THE PEOPLE' S REPUBLIC OF BANGLADESH

DATA COLLECTION SURVEY
ON
WATER RESOURCES MANAGEMENT
IN
HAOR AREA OF BANGLADESH

FINAL REPORT

December 2013

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

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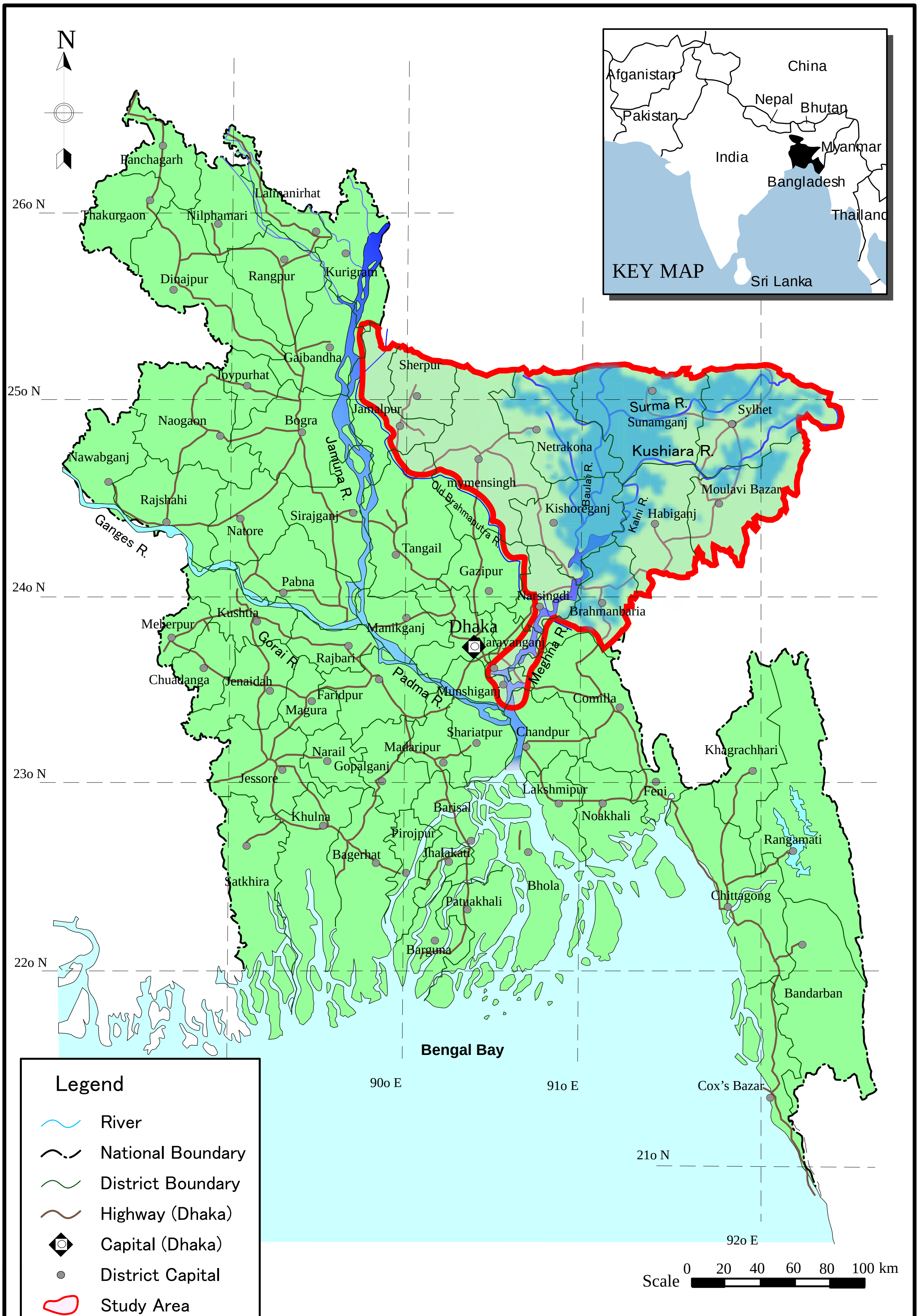


Location Map

CHAPTER 1 INTRODUCTION

1.1 Objectives of the Study

The objectives of the Study are:

1) To collect and review (i) contents of water resources management plans, such as "Master Plan of Haor Areas (the M/P, 2012)", for the haor areas in the upper Meghna area and (ii) existing relevant data and information,
2) To conduct additional study on matters having hardly been addressed so far in the said plans, and
3) To propose possible JICA cooperation projects for flood measures and river management plan in haor areas.

1.2 Study Area

The study area covers the river basins dealt with by the M/P (including their upstream and downstream areas required for the Study (limited to the Bangladeshi territory)).

1.3 Final Report

This Final Report is submitted as the product stating the results and findings in the First to Fourth Works in Bangladesh, which were conducted from November 2012 to November 2013.

CHAPTER 2 CURRENT CONDITIONS OF STUDY AREA

2.1 Physical Setting

2.1.1 Physiography and Topography

The physiography of the study area is classified based on the combination of the geological material in which particular kinds of soil have formed and the landscape on which they occur. Seven districts comprising the haor area are placed on the following eleven (11) physiographic units, based on agro-ecological regions of Bangladesh prepared by Food and Agriculture Organization (FAO)[1], as shown in **Figure 2.1.1** (Page 2-3, Chapter 2). The units are Northern and Eastern Piedmont Plains, Northern and Eastern Hills, Sylhet Basin, Eastern Surma-Kushiyara Floodplain, Old Brahmaputra Floodplain, Young Brahmaputra and Jamuna Floodplain, Active Brahmaputra-Jamuna Floodplain, Old Meghna Estuarine Floodplain, Madhupur Tract, Middle Meghna River Floodplain and Akhaura Terrace.

The study area forms such a low-lying basin compared with other regions of the country. Land below EL. 5m PWD extends virtually as far as the Meghlaya Foothills. Outside of this area, floodplain lands situated 200km from the sea are found at EL. 8 m to 20 m PWD. Approximately 25 % of the study area lies below EL. 5m and 50 % lies below EL. 8m.

[1] Classification of agro-ecological zone in Bangladesh prepared by FAO
http://www.fao.org/fileadmin/templates/faobd/img/Agroecological_Zones.jpg

2.1.2 Climate

The Northeast Region of Bangladesh is located entirely to the north of the Tropic of Cancer, and hence its climate is characterized by the sub-tropical monsoon. The sub-tropical monsoon results in intense regional and orographic rains caused by the interface of the mist air masses incoming from the Indian Ocean through the Bay of Bengal with a predominant northeastern direction and the steep and high hills located at the foothills in the states of Assam, Meghalaya and Tripura in India. The hills in these states of India experience very severe precipitation. Some of the more intense precipitations in the world fall in the hilly areas, where the average annual rainfall is around 12,000 mm.

The hydro-meteorological seasons of the Northeast Region are generally classified into:

- Pre-monsoon season extending from April to May,
- Monsoon season from June through September,
- Post-monsoon season from October to November, and
- Dry season from December through March.

2.1.3 River System

Figure 2.1.3 (Page 2-6, Chapter 2) shows the river system for the upper Meghna River including the portion of the watershed inside India. The Barak River drains the Assam region and distributes the flow through a bifurcation near the border between Bangladesh and India. Data from 1980 to 2008 indicates that an average of around 40% flows into the Surma River channel and 60% inflows to the Kushiyara River during most part of the year. During the dry season, the Kushiyara River carries around 88% of the Barak inflow due to the physiography at the bifurcation. Because of the sediment deposition at the Surma River portion of the bifurcation, the tendency is that flow proportion increases with time into the Kushiara River while the Surma River is silted over.

2.1.4 Geology and Soil

The Indian sub-continent has been formed by a collision between the northward moving Indian Plate and the static Eurasian Plate since the Cretaceous period. Part of the northeast Indian Plate has fractured and sank below the sea-level during the Oligocene period. Since then the Bengal basin has started to form subsiding tectonic basin slowly, filling up with deltaic sediment.

The soils of the area are grey silty clay and clay on the higher parts that dry out seasonally and grey clays in the wet basin. Peat occupies some wet basin centers. The soils have a moderate content of organic matter and soil reaction is mainly acidic.

About 74% of the top soil texture of the haor region is clay to silty clay, 21% is silt and the rest are clayey silt, sandy silt and sand.

2.2 Natural Resources

(1) Water Resources

It is reported in the M/P that the analysis of BWDB data (1960-2009) has shown the volume of water contribution into Bangladesh through the Meghna river system is 162,619 million m^3. Water contribution from the transboundary rivers of the Barak, Meghalaya and Tripura systems are 42,670 million m^3, 30,376 million m^3 and 15,716 million m^3, respectively.

(2) Vegetation

In the haor basin, there are hill forests, social forests, fresh water swamps, reed swamp forests, bamboo and homestead vegetation, etc. In the M/P, ecologists have grouped the typical haor vegetation areas into nine classes, which are 1) Submerged plants, 2) Free floating plants, 3) Rooted floating plants, 4) Sedges and meadows, 5) Floodplain grassland, 6) Reed swamp, 7) Fresh water swamp forest, 8) Crop field vegetation and 9) Homestead vegetation.

(3) Biodiversity and Wetland

There are a large number of wetlands of significant national and regional importance and many sites have significant local value. The sites support biodiversity at all scales especially communities (species and within the species) and are home to several internationally threatened species. The biodiversity of haor wetlands is very rich. The most significant wetlands are Hakaluki Haor, Tanguar Haor, Hail Haor, Matian Haor, Pasuar Beel Haor, Dekar Haor, Baro Haor, Gurmar Haor, Sonamorol Haor, Baram Haor, Kalni Haor, Kawadighi Haor and Pagner Haor.

In 1999, the Government of Bangladesh (GoB) declared two haors as 'Ecologically Critical Areas' (ECA) in the haor area based on "Bangladesh Environment Conservation Act (1995, amended in 2000 and 2002)", which are Hakaluki Haor (Maulvibazar/Sylhet Districts) and Tanguar Hoar (Sunamganj District). Tanguar Haor has been declared as a Ramsar site.

(4) Mineral Resources

The haor basin is a large, gentle depression, created by subsidence and tectonic adjustment. The geological setting and formations of the northeastern part of Bangladesh favors the deposit of various types of mineral and energy resources. The mineral resources discovered are natural gas, crude oil, limestone, white clay, glass sand, peat, coal, gravel and construction sand (see **Table 2.2.4** (Page 2-14, Chapter 2)). About 90% of the total gas production of the country is obtained from the haor districts.

2.3 Socio-economy

(1) Population Distribution

The total population of the seven haor districts (Kishoreganj, Netrokona, Sunamganj, Sylhet, Moulvibazar, Habiganj and Brahmanbaria districts) in the Northeast Region is 17.88 million as of 2011 Census compared to 14.94 million in 2001 Census (BBS, 2012). There are about 3.44 million households in the haor districts, which translates into an average household size of 5.2 persons per household. The sex ratio in the haor districts on average is 97.78:100, which indicates that there are 97.8 males per 100 females. The national sex ratio is 100:100. The overall population density in the haor districts is 894 per sq km, which is lower than the average population density in Bangladesh, which is 976 per km^2. The rate of urbanization in these districts is 14.8%, though the national average of urbanization is 23.3%.

(2) Land use

The haor districts cover a gross area of about 2 million ha, of which about 55 % is cropped land, and the rest is occupied by the rivers, channels (khals), water bodies, forests, homesteads, ponds, hills and infrastructure.

The number of farm households in the haor districts is 1.68 million and non-farm households 1.37 million. Of the total farm households, about 80 % are small (owning less than 1 ha of cultivated land), 17 % are medium (owning 1 to 3 ha of cultivated land) and 3 % are large (more than 3 ha of cultivated land). The large farms usually operate their lands using tenants or hired labor.

(3) Agriculture

Net cultivated area covers about 12,000 km^2 in the haor districts. The highlands (F0) and medium highlands (F1) where flood depth reaches 0 to 0.9 m occupy about two-fifths of the net cultivated area. The medium lowlands (F2) and lowlands (F3) where the seasonal flooding depth is 0.9 m to more than 1.8 m occupy about three-fifths of the net cultivated area. In the haor area, about one-fifth of the net cultivable area is in F0 and F1. The F3 comprise about four-fifths.

The Census of Agriculture in 2010 Yearbook of Agricultural Statistics indicates that 15,400 km^2 is cropped under different rice cultures. Local and high-yield-variety (HYV) boro are almost the only crops grown in the lowlands. Cropping intensity (ratio of total cropped area to net cultivated one) is 133%.

Since most of the haor areas flood to a depth of more than 0.9 m in the monsoon season, about four-fifths of the net cultivated area is used for single cropping. In this cropping pattern, HYV boro is the major crop followed by local aman.

Early flash floods and poor drainage of floodwater significantly reduces boro rice crop yields in some years.

(4) Fisheries

Wetlands are used for breeding as well as feeding grounds of most for the freshwater fish species. The estimated fish habitat area in the haor region is about 9,670 km^2. The fish production is about 4,300 tons of fish, out of which 73.7% comes from capture fishery and the rest is contributed by culture fishery. Of the capture fish production, floodplain contributes the bulk portion which is about 77.9% followed by beels (15.6%), river streams (3.5%), channels/khals (1.8%) and ditches/borrow pits (1.2%). Culture fish ponds in the area produce about 1,136 tons which is 26.3% of the total production. The fish production of 4,300 tons is derived from 2,540 tons (59%) mainly coming from the flood plains during the monsoon season and 1,780 tons (41%) from rivers, beels, fish ponds, etc., during the remaining season.

Nearly 20% of the total inland fish production of Bangladesh comes from the haor basin and this sector plays a vital role in the national economy in general and the local economy in particular for the poor.

(5) Livestock

The livestock resources of the haor region are mainly cattle, buffaloes, goats, sheep, chickens and ducks. There are around 32.68 million heads of livestock (cattle, goats, sheep, ducks and poultry) in the haor farms. They constitute approximately 22% of the total cattle population in the country.

(6) Industry

Industrialization has not taken place to a great extent in the Northeast Region and consequently the number of industries and people engaged is comparatively low (1.33% of the total population only). Most of the tea estates are in the Sylhet Region.

(7) Electricity

Energy is one of the factors that support and accelerate growth of the country. Unfortunately, the state of energy in the haor area is in poor condition. The Rural Electrification Board (REB) is entrusted with the distribution of electricity in the rural areas of Bangladesh. The total number of villages receiving electricity by 2010 was 6,740 out of 15,374, accounting for 44% as compared to 72% nationwide.

(8) Water Supply

Most of the households in the haor area are using tube-well water (groundwater) for drinking purpose. About 50% of the households are dependent on surrounding river/pond water for domestic use. As a result, in spite of having good and safe water access, the haor people are affected by many water-borne diseases.

(9) Sanitation

Bangladesh is on its way to achieving the MDGs targets. However, burdened with poverty and stressed with infrastructure inadequacy, the overall health status in the haor region continues to lag behind the national benchmark with the prevalence of both communicable and non-communicable diseases. The sanitation facilities of the haor area are poor compared to other parts of the country. Use of sanitary latrine is only 44% in the haor area.

(10) Education

The average literacy rate of the haor districts is 38%, while the national level is at 54.8 %. Among the haor districts, Moulivibazaar has the highest literate population (42%), followed by Sylhet (41%), Brahmanbaria (40%), Habiganj (37%), Kishoreganj (37%), Netrokona (34%), and Sunamganj (33%).

(11) Health

The overall health status in the haor region continues to lag behind the national benchmark with the prevalence of both communicable and non-communicable diseases. The malaria endemic districts of Habiganj, Maulvibazaar, Netrokona, Sunamgonj and Sylhet had 5,345 numbers of case loads in 2009 (DGHS 2010).

The average infant mortality rate (IMR) and under-5 child mortality rate (U5MR) in the haor area, except for Brahmanbaria District, is 57 (per 1,000 infants) and 76 (per 1,000 children) which are much higher than the national IMR of 49 and U5MR of 64. The average of under-5 child malnutrition for haor districts is approximately 46%, which is again higher than the national rate of 43% (BDHS 2007).

(12) Road Transport

Haor areas remain under water for 4 - 6 months during the pre-monsoon and monsoon seasons. The roads are submerged during these seasons making it impossible to travel from one place to another without using boats. The transportation networks of waterways and roadways have developed over the years in keeping with the unique characteristics of haors. Eleven upazilas out of the total 69 upazilas in the haor districts are not connected with the Road and Highways Department (RHD) network.

(13) Inland Navigation

Inland waterways have been used as a major way of transporting cargo and passengers in the haor area. There are 25 inland water transport (IWT) routes covering a length of 1828.8 km of inland waterways, which remain navigable during the monsoon season (May-September). However, during the lean period (October-April) inland vessels cannot navigate in about 1,000 km of the waterways.

2.4 Flood Damage and Flood Mark

The damage caused by the flash flood in the haor area can be considered as direct damage. It damaged the boro rice production, submergible embankment and house inundation. However, the most serious damage is in the boro rice production. Other damage data could not be collected.

Flood damage on the boro rice production from 2009 to 2010 was collected by district basis from the Bangladesh Bureau of Statistics (BBS). The district basis flood damage data before 2009 - 2010 was not available from the BBS office and other agencies.

No information on flood marks has been collected from existing documents related to flood events in the haor area.

CHAPTER 3 REVIEW OF STUDY APPROACH TAKEN IN FORMULATION OF THE M/P

3.1 Organization of Working Group

The Working Group (WG) was organized in the initial stage of the first work in Bangladesh for efficient and smooth practice of the M/P review. The WG is composed of members from BWDB, which is expected to be the project executing agency, Center for Environmental and Geographic Information Services (CEGIS), which actually joined in the formulation of the M/P as a consultant, and the Study Team.

During the first work in Bangladesh, three WG meetings were held at the BWDB central office, Dhaka, on 10 and 23 December 2012 and 14 January 2013. The JICA Study Team explained the purpose, members, activities and final outputs of the WG, among others, by using the operational guideline at the first WG meeting on 10 December 2012 in order to share the same understanding and information among the WG members.

3.2 Findings on Study Approach Taken in Formulation of the M/P

(1) General Study Approach for Water Resources Sector in Haor Area

In the haor area, one of the major problems related to water resources management is flooding due to flash floods having occurred during the pre-monsoon season, which starts at the end of April or beginning of May. In the M/P, integrated solutions have been derived from engineering solutions based on the flooding characteristics in the haor area and from the perception of the local people upholding ecological sustenance in the area.

The primary approach to the solutions is stated below.

1) Preparation of flood depth maps using the established relation with critical periods
2) Proposal of new engineering but eco-friendly hydraulic structures and existing practices through managing or restraining the flood levels at a reasonable extent.
3) Review of the design parameters of existing submergible embankments and suggestions or recommendations for better O&M and strengthening of existing structures.
4) Identification of infrastructure requirements, following participatory process.
5) Addressing of drainage management including dredging and restoration of khals and beels to maintain/improve the connectivity between haors and the rivers.

(2) Study Approach of Individual Projects Identified for Water Resources Sector in Haor Area

The study approach taken to formulate the WR01, WR02, WR03 and WR05 projects, which have been identified in the M/P for water management in the haor area was confirmed, as explained below, in the WG meetings and through repeated discussions between the Study Team and CEGIS.

Stage-1: Identification of the problems, issues and possible remedial measures through public consultation meetings (PCMs) at upazila level (69 Upazilas) , and review of the Flood Action Plan 6 (FAP6) report and other relevant documents

Stage-2: Compilation of the PCM results into 15 issues which were found very important for the haor area,

Stage-3: Clustering into 17 development areas (DAs) to address the 15 issues,

Stage-4: Classification of the Development Area of water resources-related issues into 6 categories, which are:

▪ Flash flood	▪ Drainage congestion
▪ River bank erosion	▪ Poor navigability
▪ Wave erosion	▪ Sedimentation

Stage-5: Conversion of the 6 categories above into the following schemes/projects for implementation to solve the issues:

1) Rehabilitation projects: WR01
2) New development projects:WR02
3) River dredging projects:WR03
4) Protection of the settlements:WR05
5) Study projects

After Stage-5, the study approach as stated below was pursed for the respective projects.

1) WR01: Pre-monsoon Flood Protection and Drainage Improvement in Haor Areas

Stage-1: Preparation of a list of all existing water-related scheme/projects in the haor area, a total of 118 projects/schemes which are flood control, flood control/drainage and flood control/drainage/irrigation projects

Stage-2: Collection of available information on the 66 screened projects, excluding the 52 projects/schemes included in DPP/2011 for rehabilitation

Stage-3: Selection of 25 projects for rehabilitation in due consideration of (i) demand of the local people and (ii) opinions of the BWDB field offices, based on the Water Management Improvement Project (WMIP) outputs

Stage-4: Validation of the selected 25 projects, as referred to in **Table 3.2.2** (Page 3-5, Chapter 3), at the Dhaka office and senior ex-officials of BWDB as well as other water experts.

2) WR02: Flood Management of Haor Areas

Stage-1: Formulation of 39 projects/schemes in consideration of information about the demands of local people collected from the PCMs and also earlier proposed projects in the haor areas,

Stage-2: Identification of 31 projects/schemes out of the 39 projects/schemes based on expert knowledge, opinions and experiences under the M/P of the haor area,

Stage-3: Validation of the identified 31 projects/schemes (see **Table 3.2.3** (Page 3-7, Chapter 3)) at the Dhaka office of BWDB as well as renowned water experts.

3) WR03: River Dredging and Development of Settlement

Stage-1: Selection of the Surma-Baulai-Gorauttara river system with its tributaries for dredging plan under the M/P.

Stage-2: Review of the North East Water Management Plan and other relevant documents to identify the potential rivers for dredging in the haor area.

Stage-3: Identification of a total of 125 km long river stretches from the Surma, the Rakti, the Bauli and the Katakhal in the Surma-Baulai-Gorauttara river system for dredging

Stage-4: Verification of the selected river stretches through field investigation, public consultation meetings and knowledge sharing with the local BIWTA and BWDB officials.

Stage-5: Finalization of the selected river stretches by consulting with BIWTA and BWDB officials, senior ex-officials and water experts at the Dhaka offices.

4) WR05: Village Protection against Wave Action of Haor Area

Stage-1: Identification of deeply flooded and erosion prone settlement areas by using high resolution Cartosat satellite images of the haor area and through field visit.

Stage-2: Collection of information about the wave action, intensity, duration, magnitude, erosion prone areas, and investigation of existing housing practices, protection measures, etc through field survey.

Stage-3: PCMs in the haor areas to seek solutions from the stakeholders in different locations and to preliminarily identify locations for green belt development/new settlement platforms and existing wave protection measures such as revetment works, wave protection walls, etc.

Stage-4: Consultation with the BWDB field offices to reflect their knowledge/experiences/ideas/opinions for selection of vulnerable locations and appropriate protection measures.

Stage-5: Validation of locations and respective measures at the Dhaka office of BWDB as well as water experts.

(3) Review of Data and Analysis Results Used for the M/P Formulation

In selecting the clusters of subprojects for the respective projects identified in the M/P for the water resources sector of the vast haor area, relevant data and information were used, particularly to fully examine the importance and urgency of subproject implementation at selected sites.

After the selection, the M/P formulation process worked out the design of subprojects at a master plan level. The design work was carried out referring to the following:

1) Available design of major project structures adopted in existing similar water-related projects, and
2) Past experiences and lessons learned by senior ex-officials of BWDB and renowned water experts.

Therefore, it is pointed out that no latest data/information of river cross-sections and foundation soil at planned structure sites was incorporated into the subproject design and no verification of subproject design through flood inundation and riverbed movement analyses was conducted.

In due consideration of the data and information used, it is essential for the Study to examine and/or confirm the soundness and necessity of project through basic study, in particular from a technical point of view, based not only on latest river, topography and foundation soil data to be obtained through river/topographic survey and geotechnical investigation, but also on hydraulic analysis of flood inundation and riverbed movement, all of which have been carried out in the Study, in order to successfully achieve the objectives of the Study.

CHAPTER 4 FIELD SURVEY AND INVESTIGATION

4.1 River Profile and Cross Section Survey

The river cross sections are required to deal with the following issues in the Study:

1) Flood run-off and inundation analyses,

2) Sediment balance study and riverbed movement analysis, and

3) Structural measures, such as embankment, river bank protection, and dredging.

River Morphology Circle, which belongs to BWDB, carries out the river cross section survey of thirty (30) rivers in Bangladesh. The river cross section survey results are checked by River Morphology Section under Flood Forecasting and Processing Circle (FFPC), which belongs to BWDB. Finally, the river cross section data are stored in the database of FFPC.

The river cross section data in the Study area surveyed by BWDB are not applied to hydraulic analysis due to low reliability of the pillar information of each cross section.

IWM has carried out river cross section survey and the preparation of simulation model in a part of haor area. The river cross section survey results partly cover the study area.

The river cross section survey is executed by a local contractor. Al-Mayeda Survey Consultants was selected through the tender process, according to JICA’s guidelines.

The number of river cross sections to be surveyed is 168 cross sections.

