinations, preparation of basic designs for the rehabilitation project and a project implementation plan, project cost estimates and a project appraisal, etc. and their results are summarized in this Report.

CHAPTER 2 BACKGROUND OF THE PROJECT

2.1 Background

The Government of Bangladesh submitted to the Government of Japan in 1976 a request for a feasibility study on an irrigation, drainage and flood control project covering some 45,000 ha of land in the Narayanganj - Narsingdi (N-N) area which is located at the centre of Bangladesh and some 20 km east of Dhaka. In response to this request, the Government of Japan entrusted JICA to conduct the Feasibility Study between 1977 and 1978 and this Feasibility Study concluded that the N-N Irrigation, Drainage and Flood Control Project was technically feasible and economically viable.

The Government of Bangladesh subsequently selected some 1,300 ha of land (irrigable area: 1,000 ha) in the Rupganj area which is located at the centre of the N-N Project Area and along Dhaka - Narsingdi (D-N) Road and, with the provision of grant aid cooperation by the Government of Japan in Fiscal 1981, implemented the Narayanganj - Narsingdi (N-N) Terminal Irrigation Facilities Construction Project between 1982 and 1984. The actual construction work commenced n April, 1982 and was completed as the Demonstration Unit in March, 1984. As a model area being equipped with modern irrigation and drainage facilities, the Unit has fully demonstrated the beneficial effects of the Project and brought forward a great deal of benefits to the local inhabitants, attracting a lot of attention in Bangladesh.

In July and August, 1987, Bangladesh experienced unusually-heavy rainfall and the resultant flooding. Due to this flooding, a part of the Demonstration Unit's flood embankment was breached on August 14 and crops in the Unit were entirely damaged, necessitating repair of the flood embankment, including rehabilitation of the breached section, by the Government of Bangladesh before the next rainy

season (June, 1988) and the Government of Bangladesh therefore submitted a request for grant aid cooperation to the Government of Japan in November.

In response to this request, the Government of Japan entrusted JICA to send a follow-up study team to Bangladesh in December to prepare emergency measures necessary for the rehabilitation of the damaged flood embankment. The Government of Japan further decided to conduct a basic design study for the full-scale rehabilitation of the flood embankment in succession to this follow-up study and JICA subsequently sent the Basic Design Study Team to Bangladesh.

2.2 Contents of the Request

The Letter of Request sent from the Government of Bangladesh to the Government of Japan in regard to this Project did not specify concrete rehabilitation measures and their scopes.

As a result, the concrete contents of the request had to be clarified through discussions which took place during the field study. At the beginning of these discussions, both sides expressed different opinions. While the Bangladesh side considered it to expand the irrigation facilities in the Project area rather than to reinforce the flood embankment, the Japanese side expressed the view that the rehabilitation and reinforcement of the flood embankment should be given priority as the expansion of the irrigation facilities in the Project area would only be viable with successful flood control. Through discussions, however, both sides reached an understanding of the opposing viewpoints and the following items were agreed on the actual contents of the rehabilitation project (see Appendix 1-4).

1) Reinforcement of entire flood embankment.

2) Improvement of intake canal and pumping station's inlet.

3) Improvement of embankment for main irrigation canal at those places where no new land acquisition is required by the Bangladesh side.

CHAPTER 3 OUTLINE OF THE PROJECT AREA

3.1 Project Area

The Demonstration Unit, which was damaged due to the breaching of the flood embankment, is located in the southwestern end of the N-N Irrigation and Drainage Project Area, some 20 km east of Dhaka, and is enclosed by D-N Road in the northwest and by the corresponding flood embankment in the south and southeast. In the north, it is bounded by Golakandail Village where the elevation is slightly higher than that of the Demonstration Unit.

The area proposed under this Basic Design Study comprises the entire Demonstration Unit including the damaged flood embankment (approx. 8.3 km in length) and other related areas which are mostly adjacent to the Demonstration Unit.

3.2 Natural Conditions of the Project Area

3.2.1 Topography, Geology and Soil

The project Area lies on a flat lowland enclosed by Meghna and Lakhya Rivers and consists mostly of a flood plain with an elevation of 6 ft - 13 ft. Villages and forests have little inundation even in every rainy seasons with relatively high elevations between 13 ft and 20 ft, scattering over the Project Area and its vicinity.

The flood plain sediment is composed of soft clay, silt and loose and very fine sand with regional variations. In comparison, the soil of a higher land is relatively hard and is composed of silt with a fairly high clay content.

3.2.2 Climate

The Project Area belongs to a typical monsoon zone and is governed by dry season, rainy season and transitional periods between the two as shown below.

a) Transitional period to rainy season (March - May)
b) Rainy season (June - October)
c) Transitional period to dry season (October - November)
d) Dry season (December - March)

3.2.3 Hydrology

The Project Area is located on the left bank of Lakhya River and, therefore, is directly affected by fluctuations in its water level. A gauging post is located at Demra and a water gauge is installed at the pumping station.

The water level of Lakhya River reaches its peak approximately one month after the rains fall in the area and the highest level is recorded between late July and early September.

3.3 Outline of the Demonstration Unit

The Demonstration Unit covering some 1,000 ha of land was developed under the N-N Terminal Irrigation Facilities Construction Project with the grant aid cooperation (840 million yen) of the Government of Japan in Fiscal 1981 as a model area for the N-N Irrigation Project. The construction work commenced in April, 1982 and was completed in March, 1984. The constructed facilities and the benefited area are outlined as follows.

Net Irrigable Area	1,000 ha
Flood Embankment	8.3 km
Pumping Station	ϕ 700 mm x 3 pumps
Main Irrigation Canal	9.2 km
Secondary Irrigation Canal	6.9 km
Main Drainage Canal	8.2 km
Secondary Drainage Canal	15.6 km
Number of Farming Households	520
Target Population	2,600
Landless Farmers	50

The construction of tertiary canals and fields canals is currently in progress by the Government of Bangladesh and farmer's organizations and their completion by 1989 is anticipated by the BWDB which is responsible for the implementation of the Project and the subsequent maintenance of these facilities.

Although the construction and improvement of the terminal facilities are still in progress, agricultural productivity in the area has already improved with remarkable effects, including a 3- or 4-fold income increase of the benefited farmers. However, such problems as the incompletion of some terminal facilities and the lack of timely irrigation during the dry season due to structural factors of the pumping station have not yet been solved.

The operation and maintenance of the facilities are being carried out by the BWDB and the operation and maintenance for the 3 years between 1984/85 and 1986/87, including the personnel cost, costed TK 19.04 million.

In regard to water management and farming, 8 farmers' organizations (Krishak Shamabay Samity: KSS) have been established to promote modern agriculture. Rice cultivation has consequently improved from the single cropping of the low productivity B-Aman variety prior to the implementation of the Project to the double cropping of the high yield and high quality T-Aman, Boro and Broush varieties.

CHAPTER 4 CONTENTS OF THE REHABILITATION PROJECT

4.1 Objective

The objective of the Project is to rehabilitate the N-N Irrigation Project's Demonstration Unit which was damaged by flooding in 1987.

4.2 Determination of Project Contents

As already described in 2.2, the Bangladesh and Japanese sides expressed different opinions on the project contents at the beginning of the discussions. While the Bangladesh side considered that higher priority should be given to the replenishment of the irrigation facilities in the area than to the reinforcement of the flood embankment, the Japanese side expressed the view that the rehabilitation and reinforcement of the flood embankment should be given priority as the replenishment of the irrigation facilities in the area would only be subject to the establishment of successful flood control. Both sides, however, made a sincere effort to understand the mutual viewpoints finally, through repeated discussions, agreed on the project contents given in the next section to be determined for a rehabilitation project which would be implemented with the grant aid cooperation of the Government of Japan.

4.3 Project Contents

4.3.1 Outline of the Rehabilitation Project

The project contents, confirmed through discussions with the related agencies of the Government of Bangladesh, are outlined below.

① Reinforcement of the entire flood embankment by means of widening in those places where the land required for the extra width has already been acquired.

② Improvement of the intake canal to prevent the collapse of slopes and improvement of the pumping station facilities with an emphasis on lowering the inlet apron in its location.

③ Improvement of the main irrigation canal embankment by means of increasing both its height and width.

The Study Team discussed the above basic items with the Bangladesh side and examined the detailed contents of the project design. The detailed contents of the discussions are given in the relevant sections of the Report.

4.3.2 Work to be Undertaken by the Bangladesh Side

In the current fiscal year, the Ministry of Irrigation, Water Development and Flood Control of the Government of Bangladesh has received IDA funds for disaster rehabilitation projects and has used them for the emergency rehabilitation and improvement of the damaged flood embankment and irrigation facilities in the Demonstration Unit. The construction work has commenced during the recent dry season.

A demarcation point for the embankment rehabilitation work has been established 4 km from the pumping station (the work in the section between the pumping station and the demarcation point to be conducted by the Bangladesh side and the work in the remaining section to be conducted by the Japanese side as grant aid cooperation) and the work to be undertaken by the Bangladesh side has been let to a local contractor so that the rehabilitation work by both sides can be simultaneously implemented.

Given completion of the rehabilitation work by both sides, the flood embankment in the Demonstration Unit would be provided with the same cross-section for most of its entire length. In preparing this Basic Design for the Project, the Study Team decided to adopt the embankment form given in the original Basic Design as the embankment form expected upon completion of the rehabilitation work.

With regard to the work to be undertaken by the Government of Bangladesh, the Study Team submitted a letter to the authorities concerned of the Government of Bangladesh in reference to the following points and the Government's consideration of the matters concerned was requested (see Appendix 1-6).

- All the emergency rehabilitation work should be completed by the next dry season, i.e. October, 1988 so that the main rehabilitation work can immediately start at the beginning of the dry season.
- Through the field investigations, the Study Team found that several sections of the flood embankment constructed by the Bangladesh side have been severely damaged by animal holes or due to artificial reasons. In particular, pumping up from the main drainage canal over the flood embankment to outside the Demonstration Unit has resulted in reducing the crest width of the embankment by less than 2.5 m in parts.

4.3.3 Project Implementation Agency

The Bangladesh Water Development Board (BWDB) will be responsible for the maintenance of all the facilities to be rehabilitated under this Project. The actual implementation of the Project will be carried out by the Dhaka O & M Division II headed by its executive engineer under the supervision of the superintending engineer of the Dhaka O & M Circle.

4.3.4 Present Operation and Maintenance System

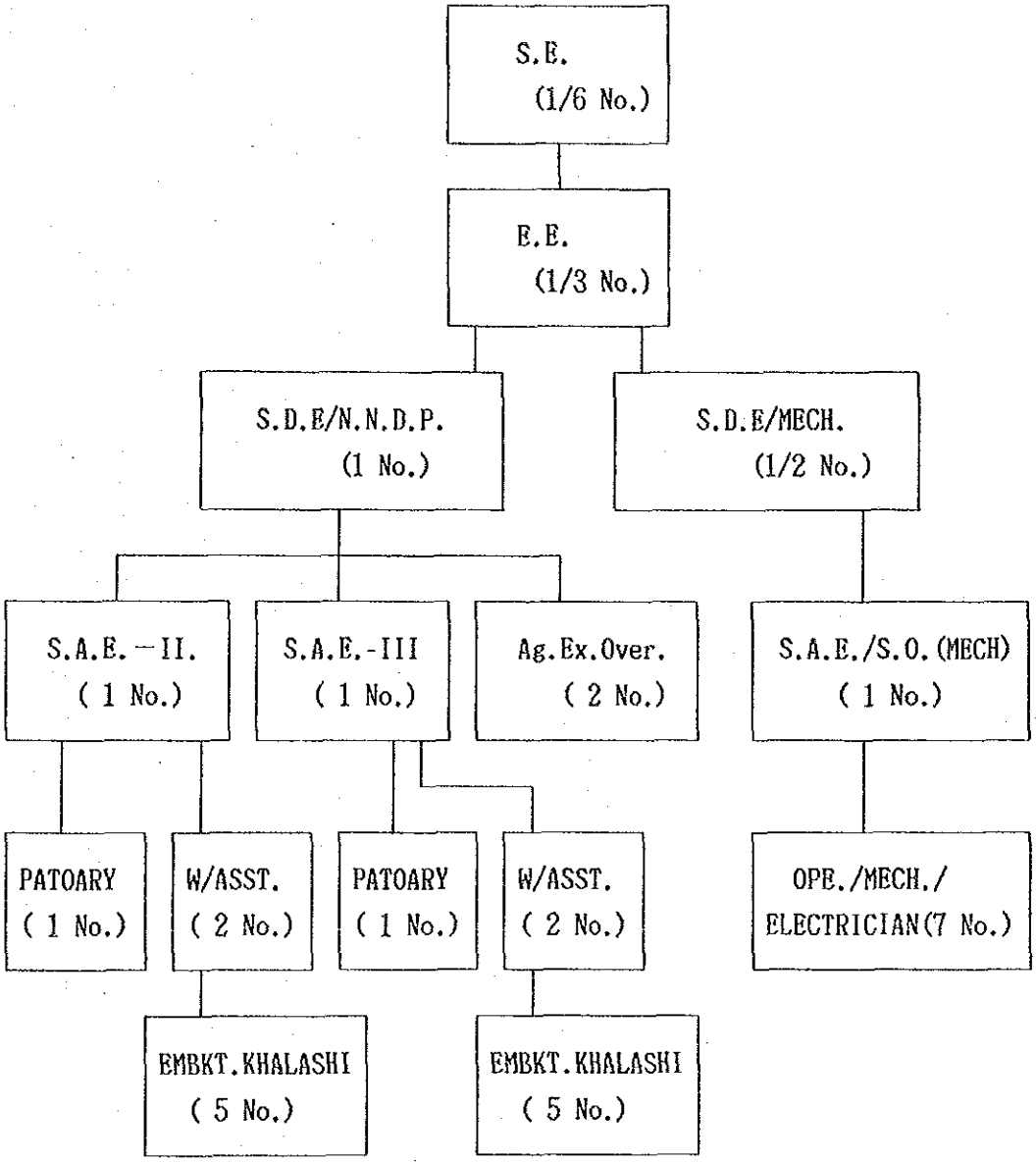
Since its completion, the Demonstration Unit has been operated and maintained by a sub-division of the N-N Demonstration Project (NNDP) under the guidance of the superintending engineer referred to in 4.3.3 above. Subsequent to the completion of this rehabilitation work, the same sub-division will also be responsible for the operation and maintenance of all the facilities to be rehabilitated under this Project. The organizational structure of the sub-division is shown in Fig. 4-3-1.

4.3.5 Project Implementation Plan

All works associated with the Project are divided into 3 categories, i.e. ① rehabilitation and improvement work, ② consultancy services and ③ work to be undertaken by the Bangladesh side, and ① and ② are subjected to the Japanese grant aid cooperation.

The construction work classified as ① will be conducted by a Japanese contractor who will be selected by the project implementation agency, i.e. the BWDB, in accordance with a standard procedure of the Japanese grant aid cooperation system. Consultancy services will include detailed design, preparation of tender documents, agency work for a tender procedure, evaluation of tenders and supervision of the construction work. The consultant will also be selected by the BWDB from Japanese consulting firms in accordance with the standard procedure of the Japanese grant aid system.

PLANNING DOCUMENTS FOR OPERATION AND MAINTENANCE
OF
IRRIGATION SYSTEM OF N.N.D.PROJECT



Notes; S.E.: Superintending Engineer
E.E.: Executive Engineer
S.D.E.: Sub-Divisional Engineer
S.A.E.: Sub Assistant Engineer
Ag.Ex.Over.: Agriculture Extention Overseer
W/ASST: Work Assistant
PATOARY: Office Worker
EMBKT.KHALASHI: Embankment Gard

F i g. 4－3－1 Planning Dodument for Operation and Maintenance

CHAPTER 5 BASIC DESIGN OF THE PROJECT

5.1 Evaluation of Present Conditions

5.1.1 Flood Embankment and Main Drainage Canal

(1) Original Design

The subject flood embankment occupies an important position in the Demonstration Unit which was designed as a pilot model for the N-N Irrigation Project. In the original design, the estimated high water level was set at HWL 6.20 m, corresponding to a 10 years return period, and the crest elevation of the flood embankment was determined at EL 6.60 m with a free board of 0.40 m. The embankment was so designed as an integrated structure in combination with the main drainage canal as to be provided with the typical cross-section illustrated in Fig. 5-1-1.