4.2 Topographic Survey and Geotechnical Investigation

4.2.1 Topographic Survey

Normally, a topographic survey is carried out after the selection of project sites. However, the field works of the topographic survey have to be finished before the rainy season because the project areas are to be located in the hoar area. Therefore, the topographic survey needs to be started before the selection of priority project sites.

The target haor projects of the topographic survey were decided to be carried out at Sunamganj, Habiganj, Netrakona, Kishoreganj, and Brhamanbaria districts. The high frequency of flash flood and only boro crop production area are widely distributed in these districts. When flash flood damage occurs in the only boro crop production area, there is a serious impact to the farmers in this area as compared with other districts, i.e. Shylet and Moulvibazar districts, due to no crop production.

On the other hand, Water Management Improvement Project (WMIP) financed by World Bank, is carrying out rehabilitation works in the surrounding of the haor area. Four (4) projects in the Haor M/P are carried out in WMIP. Therefore, there are 12 target haor projects for topographic survey.

The problems related to water resources and management in the new haor projects proposed in Haor M/P were considered during the public consultation meetings (PCMs) in 66 upazilas. The new haor projects were selected through discussions with the field offices and central office in BWDB. Twenty six new haor projects were selected.

The topographic survey was carried out under a subcontract with a selected local contractor. Al-mayeda Survey Consultants was selected through the tender process following JICA’s guidelines.

4.2.2 Geotechnical Investigation

Geotechnical investigation was conducted for the ten (10) haor projects, composed of four (4) rehabilitation projects and six (6) new projects which were identified in the M/P and their locations are shown in **Figure 4.2.3** (Page 4-10, Chapter4).

Major work items of this geotechnical investigation are: 1) Core Drilling/Wash Boring, 2) Dutch Cone Test, 3) Laboratory Test for Undisturbed Samples, 4) Laboratory Test for Embankment Materials, 5) Dry-Wet Cycle Test and 6) Riverbed Material Survey

<u>Necessity of the Work</u>

The existing source materials/data on (i) foundation soil of structures like embankment and sluices and (ii) embankment construction materials which are available in the Study are as enumerated below.

1) ”Geological Map of Bangladesh, 1:1,000,000”, Geological Survey of Bangladesh, 2001
2) Soil laboratory test results (physical, consolidation and strength tests) at two (2) locations in the haor area near the northern international border with India (one location

each in Netrokona and Sunamganj Districts) which have been described in "Report on the Feasibility Study for Capacity-Building Project for Sustainable Development of Water-Related Infrastructure (Part-1), January 2012, JICA Technical Cooperation Project".

3) Standard Penetration Test (SPT) results at several gate structures constructed in the haor projects which are been being operated and maintained by BWDB.

Furthermore, it was clarified through the M/P review that the haor M/P had conducted no geotechnical investigation for the formulation of structural plan. Therefore, it was concluded that the Study needs the geotechnical investigation with the aim of assessing the following technical points:

(a) Stability of foundation for embankment and sluices against settlement and piping,

(b) Soil materials available for embankment construction, and

(c) Durability of submergible embankment which is subject to repeated submergence and drying.

<u>Scope of Work</u>

The survey items and locations are as tabulated below under the sub-contract with DDC. Results of the geotechnical investigation are explained in Annex 4-2.

Survey Items and Locations

Survey Items		Locations			Remarks
		Existing Haor Projects	New Haor Projects	Total	
Ground survey	Core drilling/ Wash boring	4 schemes[*1]	6 schemes[*1]	10	Sluice site
	Dutch cone test	-	6 schemes[*2]	6	Submergible embankment
Soil test					
Foundation	Physical test	4 schemes[*3]	6 schemes[*2]	10	
	Consolidation test				
	Strength test				
Embankment Materials	Compaction test	-	5 schemes[*4]	5	
	Strength test				
	Dry-Wet cycle test	-	1 scheme[*4]	1	

Notes: Survey locations are selected from the haor project areas as follows:
[*1] See Figure 4.2.3
[*2] 6 core drilling survey schemes
[*3] 4 core drilling survey schemes
[*4] Selected from 6 core drilling survey schemes

4.3 Survey of Existing River and Agricultural Facilities

4.3.1 Data Collection and Review

The existing river and agricultural facilities are mainly river dike called "full embankment" in Bangladesh, revetment, submergible embankment, regulators, pipe sluices and drainage and irrigation canals. There are 118 haor projects implemented and operated by BWDB in the haor area.

<u>Detailed information of structures</u>

The information related to the facilities of haor projects were collected in Dhaka and from the site offices. However, the information on the facilities in the 37 haor projects that are funded by GOB, were collected.

During the site reconnaissance, the Study Team tried to collect as-built drawings of the existing haor projects. However, such drawings were not obtained because the staff in the BWDB site offices had no knowledge of their locations.

In addition, the facilities and work volume of the proposed rehabilitation works were mentioned in M/P. But the locations and areas for rehabilitation were not mentioned. The information on the type of facilities, dimensions, and damaged areas should be collected. Therefore, a river facility survey is needed to check the present conditions.

The flood control projects and drainage projects were also executed in the haor area. In these projects, full embankment, regulator, barrage, pump station were constructed.

<u>Flood damage of river structures in 2007</u>

The flood damage of the facilities in the haor projects and other projects was surveyed. The data on the flood damage on the structures were only from the 2007 flood damage data surveyed by BWDB. No data on flood damage is available except year 2007.

<u>Responsibility of operation and maintenance</u>

A sluice committee is established to discuss between an executive engineer of a BWDB site office and stakeholders, such as an upazila chairman and ward members. The sluice committee has a key of regulator. The operation of regulator is instructed by the BWDB staff. The sluice committee operates their regulator under the instruction of BWDB.

On the other hand, the regulators along the rivers which are not included in the haor projects have no committee. Therefore, the BWDB site office requests the operation of such regulators to respective ward members. In this case, the BWDB site office directly requests the ward members to operate the gates.

Information on the proposed rehabilitation projects of existing haor projects in the M/P is only limited to the quantities of the rehabilitation works. It is not mentioned in the M/P the damage location and situation of each structure. Therefore, information on the existing structures in the proposed rehabilitation project is collected from BWDB site offices.

4.3.2 Targets of Field Survey

The targets of the field survey are 1) the existing haor projects, and 2) the river facilities because existing facilities related to water management are located in the existing haor areas and along/across the rivers.

4.3.3 Survey Items

The field survey shall include the following items:

1) Collection and review of design drawings and design conditions/criteria,
2) Past flood overtopping and damage of submergible embankment, types and problems of drainage facilities,
3) Major causes of facility damage and malfunction,

4) State of operation and maintenance

5) Function of haor areas (method for securing irrigation water, supply of nutritive salt due to farm land sedimentation, freshwater fishing in farm land, etc.)

4.3.4 Survey Results

(1) Regulator

Many regulators are non-operational due to maintenance problems. The responsibility of maintenance of regulators rests upon the BWDB field office, however they do not have enough budget for regular maintenance.

There are 60 regulators in the survey area, in which 31 regulators are completely not operational and 6 regulators are partially damaged. The regulator cannot be operated due to conflicts between farmer and fishery committees.

On the other hand, the responsibility of the operation of the regulator lies with the sluice committee, which is organized by the stakeholders. The sluice committee coordinates with BWDB for the operation of regulator based on the instruction from BWDB. The sluice committee functions well.

(2) Embankment

Full embankment and submergible embankment were conducted for 258 km and 175km, respectively. These structures are mainly damaged for about a few meters to 10 m. Damage of several hundred meters is a few.

Damage to the embankment is classified into two cases. One is erosion due to flood overtopping and/or river flow velocity and direction, and the other is artificial cutting. According to interviews with the village people and the BWDB site office staff, the reasons for artificial cutting are to create the entrances for boat, to create drainage outlets and inlets of irrigation water and for inland fishery purpose.

(3) Canal

The canals in the haor areas, which have a total 241 km, are connected to the rivers. Many canals suffer sedimentation problems, thus resulting in lack of irrigation water and drainage problems.

(4) Flood Mark

The Study Team collected flood information from the village people and the BWDB officer in the existing haor project area. The highest flood water depth from the paddy field was confirmed by the village people for the 29 haor projects during the river facility survey. The minimum water depth is 1.5 m and the maximum is 4.0m as referred to in **Table 4.3.7** (Page 4-38, Chapter 4). The water depth varies from each location of the haor projects.

CHAPTER 5 HYDROLOGICAL AND HYDRAULIC STUDY

5.1 Data Collection and Review

Measurements exist for 46 stations in the Northeast Region. While updating the previous models the data was updated up to November 2006. These data are still available from BWDB and updated data up to March 2012 could be readily accessed, but not properly shelved.

There are 27 flow/discharge measurement stations located in the Northeast Region. BWDB maintains these measurement stations. Data till 2011 are available from BWDB.

There are as many as 45 rainfall measurement stations in the Northeast Region, which are being maintained by BWDB. The rainfall data are updated up to March 2012.

There are only 3 evaporation measurement stations in the Northeast Region, which are also being maintained by BWDB. The evaporation data are updated up to March 2012 and available for the Study.

There are 4 temperature measurement stations in the Northeastern Haor Region of Bangladesh, which are being maintained by Bangladesh Meteorological Department (BMD).

The data series available from BWDB and BMD are quite long and may be considered sufficient. However, the number of stations of evaporation measurement appear less but the variation of evaporation rate in the area is negligible.

Rainfall data seems to be inadequate for hydrologic modeling. Rainfall is measured only thrice a day and the spacing does not cover major geographic or climatic region throughout the watershed.

For watersheds without rainfall and/or rating curves at the watershed outlet, flood hydrographs were estimated by transposing the results from nearby watersheds considering the precipitation, watershed vegetation cover, soil, physical characteristics, and area size.

5.2 Hydrologic Model

IWM preserves the "General Model" and the six "Regional Models" developed under Surface Water Simulation Modeling Programme Phase-II (SWSMP II, 1992 to 1996). The Northeastern Regional Model (NERM) covered the same study area of the Study. Attempts were thus made to have an overview of the NERM available with IWM.

The WL-discharge rating curves and the discharge hydrographs at the sub-watersheds outlets are not reliable because these outlets have been frequently under the effect of the backwater formed at the confluence of the major tributaries and also large portion of the flows spillovers or inflows exchanging volumes of water with the flood plain before reaching the WL station. In addition, wherever the rating curves were not available the calibration of the model was tried utilizing the variation on the ground water table as reference. Considering the lag time between surface flow and ground water table variation, the hydrologic calibration at most of the time is unreliable.

5.3 Flood Runoff Analysis

5.3.1 General

(1) Pre-monsoon Season

The pre-monsoon season usually extends from April to May in Bangladesh. The most important impact caused by rainfall during this season is the occurrence of the flash floods, which frequently overtop river banks and natural levees. Flash floods cause devastating damage to the agricultural product, mainly boro rice in the harvest season.

(2) Monsoon Season

The monsoon season starts just after the end of the pre-monsoon season and continues to September through October. During this period, most of agricultural activities cease because a large part of the haor area is inundated: for example, the water depths in several regions reach up to 5 m.

During this season, the precipitation is not as intense as that of the pre-monsoon season, but the rainfall continues over the larger watershed with a longer duration. The runoff due to this rainfall drains over the haor area.

5.3.2 Dynamic Hydraulic Modeling

(1) NERM

IWM developed a dynamic hydraulic model utilizing the MIKE11 software. The model comprises a hydrological (rainfall-runoff) model and a hydro-dynamic (river/channel/flood plain) model. The model utilizes hydrographs from the transboundary tributaries, intermediate gauging stations and a downstream boundary condition site (the Bhairab Bazar WL station) as input data.

It is difficult to estimate a probable flood water level by the conventional method in the haor area, which is a process of rainfall–runoff analysis, runoff-flood inundation level relation, and frequency analysis of rainfall and flood water level. This is because the flood inundation in the haor area is developed by the combination of the runoff from the upstream Indian border side area and the direct runoff in the haor area. In the Study, probable flood water levels are estimated by the use of a set of flood water levels simulated by the NERM calibrated with input of recorded water levels.

(2) Verification of NERM

The design water level of the submergible embankment and full embankment for the rehabilitation project and new project are determined from the analysis result of NERM. Therefore, the verification of NERM is carried out to check the relation of the highest pre-monsoon and monsoon water levels between the simulated output and observed data.

Following table shows the comparison between the simulated water level and the expected observed water level from the regression equation under the pre-monsoon 10-year flood condition.

Comparison between Simulated Water Level and Expected Observed Water Level under Pre-monsoon 10-year Flood Condition

Location	Simulation (EL.m) A	Observed (EL.m) B	Difference	
			|A-B|	A/B
Bhairab Bazar	2.86	2.45	0.41m	1.17
Itna	4.52	3.86	0.66m	1.17
Sunamganj	6.95	7.30	0.35m	0.95
Sylhet	9.92	10.20	0.28m	0.97

Note: Observed water level is estimated from the regression equation.
Source: JICA Study Team

The simulated water level at Sunamganj and Sylhet is 3 % to 5 % lower than the observed one. On the other hand, the difference between the simulated and observed water levels at

Bhairab Bazar is 17%. The reason for this is that Bhairab Bazar is vulnerable to the impact of Padma River and old Brahmaputra River, and the hydraulic phenomenon surrounding Bhairab Bazar is complicated. However, the simulated water level is higher than the observed one. It means that the design water level is set within the safety side.

The difference of simulated and observed water levels at Itna is also 17%, where the former is higher than the latter. Itna is a hydraulically affected by Bhairab Bazar, and hydraulic phenomenon in the flood plain is complicated.

For the planar verification, the relation between observed and simulated water level at Ajimiriganj which is located at Kalni-Kushiyara River, is studied. The difference between the observed and simulated high water levels is only 9%.

Therefore, NERM adapts well with the design high water level in the haor area.

5.3.3 Water Levels for Return Period

Hydrographs of water level are simulated for 31 years from 1980 to 2010 for the four water level gauging stations at Sylhet, Sunamganj, Itna and Bhairab Bazar along the Surma-Baulai River by use of the recorded hydrologic data and the calibrated NERM. The distribution function is applied to the three (3) parameter log normal distribution and modified maximum likelihood method because “Flood Hydrology Study in FAP25, 1992” recommended to apply the log normal distribution regarding to the statistical analysis of hydrology data. The simulation results of the annual maximum 3-hour water level in the pre-monsoon season and monsoon season are shown below;

Probable Water Levels at 4 Stations in Pre-monsoon Season

(Unit: EL.m)

Year	Bhairab Bazar	Itna	Sunamganj	Sylhet
2	2.42	3.56	5.49	7.30
5	2.70	4.18	6.45	9.01
10	2.86	4.52	6.95	9.92
20	3.00	4.85	7.23	10.50

Source: JICA Study Team

Probable Water Levels at 4 Stations in Monsoon Season

(Unit: EL.m)

Year	Bhairab Bazar	Itna	Sunamganj	Sylhet
2	5.88	6.41	7.96	10.44
5	6.34	6.82	8.25	10.77
10	6.60	7.05	8.40	10.95
20	6.80	7.30	8.55	11.11

Source: JICA Study Team

The goodness of fit-test was carried out using Kolmogorov-Smirnov (K-S) test and SLSC. The goodness of fit-test results are shown below;

Goodness of Fit-Test Result of Lognormal Distribution (Pre-monsoon Period)

	Bhairab Bazar	Itna	Sunamganj	Sylhet
(1) Kolmogorov-Sminov				
$D\sqrt{n}$	0.30	0.44	0.37	0.34
Z	1.36	1.36	1.36	1.36
(2) SLSC	0.029	0.033	0.034	0.031

Source: JICA Study Team

Goodness of Fit-Test Result of Lognormal Distribution (Monsoon Period)

	Bhairab Bazar	Itna	Sunamganj	Sylhet
(1) Kolmogorov-Sminov				
D√n	0.54	0.41	0.71	0.71
Z	1.36	1.36	1.36	1.36
(2) SLSC	0.039	0.034	0.043	0.058

Source: JICA Study Team

5.4 Sediment Balance and Riverbed Movement Analysis

5.4.1 Data Collection and Review

The sediment data so far collected in the Northeast Region is sparse and of poor quality to be utilized for a comprehensive sediment study. Most of the information related to sediment are available from the FAP6 study. The sediment data is mostly riverbed material with sparse suspended sediment but no bed load sample.

5.4.2 Sediment Balance

The exercise on sediment balance in Northeast Region is mainly based on the sediment analysis made by the FAP6. FAP6 used the sediment concentration and bed material data from BWDB and Surface Water Modelling Centre (SWMC) including the primary data collected in the said study. The River Survey Project under FAP24 measured the flow and sediment in the Upper Meghna River at Bhairab Bazaar from 1994 to 1996. The quality of the data measured by FAP 24 is considered better compared with those measured by other agencies. The present exercise by the Study Team includes the analysis of FAP 24 data for comparing the sediment balance made by FAP6 using the measured data of BWDB and SWMC.

The annual average suspended sediment load at Bhairab Bazaar was 5 million tons, which is at least 3 times less than the estimation of FAP6. Out of 5 million tons, 80% is wash load while the rest is suspended bed material. If it is assumed that the suspended sediment load estimated based on FAP 24 sediment measurement is representative at Bhairab Bazaar and the total sediment of 24.5 million ton/year generated by all other rivers in the Northeast Region remained the same as the estimate by FAP6, the net deposition of suspended sediment in the Sylhet basin would be about 20 million ton/year, which is two 2.5 times higher than the FAP6 estimated magnitude (8 million ton/year, see **Figure 5.4.1** (Page 5-27, Chapter 5).

5.4.3 Riverbed Movement Analysis

Over the last centuries the rivers have shifted their courses several times. Historical changes of the Surma and Kushiyara Rivers are described below based on the old maps available in CEGIS, the cartographic surveys conducted from 1910 to 1930, and river network extracted from the 2010 satellite image.

Changes in the river courses in the Northeast Region not only occur in a century scale, but also in a decade scale. Two such changes have been identified using recent satellite images. One of these changes has occurred in the Kushiyara River downstream of Ajmiriganj. That diversion of flow of the Kushiyara River caused the water level in the Surma River to rise, which may have triggered the development of a new diversion channel from this river to further west to the Ghorautra River. The process of development of these two channels was almost simultaneous. The development of these two channels appears to have been the result of the two individual but related events of local morphology.

CHAPTER 6 REVIEW OF FLOOD MEASURES AND RIVER MANAGEMENT

6.1 Flood Protection Level and Design Rainfall in Flood Measures

6.1.1 Flood Protection Level

The standard design manual was prepared by BWDB in 1995. The flood protection level is explained in this manual.

Full Embankment

The following flood frequencies may be adopted:

- 1 in 20 year flood where agricultural damage is predominant
- 1 in 100 year flood where loss of human lives, properties and installations are predominant. In general, embankment along Jamuna, Padma and Meghna rivers shall be designed under this return period.

Having selected the flood frequency the design flood levels need to be assessed separately in two cases, as follows, depending upon whether embankments are to be provided on one bank or on both banks.

Submergible Embankment

According to the standard design manual, the design flood water level is to be decided based on a ten (10) year pre-monsoon flood before 31 May. However, the Design Circle-I adopts that before 15 May.

Technical Review of Flood Protection Level of Submergible Embankment

Main damage caused by the flash floods in haor area falls towards boro rice production. Therefore, major factor to decide the flood protection level is an impact to boro rice production.

On the other hand, drought level of irrigation water supply is generally applied 5-year drought level (Confirmed with an irrigation engineer in Bangladesh). If drought occurs, boro rice production and farmers' income also decrease. Flood and drought together can cause serious damage on crop production.

Therefore, the flood protection level of submergible embankment shall be the same level or higher level compared with the drought level of water use.

The water rising ratio between 5-year to 10-year and 10-year and 15-year is about 36%. The water rising ratio around a 10-year return period comes to slow down.

The purpose of the submergible embankment is for flood protection during pre-monsoon season, which is a very short period. The flood protection level is less than the full embankment.

It is judged to be appropriate design flood protection level of the submergible embankment considering the 10-year probable water level of pre-monsoon flood.

6.1.2 Design Rainfall

The availability of data and information about rainfall distribution in sub-watersheds and flow at their respective outlets is rather poor in the Northeast Region. No rainfall record is available inside and upstream of the border areas with India, where a large amount of rainfall occurs.

The hydrologic model study of the NERM clearly demonstrates that the estimated river flow based on rainfall data is not reliable with the currently available data set. Therefore, the rainfall data can not be applied to define the design rainfall in flood measures planning to provide probable water levels for structural design.

The procedures recommended are as follows:

1) For the design of submersible embankment (crest elevation), water level statistical analysis should be used, and;

2) For determination of rainwater volume inside the areas protected by submersible embankment, statistical analysis of local rainfalls in Bangladesh should be applied.

6.2 Flood Management in Bangladesh

The danger level at some water level gauging stations along rivers was decided and flood management has been carried out based on the danger level in Bangladesh. Danger level is defined as a level above where flood may likely cause damages to crops and homesteads. If there is no embankment along a river, the danger level set is close to the annual average flood water level. If there is a continuous embankment along a river, the danger level is set at slightly lower level of the design flood water level for the embankment. The danger levels are set at 7 locations.

6.3 Strategy of Flood Measures and River Management Plan in M/P

The strategies of flood measures and river management in the M/P were explained in Section 9.3 of Annex-1 Water Resources. The proposed strategies are 1) flood management, 2) drainage improvement, 3) riverbank erosion protection, and 4) operation and maintenance (O&M) for the existing scheme. Each strategy is explained below.

1) Flood Management

The flood management mainly has two objectives:

i) Protection from sudden intrusion of flood water is required for saving the agricultural production (especially boro rice production), and

ii) Allowance of flood water during the monsoon is crucial for maintaining the aquatic ecosystem.

The proposed structures are as follows: 1) intake structure to enter the land side area, 2) construction of submergible embankment, 3) construction of full embankment, 4) construction of bypass channel, 5) mechanized construction, and 6) preparation of flash flood forecasting model.

2) Drainage Improvement

Post-monsoon drainage is essential for Rabi (including boro) cultivation. Timely and quick recession of flood water allows cultivars to go for crop culture in the haor areas. Therefore, the following measures are proposed:

i) Dredging of mainstream rivers, and

ii) Drainage improvement of distributaries to reestablish the drainage connectivity of the haor areas.

3) Riverbank Erosion Protection

The government has recognized river bank erosion as disaster. River bank erosion is observed on all the rivers in Bangladesh including those in the haor areas.

4) Operation and Maintenance (O&M) of Existing Scheme

Problems for O&M of existing scheme are i) budget shortage, ii) inadequate equipment support, iii) inadequate manpower, iv) poor quality of O&M works, v) inadequate monitoring, and vi) non-availability of O&M manual.

6.4 Applicability of River Planning Method in Japan

1) To set control points

It will be appropriate to set the control points of the river management plan based on the danger level setting points.

2) Importance of river and setting of flood protection level

The planning scale applied the design standard in Bangladesh.

3) Selection and application of recorded rainfall(s) and planned rainfall(s)

The data and information about rainfall distribution in sub-watersheds and flow at their respective outlets are rather poor in the Northeast Region. Therefore, the rainfall data can not be applied to define the planned rainfall patterns in the river management planning. to provide probable water levels for structural design. It is not possible to apply recorded rainfall and planned rainfall.

4) Flood Discharge and Design Flood Discharge

There is poor data availability of the observed discharge. Therefore, it is difficult to evaluate the flood discharge from the observed discharge. Also the authorized rating curves are not available, and hence the indicator of the river management planning applies the simulated water level.

5) Planning of Facility Installation

The layout plan used in Japan is not applicable in the deep haor area because of the following reasons:

- The river course of the Surma-Baurai River in the deep haor area is not stable, and
- A large lake appears during the monsoon season.

The full embankment can be constructed along the upper and the lower reach of the deep haor. In this case, the planning of layout plan in Japan is applicable. The existing full embankment shall be considered when the layout plan of full embankment alignment is studied.

CHAPTER 7 STRUCTURAL MEASURES FOR FLOOD MEASURES AND RIVER MANAGEMENT PLAN IN HAOR AREA

7.1 Basic Conditions for Flood Measures and River Management Plan

(1) Target River

The Surma-Baulai River is a target river and it flows through Sylhet City, Sunamganj and Itna town areas.

(2) Control Points of Flood Control Measure

The control points of flood control measure are determined from the danger level points. It is considered that some of these control points will become candidate control points for flood control measure because they are applicable to hydraulic and hydrological analysis.

The control points were set at 1) Sylhet, 2) Sunamganj, 3) Itna and 4) Bhairab Bazar in the pre-monsoon season. And the control points were set at 1) Sylhet, 2) Sunamganj, and 3) Bhairab Bazar in the monsoon season because Itna area has a completely different condition of the pre-monsoon season and monsoon season.

(3) Importance of River and Planning Scale

The planning scale is decided according to the standard design guideline of Bangladesh.

The planning scale is set at:

Submergible Embankment: 10-year probable flood during pre-monsoon season

Full Embankment: 20-year probable flood

(4) Setting of Planned High Water Level at Control Points for Flood Control

The planned high water levels are estimated from the run-off analysis and inundation analysis as shown in following table.