The flood of 1987 responsible for the current damages was unexpectedly severe beyond the originally-designed requirements, so that this rehabilitation plan has to be so worked out as to withstand the magnitude of this current flood and to be assured with a higher grade in its contents and scale than those designed originally.

(2) Assessment of Present Conditions Based on Soil Survey Results

The objective of the soil survey on the flood embankment are to evaluate the existing flood embankment and to make a good understanding of the characteristics of the soil materials to

Detailed Design

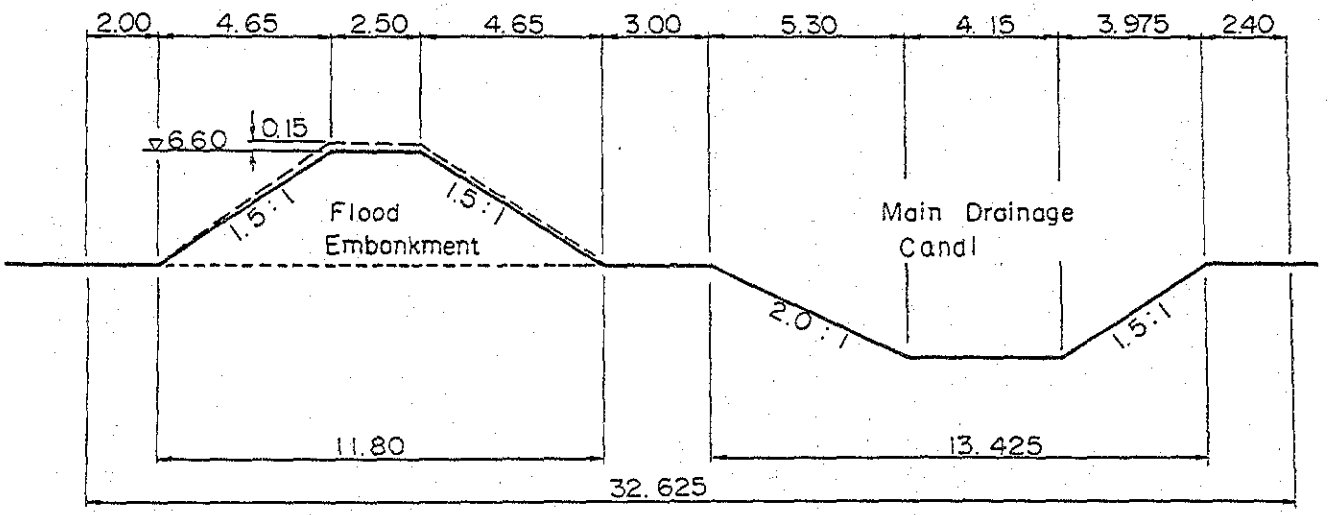


Fig. 5-1-1 Original Design of Flood Embankment

be used for rehabilitation purposes. In the former case, boring was conducted at 7 points on the flood embankment and laboratory tests (including the compression test) were also made by collecting soil samples from the bore holes and the proximity of the embankment surface. In the latter case, laboratory tests (including the compaction, compression and permeability tests) were made on 10 soil samples collected from sites along the flood embankment, which are expected to be borrow-pits and from areas along the D-N Road where it is believed to collect core materials. The survey sites, collected sample volumes and test results are summarized in Appendix 3-2.

The following general observation are made on the survey and test results.

a) The substratum of the flood embankment has two different soil characteristics by providing a boundary to somewhere around 3 - 4 km from the pumping station (probably around the 3.4 km point at the eastern edge of Bhargaon Village). The section on the pumping station side is characterized by clayey silt or silty clay and the other section which ends at Golakandail Village is characterized mainly by silt with fine sand and fine sand with silt where a predominant layer composed of fine sand is being distributed at a deeper part of this section.

b) The surface depth of the predominant layer of fine sand is shallowest at the breached section of the flood embankment and its elevation is, in fact, higher than that of the base of the main drainage canal. The layer was found to be very loose and the canal itself is also composed of very loose sand. Therefore, it can be assumed that the breached section was made vulnerable to piping of the substratum which is considered to be the main cause of the breaching of the embankment.

c) A layer of 0.5-1.0 m thick top soil with a relatively high cohesive soil content is found on the surface of the substratum of the embankment body, acting as a low permeability layer and preventing water percolation beneath the embankment body. At the breached section, however, in addition to the conditions described in b) above, there is no top soil layer as the flood embankment crosses a tributary of Tatkir River.

d) The banking materials used for the embankment section near Golakandail Village are either silt with loose sand or silty fine sand, reflecting the soil characteristics of the substratum. As these types of soil approach their liquid limit when saturated, extremely reducing their compaction strength, they are also liable to scouring due to the rainfall. The degree of damage to the flood embankment caused by flooding exactly reflects these characteristics.

e) The soil characteristics determined by the soil test results and used for the examination of the permeability and stability of the embankment body to be described later are given in Table 5-1-1.

(3) Assessment of Present Conditions Based on Damage

The assessment of the damage to the flood embankment in view of maintaining the long-term stability of the flood embankment and the adjacent main drainage canal is based on the results of the longitudinal and cross-section survey conducted in December, 1987 and the results of the current field survey, and the following conclusions are made.

a) Traces of piping due to seepage water running beneath the embankment body, as in the case of the breached section, were observed at many places although this piping has not

Table 5-1-1 Soil Characterislics for Basic Design

Object \ Item / Section		Wet Density Pt (t/m^3)	Saturated Density Psat (t/m^3)	Cohesion c (tf/m^2)	Angle of Internal friction ϕ (°)	Permeability K (cm/sec) *1 [D_{10} : Particle size at 10%]
Existing Embankment Body	0 -3.4 km	1.81	1.87	6.4	3	2×10^{-5} ($D_{10}=4.1\times10^{-3}$mm)
	3.4-8.3 km	1.75	1.86	3.0	20	6×10^{-5} ($D_{10}=6.9\times10^{-3}$mm)
Substrata	0 -3.4 km	1.84	1.84	4.0	0	2×10^{-6} ($D_{10}=1.3\times10^{-3}$mm)
	3.4-8.3 km (top soil)	1.75	1.80	3.0	15	4.5×10^{-6} ($D_{10}=1.9\times10^{-3}$mm)
	3.4-8.3 km (deeper part)	1.80	1.80	2.0	30	1.6×10^{-5} ($D_{10}=3.5\times10^{-3}$mm)
Filling Material *2		1.75	1.90	3.2	15	4.5×10^{-5} ($D_{10}=1.9\times10^{-3}$mm)
Material for Core		1.75	1.85	1.5	5	2×10^{-7}

Notes: *1; Estimation of K-value is calculated on the basis of Hazen's formula as follows:

$$K=c.(0.7+0.03t).D_{10}^{2}$$

K: penmeability
c: 120 ("c" varies between 50 and 150 according to the characteristics of grain)
t: temperature (°c)

*2; The Filling Material which was used in the emergency works is included in this one.

caused any breaching of the embankment. These places well coincide with the following topographical characteristics of the flood embankment.

i) crossing points of rivers
ii) places adjacent to Tatkir River
iii) places where ditch have been excavated next to the river side part of the embankment body

The above characteristics imply that the path of percolation beneath the embankment body at these places is shorten due to the lack of a top soil layer acting as a low permeability layer on the river side of the embankment body. Measures to prolong the path of percolation beneath the embankment body are, therefore, required in order to maintain its long-term stability.

b) Many places, which have been damaged by seepage water flowing inside the embankment body, are irregularly scattering along the entire length of the flood embankment and emergency measures, including the hammering of bamboo piles in the slopes, have been taken at these places. The damage was caused by scouring due to the flow of seepage water via animal holes or local voids.

Animal holes were found along the entire length of the flood embankment and were particularly noticeable in the section between the 3.4 km point from the pumping station and the far end of the embankment where sand fraction is high. In addition to animal holes, snake eggs were also found at cut sections of emergency rehabilitation work sites. According to interviews, rats, lizards and some insects (something like mole crickets and ants) are responsible for the holes.

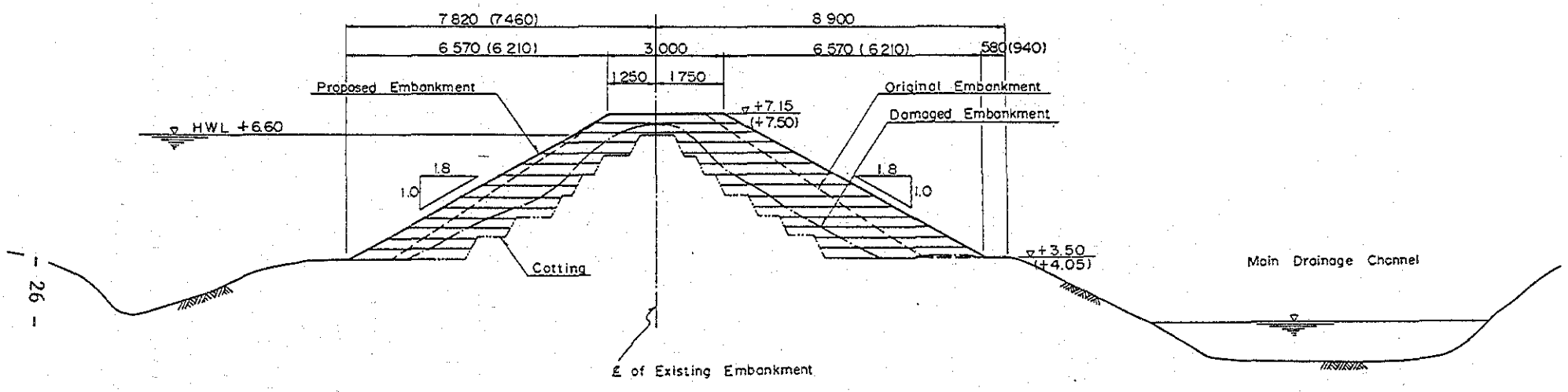
The possible causes of the voids are (i) inadequate breaking of clods during banking work, (ii) occurrence of cracks due to the settlement of embankment sections crossing the river and (iii) irregular intercalation of sand layers.

(4) Emergency Rehabilitation Work

The flood embankment starts at the pumping station and ends at Golakandail Village with a total length of 8.3 km. The flooding in August, 1987 caused not only the breaching of the flood embankment at the 4.3 km point but also heavy damage to other parts of both the flood embankment and the main drainage canal. The damage is particularly acute in the section between the 4.0 km point and the end of the flood embankment.

The emergency rehabilitation work commenced during the recent dry season (1987/1988) with Japanese grant aid cooperation to protect the heavily-damaged sections from flooding during the next rainy season. For the slightly-damaged section between the pumping station and the 4.0 km point, the BWDB is conducting its own emergency rehabilitation work with IDA funds in conformity with the work on the Japanese side. Fig. 5-1-2 shows the typical cross-section of the embankment body subject to the Japanese emergency rehabilitation work, which is finalized by the completion of this work. An extensive impervious blanket is being applied to the river side of the embankment body at the breached section to prolong the path of percolation beneath the embankment body.

The emergency rehabilitation work is, however, being implemented with a short-term objective to prevent flooding in the 1988 rainy season due to constraints in the construction period and the resultant workability of the earth work. As a result, the sectional form of the rehabilitated embankment is slightly inferior to those of many other flood embankment in Bangladesh. It is, therefore, essential to take radical reinforcement measures for this Project.



Notes : ( ) : 4.0 ~ 5.75km from Pumping Station.

Fig. 5-1-2 Typical Cross Section of Emergency Work

(5) Problems in Terms of Long-Term Stability

Based on the aforegoing, the present problems to be solved to maintain the long-term stability of the flood embankment are summarized as follows.

a) Due consideration should be given not only to reinforcement measures but to the widening of the embankment due to the poor sectional form of the embankment body, irregular damage caused by animal holes and other reasons and the difficulty in obtaining good banking materials in the vicinity.

b) It is necessary to adopt measures to lengthen the path of percolation as far as possible through the substratum of the flood embankment in those places where the path is currently short.

5.1.2 Intake Canal and Pumping Station

The supply of irrigation water to the Demonstration Unit by pumping up during the dry season is, at present, inadequate and the field study found the following to be responsible for.

(1) Intake Canal

The intake canal can be divided into two sections, i.e. the section using part of Tatkir River (approx. 840 m) and the section between the diverging point of Tatkir River and the pumping station (approx. 110 m). Tatkir River flows down towards a south-westerly direction along the flood embankment which is located in the south-eastern part of the Demonstration Unit and joins with Lakhya River after crossing D-N Road. The part of Tatkir River used as an intake canal is in the lower reaches. The intake canal is used for both irrigation and

drainage purposes, i.e. to convey water from Lakhya River to the pumping station in the dry season and to drain out water remaining in the drainage basin of Tatkir River and within the Demonstration Unit to Lakhya River in the rainy season.

The intake canal is currently provided with a brick lining on three faces at the section crossing D-N Road while other parts are of an earth canal with a slope height of 6 - 7 m. There are many places on canal slopes where erosion or earth falling is observed which are probably caused by the following.

① The slopes have become unstable and resulted in earth falling due to repeated erosion by fluctuations in the water level caused by tides, fluctuations during the transitional periods between the dry and rainy seasons and also due to the year-round use of the canal, i.e. as a drainage canal in the rainy season and an intake canal in the dry season.

② When a discharging work for the sediments deposited at the bottom of the intake canal is conducted, the section near the bottom is often cut at a steeper angle then the original slope gradient. As a result, the stability of the cut section cannot be maintained, resulting in earth falling and, in turn, leading to the falling or sliding of the slope above it.

③ Those sediments discharged using the method in ② above are left in an unstable condition on the slopes and are eroded by rainfall or surface water runoff.

④ At the time of rainfall, the surface runoff water from those areas near the intake canal is concentrated on places where the crest of the canal bank is lower and then flows down on the slopes and, thereby, leading to erosion.

⑤ The outflow of groundwater to the canal slopes causes erosion.

⑥ The lower part of the slopes is composed of soft clayey silt containing humus and, therefore, has less resistance to slope failure than the flood embankment. Sequent on the current boring survey and soil tests, the layer's composition and the geological and soil engineering characteristics of the intake are summarized in Appendix 3-2.

As those sediments generated by falling earth and erosion and those contained in the river water are deposited at the bottom of the intake canal, the irrigation function of the canal during the dry season is disrupted, leading to a failure to supply sufficient irrigation water to the pumping station. The BWDB is forced to spend a lot of money, as well as labour, every year on discharging sediment deposits from the bottom of the intake canal. Measures to prevent earth falling from the canal slopes should be taken to remedy this situation.

(2) Pumping Station

Sequent on surveying at the major points of the pumping station, the elevation of the station was found 0.55 m higher than in the original design, as shown in Fig. 5-1-3. The fixed water level for an automatic water level detection equipment, which controls pumping operations, is also set at 0.55 m higher than originally given.

To be more precise, as the fixed water level for the automatic water level detection equipment (which stops pumping operations when the water level of the intake canal falls during the dry season) is 0.55 m higher than given in the original design, the pumping station cannot pump up irrigation water at the water level designed originally.

In order to increase the supply of irrigation water to the Demonstration Unit, therefore, the water level detection equipment should be improved within the limitation of being capable of ensuring safety against cavitation of the pumps.