Planned High Water Level at Control Points

Control Points	Pre-monsoon (EL.m)	Monsoon (EL.m)
Bairab Bazaar	EL. 2.86m	EL.6.80m
Itna	EL. 4.52m	-
Sunamganj	EL. 6.95m	EL.8.55m
Slyhet	EL. 9.92m	EL.11.11m

Source: JICA Study Team

7.2 Structural Measures for Flood Measures and River Management Plan

7.2.1 Pre-monsoon Flood Protection and Drainage Improvement Project

(1) Proposed Facilities

Twenty four (24) rehabilitation projects are selected. On the other hand, twenty six (26) new projects proposed in the M/P are also considered.

(2) Selection of Facilities

1) Proposed Rehabilitation Project

Twenty three (23) existing haor projects are selected. Of these selected projects, 12 are proposed projects in M/P and the rest are not selected by BWDB.

Twelve (12) projects are proposed because these projects are authorized by the GOB. Three (3) project are proposed because of their high priority and efficiency projects.

Therefore, fifteen (15) rehabilitation projects are proposed in this study.

2) Proposed New Project

Twenty four (24) new projects are proposed because these projects are also authorized by the GOB. In this Study, twenty two (22) projects are proposed considering the hydraulic condition after the construction of the new project.

The proposed projects are listed below;

Proposed Project

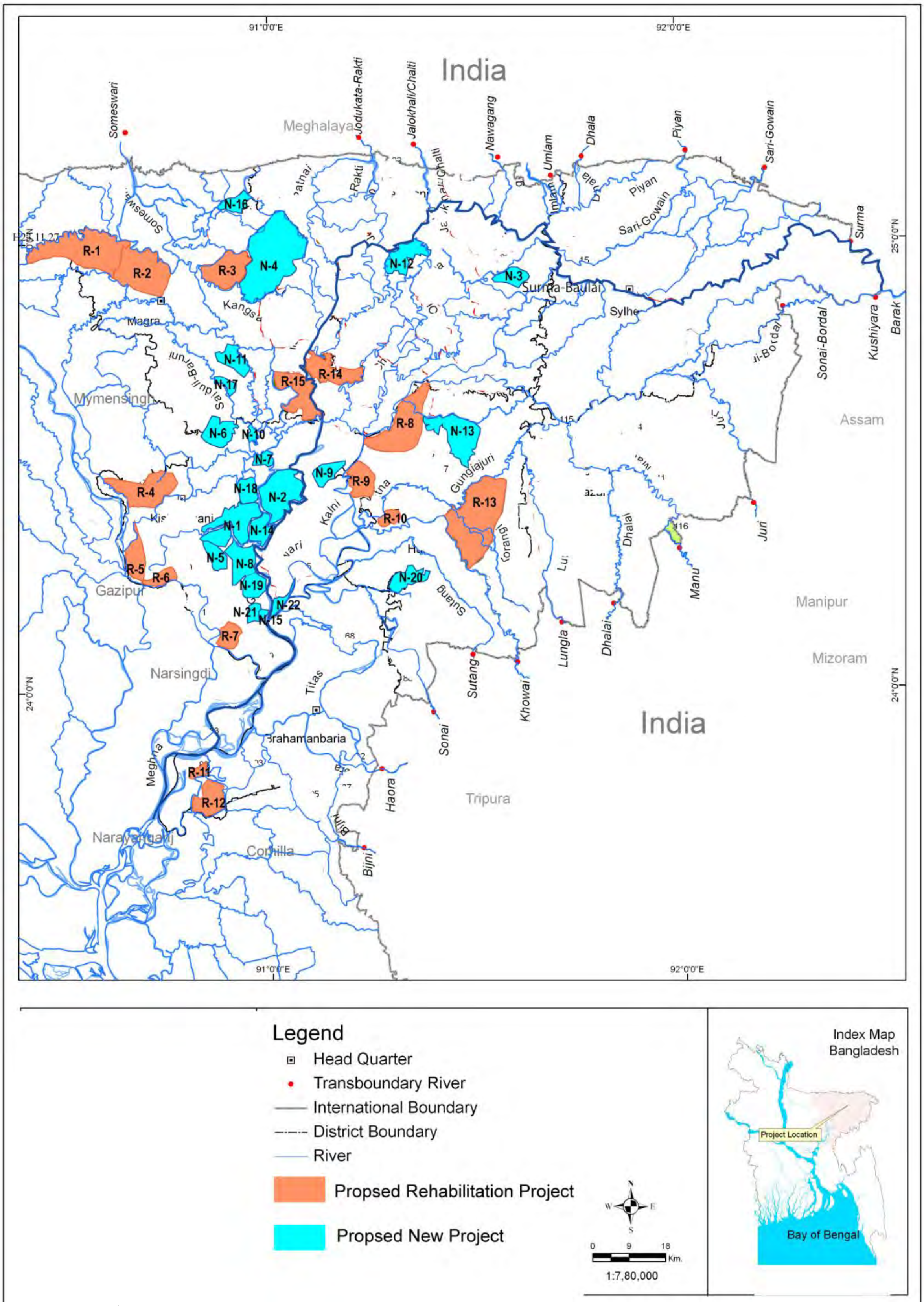
(1) Rehabilitation Project

No.	Name of Project	Annualized Benfit B	Cost (mil. BDT) C	B'/C	Rank	Remark
R-1	Dampara Water Management Scheme	1,166.5	32.0	36.496	9	Proposed Project in M/P
R-2	Kangsa River Scheme	1,148.6	4.6	248.163	3	Proposed Project in M/P
R-3	Singer Beel Scheme	359.6	7.9	45.793	7	Proposed Project in M/P
R-4	Baraikhali Khal Scheme	767.8	6.2	123.842	5	Proposed Project in M/P
R-5	Alalia-Bahadia Scheme	134.6	17.0	7.912	12	Proposed Project in M/P
R-6	Modkhola Bhairagirchar sub-project Scheme	166.5	16.3	10.231	11	Proposed Project in M/P
R-7	Ganakkhalli Sub-scheme	154.1	0.3	494.123	2	Proposed Project in M/P
R-8	Kairdhala Ratna Scheme	757.9	1.1	677.758	1	Proposed Project in M/P
R-9	Bahira River Scheme	273.3	113.6	2.405	15	Proposed Project in M/P
R-10	Aralia Khal Scheme	99.8	5.5	18.295	10	Proposed Project in M/P
R-11	Chandal Beel Scheme	104.2	25.8	4.032	14	Proposed Project in M/P
R-12	Satdona Beel Scheme	187.6	34.7	5.413	13	Proposed Project in M/P
R-13	Gangajuri FCD sub-project	1,368.4	36.2	37.840	8	High ranking and high efficiency project
R-14	Kaliajuri polder #02 scheme	410.6	5.0	81.515	6	High ranking and high efficiency project
R-15	Kaliakjuri polder #04 scheme	399.3	2.7	148.241	4	High ranking and high efficiency project

(2) New Project

No.	Name of Project	Annualized Benfit B'	Cost (mil. BDT) C	B'/C	Rank	Remark
N-1	Boro Haor Project (Nikli)	479	236.9	2.022	1	
N-2	Naogaon Haor Project	667	380.3	1.754	2	
N-3	Jaliar Haor Project	114	95.4	1.198	3	
N-4	Dharmapasha Rui Beel Project	1,286	1,119.5	1.148	5	
N-5	Chandpur Haor Project	70	58	1.191	4	
N-6	Suniar Haor Project	118	149	0.796	6	
N-7	Badla Haor Project	85	135	0.629	7	
N-8	Nunnir Haor Project	207	350	0.592	9	
N-9	Dakhshiner Haor Project	180	289	0.623	8	
N-10	Chatal Haor Project	43	111	0.387	10	
N-11	Ganesh Haor Project	117	312	0.375	11	
N-12	Dhakua Haor Project	228	620	0.367	12	
N-13	Mokhar Haor Project	451	1,444	0.313	13	
N-14	Noapara Haor Project	141	566	0.250	14	
N-15	Dulapur Haor Project	29	198	0.145	16	
N-16	Bara Haor (Kamlakanda)	164	1,002	0.164	15	
N-17	Bansharir Haor Project	27	238	0.115	18	
N-18	Korati Haor Project	123	962	0.128	17	
N-19	Sarishapur Haor Project	10	101	0.103	19	
N-20	Shelnir Haor Project	10	324	0.032	21	
N-21	Kuniarbandh Haor Project	7	217	0.033	20	
N-22	Ayner Gupi Haor	3	329	0.009	22	

Source: JICA Study Team



Source: JICA Study Team

Location Map of Proposed Projects

7.2.2 River Dredging Project

The inundated water in the paddy field is drained in the direction of the river through the channels/canals and regulators from the post-monsoon to the dry season due to boro rice planting. It is important that the inundated water dries quickly.

An adequate flow capacity is required to prevent flood damage at the small- or medium-scale flooding in the flood plain area.

In addition, the minimum water depth for navigation purpose shall be kept because the Suruma-Baulai River is important one for water transport.

Five (5) stretches of dredging works were proposed in the M/P as shown in **Figure 5.4.4** (Page 5-33, Chapter 5).

1) Downstream stretch from Dharmapasha in the Surma-Baulai River
2) Katkhal Channel
3) Stretch between Chatak and Sunamganj in the Surma-Baulai River
4) Stretch between Kanalghat and Border
5) Jadukata River

Three (3) stretches are selected for the following reasons;

- The expectation of the dredging effect in Kanalgaht to the border in the Surma-Baulai Rivers is increase in run-off volume. However, the efficiency is very small.
- Frequent maintenance dredging will be required in the Jadukata River. It will be difficult to prepare the budget for maintenance dredging.

The following stretches are thus considered for carrying out the dredging works.

1) Downstream stretch from Dharmapasha
2) Katkhal Channel
3) Stretch between Chatak and Sunamganj

<u>Possibility of JICA Cooperation Project</u>

The necessity of the dredging works is confirmed for the three stretches. However, it is difficult to propose a JICA cooperation project for the following reasons:

- The budget for maintenance dredging has to be prepared by the GOB. The budget preparation will be difficult considering the present maintenance situation. Therefore, it is difficult to propose these dredging works for possible projects for JICA's cooperation.

CHAPTER 8 PLAN AND DESIGN OF STRUCTURES FOR FLOOD MEASURES

8.1 Assessment of Present Situation and Appropriateness regarding Existing Structural Measures

8.1.1 Structural Measures in Pre-monsoon Season

(1) Present Situation regarding Existing Structures

The structural measures of flood control were not applied in the deep haor area during the monsoon season. The submergible embankment was constructed to protect against pre-monsoon floods, Channel/canal and regulators were also constructed for drainage improvement.

At present, the submergible embankment doesn’t function well due to partial damage by flood overtopping and artificial cutting.

Fertile soil is transported from the upstream during the monsoon season where it is deposited in the deep haor area. Therefore, the channel/canal is also silted up by the fertile soil. In addition, the erosion of channel/canal slope has occurred and eroded material is deposited in the channel/canal. Finally, the flow capacity for drainage and the storage volume for water supply in the channel/canal are decreased.

The regulator was constructed near the confluence of the channel/canal and river. At present, about 50% of regulators have malfunctioned. Problems in drainage, water storage and prevention of river water during flash flood have been encountered.

The gate regulator is manually opened to control river water levels and landside water levels before the start of the monsoon season. At present, the causeways are constructed in Kaliajuri polder-4 to check ease of O&M.

(2) Evaluation of Existing Facilities

The evaluation of existing facilities is carried out from a planning, design, construction and operation and maintenance points of view.

1) Planning

The submergible embankment was arranged against a 10-year probable pre-monsoon flood. The channel/canal and regulator were arranged to drain the landside water of the submergible embankment and to store water in the channel/canal. The planning concept is acceptable for the deep haor area. However, the specification of each haor project in the deep haor area shall be decided with considering the Surma-Baulai River Management Plan.

2) Design

A standard design guideline is available. The flood protection level of the submergible embankment, grain size distribution, and stability analysis method of the embankment are included in the standard design guideline. The design guideline has been prepared for review by the BWDB’s senior engineers and experts. Therefore, the design method of the river facilities is satisfactory.

The grain size distribution is decided during the design stage. The required materials for construction are not available at many sites. Material on-site is used for the embankment. It is necessary to carry out adequate material survey before designing the submergible embankment.

3) Construction

Repair works for the embankment were carried out without compaction. Therefore, the deterioration of local durability of the loose compacted embankment material under the submerged condition is faster than that of the good compacted one. The design drawings indicate grain size distribution of the embankment material. However, the materials from the design drawings were not followed at the site due to the difficulty in collecting the blend material. The structures did not follow the instructions indicated on the geotechnical design, such as the grain size distribution, water contents, compaction criteria, etc. Therefore, the durability of the structures may be weaker than the initial design strength

4) Operation and Maintenance

Regarding the O&M, lack of O&M budget is a serious problem in BWDB field offices. LGED has applied a way where the constructed facilities are transferred to the stakeholders. The stakeholders then carry out O&M. BWDB shall consider how to carry out O&M. In the facility survey, the staffs of BWDB site offices explained the difficulty of O&M activities because the O&M budget is only 10%-20% of the initial budget requested from the central office in BWDB. With that, many facilities are not maintained and do not function.

If O&M system is not improved, similar problems on O&M may be occurred in the O&M for rehabilitation and new projects after a few years to about 10 years.

8.1.2 Structural Measure in Monsoon Season

(1) Present Situation regarding to Existing Structure

The existing haor projects are constructed not only in the deep haor area but also in the flood plain area. Structural measures are composed of full embankment, submergible embankment, channel/canal and regulators.

The problems of the full embankment are 1) erosion of embankment, 2) lack of extra embankment during the construction stage, and 3) artificial cut.

The channel/canal and regulators have the same conditions as in the deep haor area.

(2) Evaluation of Existing Facilities

1) Planning

In the flood plain, the construction of full embankment is planned to cultivate two cropping. On the other hand, the area sandwiched between the Surma-Baulai River and the Kalni-Kushiyara River has drainage problems. To solve the problems, the pumping stations and regulators were constructed. The construction of the required facilities for flood control measures is an appropriate input. However, the concrete river management plan is not proposed in the M/P. It is necessary to prepare this plan in the Surma-Baulai River.

The river facilities shall be planned based on the river management plan.

2) Design

The full embankment is designed based on the design flood water level of the 20-year probable flood. The calculation of the water level is carried out based on NERM. It is a normal approach to estimate the flood water level in Bangladesh. However, the embankment material survey is not sufficient for design works.

3) Construction

The full embankment is constructed to protect the haor area located in the flood plain area. However, it is required to control the embankment material, water content, and compaction.

4) Operation and Maintenance

It is necessary to improve the O&M as in the case during the pre-monsoon season. If the O&M works of the BWDB field office are not improved, the river facility conditions will worsen.

8.1.3 Issues on Design and Construction of Existing Submergible Embankment in Terms of Durability

The geotechnical investigation, interview survey with BWDB and site reconnaissance in the Study pointed out three issues regarding the durability of existing submergible embankment, namely: 1) low quality of embankment materials, 2) inferiority of embankment works and 3) lack of surface protection.

(1) Low Quality of Embankment Materials

Very fine silt and clay (under 0.075 mm) soil materials on normal embankment may bring cracks causing erosion and deterioration through the dry and wet process. Shortage of fine soil materials (under 0.075 mm in grain size) may bring comparatively high permeability with seepage. Embankment materials composed of 15 % – 50 % silt and clay (under 0.075mm) are usually used to achieve the required durability and impermeability in Japan. According to the grain size investigations for embankment materials from 15 locations in five candidate haor projects, soil materials from each site include more than 90 % of silt and clay. These soil materials can induce cracks and erosion easily and result in low compaction workability.

(2) Inferiority of Embankment Works

The technical requirements for compaction works of submergible embankment are usually specified in the bid drawing notes, with a required 7.0 kg rammer compaction. However, no specification regarding the degree of compaction is stipulated in the drawings. There is an opinion in the Design Circle that a 90 % degree of compaction should be required. This idea is considered to be appropriate, as a 90 % degree of compaction is usually applied for river dykes as the average limit degree of compaction, in Japan. However, more than a 90 % degree of compaction may not be achieved without heavy equipment. As the adjustment of moisture content is not also stipulated in any specification and drawing, it is one of the important issues for embankment works.

(3) Lack of Surface Protection

Although the Design Circle of BWDB understands that the slope protection and crest pavement of embankment increase its durability, crest pavement is not applied for any submergible embankment due to budget constraints at present.

It is expected that durability would be increasing by applying pavement of crest and gentler slope than 1:2 with turfing for submergible embankment. However, deterioration seems to be significantly seen on existing submergible embankment with steep slope without protection on the crest.

(4) BWDB Design Manual regarding Embankment

BWDB has issued “Standard Design Manual Volume-I: Standard Design Criteria”, and describes design criteria of embankment in “Section “7. Design Criteria for Embankment”.

However, issues such as standard grain size distribution of embankment materials, degree of compaction and adjustment of moisture content are not mentioned in the manual. Regarding compaction, though contract drawings instruct to use a 7.0 kg rammer as notes, they do not mention degree of compaction.

Though the grain size distribution of embankment material is also mentioned in the contract drawings as follows, the instruction above allows fine materials which include “0 %” of coarse material like sand and gravel. Practically, the ground adjacent to a submergible embankment site does not include sand and gravel. It means that most of the embankment materials may consist of silt and clay. In effect, the repeated submergence in the area is feared to cause the deterioration of embankment due to cracking and erosion.

8.2 Proposal of Basin Standard Design of Structures for Flood Measures

8.2.1 Design Review of Existing Structural Measures

(1) Present Situation of Gate Equipment

A standard gate size (1.5 m wide x 1.8 m high) is usually used when installing regulators. Therefore, the flow capacity of the regulator is determined from the number of its gates (number of vents). It was confirmed through the site reconnaissance in the Study that half of the gates on the existing regulators at present do not function well. Factors which caused the malfunction of these gates include robbery, loss of gate parts, corrosion and deterioration of gate equipment.

Maintenance work, even greasing and tightening of the bolts, has not been carried out. Nearby residents say that BWDB should be responsible for the gate even for its simple maintenance work such as greasing and bolt tightening. Any sense of ownership was not found among the residents.

(2) Present Situation of Concrete Structures

Though many sound concrete structures were confirmed during the site reconnaissance, some of these structures have serious problems like cracks and deterioration.

According to the contract drawings, the required quality of concrete is described at a specified strength of 20 N/mm^2. However, quality confirmation of the concrete through compaction test might not have been undertaken because the concrete was mixed at the site by local people. Standardization of mix proportion and quality control system need to be prepared.

Though the contract drawings of regulators usually instruct the clear cover of reinforcement bars, concrete exfoliation and exposure of corroded reinforcement bars were observed on some of the regulators, which are caused by too small clear cover and lack of mortar.

Concrete edges under the hoists chip on the deck slabs of the some of the regulators. Shearing force might not be considered for the design of contact portion of deck slabs and plates of hoists.

8.2.2 Consideration for Structure Design

(1) Consideration for Design of Submergible Embankment

- The crest elevation of submergible embankment shall be a 10-year probable water level during the pre-monsoon season with a + 0.3 m freeboard in accordance with the stipulation stated in the Standard Design Manual of BWDB.

- The manual stipulates that the crest width of the submergible embankment shall be 4.3 m. However, the crest width of submergible embankment is designed to be 3.6 m for cost reduction purposes in many cases. The crest width of 4.3 m is considered to be appropriate in terms of slope shoulder protection against traffic vehicles during inspection and maintenance.
- The geotechnical investigation done by the Study shows that the thickness of soft ground (N-value < 4 in clay foundation) is usually less than 5 m in the haor area. Settlement calculations based on consolidation tests have a result that residual settlements are less than 10 cm. The contract drawings of submergible embankment usually instruct an extra embankment of 15 cm, which seems to be enough in the light of the result of the settlement analysis.
- Dutch Cone Test (DCT) carried out in the Study shows that cone resistance is generally greater than 0.8 MPa, which is equivalent to 26.7 kN/m^2 in clay soil, except for areas with very soft ground sites. According to the result of circulate slip analysis including ground foundation. Embankment with a slope gradient of 1:2.0 satisfies the required safety factor (FS > 1.2) in the case of cohesion greater than 23 kN/m^2 (cone resistance > 0.7 MPa). In the case of very soft ground (cone resistance < 0.4 MPa), countermeasures like revision of embankment alignment are needed, if the height of embankment is greater than 2.0 m. Boring survey is recommended in the implementation stage at maximum intervals of 500 m and at specific sites to be investigated from a topographic view point.
- Embankment material must be borrowed from adjacent areas even if the grain size distribution is not suitable for the embankment because of the cost and technical aspects. However, a 95 % degree of compaction is expected as the target degree to keep required local durability and reduce the frequency of maintenance.

(2) Consideration for Design of Regulator

Present standard regulators are usually sluice way type structures with lift gates. Basic design condition such as design flow capacity and elevation of operation deck should follow the design manual of BWDB. Considering the present problem regarding regulators, basic issues regarding design and concrete quality should be improved rather than revision of structure type and material.

Proposal for Improvement of Quality Control of Regulator

Item	Proposal
Enhancement of Design and Quality Control	- Standardization of maximum coarse aggregate, classification of aggregate, standard gradation of coarse and fine aggregate - Standardization of mix proportion (aggregate, cement and water) - Stipulation of slump value - Establishment of quality control method during construction stage (quality control by aggregate physical test and slump test) - Revision of clear cover according to the size of aggregate - Execution of structural calculation using hoist load - Proposal for maintenance method and budget in the design stage (reflecting to DPP)

CHAPTER 9 NON STRUCTURAL MEASURES IN HAOR AREA

9.1 Assessment of Present Situation and Appropriateness regarding Existing Non-Structural Measures

Non-structural measures refer to any measure that does not involve physical construction (like retarding basins, embankments, dredging, diversions, etc.) but instead uses knowledge, practices, and/or agreements to reduce the potential negative impacts of a flood. A non-structural approach can be a cost-effective alternative to traditional engineering and an ecological solution. Though the main tools of flood damage reduction revolve around structural measures, non structural flood measures are also considered as means of damage reduction.

Not all non-structural measures are effective in all types of flood damage and it is always better to adopt multiple non-structural measures along with some structural measures for better flood risk management. Since the crop damage is the main issue of concern in the haor area, rather than threat to human life, more focus is given on asset loss reduction by government and non-government organizations.

Different types of non-structural measures practiced in the haor area are analyzed covering present situation, on-going and planned activities, assessment of appropriateness and potential for further interventions. These includes, (1) Regulation of development in river areas, (2) Flood forecasting and warning system, (3) Warning dissemination, (4) Simplified warning system, (5) Local disaster management planning (namely, (a) evacuation planning, (b) hazard mapping, (c) flood shelter, (d) disaster prevention edification, (e) seed bank and food bank, and (f) crop insurance), (6) Livelihood diversification (namely, (a) paddy variety diversification, (b) crop diversification, (c) job diversification, and (d) improved market access), (7) Flood proofing of living environment (namely, (a) raising of houses and related facilities, and (b) construction of new platform or raising entire village), and (8) Participatory water resources management.

Based on the analysis, it can be inferred that the most appropriate non-structural measures suitable for the haor area are (1) Local disaster management planning, (2) Livelihood diversification, (3) Flood proofing of living environment, and (4) Participatory water resources management. Well planned interventions in these 4 types of measures can bring about considerable benefits in terms of flood damage reduction in the haor area.

9.2 Non-structural Measures Effective for Haor Area

The 4 most appropriate non-structural measures were examined by sub sector considering on-going and planned projects, and implications and intervention possibilities. Based on the analysis 6 conceivable projects were identified. Although each of these projects can significantly contribute towards flood related damage reduction, not all projects are suitable for JICA cooperation. It may be mentioned that even a project is not suitable for JICA cooperation, GOB should implement these from other financial sources.

Suitability analysis of these 6 conceivable projects were conducted and 4 projects are found to be suitable for JICA cooperation. These are,

- NSM-1: Planning and implementation of user friendly flood shelter cum market
- NSM-2: Pilot study on seed bank and food bank
- NSM-3: Flash flood resilient agricultural diversification with improved market access
- NSM-4: Extension of Beel Nursery

Brief outlines of the 4 potential projects are provided covering project location, objectives, major components, benefited areas/beneficiaries, expected execution agency and urgency of JICA cooperation. Two projects are found to have higher implementation urgency and those are NSMs 3 and 4.

CHAPTER 10 FLOOD CONTROL AND RIVER MANAGEMENT PROJECTS UNDER JICA ASSISTANCE

10.1 Proposal of JICA Cooperation Projects

The Study selected the following structural and non-structural measures as priority projects for flood measures and river management plan in the haor areas:

(1) Structural measures

(1-1) Pre-monsoon Flood Protection and Drainage Improvement Project in Haor Areas (rehabilitation and new development of haor projects, hereinafter referred to as "the Haor Project")

(1-2) Dredging Project in the Surma-Baulai Rivers

(2) Non-structural measures

(2-1) Flash Flood Resilient Agricultural Diversification with Improved Market Access

(2-2) Extension of Beel Nursery

The above priority projects are in harmony with the policy of cooperation in the "JICA Country Analysis Paper (Bangladesh)". However, it is pointed out that periodical maintenance dredging after capital dredging would be essential for securing continuous dredging effects in the case of the Surma-Baulai Rivers and hence it is rather difficult to demarcate the project effects between the capital dredging to be executed in the Dredging Project of the (1-2) and the maintenance dredging to be repeated after the (1-2).

Therefore, the Study has proposed three priority projects excluding the (1-2) as possible JICA cooperation projects.

10.2 Contents of Project

(1) Project Area

The project area is located in the Sunamganj, Kishorganj, Haniganj and Brahmanbaria districts.

(2) Objectives of the Project

The objectives of the project are as follows:

1) Protect the boro rice during the harvesting period and the fish cultivation from the flash flood during the pre-monsoon season in the haor area,
2) Improve the flow capacities of drainage channels in the haor area,
3) Enhance agricultural productivity including crop diversification and fishery,
4) Improve the boat transportation of the people in the haor area, and
5) Secure the sustainability of the project in order to maintain a new O&M system related to the flood control structures.

(3) Main Activities

The Project consists of i) the rehabilitation of existing haor projects and ii) the construction of new haor project. Both components include the following issues;

- Detailed design and environmental impact assessment related to the projects are carried out, and
- Rehabilitation works and new construction of submergible embankment, regulators, sluices, and removal of the sedimentation material in the drainage. The capacity development of O&M for flood control structures and the community level organization development including the formulation of sustainable O&M organization are carried out.

(4) Beneficiary Area and Beneficiaries

The beneficiary area and the beneficiaries are as follows;

i) Rehabilitation of the existing haor projects

Beneficiary area: 84,000 ha

Beneficiaries[2]: 798,000 persons

ii) Construction of the new haor projects

Beneficiary area: 63,500 ha

Beneficiaries: 543,000 persons

iii) Total

Beneficiary area: 147,900 ha

Beneficiaries: 1,341,000 persons

(5) Executing Agency

Bangladesh Water Development Board (BWDB)

(6) Implementation Schedule

A total of 37 sub-projects (15 for rehabilitation and 22 for new construction) are selected for the Haor Project. The 37 sub-projects are widely scattered in the haor area (see **Figure 10.2.2** (Page 10-9, Chapter 10)**)**, and it is proposed to implement these sub-projects stepwise

[2] Number of beneficiaries is composed of direct and indirect ones.

through phasing under the Haor Project. In addition, it is proposed that the sub-projects be divided into two groups for rehabilitation and new construction, respectively so as to realize higher efficiency of construction works and reduction of construction costs (see **Table 10.2.1** (Page 10-4, Chapter 10)**)**. The grouping is delineated taking into account (i) the geographical position of each sub-project (in particular, the right or left side of the Surma-Baulai Rivers, which is anticipated to be a constraint of smooth filed activities in hauling and movement of construction materials and equipment) and (ii) a planned construction period (five years on the assumption of implementation as a yen-loan project).

The implementation priority of each group has been examined in the Study from the viewpoint of economical efficiency of project, with an index of "expected average annual reduction of flood damage ("annualized expected benefit: B") divided by the direct construction cost: C.

The following table explains the results on economic efficiency (B/C) of project by group. As shown in this table, the group on the right side has a higher B/C, and hence priority for implementation in each case of i) rehabilitation and ii) new construction.

Analysis on Economic Efficiency/Priority for the Haor Projects

Group name	Annualized expected benefit: B	Direct construction cost: C (BDT mil.)	B/C	Priority	Phase
i) Rehabilitation of existing haor projects					
R-rgt	5,356	87	61.56	1	Ph-1
R-lft	4,342	222	19.56	2	Ph-2
Sub Total	9,698	309			
ii) Development of new haor projects					
N-rgt	3,576	3,825	0.93	1	Ph-1
N-lft	983	1,558	0.63	2	Ph-2
Sub Total	4,559	5,383			
Ground Total	**14,257**	**5.692**			

Source: JICA Study Team
Note: rgt/lft=right/left side of the Surma-Baulai River

Furthermore, an examination on the urbanization and properties in the haor area has presented that the right side area exceeds with respects to urban population, agricultural products, and economic activity level compared to the left side.

In due consideration of the above analysis and examination results, it is proposed that the Haor Project be implemented in the order of Phase -1 and Phase -2 with a combination of the groups as presented in the following table (see **Figure 10.2.1** (Page 10-6, Chapter 10)**)**.

Phasing of the Haor Project

Phase	i) Rehabilitation	ii) New construction
Phase - 1	R-rgt	N-rgt
Phase - 2	R-lft	N-lft

Source: JICA Study Tam
Note: rgt/lft = right/left side of the Surma-Baulai Rivers

(7) Project Cost

The project cost is shown below;

Project Cost

Items	F/C (mil. J. Yen)	L/C (mil. BDT)	Total (mil. J. Yen)
1) Flood control measures	0	5,692	7,286
2) Price escalation	0	1,294	1,656
3) Physical contingency	0	348	445
4) Consulting services	590	217	868
5) Land Acquisition cost	0	4,767	6,102
6) Administration cost	0	966	1,236
7) Tax (VAT)	0	2,062	2,639
Ground Total	590	15,346	20,233

Source: JICA Study Team

CHAPTER 11 CONCLUSIONS AND RECOMMENDATIONS

The Bangladesh Haor and Wetland Development Board (BHWDB) formulated "Master Plan of Haor Areas (the M/P)" in April 2012 as a comprehensive development plan of the haor areas for the next 20 years. The M/P is to be positioned as an overarching plan and a base of formulation/implementation for future JICA cooperation in the haor areas. The M/P has worked out priority projects through (i) problem/issue analysis and (ii) reflecting the peoples' needs clarified through a participatory approach. However, it was pointed out that project impacts on the upstream and/or downstream areas after project implementation are not necessarily verified in the M/P yet.

In such a situation, the Study conducted (i) review of the M/P and (ii) basic study to supplement the M/P, and has proposed the following structural and non-structural measures as possible JICA cooperation projects for flood measures and river management plan in the haor areas:

(1) Structural measures

- Pre-monsoon Flood Protection and Drainage Improvement Project in Haor Areas (rehabilitation and new development of haor projects, hereinafter referred to as "the Haor Project")

(2) Non-structural measures

- Flash Flood Resilient Agricultural Diversification with Improved Market Access
- Extension of Beel Nursery

Furthermore, the Study has worked out the project design of the structural measures, giving priority to the technical aspect. In these situations, the following are recommended for the succeeding project stage:

(1) The Haor Project, composed of 37 subprojects (15 for rehabilitation and 22 for new development), has been designed based principally on study and examination of the technical aspect. Therefore, it is essential in the succeeding stage for project

implementation to review and design the project including economic evaluation and environmental/social assessment.

(2) River water level and discharge measurements have been conducted in the haor areas. Ocular observation of water level (usually from 6:00 a.m. to 6:00 p.m.) has been the major work of the measurements in accordance with the need for current river management in the country using flood water levels. In the haor areas it is important to incorporate quantitative management of river water into the future water resources management. Therefore, it is recommended to measure water levels by automatic water level gauges including the time from 6:00 p.m. to 6:00 a.m. and provide proper water level-discharge rating curves.

(3) Currently, the design water levels of flood control facilities such as submergible embankment and regulators of the haor project have been determined basically through frequency analysis of water level data obtained from NERM. However, considering future land use change and river channel movement in the haor area, it is also recommended to incorporate into the design of flood control facilities the different approach wherein a design flood discharge at a facility site is set up first and the design water level is determined based on the design flood discharge.

(4) In the Study, the flood flow analysis in the haor areas, which have a vast area of 8,500km^2 in total, was carried out, partially modifying the flood runoff model of IWM. In the project implementation stage, it is recommended to confirm the flood flow conditions through detailed hydraulic analysis for specific project areas.

(5) Through the Dutch corn test, soft layers were found to exist at very few sites in the haor areas. The soft layer requires countermeasures such as counterweight embankment for embankment construction of more than 2.0 m to 2.5 m in height. Therefore, it is recommended to confirm the existence of soft layer through core boring investigations at around 500 m intervals in the planned alignments of submergible embankment in the project implementation stage so as to correctly reflect the soft layer properties in the detailed structural design.

(6) As mentioned above, the haor areas have been subjected to serious Boro rice damage due to frequent flash floods during the pre-monsoon season. The Haor Project can mitigate the flood damage and contribute towards raising the level of economic and social activities and realizing poverty reduction and livelihood improvement in the haor areas. In due consideration of the disastrous situation in the haor areas having been repeatedly devastated by the flash floods, earlier realization of the Haor Project is strongly needed. It is recommended for the GOB to timely take necessary actions for further steps such as securing finance, technical assistance and so forth to realize the Haor Project.

Abbreviation（1/2）

Abbreviation	Description
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
ASTM	American Society for Testing and Materials
BBS	Bangladesh Bureau of Statistic
BDHS	Bangladesh Demographic and Health Survey
BDT	Bangladesh Taka
BHWDB	Bangladesh Haor & Wetland Development Board
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BRRI	Bangladesh Rice Research Institute
BUG	Beel User Group
BWDB	Bangladesh Water Development Board
CALIP	Climate Adaptation and Livelihood Protection
CCTV	Closed Circuit Television
CDM	Comprehensive Disaster Management
CDMP II	Comprehensive Disaster Management Programme II
CEGIS	Center for Environmental and Geographic Information Services
CFB	Community Food Bank
CNRS	Center for Natural resource Study
CRA	Community Risk Assessment
DA	Development Area
DAE	Department of Agricultural Extension
DCRMA	Disaster and Climate Risk Management in Agriculture
DCT	Dutch Corn Test
DEM	Digital Elevation Model
DG	Director General
DGHS	Directorate General of Health Services
DPP	Development Project Proposal
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FFPC	Flood Forecasting and Processing Center
FFWC	Flood Forecasting and Warning Center
FTRA	Fast Tracked Risk Assessment
GDP	Gross Domestic Production
GOB	Government of Bangladesh
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HILIP	Haor Infrastructure and Livelihood Improvement Project
HYV	High Yield Variety
IDM	Introduction to Disaster Management
IFAD	International Fund for Agricultural Development
IRRI	International Rice Research Institution
IVR	Mobile Phone Instant Voice Response
IWM	Institute of Water Modelling
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
LGED	Local Government Engineering Department
M/P	Master Plan
MDGs	Millennium Development Goals
NERM	North East Region Model

Abbreviation（2/2）

Abbreviation	Description
NGO	Non-Governmental Organization
NWMP	National Water Management Plan
O&M	Operation and Maintenance
PCM	Public Consultation Meeting
PWD	Public Works Datum
POPI	People's Oriented Program Implementation
RHD	Bangladesh Roads and Highways Department
RRAP	Risk Reduction Action Plan
SCBRMP	Sunamganj Community Based Resource Management Project
SLSC	Standard Least Square Criterion
SSWRDP	Small Scale Water Resources Development Project
SWMC	Surface Water Modeling Center
SWSMP II	Surface Water Simulation Modeling Programme Phase-II)
UNESCO	United Nations Educational, Scientific and Cultural Organization
USBR	United States Bureau of Reclamation
WG	Working Group
WMA	Water Management Association
WMCA	Water Management Cooperative Association
WMIP	Water Management Improvement Project

The People's Republic of Bangladesh

DATA COLLECTION SURVEY ON
WATER RESOURCES MANAGEMENT
IN
HAOR AREA OF BANGLADESH

FINAL REPORT

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CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Bangladesh is situated in the Bengal Delta area flowed into by three transboundary rivers, namely, the Ganges (Padma), Brahmaputra (Jamuna) and Meghna, which drain a total catchment area reaches of 1.72 million km^2.

Around 90% of the Bangladeshi territory is occupied by flat lowlands of less than 10m in elevation, and rivers in these lowlands are characterized by very easy riverbed gradients. Therefore, serious inundation occurs to more than 20% of the territory annually because floodwater overflows the river channels during rainy season, which generally receives more than 80% of annual rainfall.

After the formulation of the National Water Policy in 1999 and the National Water Management Plan (an implementation plan of the policy) in 2004, Bangladesh set forth a definite direction of flood measures that provide a living environment adaptable to floods by allowing floodwater to overflow rather than confining into the river channels. In Bangladesh, the stable growth of economy will not be achieved without flood damage mitigation, while in reality the soil has remained rich and fertile owing to the annual occurrence of flooding. Therefore, realization of living together with floods in harmony with sustainable water resources development and management is one of the most important focused areas of the country.

Out of the three transboundary rivers, the Japan International Cooperation Agency (JICA) has decided to place much importance on cooperation to the Meghna River, which need flood measures and integrated water resources management, according to the findings stated in “the Preparatory Survey on Disaster Prevention Sector in Bangladesh (Program Formulation)” conducted in 2009 and 2010 by JICA.

In the upper Meghna area, situated in the Northeast Region of Bangladesh, there are swampy lowland areas called “haors” extended widely. The whole haors (about 8,500 km^2) are submerged during rainy season because of flood inundation, and it is said that the inundation of haor has contributed toward flood control for the Dhaka area with a population of 16 million.

The upper Meghna area has been supporting the Bangladeshi economy as a food basket during the dry season and a rich fishing ground in the rainy season. However, the whole upper Meghna area has suffered from serious flood damage due to (i) flash floods brought about by river water coming from the hilly areas in the Indian territory during pre-monsoon season, which are counted among the heaviest rainfall zones in the world, and (ii) long-term flood inundation during rainy season. Although flood control facilities such as submergible embankments and sluices have been constructed in the haor areas since the early times, flood damage has repeatedly been occurring in reality. Hence, effective flood measures are still needed.

The Bangladesh Haor and Wetland Development Board (BHWDB) was established as a coordination body for the haor areas and formulated “Master Plan of Haor Areas (hereinafter referred to as "the M/P")" in April 2012 as a comprehensive development plan covering 17 development sectors of the haor areas for the next 20 years. The M/P has concluded that it is essential to implement flash flood measures, village protection measures against wave erosion, drainage improvement, irrigation facility maintenance/improvement and promotion of agricultural/fishery sectors as priority projects for appropriate water resources management in the haor areas.

The M/P has worked out priority projects through (i) problem/issue analysis including some hydraulic analysis, and (ii) reflecting peoples' needs clarified through a participatory approach, and this is to be positioned as an overarching plan for future cooperation of JICA in the haor areas. However, it might be pointed out that project impacts in the upstream and/or downstream areas after project implementation have not been necessarily verified in the M/P yet. In such situations, the "Data Collection Survey on Water Resources Management in Haor Area of Bangladesh (hereinafter referred to as "the Study")" has conducted the following:

(1) Review of the M/P contents, which will be the base of formulation/implementation of future JICA projects in the haor area,

(2) Collection of additional data and information related to the formulation process of the M/P, and

(3) Basic study to supplement the M/P.

1.2 Objectives of the Study

The objectives of the Study are:

1) To collect and review (i) the contents of water resources management plans, such as "Master Plan of Haor Areas (the M/P, 2012)", for the haor areas in the upper Meghna area and (ii) existing relevant data and information,

2) To conduct additional study on matters that have been hardly addressed so far in the said plans, and

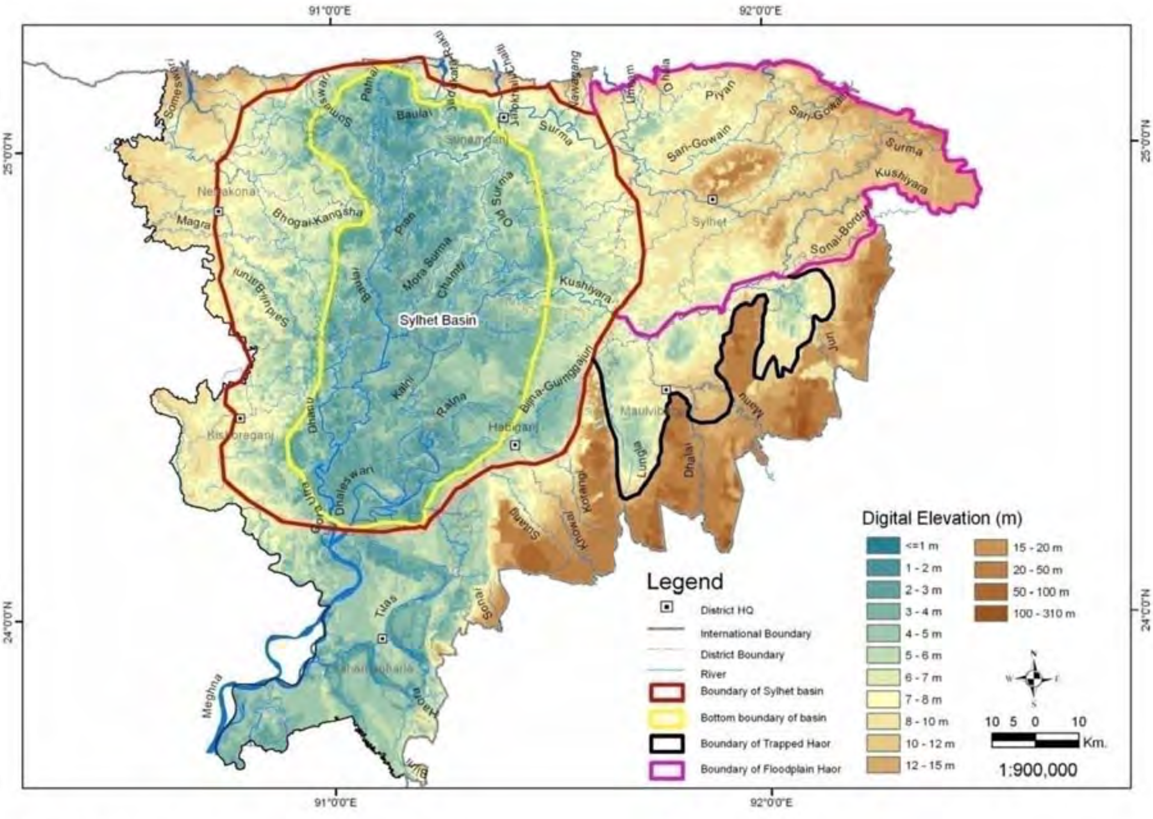
3) To propose possible JICA cooperation projects for flood measures and river management plan in the haor areas.

1.3 Study Area

The study area covers the river basins dealt with in the M/P (including their upstream and downstream areas required for the Study (limited to the Bangladeshi territory).

In the study area, special wetlands, namely, "haors" are situated. The haor areas having unique hydro-ecological characteristics are large bowl shaped floodplain depressions in the Northeast Region of Bangladesh covering about 1.99 million ha and accommodating about 19.37 million people. There are about 373 haors/wetlands located in the districts of Sunamganj, Habiganj, Sylhet, Maulvibazar, Netrakona, Kishoreganj and Brahmanbaria.

As presented in **Figure1.3.1**, the haors are largely classified into three areas based on their geo-morphological characteristics: (i) haors within Sylhet basin, (ii) haors in simple floodplain and (iii) trapped haors, which are delineated in the figure with red, purple and dark blue lines, respectively. In the center part of the Sylhet basin, a low land bottom area of which the elevation is less than 2m to 3 m is widely extended.

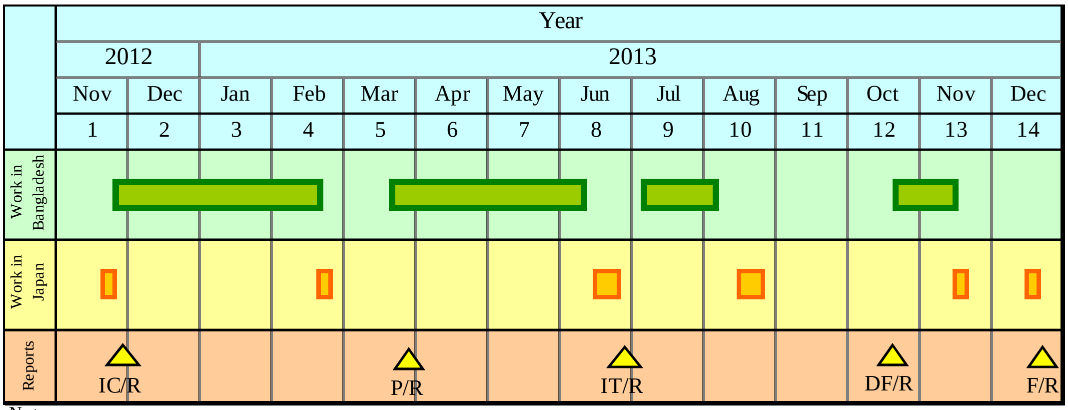


Source: "Master Plan of Haor Area, Water Resources, Ministry of Water Resources, 2012"

Figure 1.3.1 Division of Haor Areas

1.4 Schedule of the Study

The study period is 14 months from November 2012 to December 2013 and the schedule of the Study is presented in **Figure 1.4.1**.



Notes:
IC/R=Inception Report P/R=Progress Report IT/R=Interim Report DF/R=Draft Final Report F/R=Final Report

Figure 1.4.1 Schedule of the Study

1.5 Final Report

This final report is submitted as the product including the results and findings in the First to Fourth Works in Bangladesh, which were conducted from November 2012 to November 2013.

CHAPTER 2 CURRENT CONDITIONS OF STUDY AREA

2.1 Physical Setting

2.1.1 Physiography and Topography

(1) Physiography

The physiography of the Study area is classified based on the combination of geological material in which particular kinds of soil have formed and the landscape on which they occur. Seven districts comprising the haor area are placed on the following 11 physiographic units, based on agro-ecological regions of Bangladesh prepared by the Food and Agriculture Organization (FAO)[1], as shown in **Figure 2.1.1**. The units are as follows: a) Northern and Eastern Piedmont Plains, b) Northern and Eastern Hills, c) Sylhet Basin, d) Eastern Surma-Kushiyara Floodplain, e) Old Brahmaputra Floodplain, f) Young Brahmaputra and Jamuna Floodplain, g) Active Brahmaputra-Jamuna Floodplain, h) Old Meghna Estuarine Floodplain, i) Madhupur Tract, j) Middle Meghna River Floodplain and k) Akhaura Terrace. Among these units, six major units are described briefly in the following paragraphs:

1) Northern and Eastern Piedmont Plain

The Northern and Eastern Piedmont Plains are placed at the Northern and Eastern hills with a gentle outward slope from the foot of the hills. Alluvial fans at the north border of the area are its main features. Someswari, Jadukata, Jalukhali and Piyain along with some other trans-boundary rivers have mainly developed alluvial fans in this area. Piedmont floodplains are formed at the eastern border of the Study area by some steep streams like Khowai, Manu, Sutang, Dhalai, and Juri Rivers that flow from Tripura Hills in India to meet the Kushiyara River.

2) Northern and Eastern Hills

The Northern and Eastern Hills covers the series of northward plunging anticlines in the eastern part of the Study area with scattered patches along the northern border of the Jamalpur, Sherpur and Sylhet districts. The hills are formed with consolidated and unconsolidated sandstones, siltstones and shale of various Tertiary ages. The rocks have been uplifted, folded, faulted and dissected to form hill ranges or areas of complex hill and valley relief. Slopes are mainly very steep but the relief varies from very steeply dissected to gently rolling.

3) Sylet Basin

Sylhet basin comprises extensive low-lying, bowl-shaped depression and is deeply flooded during the monsoon season. The main feature of this area is the big bowl shaped depression, which is subsiding with a considerably high rate. Presently, subsidence is the dominating geo-morphological process as this area is isolated from its sediment sources after avulsion of the Brahmaputra River since 200 years ago. Flood basins within this large subsiding basin form the deeply inundated haor such as Tangua, Shanir, Matian, Karcher, and Kalner haors.

[1] Classification of agro-ecological zone in Bangladesh prepared by FAO
http://www.fao.org/fileadmin/templates/faobd/img/Agroecological_Zones.jpg

The haors are divided by natural dikes of channels and are very poorly drained. The bottom elevation of these haors is less than EL. 2 m, PWD[2]. Flooded water in this area after the monsoon season does not drain immediately as perennial water bodies occupy the lowest point of the haors and adjacent river dikes prevents rapid drainage. A large area in the basin stay wet for most or all of the dry season.

4) Eastern Surma-Kushiyara Floodplain

The Eastern Surma-Kushiyara Floodplain comprises parts of Sunamganj, Habiganj, Sylhet and Moulavibazar. The landforms are mainly very broad, smooth ridges and extensive basins. There is a broad belt of irregular relief, with narrow and linear ridges and inter-ridge depressions along the lower Kushiyara River. This area is flooded with shallow depth and is subject to early floods and rapid rise in water levels due to heavy rainfall locally and in adjoining hills. Gungiajuri, Hail, Kawadighi, Hakaluki, Dubriary, Dhamrir, Patharchuli and Zilkar are the major haors in this floodplain.

5) Old Brahmaputra Floodplain

The Old Brahmaputra Floodplain prevails in the western part of the region and was abandoned after the avulsion of the Brahmaputra River to the west of Madhupur Tract from its east about 200 years ago. There are silt loams and silty clay loams on the ridges and extensive areas of clays in the basins. Some basins near the northern and eastern boundaries of the subunit are occupied by clay sediments derived from the adjoining piedmont plain and the Sylhet basins. High water levels in the adjoining rivers and floodplains unable to drain off, and hence causes seasonal flooding accumulated by rainfall. Flooding becomes deeper toward the east and south.