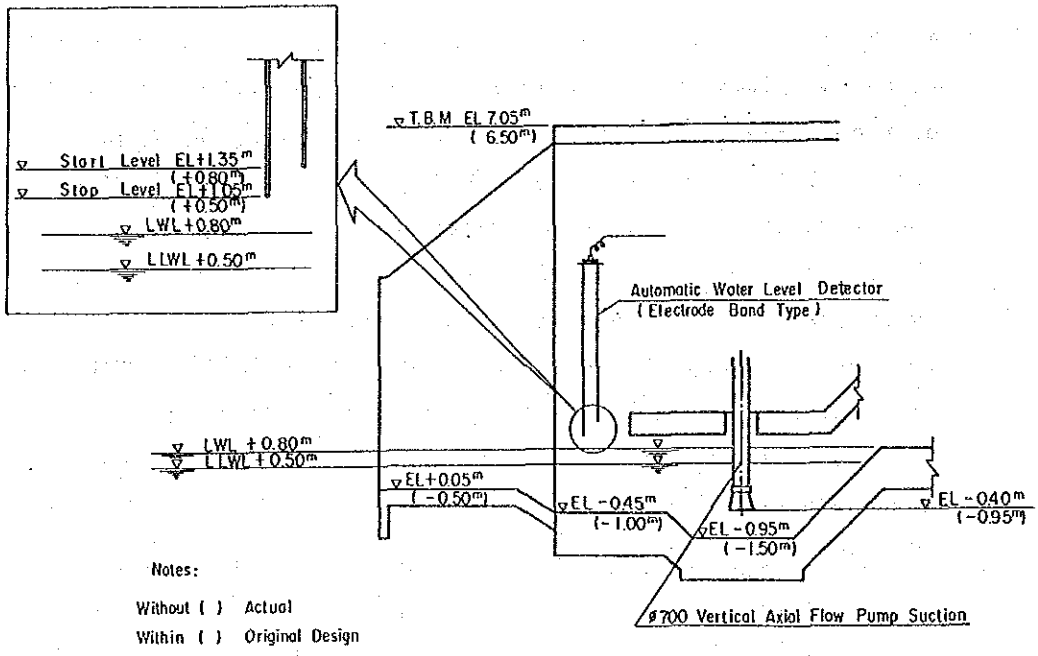


Fig. 5-1-3 Part Elevation at Pumping Station

5.1.3 Main Irrigation Canal and Its Embankment

(1) Main Irrigation Canal

The 9.2 km-long main irrigation canal is running from the pumping station along D-N Road which forms the northwestern boundary of the Demonstration Unit and serves as the flood embankment. It is edged by the D-N Road embankment and the reinforced old embankment and provided with a width of more than 20 m. Excepting for the section of some 150 m between the pumping station and D-N Road, the main irrigation canal was so designed as to effectively utilize ditches which are old borrow-pits used for the construction of D-N Road.

The main irrigation canal currently has many crossing banks through which pipes run. The banks were originally constructed as connecting roads between D-N Road and villages, brick factories and roads, etc. in the Demonstration Unit and of these, the road originally designed as the only access to the brick factory has been left poorly operable and maintainable since the factory was closed down.

The pipes running through the banks play an extremely important role in driving the irrigation water. If they become clogged due to sedimentation and/or differential settlement, not only damage to the main irrigation canal's function occurs but there is also the danger of overflow or even breaching of the embankment due to a rapid rise in the water level of the upstream canal. Proper operation and maintenance are, therefore, essential to prevent such damage.

(2) Main Irrigation Canal Embankment

Gate type turnouts are provided at 6 points along the main irrigation canal embankment, providing water to the secondary irrigation canals (SICs). Appendix 3-1 shows the results of the survey on the elevation of the turnouts.

At about 250 m-long embankment near Barba Village at the edge of the Demonstration Unit is functionally used as a part of the flood embankment.

Sequent on the survey and the field investigations, the present conditions of the main irrigation canal embankment are outlined below.

① The embankment was inundated due to the breaching of the flood embankment in August, 1987. Although no conspicuous scouring or falls are observed, the cross-section was generally become irregular.

② Surveying found the crest elevation of the embankment to be lower than 5 m in parts but generally higher than 5 m, indicating that it was originally constructed 0.55 m higher than the height in the original design, as in the case of the pumping station. However, the current crest elevation for the entire length of the embankment is less than 5.55 m, possibly because of differential settlement after its completion or due to deformation resulting from its use for roads to connect farms and villages, etc.

③ The submerged section of the canal side slope has been scoured due to fluctuations in the water level or runoff water.

④ At the beginning of the recent dry season, the BWDB commenced the implementation of the emergency rehabilitation work in those places where the embankment elevation is relatively low. A large-scale work is in progress at an about 250 m-long section used as a part of the flood embankment near Barba Village. After the completion of the work, the embankment would be assured with a crest elevation of 7.00 m, a crest width of 3.00 m and a slope gradient of 1:1.75.

Based on the above, it is concluded that reinforcement measures are hopefully taken for the embankment in view of securing a water level which is capable of smooth water distribution and maintaining the long-term stability of the embankment.

5.1.4. Other Facilities

Based on the results of the field investigations, the topographical survey and local interviews, the present conditions and problems of such irrigation facilities as secondary irrigation canals, tertiary irrigation canals and drainage canals in the Demonstration Unit are outlined below.

(1) Progress of Facility Construction

The construction of one main irrigation canal (MIC), seven secondary irrigation canals (SICs), twenty tertiary irrigation canals (TICs), one main drainage canal (MDC) and eight secondary drainage canals (SDCs) was originally planned and, excepting the TICs, these were completed with the Japanese grant aid cooperation in Fiscal 1981 based on the Irrigation and Drainage Plan shown in Fig. 5-1-4. While the construction of the TICs was also originally planned as a part of the Japanese grant aid cooperation, some of these were excluded from the list of items subject to the cooperation due to the delay in land acquisition and it was decided to construct them at the expense of the Government of Bangladesh.

With regard to the TICs, four routes have been partially completed and two routes are still waiting for construction to commence while all the necessary land has been acquired. The construction of field canals beyond the TICs is currently in progress by farmer's organizations. The locations of the existing irrigation canals and drainage canals are illustrated in Fig. 5-1-5.

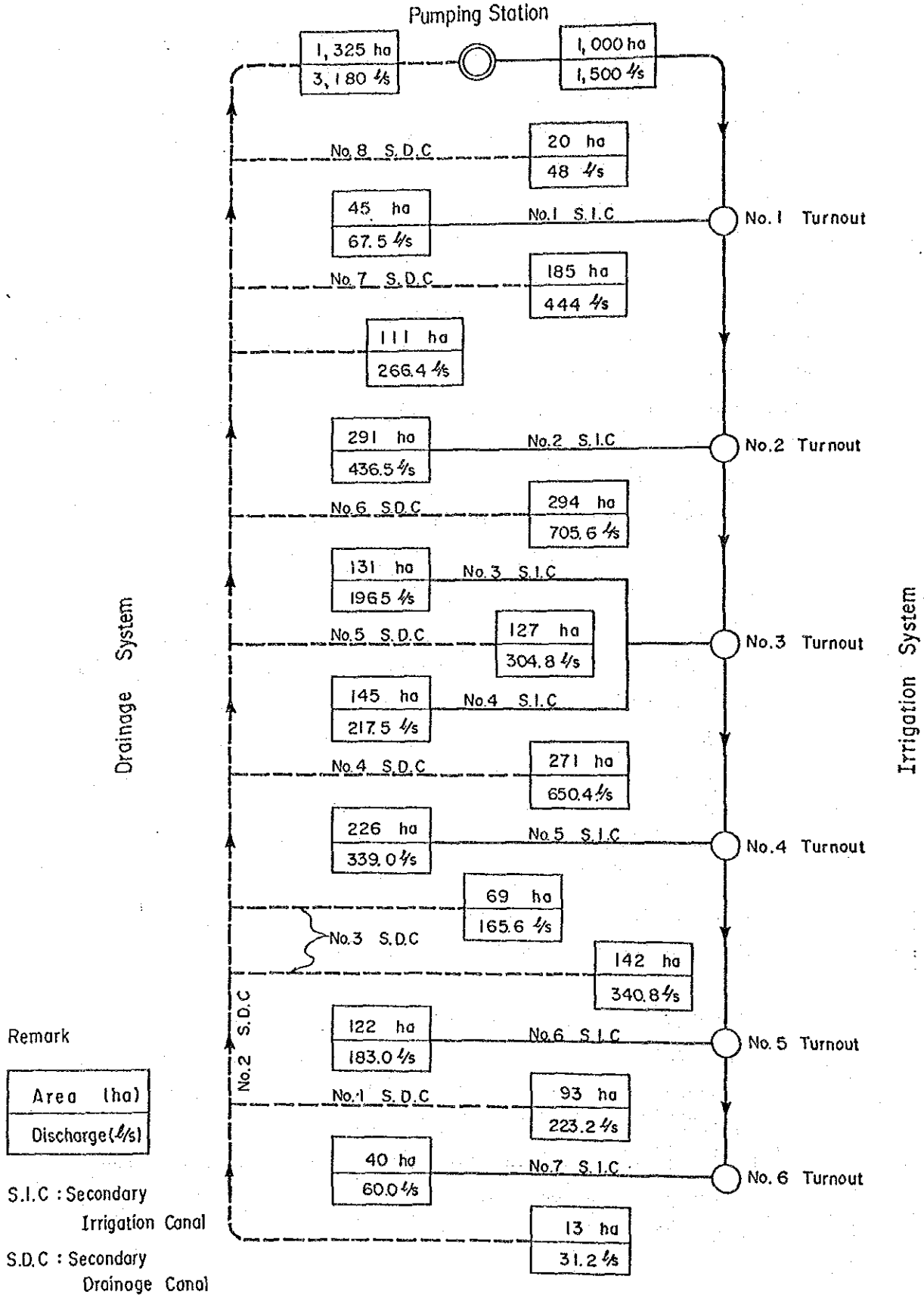
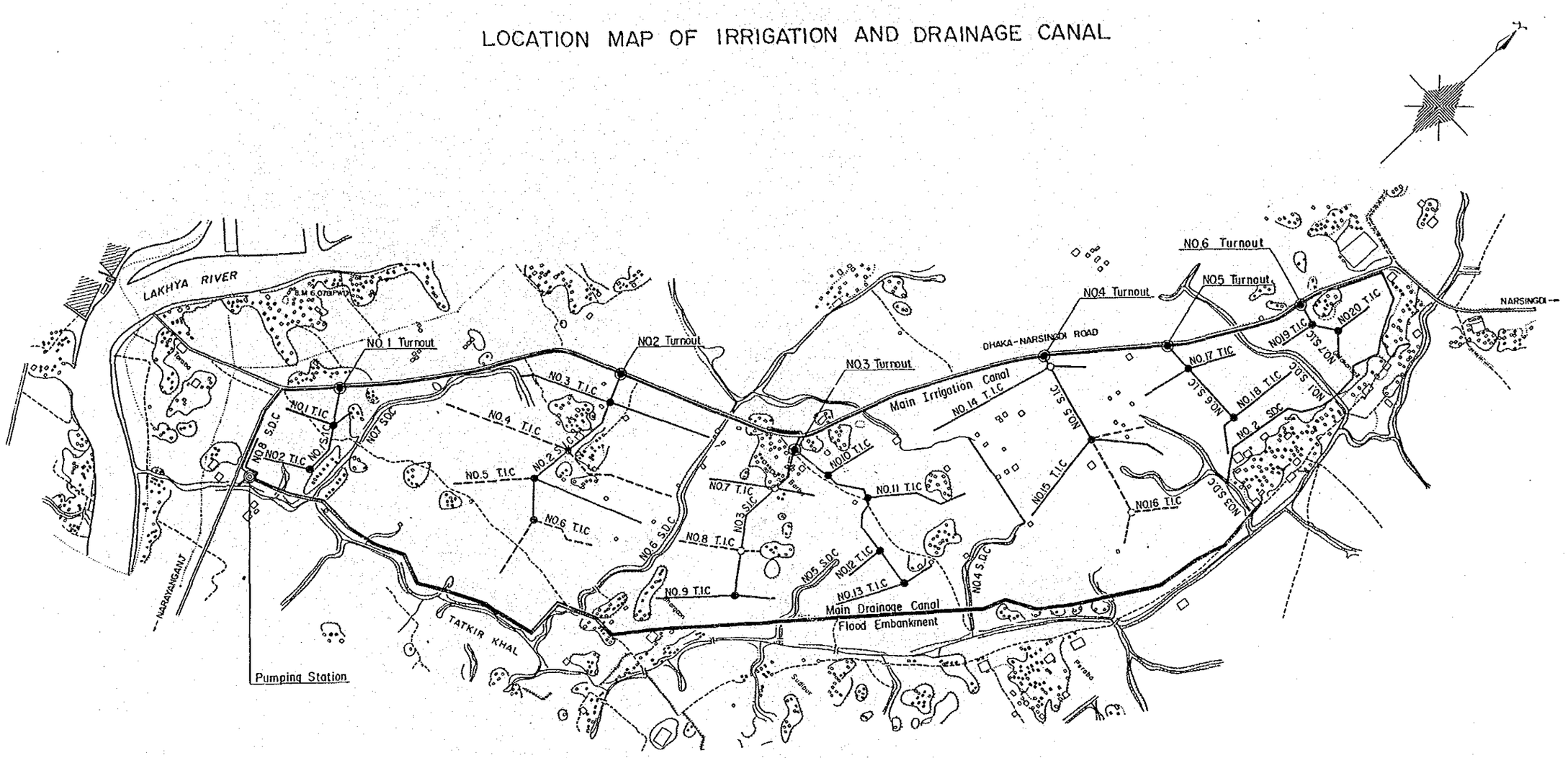


Fig. 5-1-4 Block Diagram of Canal System

LOCATION MAP OF IRRIGATION AND DRAINAGE CANAL



Remark :

◉	:	Pumping Station
◉	:	Sluice Gate Type Turnout (M.I.C~S.I.C)
●	:	Division Box Type Turnout (S.I.C~T.I.C)
○	:	Turnout (S.I.C~T.I.C)
○	:	Planed Turnout (S.I.C T.I.C)
——	:	Constructed Irrigation / Drainage Canal
----	:	Planed Canal (Un Constructed)
M.I.C	:	Main Irrigation Canal
S.I.C	:	Secondary Irrigation Canal
T.I.C	:	Tertiary Irrigation Canal
M.D.C	:	Main Drainage Canal
S.D.C	:	Secondary Drainage Canal

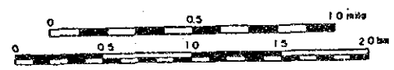


Fig. 5-1-5 Location Map of Irrigation and Drainage Canal

(2) Conditions of Facilities

The breaching of the flood embankment in August, 1987 severely damaged the main drainage canal by causing slope failures at sections near the breached part. In addition, farms located near the breached section also suffered heavy damage due to the large sediment deposit volume. Although all facilities in the Demonstration Unit were flooded, no conspicuous scouring or slope failure of the facilities were observed. In general, damage to the Demonstration Unit was slightly done, excepting for a shallow sediment deposit transported by the flood all over the area.

The SICs have been made by constructing banks on the ground and borrow-pits for the bank construction have utilized as ditches along the canals. The sectional form of the canals is generally good as the annual repair work is regularly implemented. However, the bank elevation has been lowered or the cross-section deformed in some parts, probably due to artificial cutting and filling to provide water intakes or due to the use of the banks as passageways between farms or as main transportation routes between villages.

As shown in Table 5-1-2, the assumed flow capacity of the SICs' current sectional form based on the survey results is capable of handling the design discharge. However, a local repair work is required in those places where the canal elevation is high or where freeboard cannot be provided in view of maintaining their function. The sectional forms of the TICs and field canals are diverse and the maintenance of there canals is inadequate, consequently reducing their function.