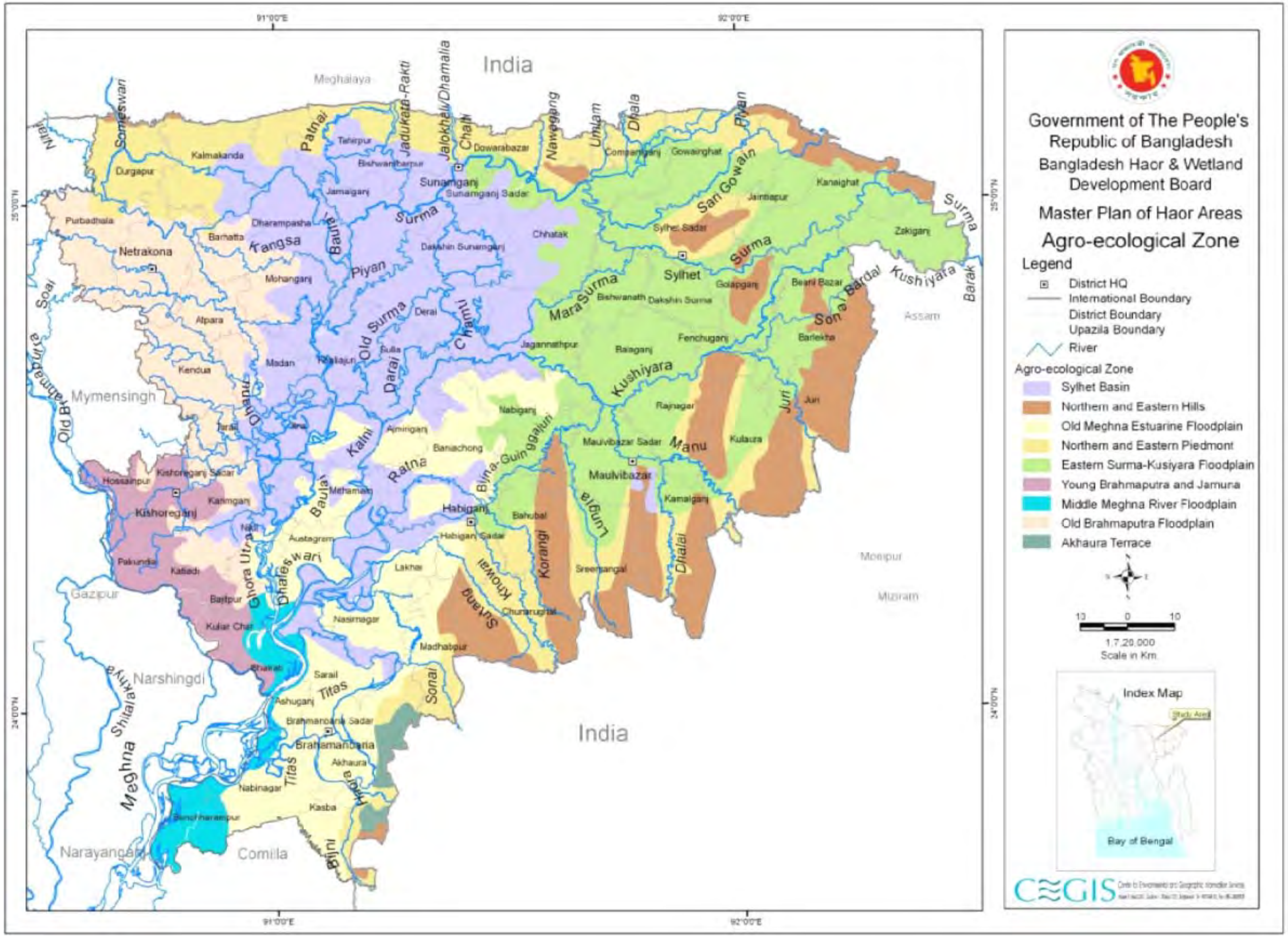
6) Old Meghna Estuarine Floodplain

The Old Meghna Estuarine Floodplain occurs in the southern part of the Study area including some parts of Kishoreganhj, Habiganj and Narayanganj districts. This unit is almost level with uniform soil predominating by silty soil. It is moderately deep in the north and west, but shallow in the southeast.

(2) Ground Elevation

Figure 2.1.2 shows a map of digital elevation model (DEM). This map illustrates that the Study area forms such a low-lying basin compared with other regions of the country. Land below EL. 5m PWD extends virtually as far as the Meghlaya Foothills. Out-side of this area, floodplain lands situated 200 km from the sea are found at EL. 8 m to 20 m PWD. Approximately 25 % of the Study area lies below EL. 5m PWD and 50 % lies below EL. 8 m PWD.

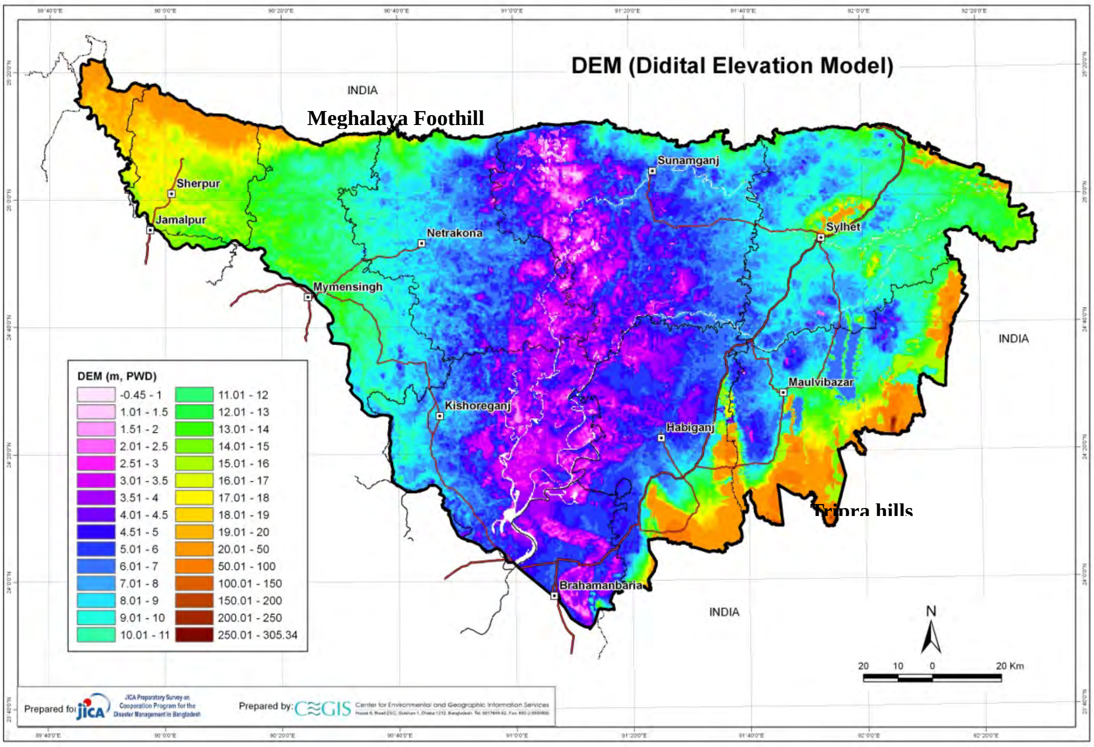
[2] Public Works Datum



Note: Nine units are shown in this figure because small units in this area are not indicated.

Source: Master Plan of Haor Area, April 2012

Figure 2.1.1 Physiography Map



Source: CEGIS

Figure 2.1.2 Digital Elevation Model

2.1.2 Climate

(1) Climate in Bangladesh

Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Regional climatic differences in this flat country are minor. Three seasons are generally recognized as follows: a hot and humid summer season from March to June; a cool and rainy monsoon season from June to October; and a cool and dry winter from October to March. In general, maximum summer temperatures range between 32 °C and 38 °C. April is the warmest month in most parts of the country. January is the coldest month, when the average minimum temperature for most of the country is 10 °C. Winds come mostly from the north and northwest during winter.

About 80 % of Bangladesh's rain falls during the monsoon season. During the hot months of April and May, hot air rises over the Indian subcontinent, creating low-pressure areas into which rush cooler, moisture-bearing winds from the Indian Ocean. This is the southwest monsoon, commencing in June and usually lasting through September.

(2) Climate in the Northeast Region

The Northeast Region is located entirely to the north of the Tropic of Cancer, hence its climate is characterized by sub-tropical monsoon. The sub-tropical monsoon climate tends to have more sharply defined seasons than the tropical one. The monsoon results in intense regional and orographic rains caused by the interface of mist air masses coming from the Indian Ocean through the Bay of Bengal with a predominant northeastern direction and the steep and high hills located at the foothills in the states of Assam, Meghalaia and Tripura in

India. The hills in Indian states experience very severe precipitation, causing very high flows in the major rivers draining through the Northeast Region of Bangladesh such as the Surma, Kushiyara, Manu, Khowai and Someswari. Some of the more intense precipitations in the world fall in this region where the average annual rainfall is around 12,000 mm.

As a result of the said unique climatic and physiographic settings of the upper Meghna area, the meteorology, hydrology, fluvial regimes and geomorphology are quite and distinct from other regions of Bangladesh.

The hydro-meteorological seasons of the Northeast Region are generally classified into:

- Pre-monsoon season extending from April to May;
- Monsoon season from June through September;
- Post-monsoon season from October to November; and
- Dry season from December through March.

1) Monsoon Season

The southwest monsoon brings moist winds into the Northeast Region from the Bay of Bengal along a circular route over the Chitagon Region so that the winds actually approach the region from the southeast. Rainfall in the season is abundant and it is often referred to as “monsoon”, meaning rainy season.

2) Pre- and Post-monsoon Seasons

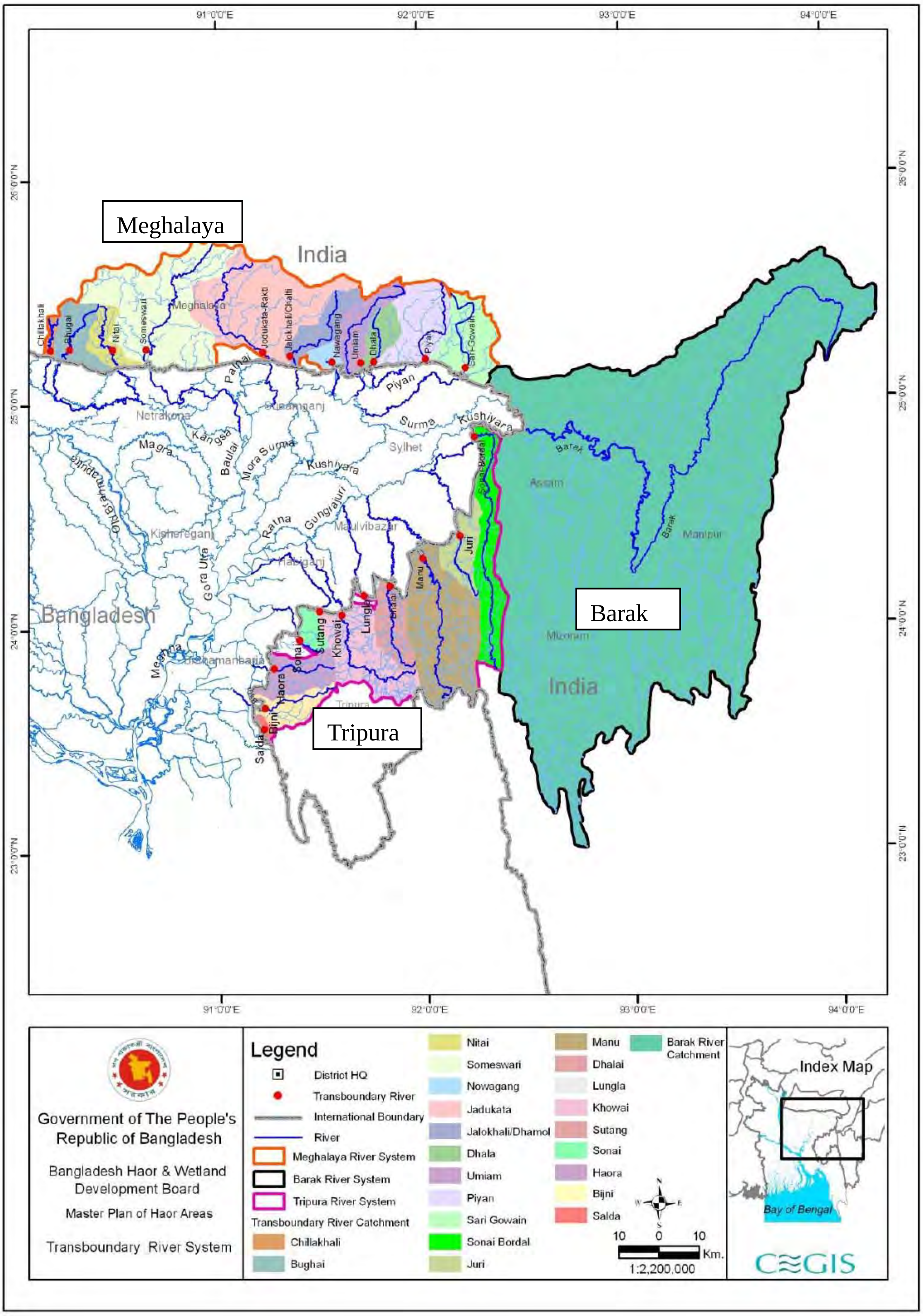
The pre-monsoon season occurs from April to May and is characterized by an increase in precipitation with rainfall ranging from nearly 490 mm in the southwest to around 1,290 mm in the northeast. The intensification of rainfall during the pre-monsoon season increases the incidence of flash floods in the region, which can potentially damage the crops when the river flows overtop and inundate agriculture land during the harvest season, causing serious damage to farmers as well as the country.

The post-monsoon season happens during October and November. The rainfall is sporadic and ranges from near 170 mm in the southwest to about 320 mm in the northeast.

2.1.3 River System

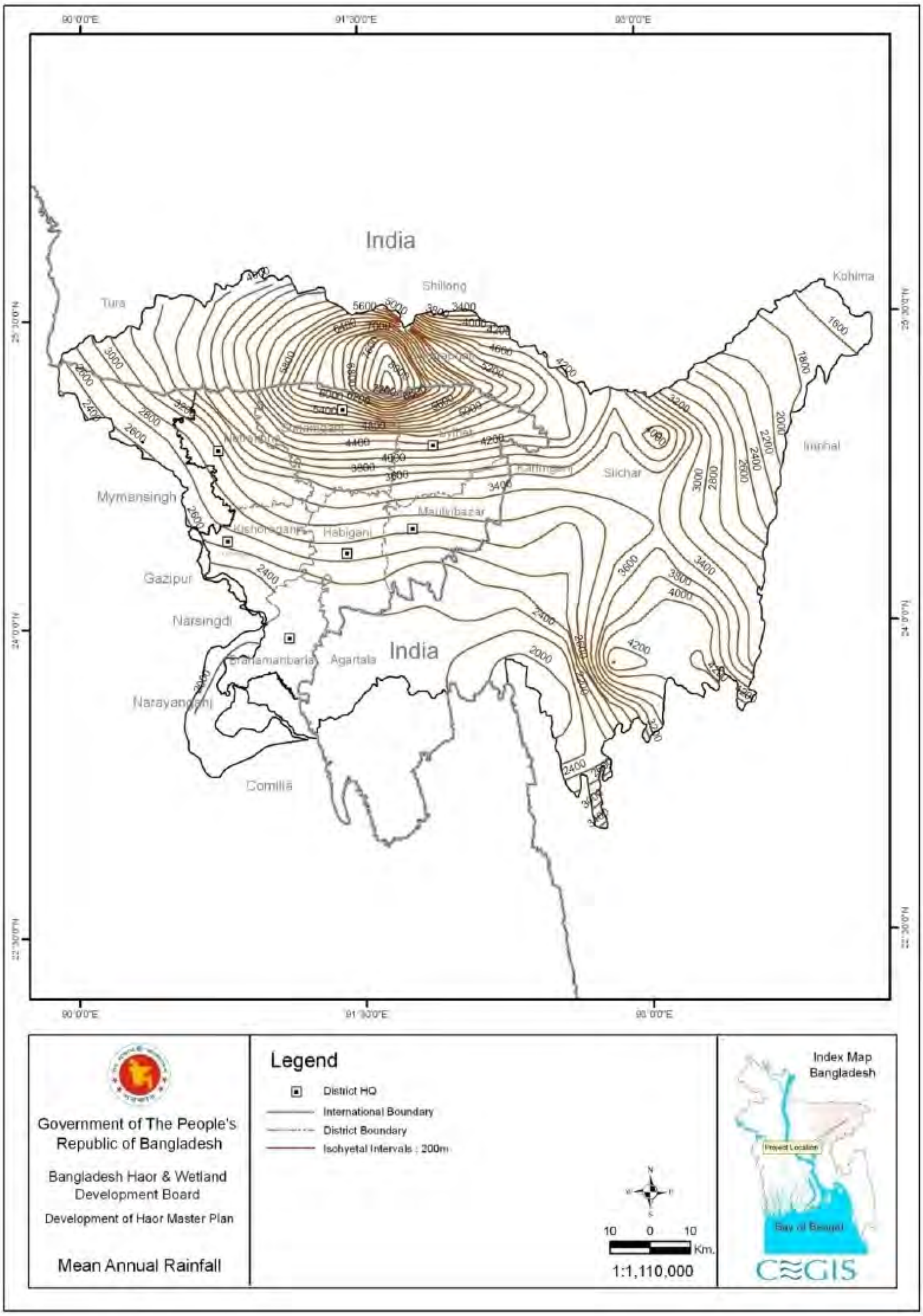
The majority of the rainfall volume that flows through the Bangladeshi Northeast Region comes from India where the largest flow volumes, floods, and sediment yield occur.

Figure 2.1.3 shows the river system for the upper Meghna River including the portion of the watershed inside India. **Figure 2.1.4** presents the average rainfall distribution throughout the Upper Meghna River Watershed.



Source: Master Plan of Haor Area, April 2012

Figure 2.1.3 Transboundary River System in Upper Meghna River Basin



Source: Master Plan of Haor Area, April 2012

Figure 2.1.4 Isohyet Graph in Upper Meghna River Basin

Large volumes of water and sediment inflows that supply the Northeast Region from Bangladesh are yield through the Assam (Barak), Meghalaya and Tripura catchments. Most of the watershed is located inside India and only 35% is in the Haor areas.

Table 2.1.1 summarizes the drainage areas and the average flow distribution of the river system main rivers. **Table 2.1.2** shows the rivers distribution draining the trans-boundary catchment system from India.

Table 2.1.1 Distribution of Transboundary and International River Catchments

Catchment system	Area (km^2)	Total area (%)
Meghalaya	9,904	15
Tripura	7,434	11
Barak	26,165	39
Bangladesh	23,137	35
Total	66,640	100

Source: JICA Study based on" Master Plan of Haor Area, April 2012"

Table 2.1.2 Transboundary Rivers contributing in different Catchment System

Catchment system	River name
Meghalaya	Nitai, Someswari, Jadukata, Jalokhali/Dhomali, Dhala, Piyan, Sari-Gowain
Barak	Surma, Kushiyara
Tripura	Lungia, Khowai, Sutang, Haor, Dhalai, Manu, Sonai-Bordal

Source: Master Plan of Haor Area, April 2012

The Barak River drains the Assam Region and distributes the flow through a bifurcation near the border between Bangladesh and India. Data from 1980 to 2008 indicates that an average of around 40% flows into Surma River channel and 60% inflows to the Kushiyara River during most part of the year. During the dry season and due to the physiography at the bifurcation, the Kushiyara River carries around 88% of the Barak River inflow. Because of sediment deposition at the Surma River portion of the bifurcation, the tendency is that flow proportion increases with time into the Kushiyara River while the Surma River will be silted over.

Table 2.1.3 summarizes the average seasonal inflow distribution for the Kushiyara and Surma Rivers.

Table 2.1.3 Distribution of Average Seasonal Inflow of Kushiyara and Surma Rivers

(Unit: million m^3)

River name	Station name	Pre-monsoon	Monsoon	Post-monsoon	Dry	Total annual flow
Kushiyara	Sheola	3,670	16,172	3,459	1,111	24,412
Surma	Kanairghat	2,416	13,345	2,056	146	17,963
Total		6,086	29,518	5,515	1,257	42,376

Note: Data from 1965 to 2007, Source: BWDB

The Meghalaya system drains the Someswari and Jadukata trans-boundary rivers. The Someswari system drains around 23% of the flow while the Jadukata flows around 21% of this system.

Table 2.1.4 shows the seasonal distribution for the Meghalaya system while **Table 2.1.5**, summarizes the distribution flows for the Tripura system. **Tables 2.1.6 and 2.1.7** tabulate the average input flows and percentages through several catchments.

Table 2.1.4 Distribution of Average Seasonal Inflow among the Rivers of the Meghalaya System

(Unit: million m³)

River name	Station name	Pre-monsoon	Monsoon	Post-monsoon	Dry	Total annual flow
Nitai	Ghosegaon	104	873	101	29	1,107
Someswari	Durgapur	602	5,270	845	247	6,964
Jadugata	Laurergarh Saktiarkhola	576	5,034	570	218	6,398
Jalokhali/ Dhomali	Muslimpur	261	2,486	268	118	3.133
Dhala	Islampur	383	2,401	247	63	3,094
Piyan	Jaflong (Spill)	542	3,970	371	113	4,996
Sari-Gowain	Sarighat	752	3,346	398	90	4,586
計		3,220	23,380	2,800	878	30,278

Note: Data from 1965 to 2007, Source: BWDB

Table 2.1.5 Distribution of Average Seasonal Inflow among the Rivers of the Tripura System

(Unit: million m³)

River name	Station name	Pre-monsoon	Monsoon	Post-monsoon	Dry	Total annual flow
Lungla	Motiganj	61	147	36	18	262
Khowai	Shaistaganj	311	729	206	127	1,373
Sutang	Sutang Railway Bridge	102	345	104	58	609
Haora	Gangasagar Railway Bridge	137	273	74	101	585
Dhalai	Kamalganj	228	665	147	53	1,093
Manu	Monu Railway Bridge	648	1,784	356	125	2,913
Sonai-Bordal	Jaldhup	868	3,242	682	109	4,901
Total		2,355	7,185	1,605	591	11,736

Note: Data from 1965 to 2007, Souce: BWDB

Table 2.1.6 Average Seasonal Inflow through Different Catchments (Volume)

(Unit: million m³)

Catchment System	Pre-monsoon	Monsoon	Post-monsoon	Dry	Total Annual flow
Barak	6,086	29,518	5,515	1,257	42,376
Meghalaya	3,320	23,380	2,800	878	30,278
Tripura	2,355	7,185	1,605	591	11,736
Total	11,661	60,082	9,920	2,725	84,389

Note: Data from 1965 to 2007, Source: Master Plan of Haor Area, April 2012

Table 2.1.7 Average Seasonal Inflow through Different Catchments (Per cent)

(Unit:%)

Catchment system	Pre-monsoon	Monsoon	Post-monsoon	Dry	Total annual flow
Barak	52	49	56	46	50
Meghalaya	28	39	28	32	36
Tripura	20	12	16	22	14
Total	100	100	100	100	100

Note: Data from 1965 to 2007, Source: Master Plan of Haor Area, April 2012

2.1.4 Geology and Soil

The Indian sub-continent has been formed by a collision between the northward moving Indian Plate and the static Eurasian Plate since the Cretaceous period. Part of the northeast Indian Plate has fractured and sank below sea-level during the Oligocene period. Since then the Bengal basin has started to form subsiding tectonic basin slowly, filling up with deltaic sediment.

Figure 2.1.5 shows the geological map in the study area. The geology of the study area is generally divided as follows;

1) Alluvial Fans (described in the M/P report by BHWDB) are normally found, as young gravelly (light purple area), in the limited transition zones between mountainous areas and floodplains along the northern national border with India.
2) The central study area (yellowish green area) is underlain by alluvial deposits, composed of mainly soft cohesive soil such as clay and silt. Especially, marsh clay and peat are distributed in the vicinity of the Dhanu and the Baulai Rivers, situated east of Netrokona and Kishoreganj Districts. Therefore, very soft peat is considered to exist in the central area.
3) Surrounding the central area, Netrokona, Kishoreganj and south of Sylhet area are underlain by alluvial silt and clay (light brown area).
4) Moreover, the western border area is generally underlain by alluvial silt (grave blue area).
5) Recent river deposits are distributed along big rivers which flow into the study area. River deposits are mainly composed of sand and gravel with silt and clay. Cobble stone, gravel and sand are quarried in the river bed at some places.