Division boxes are provided at some of the distribution points from the SICs to the TICs and from the TICs to the farm canals. The sluices are made of concrete and equipped with wooden gates to regulate the distribution water volume. However, many of

Table 5-1-2 Hydraulic Calculation of Existing Secondary Irrigation Canal

Item / Canal No.	Q (m^3/s)	B (m)	1:m	I	d (m)	A (m^2)	P (m)	R (m)	V (m/s)	H (m)
No.1	0.0675	0.6	1.0	1/6000	0.409	0.412	1.756	0.235	0.164	0.65
NO.2	0.4365	1.5	"	1/5000	0.714	1.579	3.518	0.449	0.276	0.90
No.3	0.1965	1.0	"	1/5000	0.555	0.863	2.570	0.336	0.228	0.95
No.4	0.2175	1.0	"	1/5000	0.586	0.929	2.657	0.350	0.234	0.65
No.5	0.3390	1.5	"	1/2000	0.479	0.948	2.855	0.332	0.357	0.50
No.6	0.1830	1.0	"	1/2000	0.415	0.587	2.174	0.270	0.312	0.55
No.7	0.0600	0.6	"	1/1500	0.264	0.228	1.346	0.169	0.264	0.35

Notes: Discharge is calculated on the basis of Manning's formula as follows:

$$Q=A.V=A.\frac{1}{n}.R^{2/3}.I^{1/2}$$

In which
- Q: Discharge
- n: Coeficient of roughness, n=0.03 (earthen canal)
- R: Hydraulic mean depth
- A: Cross section area of flow
- P: Wetted perimeter
- I: Slope of canal bed
- d: Depth of water
- B: Width of canal bed
- H: Height of existing canal bank

. Discharge is calculated on the basis of the original irrigation plan (see Fig. 5-1-4).
. "I" and "H" are calculated on the basis of the result of topographical survey.

the sluices are broken or their foundation height does not coincide with the canal bed height, resulting in their failure to function properly. Therefore, improvement of the TICs, farm canals and turnouts is required to ensure a smooth supply of irrigation water to the terminal canals.

As all the drainage canals with the exception of the main drainage canal, those along Golakandail Village and those along D-N Road near the pumping station use the area's original drainage canals, their flow capacity would be assured with a large margin.

5.2 Basic Design Policy

The Project is proposed to be implemented after the completion of the emergency rehabilitation work on the breached flood embankment (implemented during the 1988 dry season) and consists of a rehabilitation work plan which is centering on the following three main areas of work for the main facilities in the Demonstration Unit and the subsequent operation and maintenance plan.

① Reinforcement of the damaged flood embankment (approx. 8.3 km) mainly by widening the embankment body and preventing the outflow of seepage water from the embankment during flooding.

② Rehabilitation and improvement of the intake canal (approx. 0.95 km) by means of recutting the existing slope and slope protection measures, partial modification of the pumping station (lowering of the inlet apron) to restore its irrigation function and rehabilitation and improvement of the pumping station by the partial improvement of the equipment controlling pumping operations (lowering of the location of the water level detection equipment).

③ Rehabilitation and improvement of the main irrigation canal embankment (approx. 9.2 km) mainly by means of increasing both its height and width in order to ensure a stable supply of irrigation water during the irrigation period (November - February).

The basic conditions for the design work for the above is as follows.

(1) General Design Conditions

a) No new land acquisition for the rehabilitation and improvement work will be conducted.

b) All construction materials will be locally purchased.

c) Local construction methods will be used wherever possible.

d) The required labour force for the Project will be provided by employing local inhabitants as many as possible.

e) Due consideration will be given to the point that all facilities in the Demonstration Unit function independently from those in the surrounding areas (for example, neighbouring area Block A-1 where a separate construction project is planned).

(2) Reinforcement of Flood Embankment

a) The reinforcement of the flood embankment will be mainly conducted by widening the embankment body within the limits of the acquired land while considering the flood embankment and the main drainage canal to form a single structure.

b) The sectional form of the flood embankment will be made possibly to meet the requirements of Bangladesh standards.

c) As piping is considered to be the main factor for the breaching of the embankment, appropriate measures will be taken for the embankment body and its substratum to avoid the occurrence of piping.

d) Measures will be taken to deal with the holes made by small animals like rats, snakes and lizards.

e) Traffic on the crest of the embankment will be limited to pedestrians, bicycles (including motorbikes) and carts, etc. and automobiles will be prohibited.

f) At the time of planning each rehabilitation measure, due consideration will be given to reducing as far as possible the cost and labour required for the maintenance and repair work to be undertaken by the Bangladesh side after the completion of the Project.

(3) Improvement of Intake Canal and Pumping Station

a) The rehabilitation and improvement plan will be prepared with consideration given to the fact that both the intake canal and pumping station are utilized for irrigation and drainage purposes.

b) The slope gradient for the intake canal will be decided by taking into consideration its stability. The slopes will be protected by providing turf for the upper parts and brick lining for the lower part.

c) The dry pitching method will be used for the brick lining to prevent the theft of the bricks and to facilitate

groundwater drainage behind the lining. The bricks will be as large as possible by taking into consideration their workability.

d) Prior to the commencement of the work of lowering the intake apron at the pumping station, the possibility of causing adverse effects on other structures will be thoroughly checked.

e) By taking into due consideration the advice given by a pump manufacturer to determine the installation level of the water level detection equipment, the new level will be sufficiently low enough for the proper starting and stopping of the pumps but will not result in any adverse effects such as pump cavitation.

(4) Improvement of Main Irrigation Canal Embankment

a) The main work will consist of increasing both the height and width of the embankment body within the limits of the acquired land, i.e. widening towards the irrigation canal side. To implement this work, the main irrigation canal should be dried up during the work period, recessitating the temporary stoppage of the irrigation water supply. The Study Team was informed by a BWDB official that stoppage of the irrigation water supply would be possible for a limited period.

b) The design height of the embankment crest will be determined on the basis of the required volume and water level at each turnout allowing for the necessary freeboard.

c) The slopes of the embankment will be protected by turfing.

5.3 Design Conditions and Standards

(1) Water Level

1) HWL : EL 6.60 m (25 years return period, quoted from the basic design for the N-N Project Block A-1)

2) LWL : EL 0.80 m (10 years return period, quoted from the original basic design for the Demonstration Unit)

3) LLWL: EL 0.50 m (as above)

(2) Irrigation and Drainage Volumes

1) Maximum Irrigation Water Volume : $Q = 2.20\ m^3/sec$

2) Maximum Drainage Water Volume : $Q = 3.10\ m^3/sec$

(Both figures are quoted from the original basic design for the Demonstration Unit.)

(3) Design Conditions for Flood Embankment

1) Land Acquisition

Reinforcement of the flood embankment is conducted without new land acquisition.

2) Main Drainage Canal

Although the cross-sectional area of the canal is reduced by widening the flood embankment, the cross-sectional area of the flow required to achieve the design discharge will be secured.

3) Features of Flood Embankment

a) Crest Width : 4.00 m or more

b) Berm Width : 3.00 m or more

c) Freeboard : 0.90 m (quoted from the basic design for N-N Project Block A-1)

d) Crest Elevation : 7.50 m (as above)

e) Slope Gradient : 1:1.80 or more

f) Use of free space : all free space in the acquired land can be used (confirmed with BWDB)

(4) Design Conditions for Main Irrigation Canal Embankment

1) Land Acquisition

No new land acquisition is expected. The height and width will be increased towards the canal side.

2) Features of Main Irrigation Canal Embankment

a) Design HWL : EL 4.95 m

b) Freeboard : 0.60 m

c) Crest Elevation : EL 5.55 m

d) Crest Width : 2.00 m

e) Slope Gradient : 1:2.0 (canal side)
1:1.5 (farm side)

5.4 Basic Design

5.4.1 Reinforcement Measures for Flood Embankment

(1) Examination of Typical Cross-Section

In view of the fact that the flood embankment is an integrated structure with the main drainage canal running along the embankment, flood embankment reinforcement is subjected to the widening of the embankment's cross-section by reducing the cross-section of the main drainage canal. This work must be conducted without requiring any further land acquisition.

In addition, as it is difficult to obtain good banking materials, such a method as to lower the seepage face inside the embankment body must be examined for the subsequent selection of an optional plan.

1) Analysis of Seepage in Embankment Body

Three alternative measures are suggested to improve the embankment stability against seepage by lowering the seepage face inside the embankment body with consideration given to the maximum use of the existing embankment body.

a) Construction of a toe-drain on the land side of the embankment body to prevent the outflow of seepage water on the slope.

b) Construction of a core-wall on the river side of the embankment body to avoid the seepage face rising above the calculated value due to ununiformity of the embankment body.

c) Construction of both a) and b) above.

Four alternatives are examined here in terms of Casaglande's method, including the case where special measures are not applied for the seepage face inside the embankment body, and the detailed examination results are given in Figs. 5-4-1 to 5-4-4.

- No Reinforcement Measures Taken (Fig. 5-4-1)

The head at the central part of the embankment body is as high as 2.03 m from the base and the outflow of seepage water on the land side slope occurs within a maximum height of 1.26 m from the toe of the slope. When the location of the seepage face inside the embankment body is high, seepage pressure increases and soil strength decreases. In general, if seepage water outflows on the slope surface of the embankment body which is composed of sandy soil, piping may occur due to soil grains being washed away by the seepage pressure.

The question of piping is considered here in terms of the concept of critical hydraulic gradient. While the resistance of soil against seepage water varies with its degree of compaction and other characteristics, piping generally occurs when the hydraulic gradient of the seepage water exceeds the critical hydraulic gradient as shown below.

$$ic = \frac{Gs - 1}{1 + e}$$

where: ic: critical hydraulic gradient
Gs: specific gravity of soil particle
e: void ratio of soil

Using the values of the void ratio and the specific gravity of soil particle in the case of the compaction rate of a prospective banking material being 90% of the maximum dry density, the value of the critical hydraulic gradient is calculated to be ic = 0.89 - 0.94. Since the hydraulic gradient of an outflow point is the same as the slope gradient, i.e. 0.55, in theory piping is not expected to occur at the present embankment body. However, as the moisture content of the saturated soil below the seepage face approaches the liquid limit, slope sections with a gradient exceeding the critical hydraulic gradient may result from any alteration of the slope gradient due to the passing by of livestock or other reasons. Once any part of the slope has been scoured by local piping, further piping is easily induced and, thereby, leading to a continual collapse of the slope. In view of this danger, it is extremely important that measures to prevent any outflow of seepage water on the land side slope surface of the embankment body be taken.

- Construction of Toe-Drain (Fig. 5-4-2)

The construction of a toe-drain inside the embankment body near the land side toe will prevent the outflow of seepage water on the slope surface and the weight of the new embankment following the banking work to widen it will prevent piping. Nevertheless, there is a danger of the seepage face rising above the calculated level due to the embankment body's irregular intercalations of loose sand layers and animal holes. In this case, the level of the seepage face may exceed the height of the toe-drain, causing a partial outflow of seepage water on the land side slope surface, and in turn resulting in the collapse of the slope as in the case where no measures are taken.

- Construction of Core-Wall (Fig. 5-4-3)

If a core-wall is constructed inside the land side part of the embankment body by use of impermeable earth materials with a permeability coefficient of 1/100 of that of the present embankment body, the seepage face inside the embankment body will be lowered to 0.60 m from the base at the centre of the embankment body, limiting the outflow of seepage water on the land side slope surface to a section of a few centimetres from the slope toe. The fact that the seepage volume is conspicuously reduced by a core-wall reflects in the little rise of the seepage face despite that the embankment body is provided with local permeable layers and/or rat holes. However, as the outflow of seepage water on the land side slope surface is not entirely prevented, this measure cannot be said to be perfectly effecting against piping.

- Combined Use of Toe-Drain and Core-Wall (Fig. 5-4-4)

In this case, the level of the seepage face inside the embankment body will be lowered and no outflow of seepage water on the land side slope surface will occur. Therefore, it is judged that the stability of the embankment body against seepage water will be sufficiently secured.

2) Stability Analysis of Embankment Body

Sequent on the soil study and permeation analysis, the stability of both the land side and river side slopes was analysed for two cases, i.e. ① where no embankment reinforcement measures are taken and ② where the level of the seepage face is lowered by the construction of a core-wall. The design water level was identified with the high water level, but the case of the low water level was

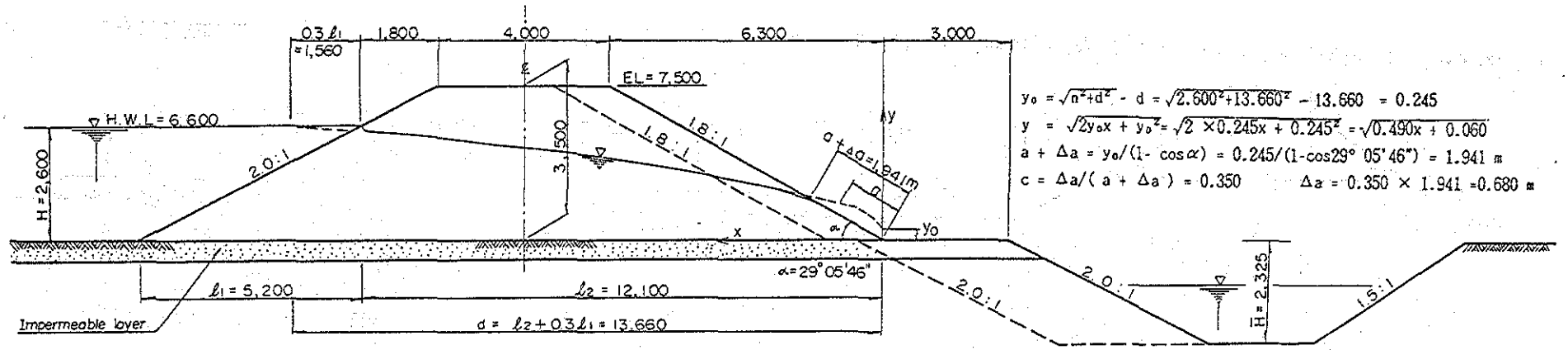


Fig. 5－4－1 Result of Seepage Annalysis (without Special Measures)

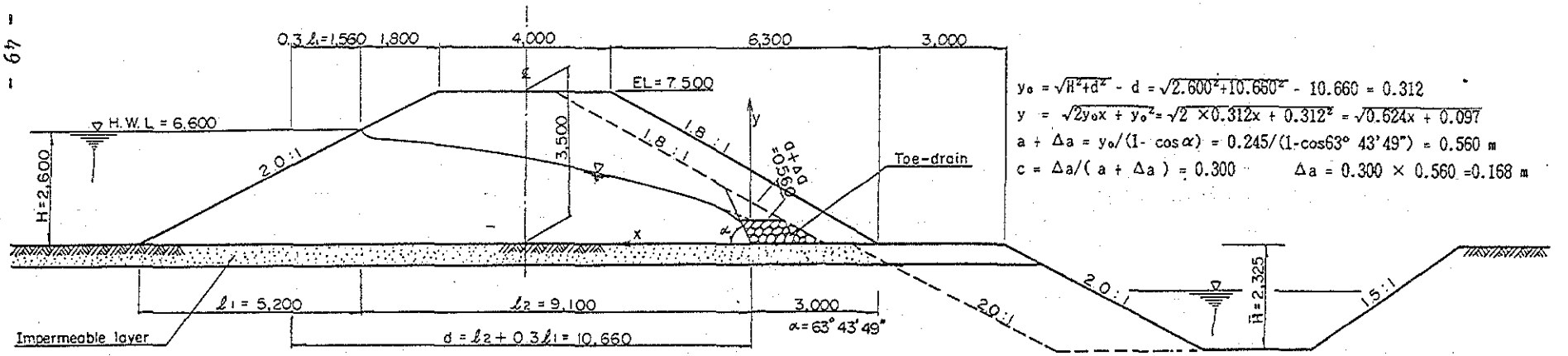


Fig. 5－4－2 Result of Seepage Annalysis (with Toe-drain)