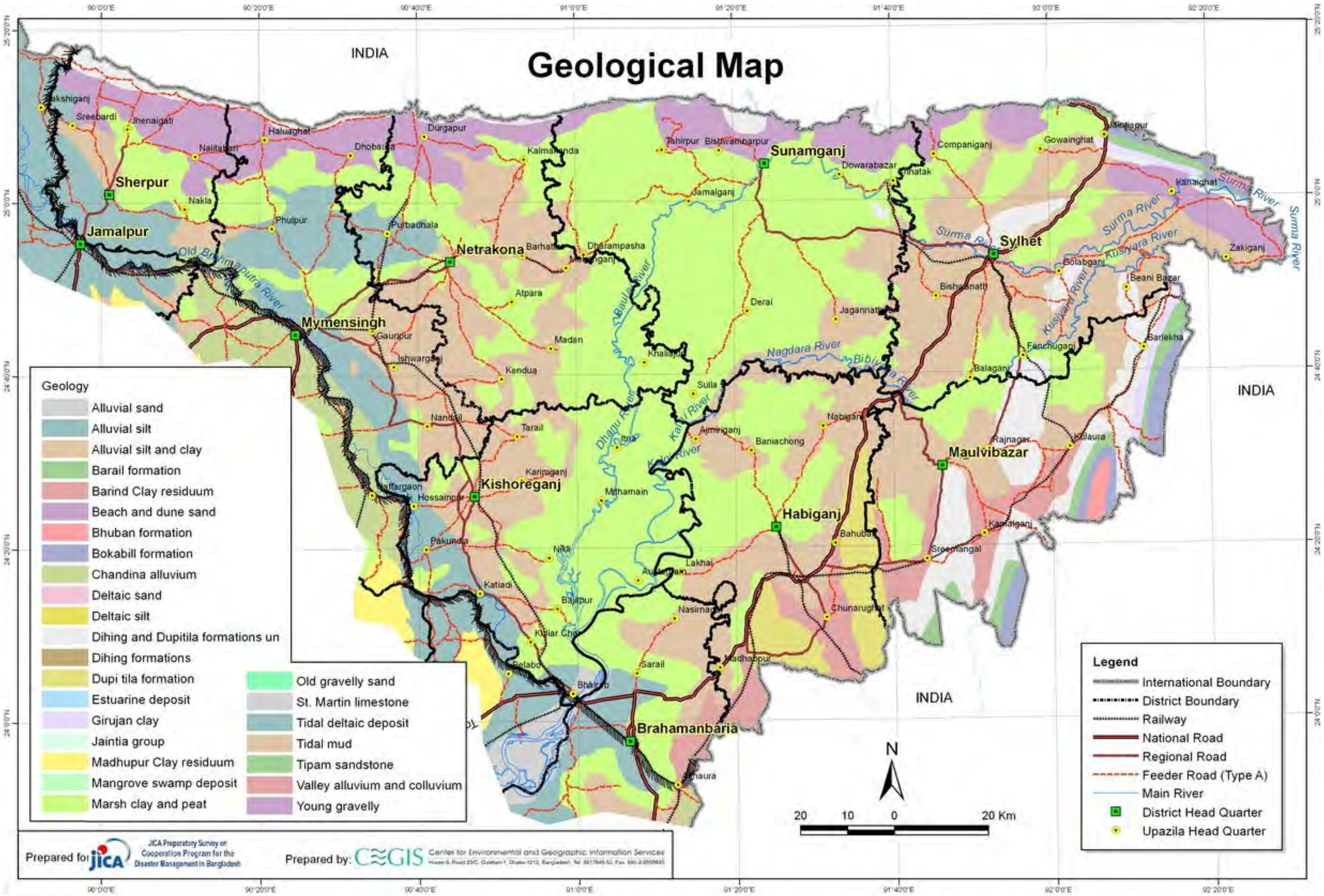
The central study area, called as the Sylhet Basin (pale purple color in **Figure 2.1.2**), has experienced some of the greatest subsidence. This basin has subsided 30-40 feet (10-12 m)[3] in the last several hundred years.

Referring to other areas' data[4], on condition that the Sylhet basin is subsiding at a rate of 2-4 mm/yr and the soil compaction rate is 1-2 mm/yr, the actual subsidence rate of the Sylhet basin might be 3-6 mm/yr.

The soils of the area are grey silty clay and clay on the higher parts that dry out seasonally and grey clays in the wet basin. Peat occupies some wet basin centers. The soils have a moderate content of organic matter and soil reaction is mainly acidic.

About 74% of the top soil texture of the haor region is clay to silty clay, 21% is silt, while the rest are clayey silt, sandy silt and sand.

[3] Source：Master Plan of Haor Area, Volume II Main Report and Annex 1 Water Resources
[4] A subsidence rate of 21 mm/year in the Surma basin was reported in the Master Plan Organization(PMO) (1985) and FEC (1989).



Source: Adapted from Geological Map provided by CEGIS

Figure 2.1.5 Geological Map in Project Area

2.2 Natural Resources

(1) Water Resources

The study area lies in the Meghna River basin, which is one of the largest GBM basins. About 66,640 km^2 of the Meghna River basin is drained ultimately into the Bay of Bengal through the Kalni-Kushiyara and Surma-Baulai river systems. Of this area, 35 % or 23,137 km^2 lies in Bangladesh. The total inflow in the haor area comes from India through Meghalaya, Barak and Tripura catchments. In addition, Old Brahmaputra carries water from the Indian part. The combined flow of Meghalaya, Barak and Tripura systems and Old Brahmaputra finally drain out through the Meghna River at Bhairab Bazar. Bhairab Bazar also internally drains flow generated by local rainfall in the Bangladesh territory.

It is reported in the M/P, that the analysis of BWDB data (1960-2009) showed a volume of water contribution into Bangladesh through the river system is 162,619 million m^3. Water contribution from transboundary rivers of Barak, Meghalaya and Tripura systems is 42,670 million m^3, 30,376 million m^3 and 15,716 million m^3, respectively. The contribution of water from transboundary river systems from India and Bangladesh in the region are described below.

- The catchment area of the Barak River system is 26,165 km^2, which contributes 26% of the total inflow in the region.
- The catchment area of the Meghalaya river system is 9,904 km^2, which contributes 19 % of the total inflow in the region.
- The catchment area of the Tripura river system is 7,434 km^2, which contributes 10 % of the total inflow in the region,
- The water contribution inside Bangladesh is 23,137 km^2, which is 43% of the total inflow in the region. And
- The water contribution from the Old Brahmaputra in the region is 2%.

The water balance for the study area is presented in **Table 2.2.1**. The proportion of annual average flow between the India and Bangladesh territories is 57 : 43.

Table 2.2.1 Water Balance in the Haor Area (1960-2009)

River system	Total flow (million m^3)
(A) Barak	42,670
(B) Meghalaya	30,376
(C) Tripura	15,719
(D) Brahmaputra	3,532
(E) Total inflow from India (A+B+C+D)	92,297
(F) Local contribution from Bangladesh	69,422
Total Inflow (E+F)	*162,619*

Source: Compiled by JICA Study Team based on Haor MP, 2012

(2) Vegetation

In the haor basin there are hill forests, social forests, fresh water swamps, reed swamp forests, bamboos and homestead vegetation, etc. **Table 2.2.2** shows the natural forest coverage in the study area.

In the M/P, ecologists have grouped the typical haor vegetation areas into nine classes, which are 1) submerged plants, 2) free floating plants, 3) rooted floating plants, 4) sedges and meadows, 5) floodplain grassland, 6) reed swamp, 7) fresh water swamp forest, 8) crop field vegetation and 9) homestead vegetation.

Table 2.2.2 Natural Forest Area

District	Natural forest area (ha)
Sunamganj	7,293
Habiganj	13,153
Netrokona	739
Sylhet	262,832
Maulvibazar	25,142
Total	*296,005*

Source: Haor MP, 2012

(3) Biodiversity and Wetland

There is a large number of wetlands of significant national and regional importance, and many of these sites have significant local value. The sites support biodiversity at all scales especially communities (species and within the species) and are home to several internationally threatened species. The biodiversity of haor wetlands is very rich. The most significant wetlands are Hakaluki Haor, Tanguar Haor, Hail Haor, Matian Haor, Pasuar Beel Haor, Dekar Haor, Baro Haor, Gurmar Haor, Sonamorol Haor, Baram Haor, Kalni Haor, Kawadighi Haor and Pagner Haor. These wetlands have rich wildlife communities including birds, reptiles, mammals and amphibians. Most of the important haor areas are also enriched by wetland plants through lowland plantation.

In 1999, the Government of Bangladesh (GoB) declared two haors as ‘ecologically critical areas’ (ECA) in the haor area based on “Bangladesh Environment Conservation Act (1995, amended in 2000 and 2002)”, which are Hakaluki Haor (Maulvibazar/Sylhet Districts) and Tanguar Hoar (Sunamganj District) . Tanguar Haor has been declared as a Ramsar site.

In addition, the Bangladesh National Herbarium (BNH) carried out a survey in 2001. Extent of flora and fauna is as shown in **Table 2.2.3**.

Table 2.2.3 Extent of Flora and Fauna

Flora and fauna	Number of spices
Amphibians	9
Birds	257
Mammals	29
Reptiles	40
Fish	141
Free floating plants	11
Anchored plants	38
Suspended plants	5
Rooted plants	2
Emergent species	116
Climbers	5
Swamp plants	8

Source: Compiled by the JICA Study Team based on Haor MP, 2012

The haor ecosystem is the major habitat of birds and fishes in Bangladesh. Tanguar Haor is characterized having an approximately 141 fish species including some introduced exotic species which represents more than half of the country’s fresh water fish species (266 spp.).

There are 208 bird species avifauna in the haor area.

(4) Mineral Resources

The haor basin is a large, gentle depression, bounded by the Old Brahmaputra floodplain in the west, the foothills of the Meghalaya Plateau in the north, the Sylhet High Plain in the east and the Old Meghna floodplain in the south. This depression is created by subsidence and tectonic adjustment.

The geological setting and formations of the Northeast Region of Bangladesh favors the deposit of various types of mineral and energy resources. The mineral resources discovered are natural gas, crude oil, limestone, white clay, glass sand, peat, coal, gravel and construction sand (see **Table 2.2.4**). About 90% of the total gas production of the country is obtained from the haor districts.

Table 2.2.4 Mineral Resources of Haor Area

Type	Brief description of mineral resources
Coal	The coal consists of 18.96-39.32% carbon, 15-46.16% ash, 0. 62-1.44% moisture and 32.64-48.22% gaseous materials.
Crude Oil	Small commercial oil discovered at Haripur, Sylhet, was in operation for about 7 years only.
Glass Sand	Glass sand is found in Habiganj, Shajibazar and Noapara.
Gravel	Gravel is composed of rock types like quartzite, granite, amphibolite, basalt, sandstone, and conglomerate
Lime Stone	Limestone is mainly found in the subsurface at Boglibazar, Lalghat, Takerghat and Bhangerghat of Tahirpur Upazila, Sunamganj District.
Natural Gas	Among the 23 natural gas fields, 10 fields are located in the haor region.
Peat	Peat is available around Maulvibazar District; Chatal beel of Maulvibazar District; Pagla, Derai and Shalla of Sunamganj District; Charkai of Sylhet District; Katanga of Brahmanbaria District and Mukndapur of Habiganj District.
White Clay	White clay deposit is found nearly in the surface to subsurface at Bijoypur and Gopalpur of Durgapur Upazila in Netrakona District.

Source: Compiled by JICA Study Team based on Haor MP, 2012

2.3 Socio-economy

(1) Population Distribution

The total population of the seven haor districts in the Northeast Region is 17.88 million as of 2011 Census compared to 14.94 million in 2001 Census (BBS, 2012). The average yearly growth rate for the past 10 years is 1.97%, which is higher than the national rate of 1.47%. There are about 3.44 million households in the haor districts, which translates into an average household size of 5.2 persons per household. The highest number of population lives in Sylhet (3.43 million) and the lowest in Maulvibazaar (1.92 million). Similarly, Sylhet has the largest household size of 5.76, while Kishoreganj has the smallest size of 4.64. The average gender ratio in the haor districts is 97.78:100, which indicates that there are 97.8 males per 100 females. The national gender ratio is 100:100. Brahmanbaria District has the highest population density (1,510 per km^2), while only 659 people live per km^2 in Sunamganj District. The overall population density in the haor districts is 894 per km^2, which is lower than the average population density in Bangladesh, which is 976 per km^2. The district-wise population, its density and gender ratio are given in **Table 2.3.1.** The rate of urbanization is highest in Sylhet District at 21.94%, followed by Kishoreganj, where the rate is 16.79%. The lowest urbanization is in Sunamganj, which is only 10.38% as compiled in **Table 2.3.2**. The national average of urbanization is 23.3%.

Table 2.3.1 District-wise Population, Density and Gender Ratio, 2010

District	Population (mil.)	Household (thousand HH)	Person per Household (People)	*Gender* Ratio (M:F)	Population density (person/ km^2)
Sunamganj	2.47	440.3	5.6	100.35	659
Habiganj	2.07	393.3	5.3	96.88	792
Netrakona	2.23	479.1	4.6	99.37	798
Kishoreganj	2.91	627.3	4.6	96.80	1,083
Sylhet	3.43	596.1	5.7	101.16	995
Maulvibazar	1.92	361.2	5.3	96.96	686
Brahmanbaria	2.84	538.9	5.3	92.74	1,510
Haor Total Area	*17.88*	*3,436.2*	*5.2*	*97.78*	*894*

Source: Compiled by JICA Study Team based on 2011 Census (BBS, 2012)

Table 2.3.2 Urbanization Rate by District (2011)

District	Population (10^3)	Population in urban areas* (10^3)	Urbanization Rate (%)
Sunamganj	2,468	256	10.4
Habiganj	2,089	245	11.7
Netrokona	2,230	247	11.1
Kishoreganj	2,912	489	16.8
Sylhet	3,434	753	21.9
Maulvibazar	1,919	208	10.8
Brahnmanbaria	2,840	448	15.8
Haor Total Area	*17,892*	*2,646*	*14.8*

Note: * Population in “2 Urban” and “3 Other Urban” under BBS’s census
Source：Bangladesh Population and Housing Census (BBS,2011)

The upazila-wise 2011 population for the 7 haor districts is shown in **Figure 2.3.1**. This is superimposed by the 373 haors as defined by the MP.

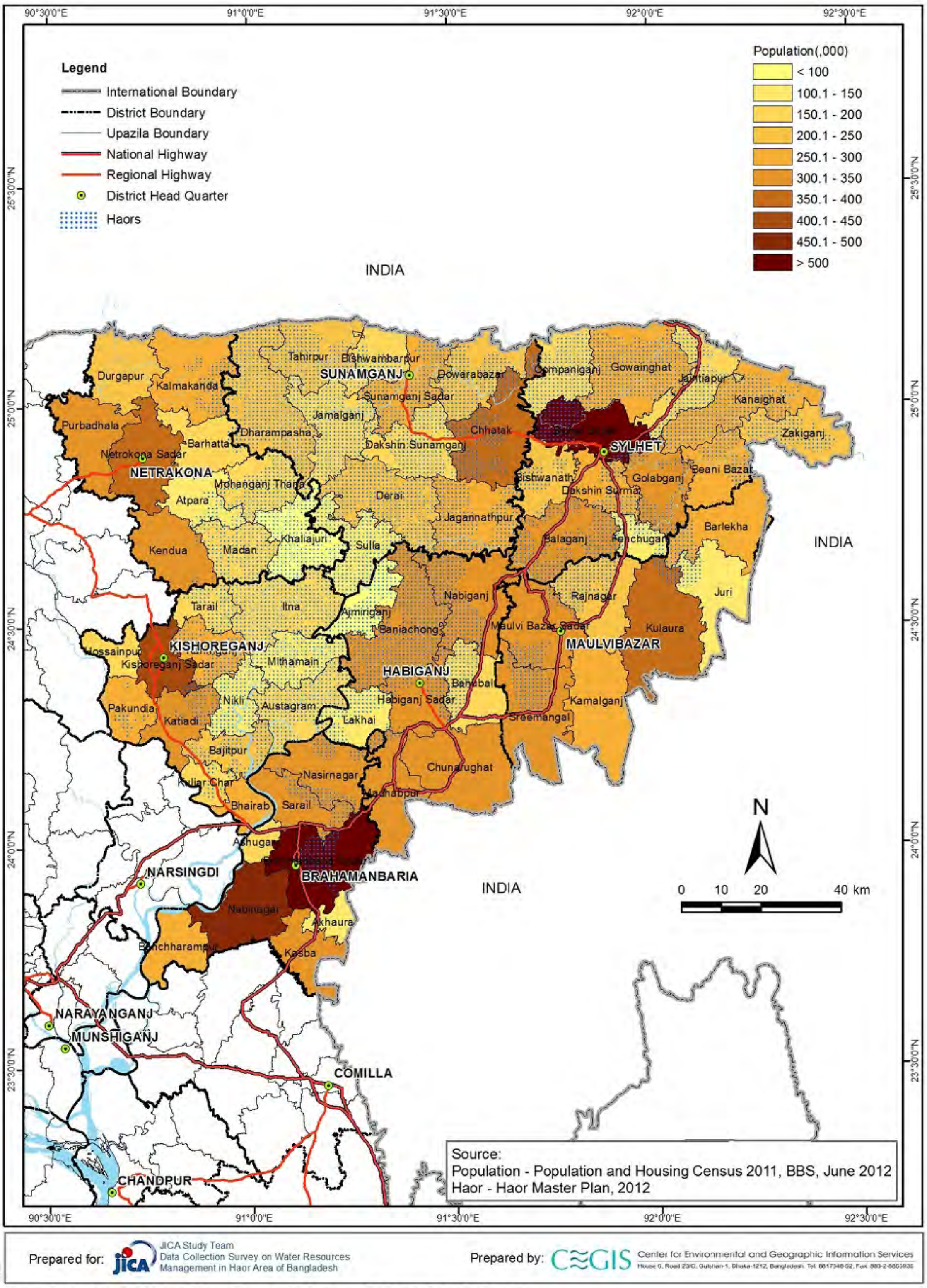
(2) Land Use

<u>Land:</u> The haor area extends over Kishoreganj, Netrakona, Sunamganj, Sylhet, Moulvibazar, Habiganj and Brahmanbaria districts in the Northeast Region of Bangladesh. These seven districts cover a gross area of about 2 million ha, of which about 55 % is cropped land, and the rest is occupied by rivers, channels (khals), water bodies, forests, homesteads, ponds, hills and infrastructure.

The haor area covers about 0.86 million ha. About 9.5 % of the haor area is under permanent water bodies, of which 37,000 ha are beels[5] and 45,000 ha are channels[6]. Multi-use lands including grazing lands, waste lands, village grounds and riverbanks cover about 40,000 ha. People in the locality use the beels and multi-use lands as “common property resources”. The beels are for fisheries and source of irrigation water in the dry season. Grazing lands are

[5] Beels: Static water bodies or shallow lakes found at the centre or in the lowest part of every haor in the dry season
[6] Channel: Stream channels known as khals, connecting the beels to nearby rivers: most of the haors are interconnected with channels through which floodwater spills into the haor area from the rivers during the flood season and drains out at the end of the monsoon season

the source of livestock feeds in the winter season. Rice crops harvested in the pre-monsoon season are threshed on the village grounds on a community basis. Many of these common lands have been converted into cultivated land.



Population (2011) by Upazila and Haors of North East Region

Figure 2.3.1 Upazila-wise Population of 2011 and Haors of Northeast Region

Land Ownership: The number of farm households in the 7 districts is 1.68 million and non-farm households is 1.37 million. Of the total farm households, about 80 % are considered small (owning less than 1 ha of cultivated land), 17 % are medium (owning 1 to 3 ha of cultivated land) and 3 % are large (more than 3 ha of cultivated land). The large farms are usually operated using tenants or hired labor.

Land Tenure: Owner operation is common. About 71 % of the total farm households operate their own land. Owner-cum tenant operated and tenant operated households account for 20 % and 9 % of the total farm households, respectively. The large landowners generally share out their lands to tenants for operation. The share cropping system is being practiced where one-half of the produce is retained by the landowners without providing inputs. The landowners generally provide 50 % of the inputs costs.

(3) Agriculture

Cultivated Area: Net cultivated area covers about **12,000 km^2** in the above-mentioned 7 districts. The highlands (F0) and medium highlands (F1) where flood depth reaches 0 to 0.9 m occupy about two-fifths of the net cultivated area. The lands are therefore subject to moderate cropping constraints during the monsoon season. The medium lowlands (F2) and lowlands (F3) where the seasonal flooding depth is 0.9 m to more than 1.8 m occupy about three-fifths of the net cultivated area. In the haor area about one-fifth of the net cultivable area is in F0 and F1. The F3 comprise about four-fifths.

Cropped Area: Rice is the major and most important crop. This crop accounts for 99 % of the total food grain cropped area in the 7 districts. It is grown in three cropping seasons, mainly solely or in rotation with dry land crops. The Census of Agriculture in the 2010 Yearbook of Agricultural Statistics indicates that **15,400 km^2** is cropped under different rice cultures (refer to **Table 2.3.3**). Local and high-yield variety (HYV) boro are almost the only crops grown in the lowlands. Cropping intensity (ratio of total cropped area to net cultivated one) is 133%.

Cropping Patterns: It uses rice-based cropping patterns. Almost all segments of the cultivated land are cropped with at least one rice crop a year. Since most of the haor areas flood to a depth of more than 0.9 m in the monsoon season, about four-fifths of the net cultivated area is used for single cropping. In this cropping pattern, HYV boro is the major crop followed by local aman.

Crop Yields: The annual average rice yield is 2.93 ton/ha in the 7 districts, more than the national

Table 2.3.3 Cropped Area in 7 Districts

Crop Season	Name of Crop	Area (% of net cultivated area)
Kharif 1 (Pre-monsoon)	Local aus	1.30
	HYV aus	8.17
	Jute	0.93
Kharif 2 (Monsoon)	Local aman*	22.17
	HYV aman	33.51
Rabi/Boro (Dry)	Local boor	5.90
	HYV boro	57.61
	Wheat	0.98
	Pulse	0.31
	Oilseeds	0.84
	Potato	0.93
	Sweet potato	0.31
	Sugarcane	0.17
Total cropped area (km^2)		15,400
Net cultivated area (km^2)		12,000
Cropping Intensity (%)		133

Note: *Local aman includes deepwater aman broadcast.
Source: Agriculture Census 2010 Yearbook of Agricultural Statistics.

average of 2.82 ton/ha as compiled in **Table 2.3.4**. The average rice yield is higher in aus (pre-monsoon) and aman (monsoon season) compared to that of the national average. It is below than the national average in the boro season. The average yield is higher for local boro rice. However, the average HYV boro rice yield is 3.74 ton/ha which is below than the national average of 3.88 ton/ha. The HYV boro rice accounts for about two-thirds of the net cultivated area in the 7 districts. The yield levels of wheat, oilseeds and potato are low compared to the national average. Yield levels of jute, pulses and sweet potato are relatively better.

Table 2.3.4 Crop Yields

Crops	**Yield (ton/ha)**					
	Bangladesh	Sylhet Region	Kisoreganj Region	Brahaman-baria District	**Haor Area***	Difference between haor & Bangladesh (%)
a	b	c	d	e	f	(f-b)/b×100
L aus	1.17	1.41	1.56	1.04	1.38	17.95
HYV Aus	2.03	2.25	1.93	1.82	2.18	7.39
Average Aus	1.74	2.13	1.90	1.39	2.07	18.97
B. Aman	1.19	1.61	0.00	1.35	1.49	25.21
T. Aman	1.58	1.93	1.44	1.74	1.76	11.39
HYV Aman	2.49	3.16	2.23	2.31	2.74	10.04
Average Aman	2.16	2.61	2.00	1.88	2.32	7.41
L Boro	2.00	2.20	1.95	1.83	2.19	9.50
HYV Boro	**3.88**	**3.63**	**3.85**	**3.69**	**3.74**	**-3.61**
Average Boro	3.84	3.35	3.84	3.67	3.60	-6.25
Average Rice	**2.82**	**2.87**	**3.05**	**2.86**	**2.93**	**3.90**
Wheat	2.41	1.75	1.76	1.45	1.58	-34.44
Pulses	0.93	1.35	1.29	0.83	0.94	1.08
Oilseeds	2.15	1.38	1.15	0.80	1.07	-50.23
Potato	18.24	11.00	13.14	13.86	12.41	-31.96
S Potato	9.85	7.87	13.18	9.97	10.80	9.64
Jute (bales)	12.2	8.43	15.34	11.32	14.30	17.21

Note: * Comprising Kishoreganj and Sylhet Regions.
Source: JICA Study Team

Early flash floods and poor drainage of floodwater significantly reduce boro rice crop yields in some years. Available data related to flood damage to crops from 2000 to 2010 estimated higher loss of boro rice from 3.04 ton/ha (2000) to 3.87 ton/ha (2010) in Kishoreganj Region compared to the national average, as presented in **Table 2.3.5**. The loss ranged from 2.09 ton/ha (2000) to 3.18 ton/ha (2003) in Sylhet Region (**Table 2.3.5**). In general, boro rice yields listed in **Table 2.3.5** are lower, compared to 3.60 ton/ha (**Table 2.3.4**), in the haor area in most of the years due to the floods and poor drainage.

Table 2.3.5 Loss of HYV Boro Rice Production

Year	Country/Region*	Area damaged (ha)	Loss of production (ton)	Loss of yield (ton/ha)	Total Area (ha)	Total Production (ton)	Yield (ton/ha)
2000	Bangladesh	117,398	317,460	2.70	3,652,036	11,027,010	3.02
	Kishoreganj	33,469	101,750	3.04	317,016	951,063	3.00
	Sylhet	57,696	120,700	2.09	317,115	709,800	2.24
2001	Bangladesh	7,009	18,440	2.63	3,761,995	11,920,940	3.17
	Kishoreganj	0	0	0	270,734	876,160	3.24
	Sylhet	5,547	13,800	2.49	317,406	837,900	2.64
2002	Bangladesh	92,308	275,680	2.99	3,771,485	11,765,500	3.12
	Kishoreganj	0	0		273,334	834,639	3.05
	Sylhet	33,226	86,480	2.60	340,295	883,100	2.60
2003	Bangladesh	4,852	15,610	3.22	3,844,998	12,221,850	3.18
	Kishoreganj	0	0		277,865	848,975	3.06
	Sylhet	3,595	11,450	3.18	328,907	870,680	2.65
2004	Bangladesh	177,591	497,220	2.80	3,943,671	12,837,230	3.26
	Kishoreganj	49,745	154,420	3.10	241,210	742,292	3.08
	Sylhet	124,810	332,690	2.67	310,461	759,550	2.45
2010	Bangladesh	124,819	369,591	2.96	4,707,066	18,058,962	3.84
	Kishoreganj	43,914	169,742	3.87	309,852	1,189,705	3.84
	Sylhet	80,947	199,849	2.47	339,087	1,136,187	3.35

Note: * Kishoreganj Region is composed of Kishoreganj and Netrokona Districts; Sylhet Region is composed of Sylhet, Sunamganj, Habiganj and Moulvibazar Districts.
Source: Yearbook of Agricultural Statistics, BBS.

Crop Production Cost and Return: The crop production cost is higher in the dry season than in other crop seasons. The labor wage accounts for around 30% to 50% of the total production cost. The estimated cost to produce HYV boro rice is about BDT 43,500 per ha. The labor wage accounts for more than 36 %, irrigation 24 %, and fertilizer 19 % of the total production cost.

The net return as calculated from the difference between the gross value and production cost for different crops are provided in **Table 2.3.6**. The highest return is obtained in HYV aman production. The crop is grown under rainfed condition. Input cost for the production of the crop is lesser than that for HYV boro rice production. However, land available for HYV aman cultivation is limited and almost nil in the haor area. The return obtained from HYV boro production is less attractive compared to that from HYV aman. However, HYV boro requires more laborers than any other crop. Small and landless households mainly benefit from the increased demand.

Table 2.3.6 Crop Production Benefit

Crop	Price (BDT/ton)	Gross value (BDT/ha)	Total cost (BDT/ha)	Net return (BDT/ha)
B. Aman	13,550	21,680	16,055	5,625
Local T. Aman	14,050	25,290	17,290	8,000
HYV Aman	13,720	37,044	20,995	16,049
Local Boro	15,000	33,000	24,206	8,794
HYV Boro	15,710	58,127	43,472	14,655
Jute	17,500	31,500	18,525	12,975
Oilseeds	22,300	24,530	20,501	4,029

Source: Field survey 2012

(4) Fisheries

Wetlands are used for breeding as well as feeding grounds for most of the freshwater fish species. The fish habitat area in the haor region is estimated at about 9,670 km^2. The fish production is about 4,300 tons of fish, of which 73.7% comes from capture fishery and the rest is contributed by culture fishery. Among the haor districts, Sunamganj contributes about 23.4% in the total fish production followed by Netrokona (16.9%), Kishoreganj (16.2%), Sylhet (14.8%), Brahmanbaria (12.7%), Habiganj (8.1%) and Maulvibazaar (7.9%). Of the capture fish production, floodplain contributes the bulk portion which is about 77.9% followed by beels (15.6%), river streams (3.5%), channels/khals (1.8%) and ditches/borrow pits (1.2%). Culture fish ponds in the area produce about 1,136 tons which is 26.3% of the total production. The total fish production of 4,300 tons is derived from 2,540 tons (59%) mainly coming from the flood plains during the monsoon season and 1,780 tons (41%) from rivers, beels, fish ponds, etc. during the remaining season.

Nearly 20% of the total inland fish production of Bangladesh comes from the haor basin and this sector plays a vital role in the national economy in general and the local economy in particular for the poor. Of the fisheries contribution to the national gross domestic product (GDP), the haor basin alone contributes around 0.6% while 3.14% is contributed by the rest of the country. About 450 tons of fish were exported from the haor basin in the 2009-2010 fiscal year (DoF, 2011).

The contribution of haor capture fisheries to the livelihood of the rural poor of the area is very significant. Although 2.59% of the area population are full-time fishermen, over 65% of the households are engaged in fishing activities as part-time or subsistence fishermen.

(5) Livestock

Livestock is a major component of the agricultural economy of Bangladesh performing multiple functions such as food nutrition, income, draft power, manure, fuel, transport and foreign exchange (i.e. export of processed leather of cows and goats to abroad). About 44% of the animal protein comes from livestock sources. Livestock resources also play an important role in the sustenance of the landless poor.

The livestock resources of the haor region are mainly cattle, buffaloes, goats, sheep, chickens and ducks. There are around 32.68 million heads of livestock (cattle, goats, sheep, ducks and poultry) in the haor farms. They constitute approximately 22% of the total cattle population in the country.

(6) Industry

Industrialization has not taken place to a great extent in the Northeast Region and consequently the number of industries and people engaged is comparatively low (1.33% of the total population only). However, most of the tea estates are in the Sylhet Region. Furthermore, the industrial product of the Sylhet Region includes fertilizer, cement and liquefied petroleum (propane) gas.

The industrial economy of the haor area is based on cottage and tea processing industries.

(7) Electricity

Energy is one of the factors that support and accelerate growth of the country. The electricity supply in the haor area in general is far from sufficient compared with its demand. The Rural Electrification Board (REB) is entrusted with the distribution of electricity in the rural areas of Bangladesh. The total number of villages receiving electricity by 2010 was 6,740 out of 15,374, accounting for 44% as compared to 72% nationwide. As compared to the nationwide average consumption of about 200 kWh per capita, the haor area showed only 47 kWh in 2010. Sunamganj District had the lowest consumption of electricity with only 17 kWh per capita followed by Kishoreganj and Netrakona.

(8) Water Supply

Most of the households in the haor area are using tube-well water (groundwater) for drinking purpose. About 50% of the households are dependent on surrounding river/pond water for domestic use. As a result, in spite of having good and safe water access, the haor people are affected by many water-borne diseases.

(9) Sanitation

Bangladesh is on its way to achieve the MDGs targets, attesting to marked progress compared to other developing countries. However, burdened with poverty and stressed with infrastructure inadequacy, the overall health status in the haor region continues to lag behind the national benchmark with the prevalence of both communicable and non-communicable diseases. The sanitation facilities of the haor area are poor compared to other parts of the country. Use of sanitary latrine is only 44% in the haor area (Haor MP, 2012). Flooding, high water table, excessive rainfall and loose soil formation are the causes of overflow and collapse of pit latrines.

(10) Education

The average literacy rate of the haor districts is 38%, while the national level is at 54.8%. Among the haor districts, Moulivibazaar has the highest literate population (42%), followed by Sylhet (41%), Brahmanbaria (40%), Habiganj (37%), Kishoreganj (37%), Netrokona (34%), and Sunamganj (33%). The distribution of educational institutes is shown in **Table 2.3.7**

Table 2.3.7 District-wise Educational Institutes

District	Primary school	High school	College	Vocational school
Sunamganj	1,447	149	27	2
Habiganj	1,053	108	22	2
Netrokona	1,166	186	30	6
Kishoreganj	1,305	202	30	9
Sylhet	1,350	256	60	3
Maulvibazar	1,027	141	27	-
Brahmanbaria	1,033	182	36	7
Haor Area Total	*8,381*	*1,224*	*232*	*29*

Source: MoE, 2010 and BBS, 2010

(11) Health

The overall health status in the haor region continues to lag behind the national benchmark with the prevalence of both communicable and non-communicable diseases. The malaria endemic districts of Habiganj, Maulvibazaar, Netrokona, Sunamgonj and Sylhet had 5,345 numbers of case loads in 2009 (DGHS 2010).

The average infant mortality rate (IMR) and under-5 child mortality rate (U5MR) in the haor area, except for Brahmanbaria District, is 57 (per 1,000 infants) and 76 (per 1,000 children) which are higher than the national IMR of 49 and U5MR of 64. The high infant and child mortality is also due to malnutrition. The average of under-5 child malnutrition for haor districts is approximately 46%, which is again higher than the national rate of 43% (BDHS 2007).

(12) Road Transport

Haor areas remain flooded under water for 4-6 months during the pre-monsoon and monsoon seasons. The roads are submerged during these seasons making it impossible to travel from one place to another without using boats. The transportation networks of waterways and roadways have developed over the years in keeping with the unique characteristics of the haors.

The Bangladesh Roads and Highways Department (RHD) is responsible for constructing roads at the national, regional and district levels. The rural roads consisting of Upazila[7], union[8] and village roads are constructed by the Local Government Engineering Department (LGED). Eleven upazilas out of the total 69 upazilas in the haor districts are not connected with the RHD network.

(13) Inland Navigation

Inland waterways have been used as a major way of transporting cargo and passengers in the haor area. There are 25 inland water transport (IWT) routes covering a length of 1828.8 km of inland waterways, which remain navigable during the monsoon season (May-September). However, during the lean period (October-April) inland vessels cannot navigate in about 1,000 km of the waterways.

[7] Districts of Bangladesh are divided into sub-districts called “Upazila”

[8] Upazilas of Bangladesh are administratively divided into sub-upazilas, called "Union", which is the smallest rural administrative and local government unit in Bangladesh and usually composed of nine villages (Ward).

2.4 Flood Damage and Flood Mark

The flood damage in Bangladesh is shown in **Table 2.4.1**.

Table 2.4.1 Recent Flood Damage in Bangladesh

Year	Description
1987	The flood has occurred from July to September. Serious damage occurred along the Ganges and the Brahmaputra rivers. Damages in Bangladesh totaled to: Inundation area[1)]:57,491km^2, Amount of damage [2)]: BDT 35,000 million, Number of affected person[3)]: 29.7million.
1988	The flood has occurred at the Southeastern Region in May. Serious damage occurred in the North and Northeastern Regions due to heavy intensive rainfall. Big damage occurred along the Gangues, Brahmaputra, and Padma rivers. Damages in Bangladesh totaled to: Inundation area[1)]:120,973km^2, Amount of damage [2)]: BDT 100,000 million, Number of affected person[3)]: 73million
1998	The nationwide flood has occurred from the beginning of July. The river water level at Bhairab Bazar located at the Meghna River was higher than the dangerous water level for 79 days due to the occurrence of high waves and backwater impacts. Damages in Bangladesh totaled to: Inundation area[1)]:100,000km^2, Amount of damage [2)]: BDT 100,000 million, Number of affected person[3)]: 15million
2004	The monsoon flood has occurred in the Ganges, Brahmaputra and Meghna River basins. Especially, the rainfall in the Northeastern Region was 1.5 times of the normal year. The water level of the Surma and the Kushiyra Rivers located in the upper Meghna River basin, was higher than the dangerous water level for 2 to 10 days due to the rainfall on April 11. Then the agricultural productions suffered due to the huge damage. Number of affected person in Bangladesh[4)]: 74.7 million people
2007	The floods have occurred on June 24 and September 5. <u>Flood in June</u> Nilphamari and Kurigram districts along the Jamuna River located at the Northern region, were damaged. Sylhet and Sunamganj districts along the Surma River were damaged. <u>Flood in September</u> The inundation ratio along the Jamuna River became 60 to 80%. The inundation ratio in Sunamganj District was 15 to 30%. And the inundation ratio at the other districts along the Surma River was 0 to 15%. The flood damage along the Jamuna River was bigger. Number of affected person in Bangladesh[4)]: 28.5million
2010	Continuous heavy rainfall has occurred at Sylhet and Sunamganj districts from March 30 to April 10. It brought a lot of rain at the Kushiyara, Sari-Gowain, and Piyain Rivers. Flash flood has occurred in June. Flood damage has occurred at Netrakona and Sunamganj and Kishoreganj. The rivers from Assam area and Meghalaya Hill were flooded continuously for two weeks.

1) Bangladesh Compendium of Environmental Statistics (BBS, 1999), 2) BWDB and BBS ,3) Centre for Research on Epidemiology of Disasters、4)Ministry of Disaster Management and Relief,
Source: Prepared by the JICA Study Team based on the "Preparatory Study for Planning on Meghna River Basin Management , March 2011, JICA"

The extent of inundated areas per year in Bangladesh is shown in **Table 2.4.2**.

Table 2.4.2 Inundation Area in Bangladesh

Year	Inundation Area		Year	Inundation Area		Year	Inundation Area	
	km^2	%		km^2	%		km^2	%
1954	36,800	25	1975	16,600	11	1995	32,000	22
1955	50,500	34	1976	28,300	19	1996	35,800	24
1956	35,400	24	1977	12,500	8	**1998**	**100,250**	**68**
1960	28,400	19	1978	10,800	7	1999	32,000	22
1961	28,800	20	1980	33,000	22	2000	35,700	24
1962	37,200	25	1982	3,140	2	2001	4,000	2.8
1963	43,100	29	1983	11,100	7.5	2002	15,000	10
1964	31,000	21	1984	28,200	19	2003	21,500	14
1965	28,400	19	1985	11,400	8	**2004**	**55,000**	**38**
1966	33,400	23	1986	6,600	4	2005	17,850	12
1967	25,700	17	**1987**	**57,300**	**39**	2006	16,175	11
1968	37,200	25	**1988**	**89,970**	**61**	**2007**	**62,300**	**42**
1969	41,400	28	1989	6,100	4	2008	33,655	23
1970	42,400	29	1990	3,500	2.4	2009	28,593	19
1971	36,300	25	1991	28,600	19	**2010**	**26,530**	**18**
1972	20,800	14	1992	2,000	1.4	2011	29,800	20
1973	29,800	20	1993	28,742	20	2012	17,700	12
1974	52,600	36	1994	419	0.2			

Source: Annual Flood Report 2012, FFWC, BWDB

The water level by monsoon flood gradually rises. Therefore, no lives are lost by monsoon floods. However, the properties, agricultural production, employment circumstance and hygienic environment are damaged because flood spread in wide areas from the topographical point of view.

The water level by flash flood suddenly rises. The damage caused by flash floods in the haor area during the pre-monsoon season can be considered as direct. It damaged the boro rice production, submergible embankment and houses through inundation. The most serious damage is on the boro rice production. Other data on flood damages could not be collected.

Flood damage on the boro rice production is summarized in the “Preparatory Survey on Cooperation Program for the Disaster Management in Bangladesh, July 2012, JICA”. The data on flood damage was compiled on a regional area basis in the Yearbook of Agricultural Statistics of Bangladesh published by Bangladesh Bureau of Statistics (BBS).

In this Study, the flood damage on the boro rice production from 2009 to 2010 was collected on a district basis from BBS, as compiled in **Table 2.4.3**. It was confirmed that the district basis flood damage data before 2009-2010 was not available from the BBS office and other related agencies.

No information on flood marks has been collected from the existing documents related to flood events in the haor area. In the river structure inventory survey, the flood marks and water levels were checked through information from village people as mentioned in Section 4.3.

Table 2.4.3 Flash Flood Damage on Boro Rice

(1) Local Boro Rice

District	Area (Fully Damaged) (ha)	Area (Partially Damaged) (ha)	Percentage of Full Damage in Partial Damage (%)	Area (Full Damage in Partial Damage) (ha)	Damaged Total Area (ha)	Expected yield (Million ton)/(ha)	Total Production Loss (Million Ton)
Shylet	5,213	6,699	47.94	3,212	8,424	1.69	14,259
Moulvibazar	0	0	0.00	0	0	0.00	0
Sunamganj	16,132	14,076	41.94	5,903	22,035	1.75	38,658
Habiganj	0	194	55.00	107	107	1.47	157
Sub-total	21,345	20,969	43.98	30,566	30,566	1.74	53,074
Kishorganj	97	43	36.33	113	113	1.92	216
Netrokona	316	0	0.00	317	317	1.93	609
Sub-total	412	43	36.33	428	428	1.93	825
Total	21,757	21,012	43.96	30,995	30,995	1.74	53,899

(2) High Yield Variety Boro Rice

District	Area (Fully Damaged) (ha)	Area (Partially Damaged) (ha)	Percentage of Full Damage in Partial Damage (%)	Area (Full Damage in Partial Damage) (ha)	Damaged Total Area (ha)	Expected yield (Million ton)/(ha)	Total Production Loss (Million Ton)
Shylet	8,649	5,087	54.83	2,789	11,438	2.63	30,130
Moulvibazar	0	0	0.00	0	0	0.00	0
Sunamganj	33,603	10,128	47.64	4,825	38,428	2.99	114,986
Habiganj	223	486	60.00	291	514	3.23	1,662
Sub-total	42,474	15,700	50.35	7,905	50,379	2.91	146,775
Kishorganj	12,093	17,008	33.82	5,917	17,846	3.91	69,744
Netrokona	15,996	5,101	51.91	2,648	18,644	3.66	68,255
Sub-total	28,098	22,109	38.00	8,401	36,490	3.78	137,999
Total	70,564	37,809	43.12	16,306	86,870	3.28	284,774

(3) Hybrid Boro Rice

District	Area (Fully Damaged) (ha)	Area (Partially Damaged) (ha)	Percentage of Full Damage in Partial Damage (%)	Area (Full Damage in Partial Damage) (ha)	Damaged Total Area (ha)	Expected yield (Million ton)/(ha)	Total Production Loss (Million Ton)
Shylet	0	0	0.00	0	0	0.00	0
Moulvibazar	0	0	0.00	0	0	0.00	0
Sunamganj	0	0	0.00	0	0	0.00	0
Habiganj	0	0	0.00	0	0	0.00	0
Sub-total	0	0	0.00	0	0	0.00	0
Kishorganj	3,613	4,427	37.05	1,640	5,253	4.40	23,127
Netrokona	1,672	69	40.00	28	1,700	4.58	7,791
Sub-total	5,285	4,496	37.09	1,668	6,953	4.45	30,918
Total	5,285	4,496	37.09	1,668	6,953	4.45	30,918

(4) Total

District	Area (Fully Damaged) (ha)	Area (Partially Damaged) (ha)	Percentage of Full Damage in Partial Damage (%)	Area (Full Damage in Partial Damage) (ha)	Damaged Total Area (ha)	Expected yield (Million ton)/(ha)	Total Production Loss (Million Ton)
Shylet	13,861	11,785	50.92	6,001	19,862	2.23	44,389
Moulvibazar	0	0	0.00	0	0	0.00	0
Sunamganj	49,735	24,204	44.32	10,728	60,463	2.54	153,641
Habiganj	223	680	58.57	398	621	2.93	1,819
Sub-total	63,819	36,669	46.71	17,127	80,946	2.47	199,849
Kishorganj	15,803	21,479	34.49	7,409	23,212	4.01	93,087
Netrokona	17,984	5,169	51.75	2,675	20,659	3.71	76,655
Sub-total	33,786	65,859	37.84	10,084	43,871	3.87	169,742
Total	97,605	63,317	42.98	27,211	124,817	2.96	369,591

Note: sub-total means total value of each region, 2009/2010 data
Source：BBS　(Translation from Bengal language)

CHAPTER 3 REVIEW OF STUDY APPROACH TAKEN IN FORMULATION OF THE M/P

3.1 Organization of Working Group

The Working Group (WG) was organized in the initial stage of the first work in Bangladesh for efficient and smooth practice of the M/P review. The WG is composed of members from BWDB, which is expected to be the project executing agency, CEGIS, which actually joined in the formulation of the M/P as a consultant, and the Study Team. The operational guideline for the WG was prepared, as referred to in **Annex 3.1.**

During the first work in Bangladesh, three WG meetings were held in the BWDB central office, Dhaka, on 10 and 23 December 2012 and 14 January 2013, respectively.

The Study Team explained the purpose, members, activities and final outputs of the WG, among others, by using the said operational guideline at the first WG meeting to share the same understanding and information about the WG among the members.

3. 2 Findings on Study Approach Taken in Formulation of the M/P

(1) General Study Approach for Water Resources Sector in Haor Area

In the haor area, one of the major problems related to water resources management is flooding due to flash floods during the pre-monsoon season, which starts either at the end of April or beginning of May. The traditional measure for protection is construction of submergible low height embankment which protects crops from the immediate surge of flash floods. In the M/P, integrated solutions have been derived from engineering solutions based on the flooding characteristics in the haor area and from the perception of the local people upholding ecological sustenance in the area.

The primary approach to the solutions is as stated below.

1) Flood depth maps were prepared through the following procedures:
   - (a) Identification of critical time periods of highest water levels derived from hydrological analysis,
   - (b) Collection of flood depths in the floodplains of haor areas at the critical periods through previous study and field verification, and
   - (c) Preparation of flood depth maps using the established relation with critical periods for agriculture practices.
2) Based on the flood depth maps, new engineering but eco-friendly hydraulic structures were proposed or existing practices were proposed to be continued through managing or restraining the flood levels at a reasonable extent.
3) The design parameters of existing submergible embankments were reviewed. Then, suggestions or recommendations were made for better O&M and strengthening of existing structures.
4) Infrastructure requirements were identified, following the participatory process. Initially, the infrastructure requirements and location plan were framed out, identifying problems through physical investigation and consultation with stakeholders.

5) Drainage management including dredging and restoration of khals and beels was addressed to maintain/improve the connectivity between haors and rivers. The infrastructure requirements were assessed from technical, social and environmental standpoints, which were identified and verified though stakeholder consultation meetings.

Regarding the 3) above, the M/P discusses that the strategy for plan formulation should place importance to (i) resectioning of existing submergible embankments and also (ii) the (a) to (d) below for strengthening of the O/M of existing structures:

(a) To ensure adequate budget by line agencies,

(b) To ensure adequate logistic support (transportation, computers, etc.) for such field activities as monitoring and supervision,

(c) To ensure adequate manpower by filling vacant posts in BWDB and recruiting new professionals, and

(d) To arrange training of stakeholders, including promotion of people’s participation.

This discussion in the M/P is fairly assessed to address a crucial point, in consideration of the following:

(i) In reality, not a few existing submergible embankments have aggravated a steep slope problem resulting from lack of appropriate repair/maintenance after slope failure/erosion due to flowing water attack and flood overtopping, although the BWDB’s design manual stipulates that the design slope of submergible embankment be 1:3.0.

(ii) The (a) to (d) above keenly point out the vital issues the current O/M practices have been facing.

(2) Study Approach of Individual Project Identified for Water Resources Sector in Haor Area

The study approach taken to formulate the WR01, WR02, WR03 and WR05 projects which have been identified in the M/P for water management in the haor area was confirmed, as explained below, in the WG meetings and through repeated discussions between the Study Team and CEGIS.

Stage-1: During preparation of the M/P, public consultation meetings (PCMs) were organized at upazila level (69 upazilas) to identify the problems, issues and possible remedial measures. The public consultation meetings were held in the presence of various stakeholders from each upazila. Almost 29 issues were discussed there, out of which 20 issues had been predetermined and 9 were incorporated through consultation meetings. In addition, the FAP (Flood Action Plan)-6 report and other relevant documents were reviewed to identify potential projects for the haor area. The 29 issues of the PCMs are as tabulated below:

▪ Water resources	▪ Graveyards and cremation grounds
▪ Water sharing	▪ Food godowns and cold storage
▪ Agriculture	▪ Mini hydropower

▪ Fisheries	▪ Solar power and fuel
▪ Pearl culture	▪ Tourism, settlements and public security
▪ Livestock	▪ Usage of water
▪ Social forestry	▪ Sanitation
▪ Biodiversity	▪ Industrial developments
▪ Livelihood	▪ Sports and culture
▪ Employment opportunity	▪ Social welfare
▪ Transportation	▪ Gender concerns
▪ Education	▪ Institutional infrastructure
▪ Health	▪ Natural disasters and climate change
▪ Market facility	▪ GO/NGO project interventions
▪ Religious institutions	

Stage-2: After the PCMs, the results were integrated and 15 issues were found very important for the haor area, which are as tabulated below:

▪ Flash flood	▪ Indiscriminate harvest of natural resources
▪ Siltation and sedimentation of major rivers	▪ Over exploitation of fisheries resources and swamp forest
▪ River bank erosion and wave erosion	▪ Weakness in leasing system for fisheries
▪ Reduction of navigability	▪ Illiteracy
▪ Lack of proper sanitation	▪ Poverty
▪ Scarcity of drinking water	▪ Inadequate health facilities
▪ Fragile and inadequate road network	▪ Inadequate O&M of existing infrastructure
▪ Degradation of Eco-system	

Stage-3: To address the issues, these were classified into 17 Development Areas (DAs). The problems and issues of water resources constitute the basic information required for preparing the proposed projects and schemes. The development areas are:

▪ Water Resources	▪ Mineral Resources
▪ Agriculture	▪ Pearl Culture
▪ Education	▪ Power and Energy
▪ Fisheries	▪ Tourism
▪ Forest	▪ Water Supply and Sanitation
▪ Health	▪ Transportation
▪ Housing and Settlement	▪ Social Services
▪ Industry	▪ Biodiversity and wetland
▪ Livestock	

Stage-4: The Development Areas of water resources-related issues were further classified into 6 categories, taking into account the types and locations of problems. These 6 categories are:

▪ Flash flood	▪ Drainage congestion
▪ River bank erosion	▪ Poor navigability
▪ Wave erosion	▪ Sedimentation

Stage-5: The 6 categories above were then converted into schemes/projects for implementation to solve the issues. The types of measures identified to cope with the issues are:

1) Rehabilitation projects: WR01
2) New development projects:WR02
3) River dredging projects:WR03
4) Protection of the settlements:WR05
5) Study projects*

Note: These study projects were not formulated from PCMs, but they were proposed considering the transboundary situation, climate change and capacity building. The study projects are as compiled below.