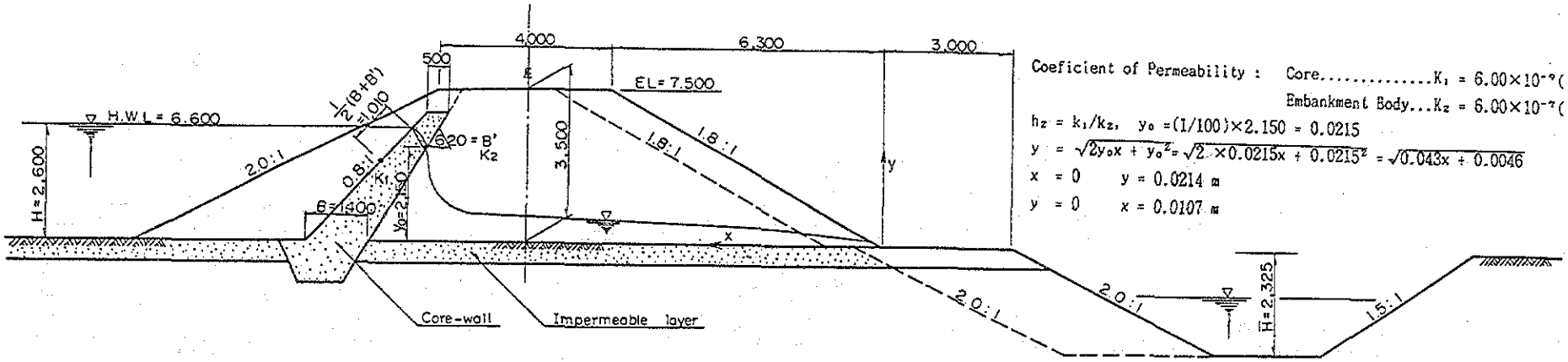


Fig. 5－4－3 Result of Seepage Annalysis (with Core-wall)

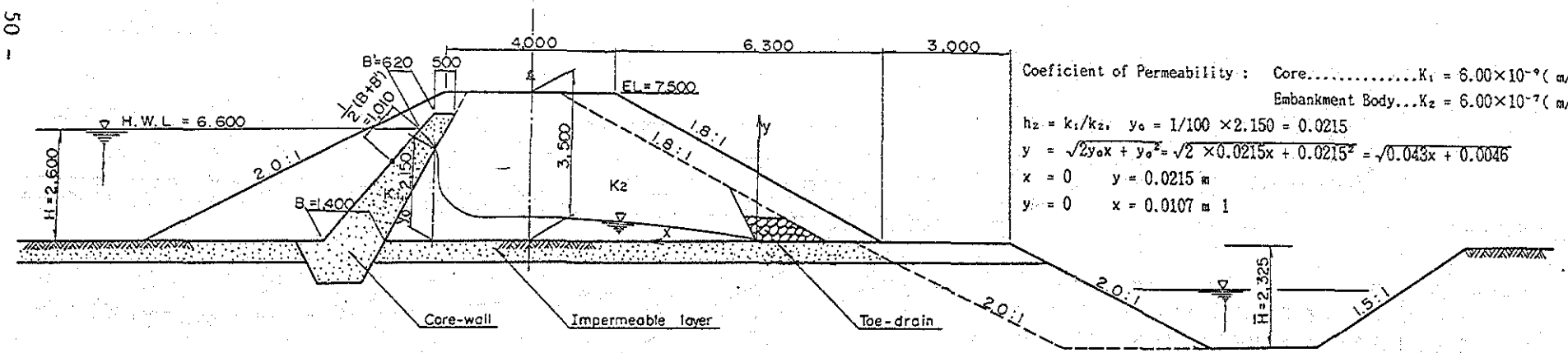


Fig. 5－4－4 Result of Seepage Annalysis (with Toe-drain and Core-wall)

also examined for the land side. The detailed calculation results are given in Appendix 2-2 while Table 5-4-1 shows the minimum safety factor for each case.

Table 5-4-1 Results of Stability Analysis of Flood Embankment

River Water Level	EL 6.60 m				EL 2.00 m
Applied Measure	None		Core-Wall		None
Side	Land Side	River Side	Land Side	River Side	Land Side
Minimum Safety Factor	2.313	4.743	2.670	5.323	2.902

3) Examination of Drainage Canal Cross-Section

The discharge distribution of the main drainage canal is determined as shown in Fig. 5-4-5 in accordance with the drainage system given in the original basic design.

Table 5-4-2 shows the results of the hydrological calculation of the cross-section of the drainage canal. If the embankment is widened as described earlier with the same slope gradient of the drainage canal as that in the original basic design, the bed width of the drainage canal will be 2.50 m. As Table 5-4-2 shows, the design drainage is deemed maintainable even if there is a groundwater inflow.

4) Determination of Typical Cross-Section

Sequent on the stability analysis on the embankment slopes and the examination of the drainage canal cross-section, slope stability and the required discharge can be secured by the cross-section shape examined in the seepage analysis. In other words, a typical cross-section is generally determined on the basis of the results of the seepage analysis.

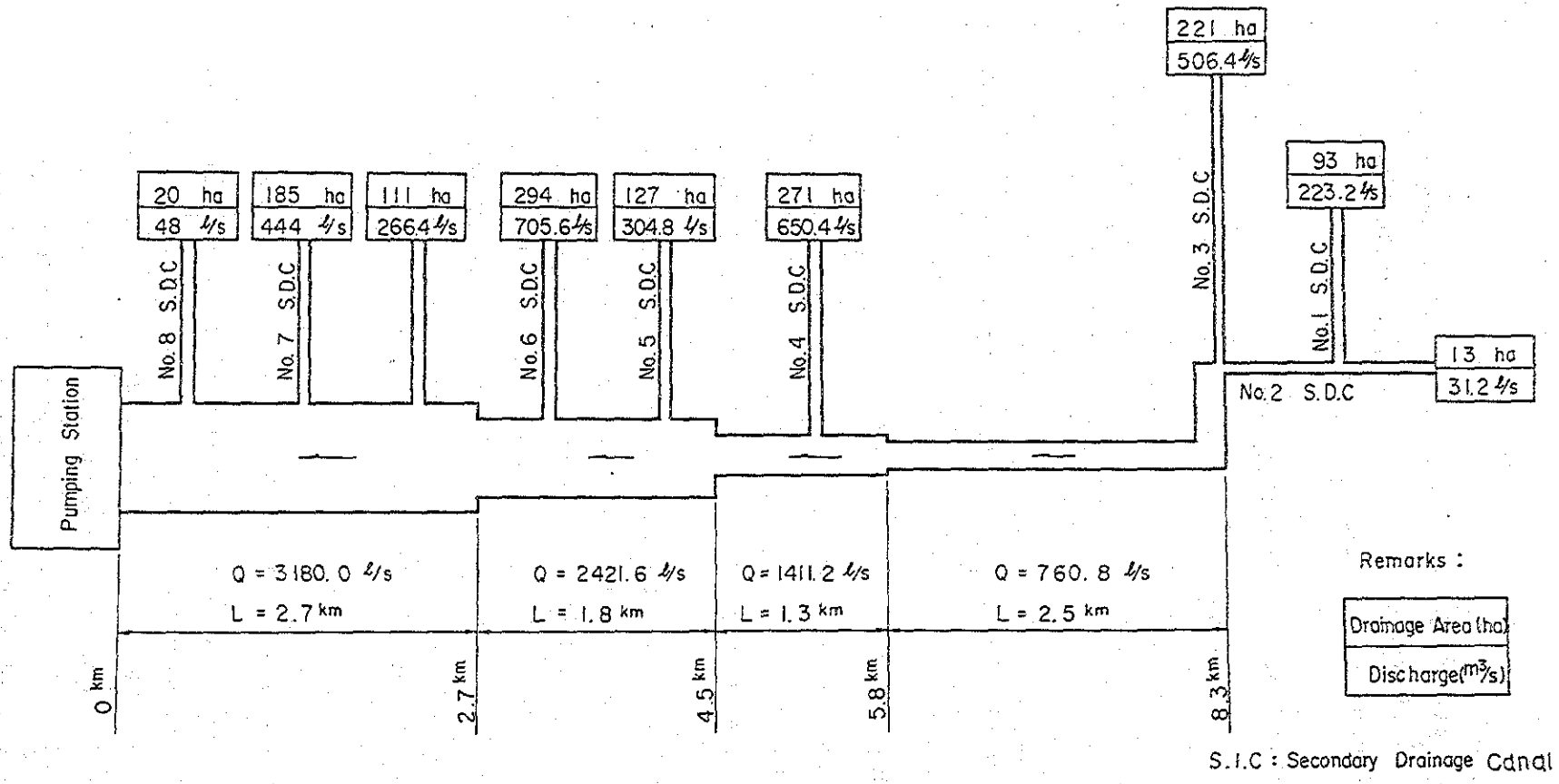


Fig. 5-4-5 Distribution of Discharge for Main Drainage Canal

Table 5-4-2 Hydraulic Calculation of Main Drainage Canal

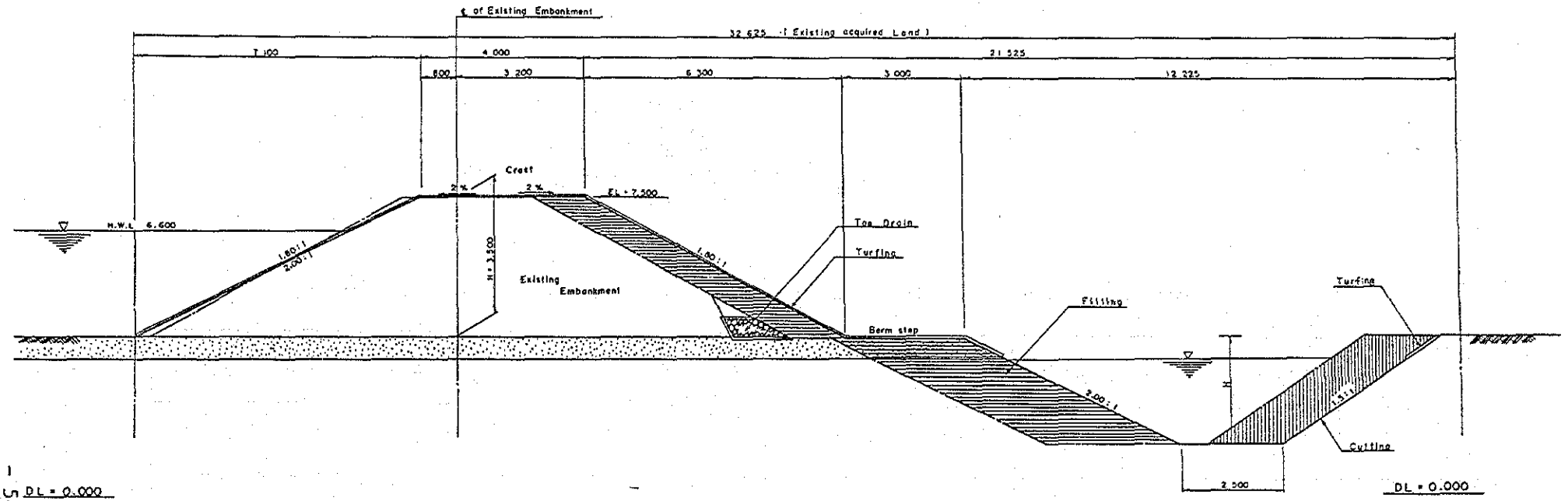
	Q (m^3/sec)	I	B (m)	d (m)	A (m^2)	P (m)	R (m)	V (m/sec)	Qo (m^3/sec)	Remarks
0 km - 2.7km	3.180	1/5800	2.500	1.52	7.843	8.639	0.908	0.410	3.216	
2.7km - 4.5km	2.422	"	"	1.33	6.421	7.872	0.816	0.382	2.453	
4.5km - 5.8km	1.441	"	"	1.01	4.310	6.579	0.655	0.330	1.422	
5.8km - 8.3km	0.761	"	"	0.74	2.808	5.489	0.512	0.280	0.786	

Notes: Discharge is calculated on the basis of Manning's formula as follows:

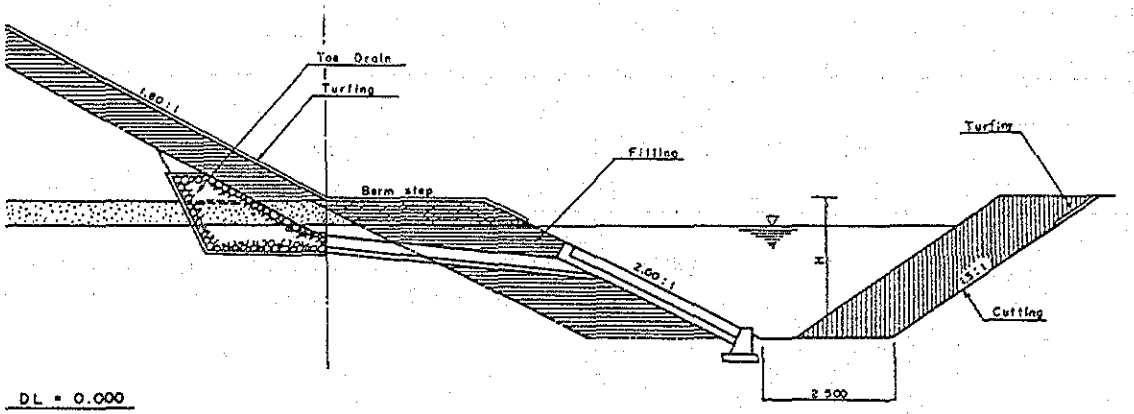
$$Q=A.V=A.\frac{1}{n}.R^{2/3}.I^{1/2}$$

In which Q: Discharge
n: Coeficient of rughness, n=0.03 (earthen channel)
R: Hydraulic mean depth
A: Cross section area of folw
P: Wetted Perimeter
I: Slope

CROSS SECTIOIN OF FLOOD EMBANKMENT



CROSS SECTION OF STRUCTURES RELATED TO TOE DRAIN (Interval at every 20.0M)



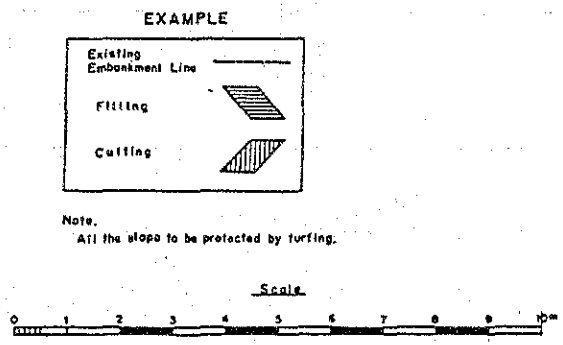


Fig. 5-4-6 TYPICAL CROSS SECTION OF FLOOD EMBANKMENT

Since the planned extension work is limited to within the available land (already acquired land), including that of the main drainage canal, the new cross-section of the flood embankment will be inferior to those of other flood embankments in Bangladesh. In addition, it will be impossible to remove in the course of the reinforcement work those specific soil materials which make vulnerable to piping, are regarded as having caused the breaching of the flood embankment and which are found throughout the flood embankment. As a result, adequate stability of the flood embankment cannot be secured by simply widening it and, therefore, the construction of a reinforcement structure is also considered necessary.

It has already been judged that seepage water-induced piping, which is considered to be one reason for the breaching of the flood embankment at the time of flooding, can be entirely prevented by toe-drain and core-wall treatments. A core-wall plays a supporting role for the toe-drain by preventing the unexpected rise of the seepage face caused by animal holes which are scattered inside the present embankment body and/or the irregular composition of the banking materials. Despite its role, however, the construction of the core-wall will increase the excavation volume of the present embankment body and, in turn, become much costly.

In view of the aforegoing, the adoption of only a toe-drain as an anti-seepage measure is recommended together with the strengthening of operation and maintenance to prevent unexpected events.

Although toe-drains have not been constructed in Bangladesh up to the present, the construction of a toe-drain for the planned reinforcement work appears absolutely necessary,

given the limited land availability and the required preservation of the present flood embankment.

Based on the above, typical cross-sections for the flood embankment and main drainage canal in the rehabilitation project are as shown in Fig. 5-4-6.

(2) Other Reinforcement Measures

In addition to the standard flood embankment reinforcement measure described in (1) above, additional measures should be employed for those places where a reinforcement work on the substratum of the flood embankment is deemed necessary (see Table 5-4-3).

1) Core-Wall

The sections where damage due to piping was observed during the field study on the land side part of the flood embankment are corresponding to those places where the substratum adjacent to the river side has been deeply scoured by Tatkir River or due to artificial excavation. Excepting the breached section where an impervious blanket has been applied in the course of the emergency rehabilitation work, land acquisition on the river side of the flood embankment cannot be expected. As a result, an underground core-wall will be constructed to prevent piping caused by seepage water flowing beneath the embankment body. This core-wall will be made of impermeable earth materials and will be constructed beneath the ground surface near the river side slope toe in order to prolong the path of water percolation from Tatkir River or the ditch. The typical cross-section for the core-wall is illustrated in Fig. 5-4-7. Its installation depth will vary according to the depth of the river or the ditch with an average depth of 2.30 m below the ground surface.

2) Timbering

In the case of the 0.4 km - 0.6 km section from the pumping station, the flood embankment was constructed right above Tatkir River and, therefore, it is standing on a soft substratum. A slow collapse of the land side slope due to sliding is, in fact, currently in progress. The timbering work will be carried out for this section to increase the resistance of the embankment body (see Fig. 5-4-8).

3) Slope Protection

Brick lining treatments will be employed for the following sections in view of slope protection.

a) Those sections where the substratum is being scoured by Tatkir River located adjacent to the river side slope toe (see Fig. 5-4-8).

b) Around existing bridges over the main drainage canal (see Fig. 5-4-9).

c) Around the box culvert (see Fig. 5-4-9).

d) The undercut slope portion of the main drainage canal's curved section (see Fig. 5-4-10).

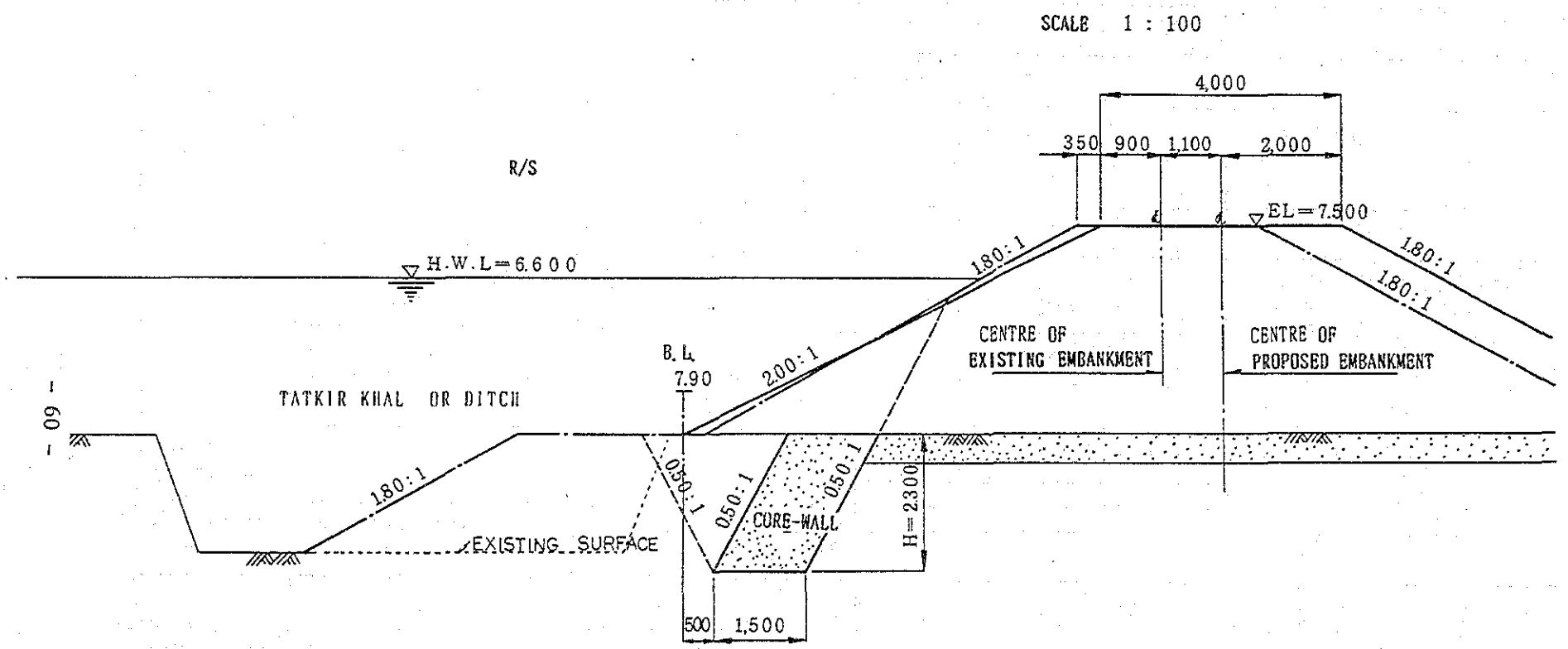
Without the above slope protection, the embankment slope will be scoured by river water or drainage canal water, facilitating percolation beneath the embankment as well as reducing slope stability.

Table 5-4-3 (1) Special Reinforcement Measures for Flood Embankment and Main Drainage Canal

Measures	Objective	Work Contents	Total Length (m)	Work Site (Distance from Pumping Station - km)	Remarks
Core-Wall	Prevention of piping by prolonging the path of percolation under the embankment body	Construction of impermeable core-wall under the ground of river side slope toe. Depth depends on depth of outer side (Fig. 5-4-7).	250	0.35 - 0.60	Section crossing or adjacent to Tatkir River
			50	1.55 - 1.70	Section adjacent to Tatkir River, scouring of slope in progress
			200	1.95 - 2.15	Section near Tatkir River
			1,000	3.75 - 5.75	Section adjacent to belt-shaped ditch resulting from excavation work
			200	5.35 - 6.55	Section adjacent to ditch resulting from excavation work
			100	7.75 - 7.85	As above
Timbering	Prevention of collapse of land side slope	Timbering work at land side slope toe at section where flood embankment is constructed above old main course of Titkir River (Fig. 5-4-8).	200	0.40 - 0.60	Slope collapsing due to sliding. Wooden pile end diameter: 10 cm, length: 5.0 m, spacing: 0.50 m (Fig. 5-4-8)

Table 5-4-3 (2) Special Reinforcement Measures for Flood Embankment and Main Drainage Canal

Measures	Objective	Work Contents	Total Length (m)	Work Site (Distance from Pumping Station - km)	Remarks
Slpoe Protection (Tatkir River)	Prevention of scouring by Tatkir River	Banking and brick lining at section where flood embankment is adjacent to Tatkir River	250	0.35 - 0.60	Including banking on river side (Fig. 5-4-8)
			50	1.64 - 1.69	As above
Slope Protection (Main Drainage Canal)	Prevention of scouring near existing bridges	Brick lining at both slopes of drainage canal (Fig. 5-4-9)	60	0.40 (Bridge)	
			60	2.58 (As aboev)	
			60	3.35 (As above)	
	Prevention of scouring at base of box culvert	Brick lining at embankment side slope (Fig. 5-4-9)	60	5.80	
	Prevention of scouring at undercut slopes	Brick lining at embankment side slope (curved section of main drainage canal (Fig. 5-4-10)	350	0.35 - 0.70	Including section crossing Tatkir River
			50	0.80	
			50	1.35	
			50	1.55	
			50	2.10	
			50	6.90	



Notes:

Cross Section of Emergency work ——·——·——

Proposed Cross Section ————————

Fig. 5—4—7 Core-wall in Substrata

TYPICAL CROSS SECTION OF REINFORCEMENT (CS-0.500 Km)

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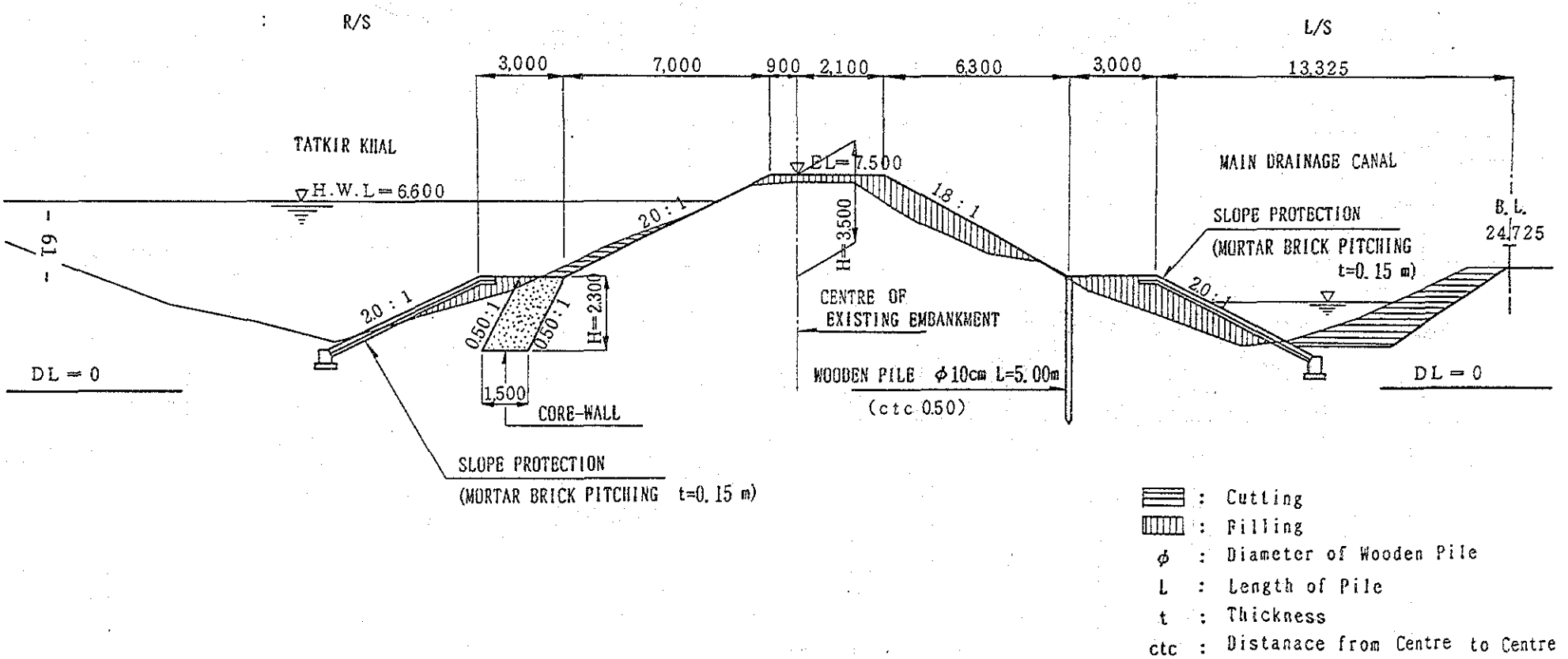


: Cutting
: Filling
ϕ : Diameter of Wooden Pile
L : Length of Pile
t : Thickness
ctc : Distanace from Centre to Centre

Fig. 5-4-8 Reinforcement of Embankment Crossing the Original Tatkir Khal

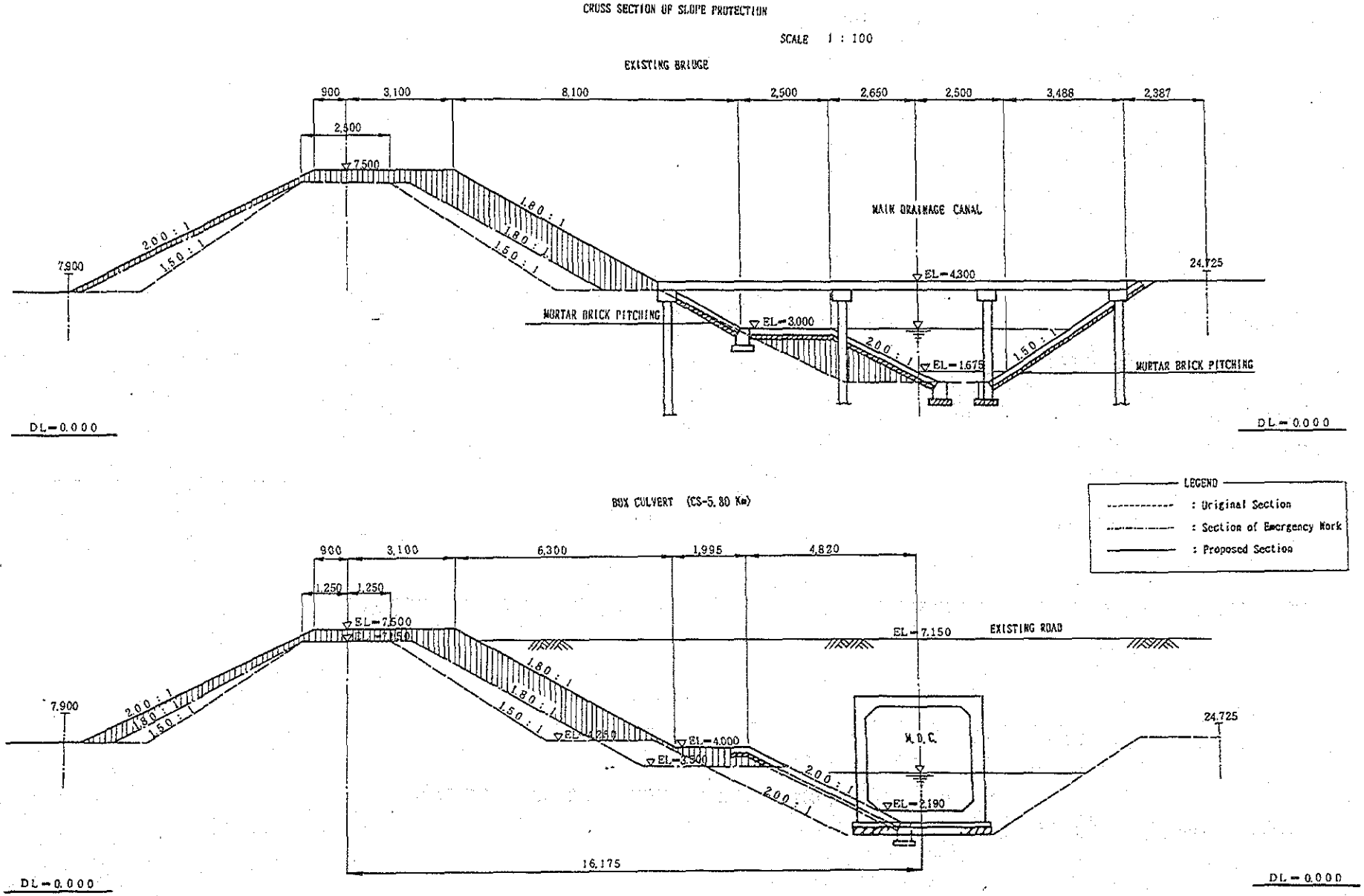
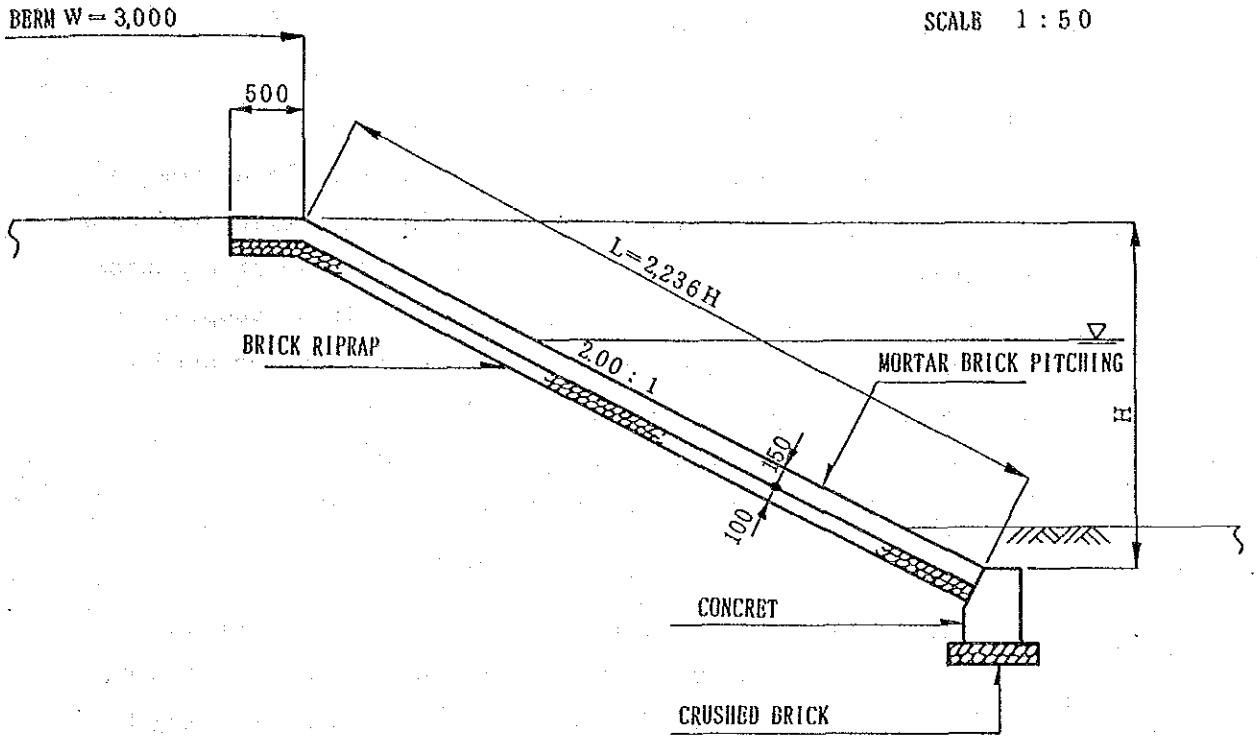


Fig. 5-4-9 Slope Protection for Part of Main Drainage Channel

PROPOSED SLOPE PROTECTION OF MAIN DRAINAGE CANAL



DETAIL OF FOUNDATION

SCALE 1 : 25

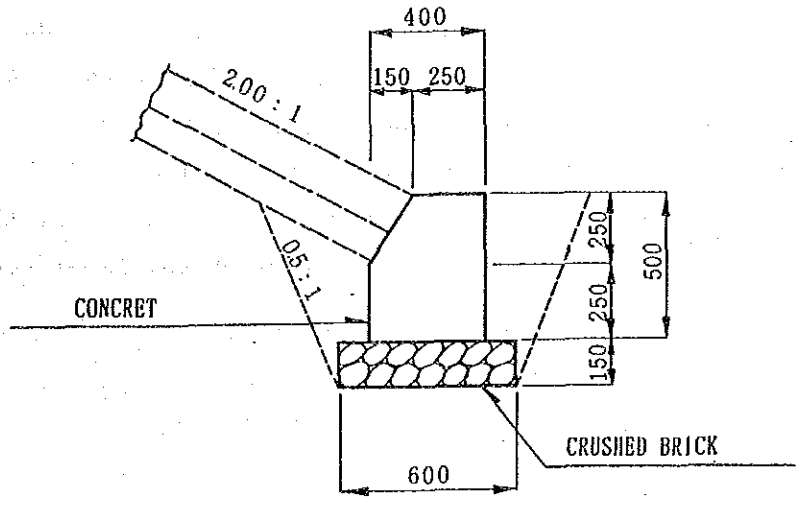


Fig. 5－4－10 Slope Protection for Part of Main Drainage Canal

5.4.2 Improvement Measures for Intake Canal and Pumping Station

(1) Improvement of Intake Canal

1) Improvement Method

In view of the current state and causes of slope erosion and failure, the underlying geological conditions and past work experience in regard to various improvement measures in Bangladesh, the following measures will be adopted to improve the intake canal with an emphasis on the need to secure a stable canal slope gradient.

Upper Slope: protection by turf

Lower Slope: protection by brick lining

Canal Bed: protection by brick lining in order to protect the foundation of the brick lining of the lower slope, to prevent scouring by runoff water and to facilitate the discharge of deposits from the canal bed

In regard to the related facilities, the intake canal will be recut immediately upstream of the pumping station to provide a settling basin in view of avoiding damage to the pumps by sediments contained in the running water during the pumping of irrigation water in the dry season. A transition with a brick lining treatment will be constructed at the confluence of Tatkir River and the intake canal to facilitate the smooth confluence of the running water and to prevent scouring of the river bed.

2) Sectional Form of Intake Canal

a) Longitudinal Slope of Intake Canal

While it is preferable for the longitudinal slope of the intake canal to incline away from Lakhya River towards the pumping station for the smooth flow of irrigation water from the intake canal to the pumping station in the dry season, this inclination would facilitate sedimentation at the canal bed during drainage operation in the rainy season when the water flows from the pumping station to Lakhya River. Therefore, the longitudinal slope of the intake canal will be level.

b) Elevation of Canal Bed

As the elevation of the inlet apron base of the pumping station will be -0.45 m and a new facility will be installed immediately on natural ground after current deposits on the canal bed have been removed, the elevation of the canal bed is estimated to be -0.45 m (the original work completion drawing indicates that the elevation of the canal bed was -0.20 - -0.10 m).

c) Width of Canal Bed

Based on the following considerations, the width of the canal bed has been decided at 2.0 m.

- To secure good workability during the implementation of the improvement work.
- A large volume of cut earth must be avoided and unstable sediments on the canal slopes must be removed.

- Facilities must be constructed within the existing canal area, i.e. no extension of the present top of either slope is anticipated.
- The current flow capacity, i.e. sectional flow area, must be increased.

d) Gradient of Canal Slopes

The results of the stability analysis based on the soil characteristics confirm that the minimum safety factor of 1.35 is achieved with a slope gradient of 1:1.5 and, therefore, a slope gradient of 1:1.5 is adopted.

e) Crest Height of Brick Lining

The crest height of the brick lining is estimated at EL 3.5 m, i.e. the average water level of Lakhya River for the last 13 years (1974 - 1986) of EL 3.0 m (see Appendix 2-2) plus freeboard of 0.5 m.

3) Brick Lining Method

The dry pitching method will be employed for the brick lining to facilitate groundwater drainage behind the slopes and to secure slope stability. The bricks used will have a maximum weight of 70 kg - 80 kg (400 mm x 400 mm x 230 mm) in view of preventing their theft and ensuring good workability.

4) Foundation Type

As the substratum of the brick lined slopes is soft and composed of clayey silt with a N value of 2 - 3, a ladder type wooden foundation will be employed to prevent the differential settlement of the facilities.

5) Typical Cross-Section

The typical cross-section of the intake canal resulting from 1) - 4) above is illustrated in Fig. 5-4-11.

(2) Improvement of Pumping Station

The following improvements will be made to the pumping station in order to increase the supply of irrigation water to the Demonstration Unit in the dry season.

1) Improvement of Water Level Detection Equipment

The following points must be noted when planning to lower the fixed water levels for the water level detection equipment which controls pumping operations:

① A minimum submerged depth of 1.2 m is required for the suction end of the pumps to prevent cavitation. Therefore, the water level to stop pumping operations should be EL 0.8 m (the current elevation of the suction end is -0.4 m).

② The water level to stop pumping operations should be different for each of the 3 pumps to avoid shock to or vibration of the discharge tank walls due to the simultaneous stopping of all 3 pumps.

③ The water level to start pumping operations should be 0.2 m - 0.3 m higher than the level to stop operations in consideration of a temporary decline of the water level and waves at the intake tank at the time of the commencement of operations.

Based on the above, the fixed water levels for the water level detection equipment will be lowered as shown in Table 5-4-4. As the revised water level to start pumping operations will be lower than the HWL and the level to stop

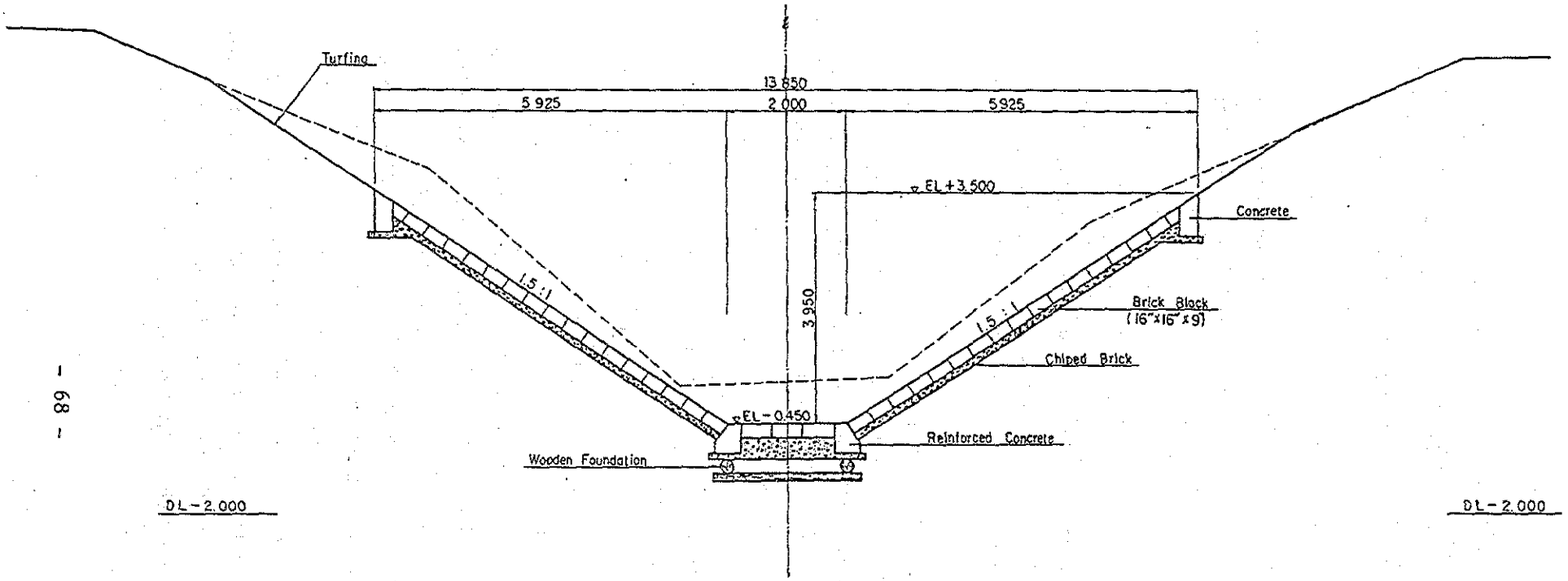


Fig. 5-4-11 Typical Cross Section of Intake Canal

operations will be higher than the LWL, continuous pumping will be made possible throughout the dry season (see Appendix 2-3). The actual discharge based on the performance curve of the pumps in use (according to the manufacturer's specifications) will be approximately 1.0 m^3/sec (or 62 m^3/min) per pump, resulting in a total discharge of 3.0 m^3/sec. This figure far exceeds the Demonstration Unit's maximum irrigation water requirement of 2.2 m^3/sec.

As the equipment uses specific electrode bands to detect the water level, these electrode bands should be replaced when such revision as to lower the fixed water levels is made.

Table 5-4-4 Fixed Water Levels for Automatic Detection Equipment

Pump	Operation Background	Start Level (m PWD)	Stop Level (m PWD)	Actual Head (m)	Discharge (m^3/min)
No. 1	Original Plan	+0.80	+0.50	4.05	63.6
	Present	+1.35	+1.05	4.05	63.6
	Revised	+1.10	+0.80	4.30	62.0
No. 2	Original Plan	+0.80	+0.55	4.05	63.6
	Present	+1.35	+1.10	4.05	63.6
	Revised	+1.10	+0.85	4.30	62.0
No. 3	Original Plan	+0.80	+0.60	4.05	63.6
	Present	+1.35	+1.15	4.05	63.6
	Revised	+1.10	+0.90	4.30	62.0

Notes: 1) Actual Head = Discharge Side Water Level - Intake Side Water Level (Start Level)

2) The design discharge is the volume of water which can be pumped given the start level.

2) Improvement of Inlet Apron

The elevation of the inlet apron will be lowered by 0.50 m to make it level with the bottom of the intake tank at a elevation of -0.45 m in view of the smooth inflow of irrigation water from the intake canal to the intake tank.

The inlet apron is an independent structure from the retaining walls consisting of a pile foundation and steel sheet piles and is also independent from the intake tank. A check of the completion drawing of the pumping station confirms that the removal of the inlet apron for improvement will not endanger the safety of the other structures. Fig. 5-4-12 illustrates the relationship between the structures.

5.4.3 Improvement Measures for Main Irrigation Canal

The following improvement measures have been decided for the two sections of the main irrigation canal embankment, i.e. the general section where the embankment functions only as the main irrigation canal and the Barba section where it also functions as a part of the flood embankment.

(1) Improvement of General Section

1) Width of Crest

The width of the crest is estimated at 2.0 m in view of the fact that it is currently used as a passageway to farms or as roads between villages.

2) Elevation of Crest

While the elevation of the crest in the original design is given to be 5.00 m, the revised elevation will be 5.55 m,

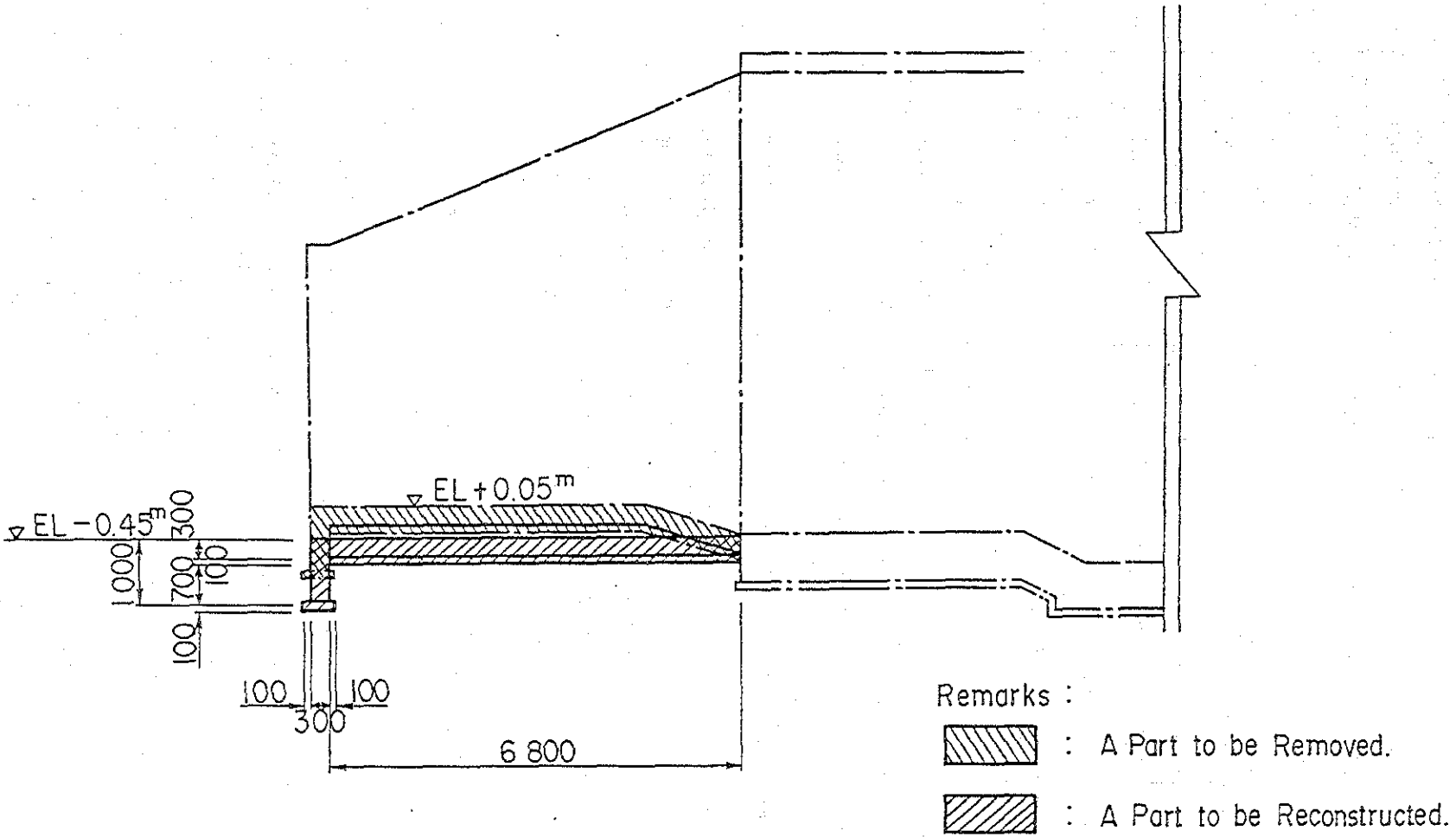


Fig. 5-4-12 Sketch of Inlet Apron to be Improved

given the fact that the elevations of all the facilities, including that of the pumping station, in the Demonstration Unit are 0.55 m higher than those given in the original design.

3) Gradient of Slopes

The slope gradients given in the original design will be kept, i.e. 1:2.0 for the canal side and 1:1.5 for the farm side.

4) HWL

With freeboard of 0.60 m, the HWL is estimated to be EL 4.95 m. In this case, the water volume distributed to the secondary irrigation canals is as shown in Table 5-4-5, ensuring adequacy of the design water distribution volume.

5) Land Requirement

New land acquisition is not anticipated. Since the present cross-section of the canal has a surplus capacity, banking will be conducted from the present farm side slope toe towards the canal side to widen the embankment.

6) Slope Protection

Turfing will be provided to protect the slopes of the embankment.

7) Typical Cross-Section

Fig. 5-4-13 shows the typical cross-section of the revised embankment.

Table 5-4-5 Hydraulic Calculation of Turnout Sluice.

h (m)	b (m)	H1 (m)	H2 (m)	H (m)	Q (m^3/s)
0.1	0.628	0.950	0.850	0.900	0.158
0.2	"	"	0.750	0.850	0.308
0.3	"	"	0.650	0.800	0.448
0.4	"	"	0.550	0.750	0.578
0.5	"	"	0.450	0.700	0.698
0.6	"	"	0.350	0.650	0.807
0.7	"	"	0.250	0.600	0.905
0.8	"	"	0.150	0.550	0.990

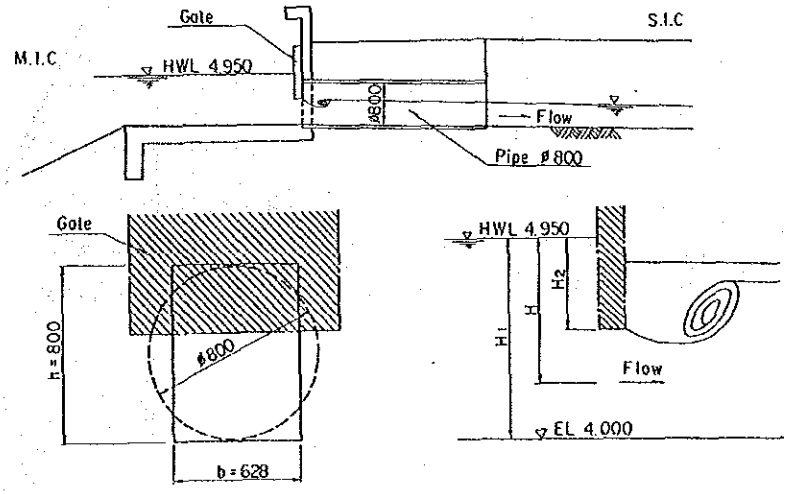
Notes: Discharge is calculated on the basis of Orifice's formula as follows:

$$Q=c.b.h.\sqrt{2.g.H}$$

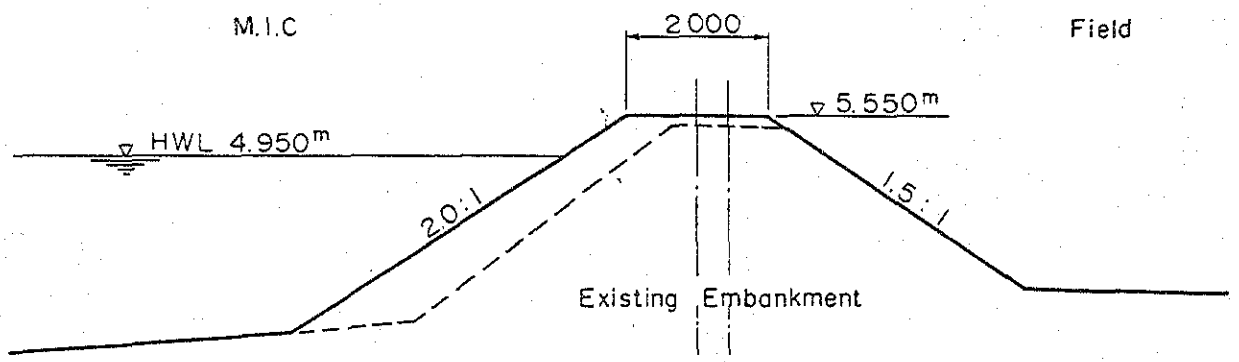
In which Q: Discharge (diversion) (m^3/sec)
c: Coeficient of discharge
b: Width of orifice
h: Height of orifice
H, H1, H2,: See the sketch showing below
g: Gravitational acceleration

The shape of orifice is estimated as the rectangle section with 800mm in height, of which area is the same as the circle with 800mm in diameter.

Circle with 800mm in diameter: $A=0.4^2\times\pi=0.503m^2$
Rectangle with 800mm in height: $A=0.628\times0.8=0.502m^2$



General Section



Portion of Flood Embankment in Barba

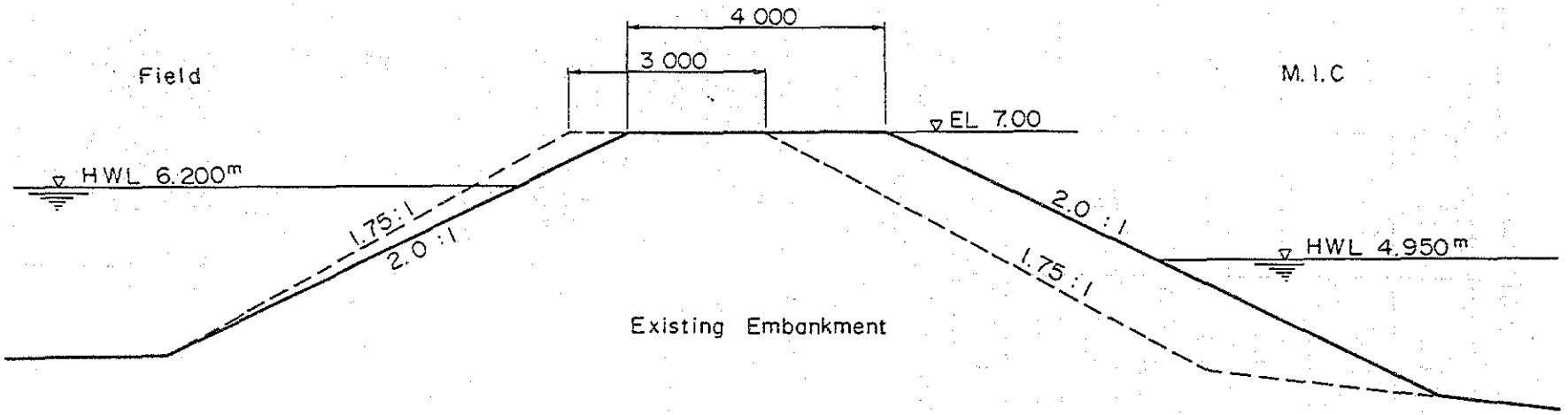


Fig. 5-4-13 Typical Cross Section of Main Irrigation Canal Embankment
Scale 1:100

(2) Improvement of Main Irrigation Canal Embankment (Barba Section)

1) Function of Barba Section

The Barba section of the main irrigation canal currently forms a part of the flood embankment. However, its function as a part of the flood embankment is provisional until the completion of the new flood embankment in N-N Project Block A-1 (Block A-1 is located to the immediate northwest of the Demonstration Unit).

2) Elevation of Crest

The design HWL of the flood embankment in the original design is EL 6.2 m which corresponds to a 10-year return period and the elevation of the crest is given to be EL 6.6 m, including freeboard of 0.4 m. Due to the following reasons, the elevation of the crest has been decided at EL 7.0 m.

① Since the repair work of the embankment being currently carried out by the BWDB uses a crest elevation of 7.0 m, there is no need to reduce this value.

② The elevation of D-N Road, which functions as the flood embankment, is less than 7.0 m in parts. There is no need to adopt a higher elevation for the Barba section vis-a-vis other parts of the flood embankment.

3) Width of Crest and Slope Gradient

In consideration of 1) and 2) above and also the design cross-section of the flood embankment in the Project, the crest width and slope gradient of the Barba section is estimated to be 4.0 m and 1:2.0 respectively.

4) Land Requirement

New land acquisition is not anticipated. As the present boundary of the canal site is formed by the farm side slope toe, the banking and widening work will be conducted on the canal side of the boundary.

5) Slope Protection

Turfing will be provided to protect the slopes.

6) Typical Cross-Section

Fig. 5-4-14 shows the typical cross-section of the revised Barba section.

CHAPTER 6 PROJECT IMPLEMENTATION PLAN

6.1 Project Implementation System

(1) Project Implementation Organization

The organization responsible for the implementation of the Project is the Bangladesh Water Development Board (BWDB) under the umbrella of the Ministry of Irrigation, Water Development and Flood Control which is responsible for from the planning and implementation stages to the final stage of operation and maintenance for such projects as flood control, water resources development and large-scale irrigation in Bangladesh.

The BWDB will select a consultant pursuant to the established system for Japanese grant aid and entrust the consultant to perform the detailed design. Based on the results of the detailed design, the BWDB will then place a construction work order to the contractor, who is selected in the same manner as the consultant, to commence the rehabilitation work under the supervision of the consultant.

Project-related items, including the various procedures required for the implementation of the Project, for which the Bangladesh side is responsible will be conducted by the BWDB in accordance with the construction schedule. The BWDB will also be responsible for the operation and maintenance of the facilities constructed under the Project.

(2) Consultant

The detailed design and supervision of the rehabilitation work to be conducted by the Japanese side will be entrusted to a Japanese consultant, selected pursuant to the established system for Japanese grant aid, based on a consultancy agreement between the consultant and the BWDB.

The consultancy services will be divided into two categories, i.e. the the detailed design and the tender/supervision of the rehabilitation work, in accordance with the project implementation schedule. A consultancy agreement in which the above categories are included will be made immediately after the signing of the E/N.

(3) Contractor

The rehabilitation work will be conducted by a Japanese contractor, selected pursuant to the established system for Japanese grant aid, based on a construction contract between the contractor and the BWDB.

The Government of Bangladesh will entrust the consultant to conduct the tender for the rehabilitation work and, following negotiations, will conclude the construction contract with a successful tenderer. The adoption of the turn-key method, where a blanket contract covering the commencement of the work to its completion, is assumed and the contractor must duly complete all the work listed in the contract within the agreed period of time.

For the actual implementation of the rehabilitation work, the contractor will select sub-contractors from Bangladesh companies.

6.2 Division of Project Work

(1) Items to be Undertaken by the Japanese Side

Of the basic design items, those for which the Japanese side is responsible in terms of the provision of grant aid cooperation, are as follows.

1) Consultancy services for the preparation of the detailed design.

2) All rehabilitation work except those for which the Government of Bangladesh is responsible.

3) Supervision of the rehabilitation work.

(2) Items to be Undertaken by the Bangladesh Side

The following items for which the Government of Bangladesh is responsible have already been agreed upon in the Minutes of Discussion concluded between the Government of Bangladesh and the Study Team (see Appendix 1-4).

1) Careful examination of the flood embankment during both the dry and rainy seasons.

2) Proper maintenance of the flood embankment as recommended in Chapter 8.

3) Completion of the resectioning work for section 0.0 km - 4.0 km of the flood embankment during the 1988 dry season so that the Japanese contractor can immediately commence the rehabilitation work at the beginning of the next dry season (November, 1988).

4) Prompt and timely completion of all domestic procedures in regard to the preparation and submission of the Project Proforma (PP), etc. for the smooth implementation of the Project.

While the following items are not referred to in the Minutes of Discussion, they are listed here as standard items for which the Bangladesh side is responsible when the Project is implemented under Japanese grant aid cooperation.

5) Provision of data and information necessary for design and construction.

6) Clearance of project sites prior to the commencement of construction, including the removal of any obstacles.

7) Provision of salaries and per diem and travel allowances for counterparts who are assigned to the Project.

8) Assurance of prompt unloading and customs clearance in Bangladesh of imported materials and equipment necessary for the Project in accordance with the relevant regulations in Bangladesh.

9) Exemption of Japanese nationals concerned of the Project, together with accompanied goods necessary for the Project, from internal taxes, customs duties and other levies which may be imposed by the relevant regulations in Bangladesh.

10) Provision of necessary permission, licences and other authorizations required for the Project.

6.3 Implementation Plan

6.3.1 Detailed Design

As described in 6.1 (2), the detailed design will be prepared in accordance with the agreement between the BWDB and the Japanese consultant selected pursuant to the established system for Japanese grant aid. The contents of and the staff required for the detailed design work are given below.

a) Review of Basic Design Study
b) Rehabilitation Plan
c) Detailed Design of Rehabilitation Work
d) Construction Plan
e) Project Cost Estimate

Staff	Main Work Assignment
General Manager	General administration of the entire work and discussions with the Project implementation agency
Designer for Flood Embankment	Detailed design for the rehabilitation work of the flood embankment (8.3 km)
Designer for Irrigation Facilities	Detailed design for the rehabilitation and improvement work of the irrigation facilities such as the intake canal, pumping station and main irrigation canal
Geologist	Detailed assessments of geological and soil conditions in and around the Demonstration Unit and the provision of advice concerning project-related plans and designs
Estimator	Estimation of construction cost

6.3.2 Construction Work Policy

Due to the fact that the rehabilitation and improvement work for which the Japanese side is responsible is mainly composed of earth works, the main work must be implemented during the dry season and 2 dry seasons will be required to complete the work in view of an estimated total earth volume of some 200,000 m^3.

To be more precise, if the work commences at the beginning of November, 1988, a work period of 7 months can be secured in the first dry season (November, 1988 - May, 1989) and an additional 5 months can be secured in the second dry season (November, 1989 - March, 1990) due to the extension of the contract period up to March, 1990 and, therefore, the construction period in the dry season totals 12 months. The work, which is suited to the rainy season rather than to the dry season or deemed executable even in the rainy season, will be accordingly implemented.

The employment of local inhabitants as workers for the Project during the construction period will be promoted as much as possible and suitable local methods will also be adopted.

6.3.3 Notable Points for Performance of Construction Work

1) The religious and secular customs of Bangladesh should be respected with a proper attention paid to these customs in the planning of the work schedule.

2) Local inhabitants should be given every consideration to attain the success of the Project with their cooperation.