Table 3.2.1 List of Study Projects

DA Code	Project title	Key Objective
WR-04**	Development of Early Warning System for Flash Flood Prone Areas in Haor and Dissemination to Community Level	Development of early flash flood warning system and dissemination to the communities
WR-06**	Monitoring of the Rivers in Haor Area	Study of the morphological characteristics of the rivers of the haor areas to identify different types of activities to keep the haor functioning
WR-07***	Impact Study of the Interventions of Transboundary River System	Assessment of the impact of any type of intervention at upstream of international boundary
WR-08**	Study of the Climate Change Impact of Haor Areas	Climate change impact study on haor areas
WR-09***	Strengthening and Capacity Development of BHWDB	Organizational Development Plan and Capacity Development of BHWDB

Note: *** Very High Priority, ** High Priority
Source: JICA Study Team

After Stage-5, the study approach, as detailed below, was pursued for respective projects, excluding the study projects.

1) WR01: Pre-monsoon Flood Protection and Drainage Improvement in Haor Areas

Stage-1: BWDB is the main organization for maintenance and implementation of water resource projects in Bangladesh. Initially, a list of all existing water-related scheme/projects in the haor area was compiled. A total of 118 projects/schemes were identified, that include flood control, flood control/drainage and flood control/drainage/irrigation projects. In Stage-1, these projects were identified as candidates for rehabilitation.

Stage-2: In Stage-2, the 52 projects/schemes included in DPP/2011 for rehabilitation were excluded from the projects/schemes identified in Stage-1. The available information on the 66 screened projects were collected to facilitate selection of projects for rehabilitation.

Stage-3: In this stage, the 66 screened projects were considered for selection based on the outputs of WMIP (Water Management Improvement Project). Based on the WMIP outputs and discussions with the BWDB field offices, 25 projects were selected for rehabilitation in due consideration of (i) demand of local people and (ii) opinions of the BWDB field offices. The following are the criteria considered during the discussions with the BWDB field offices:

- Status of existing submersible embankment,
- Status and function of other existing structures,
- Siltation in canals, and

- Connectivity between internal khals and rivers

Stage-4: Finally, the selected 25 projects, as summarized in **Table 3.2.2**, were validated at the Dhaka office in consultation with ADG (O&M), Chief Planning, Planning-1 and senior ex-officials of BWDB as well as other water experts.

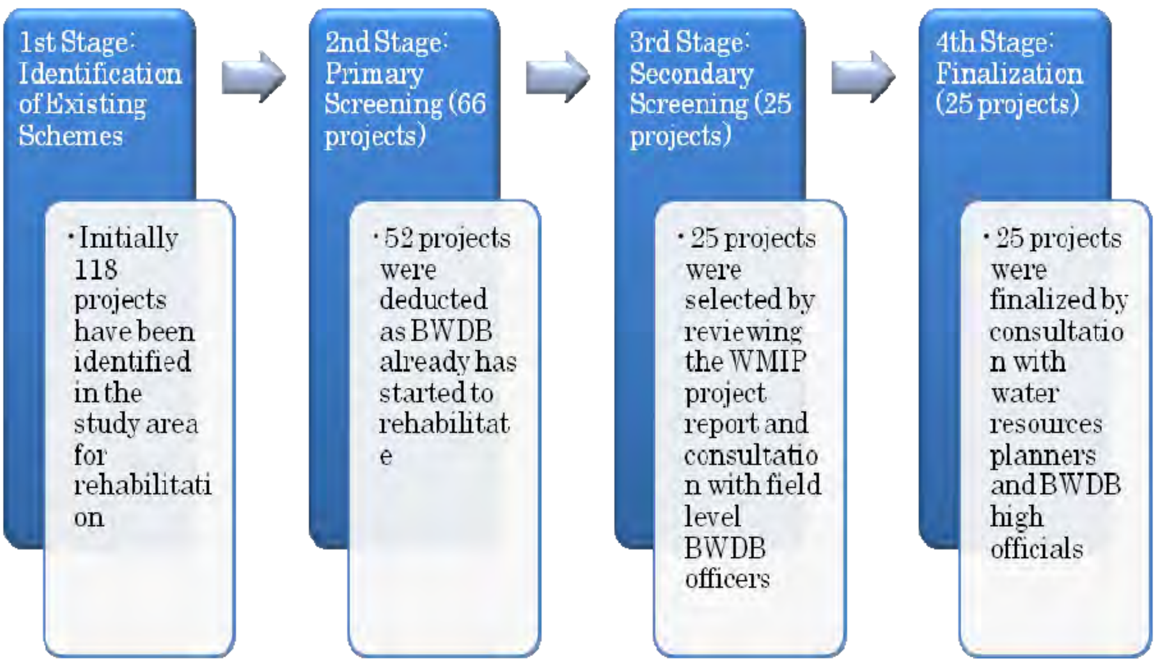
Table 3.2.2 List of Haor Projects Proposed for Rehabilitation in WR01 of Haor Master Plan

No	Project name	Haor	% of Haor*	Status of existing embankment	Status and function of existing structures	Siltation in canals	Connectivity between internal khals and rivers
1	Adampur Sub-Project			No embankment	Fully or Partially damaged	Silted up	No or Seasonal connectivity
2	Alalia Bahadia Sub-Project	Mosti Beel Haor	100	No embankment	Good condition	Partially silted up	Partial connectivity
3	Aralia Khal	Ikram-Sangar Haor	11	No embankment	Partially damaged	Silted up	No or Seasonal connectivity
4	Baraikhali Khal Sub-Project			Full protection embankment with public cut	Fully or Partially damaged	Partially silted up	Partial connectivity
5	Bashira River Re-excavation	Birat Haor	17	No embankment	Fully or Partially damaged	Partially silted up	Partial connectivity
		Boro Ghop Haor	82				
		Brithangol Haor	1				
		Char Katkhal Haor	44				
		Dilhi Akhra Haor	75				
		Kakuar Haor	96				
		Satkandir Haor	86				
		Shibpasha Haor	2				
6	Chandal Beel			Submergible embankment in good condition	Partially damaged	Silted up	No or Seasonal connectivity
7	Charfaradee Jangalia Sub-Project			Submergible embankment in good condition	Partially damaged	Partially silted up	Partial connectivity
8	Dampara Water Management Project			Full protection embankment in good condition	Good condition	Partially silted up	Partial connectivity
9	Ganakkhali Sub-Project	Madhabdi Haor	13	Full protection embankment in good condition	Partially damaged	Partially silted up	Partial connectivity
		Panch Aatiya Beel	100				
10	Gozaria Beel Project	Feualanga Haor	15	Full protection embankment in good condition	Partially damaged	Partially silted up	Partial connectivity
		Nanesshwar Haor	93				
11	Hamhami Chhara Scheme			Full protection embankment in good condition	Partially damaged	Functioning	Partial connectivity
12	Kairdhala-Ratna	Baniachang Puber Haor	4	Submergible embankment with breaching	Partially damaged	Partially silted up	Partial connectivity
		Birat Haor	22				
		Daskhin-Paschimer Haor	14				
		Khagapasha Haor					
		Luxmibaur-Nalair Haor	93				
		Makalkandi Haor	15				
13	Kakon Nadi Scheme			Full protection embankment with breaching	Partially damaged	Functioning	Active
14	Kangsha River Scheme			Full protection embankment in good condition	Partially damaged	Silted up	Partial connectivity
15	Kushiara Bardal Project			Full protection embankment with		Partially silted up	Partial connectivity

No	Project name	Haor	% of Haor*	Status of existing embankment	Status and function of existing structures	Siltation in canals	Connectivity between internal khals and rivers
				breaching			
16	Modkhola Bhairagirchar Scheme			Full protection embankment with breaching	Partially damaged	Partially silted up	Partial connectivity
17	Rahimpur Khal Scheme	Balait Haor-2	20	Full protection embankment in good condition	Good condition	Partially silted up	Partial connectivity
18	Sari Goyain Project	Baurbhag Haor-1 Lakshmi Prashad Haor	62 98	Submergible embankment with breaching	Partially damaged	Silted up	Partial connectivity
19	Satdona Beel Scheme			Submergible embankment in good condition	Partially damaged	Silted up	No or Seasonal connectivity
20	Shaka Borak Project			Full protection embankment in good condition	Good condition	Silted up	No or Seasonal connectivity
21	Sharifpur FCD System			Full protection embankment in good condition	Partially damaged	Functioning	Active
22	Singer Beel Scheme			Full protection embankment with breaching	Good condition	Partially silted up	Partial connectivity
23	Sukaijuri Bathai			Full protection embankment in good condition	Partially damaged	Silted up	No or Seasonal connectivity
24	Tarapasa Premnagar Flood Control Embankment Project			Full protection embankment with breaching		Functioning	Active
25	Thakurakona Sub-Project			Submergible embankment with breaching	Partially damaged	Partially silted up	Partial connectivity

Source: CEGIS
Note: * Share in each haor

Study approach of WR-01:



2) WR02: Flood Management of Haor Areas

Stage-1: In consideration of information about the demands of local people collected from the PCMs and also earlier proposed projects in the haor areas, 39 projects/schemes were newly formulated. The boundary and location of each project/scheme were determined based on Digital Elevation Model (DEM), haor locations and hazard maps.

Stage-2: Out of the 39 projects/schemes, 31 were identified as feasible ones based on expert knowledge, opinions and experiences under the Master Plan of the haor area.

Stage-3: Finally, the identified 31 projects/schemes were validated at the Dhaka office in consultation with ADG (O&M), Chief Planning, Planning-1 and senior ex-officials of BWDB as well as renowned water experts. The identified 31 projects/schemes are as compiled in **Table 3.2.3.**

Table 3.2.3 List of New Haor Projects Proposed in WR02 of Haor Master Plan

No	Scheme name	Haor	% of Haor*	Problems
1	Ayner Gupi Haor	Ayner Gupi Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Fragile and inadequate road network ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure
2	Badla Project	Kataiya Band Haor	42	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Reduction of navigability ▪ Fragile and inadequate road network ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty ▪ Inadequate O&M of existing infrastructure
3	Banaiya Haor	Banaiya Haor	100	▪ River bank erosion and wave erosion ▪ Scarcity of drinking water ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate O&M of existing infrastructure
4	Bansharir Haor	Bansharir Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ Reduction of navigability ▪ Poverty ▪ Inadequate O&M of existing infrastructure
5	Bara Haor	Boro Haor(Netrokona)	62	▪ Flash flood ▪ Reduction of navigability ▪ Lack of proper sanitation ▪ Poverty
		Digli Beel	100	
		Sonadubi Haor	56	
6	Boro Haor(Austagram)	Boro Haor(Austagram)	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Degradation of Eco-system
		Chaudanta Band Haor	100	
		Goradigha Haor	100	
		Mithamain Dhakhin Haor	100	

No	Scheme name	Haor	% of Haor*	Problems
		Pathar Char Bandh Haor	100	▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate health facilities ▪ Poverty ▪ Inadequate O&M of existing infrastructure
7	Boro Haor(Nikli)	Bariar Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Inadequate health facilities ▪ Poverty ▪ Inadequate O&M of existing infrastructure
		Boro Haor(Kishoreganj)	100	
		Kaliain Beel Haor (Borar Haor)	100	
		Kaliar Beel	100	
		Paschimband Haor	100	
8	Chandpur Haor	Chandpur Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Poverty ▪ Inadequate O&M of existing infrastructure
9	Charigram Project	Khunkhuni Haor	46	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Lack of proper sanitation ▪ Fragile and inadequate road network ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate health facilities ▪ Illiteracy ▪ Poverty
10	Chatal Haor	Chatal Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Reduction of navigability ▪ Fragile and inadequate road network ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty ▪ Inadequate O&M of existing infrastructure
11	Dakhshiner Haor	Dakhshiner Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Lack of proper sanitation ▪ Fragile and inadequate road network ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty ▪ Inadequate O&M of existing infrastructure
12	Dhakua Haor	Dhakua Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Reduction of navigability ▪ Lack of proper sanitation ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate health facilities

No	Scheme name	Haor	% of Haor*	Problems
				▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure
13	Dharmapasha Rui Beel	Atla Beel Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty ▪ Inadequate O&M of existing infrastructure
		Chichrar Haor	97	
		Choto Hijla- Baro Hijlar Beel Haor	98	
		Goradoba Haor	11	
		Holdir Haor	94	
		Jaldhara/ Keuti Haor	100	
		Kahilani-Sreekuli Haor	99	
		Kainjar Haor	5	
		Kalianibeel Haor	96	
		Kalnikuri Beel	100	
		Kumuria Beel Haor	100	
		Medar Beel-2 Haor	99	
		Morichapuri Haor	97	
		Naya Beel Haor	98	
		Ruiyer Beel Haor	100	
		Shaldighar Haor	99	
		Soilchapra Haor	100	
		Togar Haor	100	
14	Dubriary Haor	Dubriary Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Lack of proper sanitation ▪ Scarcity of drinking water ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate health facilities ▪ Inadequate O&M of existing infrastructure
15	Dulalpur Haor	Dulalpur Haor-1	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty ▪ Inadequate O&M of existing infrastructure
16	Ganesh Haor	Ganesh Haor	100	▪ Flash flood ▪ Reduction of navigability ▪ Poverty ▪ Inadequate O&M of existing infrastructure
17	Golaimara Haor	Golaimara Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Illiteracy ▪ Poverty
18	Jaliar Haor	Jaliar Haor	100	▪ Siltation and sedimentation of major rivers ▪ Scarcity of drinking water ▪ Poverty
19	Joyariya Haor	Joyariya Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure
20	Korati Beel	Bhusha Kanda Beel Haor	100	▪ Flash flood

No	Scheme name	Haor	% of Haor*	Problems
	Haor	Korati Beel Haor	100	▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Fragile and inadequate road network ▪ Poverty
21	Kuniarbandh Haor	Dulalpur haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure
		Kuniarbandh Haor	100	
22	Mokhar Haor	Mokhar Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Inadequate health facilities ▪ Poverty ▪ Inadequate O&M of existing infrastructure
23	Muktarpur Haor	Muktarpur Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Scarcity of drinking water ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate O&M of existing infrastructure
24	Muria Haor	Muria Haor	100	▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Reduction of navigability ▪ Lack of proper sanitation ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate O&M of existing infrastructure
25	Naogaon Haor	Gopdighi Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Lack of proper sanitation ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate health facilities ▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure
		Madhainagar haor	100	
		Mithamain Uttar Haor	100	
		Naogaon Haor	100	
26	Noapara Haor	Bhatibaratia Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Fragile and inadequate road network ▪ Poverty ▪ Inadequate O&M of existing infrastructure
		Noapara Haor	100	
27	Nunnir Haor	Bullar Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and
		Guja Haor	100	
		Gurai Haor	100	
		Jaraitala Haor	100	
		Nunnir Haor	100	

No	Scheme name	Haor	% of Haor*	Problems
				swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty ▪ Inadequate O&M of existing infrastructure
28	Rautir Haor	Rautir Haor	100	▪ Flash flood ▪ Reduction of navigability ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Inadequate O&M of existing infrastructure
io	Sarishapur Haor	Goyila Halda haor Lahundi Haor Sarishapur Haor	100 100 100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ River bank erosion and wave erosion ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure
30	Shelnir Haor	Shelnir Haor	100	▪ Siltation and sedimentation of major rivers ▪ Lack of proper sanitation ▪ Degradation of Eco-system ▪ Indiscriminate harvest of natural resources ▪ Over exploitation of fisheries resources and swamp forest ▪ Weakness in leasing system for fisheries ▪ Poverty
31	Sunair Haor	Sunair Haor	100	▪ Flash flood ▪ Siltation and sedimentation of major rivers ▪ Reduction of navigability ▪ Illiteracy ▪ Poverty ▪ Inadequate O&M of existing infrastructure

Note: * Share of each haor

Study approach of WR-02:

3) WR03: River Dredging and Development of Settlement

Stage-1: The haor area has two major river systems; namely, the Surma-Baulai-Gorautra and the Kalni Kushiyara river systems. These two river systems with their tributaries have been carrying sediment load into the haor area from India. In 2011, river dredging was initiated in the Kalni-Kushiyara river system by BWDB under their development project. Therefore, only the Surma-Baulai-Gorauttara river system with its tributaries was considered in the dredging plan of the M/P.

Stage-2: The Northeast Regional Water Management Plan and other relevant documents were reviewed to identify the potential rivers for dredging in the haor area. In the NE Water

Management Plan, 20 river systems were proposed for dredging. These rivers are the Baida, Baulai, Chamti, Darai, Dhalai, Dhaleswari, Dhanu, Gora Utra, Jadukata, Jalokhali/Dhomali, Kalni, Kushiyara, Meghna, Nawagong, Old Surma, Patnai, Rakti, Someswari, Surma and Titas Rivers. The total length of the rivers is about 845 km.

Stage-3: A total of 125 km long river stretches from the Surma, the Rakti, the Bauli and the Katakhal in the Surma-Baulai-Gorauttara river system was selected for dredging based on the following criteria:

- Navigational purpose,
- Flood reduction effect,
- New construction and extension of village platforms, and
- Expediting avulsion process of the river systems

Table 3.2.4 Proposed Dredging Plan in Haor Master Plan

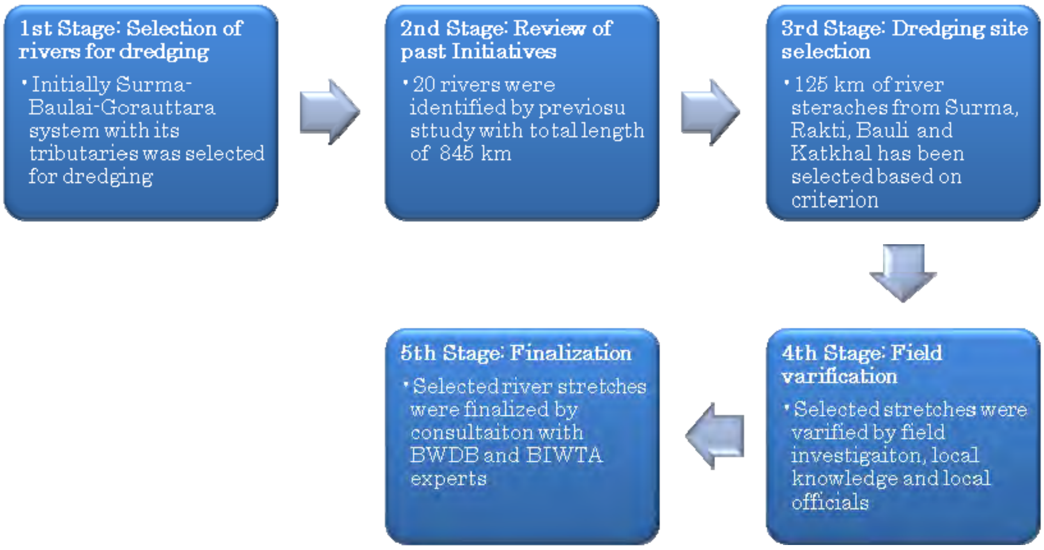
No	River name	District	Upazila	Length (km)	Selection Criteria
1	Surma	Sunamganj	Dowarabazar	5.1	▪ Navigational purpose
				3.8	
				5.9	
			Sunamganj Sadar	9.5	
		Sylhet	kanaighat	5.8	▪ Dry season flow diversion
				4.5	
				6.5	
			Sub-total	41.1	
2	Rakti	Sunamganj	Jamalpur	8	▪ Navigational purpose
			Sub-total	8	
3	Baulai	Sunamganj	Dharampasha	4.3	▪ Navigational purpose
		Netrakona	Khaliajuri	18.7	▪ Navigational purpose ▪ Flood reduction ▪ Creation of new or vertical and lateral extension of village platform
				4.4	
				4.4	
			Itna	4.7	
				8.5	
			Mithamain	6	
				4.5	
				7	
			Sub-total	62.5	
4	Katkhal channel	Kishoreganj	Mithamain	12.79	▪ Navigational purpose ▪ Flood reduction ▪ Creation of new or vertical and lateral extension of village platform ▪ Expediting the avulsion process of the river systems
			Sub-total	12.79	
	Grand Total(Surma+Baulai+Katkhal)			124.39	

Source: Technical papers prepared by CEGIS (February 2013)

Stage-4: The selected river stretches were verified through field investigation, public consultation meetings and knowledge sharing with the local BIWTA and BWDB officials.

Stage-5: The selected river stretches were finalized by consulting with BIWTA and BWDB officials, senior ex-officials and water experts at the Dhaka offices.

Study approach of WR-03:



4) WR05: Village Protection against Wave Action of Haor Area

Stage-1: During flash floods in the pre-monsoon season, high velocity waves have hit the settlements of the haor area. The wave action is one of the main reasons of erosion in the deeply flooded haor area. Initially, deeply flooded and erosion prone settlement areas were identified by using high resolution Cartosat satellite images of the haor area and through field visit.

Stage-2: Information about the wave action, intensity, duration, magnitude, erosion prone areas, etc. was collected. Furthermore, existing housing practices, protection measures, etc. were also investigated through field survey.

Stage-3: PCMs were conducted in the haor areas to seek solutions from the stakeholders in different locations and to preliminarily identify locations for green belt development/new settlement platforms and existing wave protection measures such as revetment works, wave protection walls, etc.

Stage-4: Consultation with the BWDB field offices (Executive and Sub-divisional Engineers) was made to reflect their knowledge/experiences/ideas/opinions for selection of vulnerable locations and appropriate protection measures.

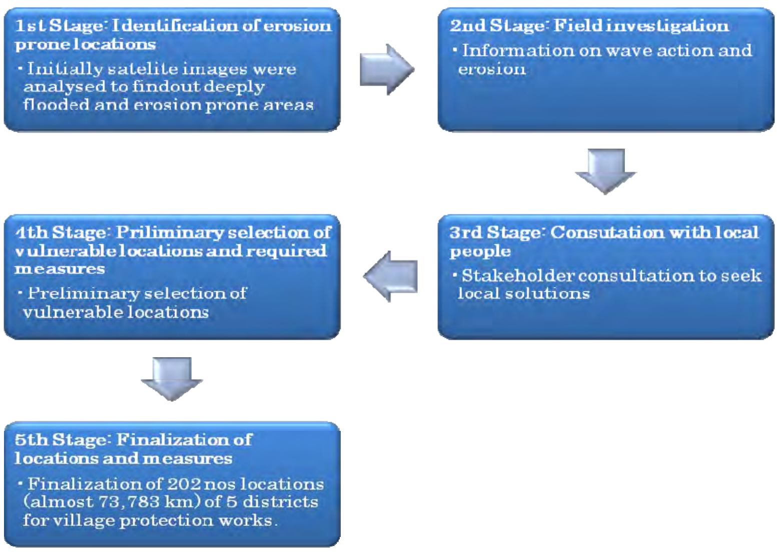
Stage-5: Finally, the locations and respective measures were validated, as referred to in **Table 3.2.5**, at the Dhaka office in consultation with ADG (O&M), Chief Planning, Planning-1 and senior ex-officials of BWDB as well as water experts.

Table3.2 5 Locations of Village Protection Work Identified in Haor M/P

District name	Upazila	Number of village locations	Length (M)
Brahamanbaria	Nasirnagar	6	3,216
	Sarail	1	544
	Total (Brahamanbaria)	**7**	**3,760**
Habiganj	Lakhai	1	2,317
	Total (Habiganj)	**1**	**2,317**
Kishoreganj	Austagram	11	5,019
	Bajitpur	11	4,823
	Bhairab	1	270
	Itna	16	6,204
	Karimganj	3	940
	Mithamain	5	2,596
	Nikli	11	2,583
	Tarail	1	500
	Total (Kishoreganj)	59	22,935
Netrakona	Khaliajuri	5	2,910
	Total (Netrakona)	**5**	**2,910**
Sunamganj	Bishwambarpur	2	704
	Derai	4	1,112
	Dharampasha	69	23,083
	Jagannathpur	1	381
	Jamalganj	43	13,558
	Sulla	9	2,137
	Tahirpur	2	886
	Total (Sunamganj)	**130**	**41,861**
Grand Total		**202**	**73,783**

Source: Technical papers prepared by CEGIS (February 2013)

Study approach of WR-05:



(3) Review of data and analysis results used for the M/P formulation

In selection of a cluster of subprojects for the respective projects indentified in the M/P for water resources sector of the vast haor area, data and information tabulated below were used, particularly so as to fully examine the importance and urgency of subproject implementation at selected sites.

Identified Projects	Data/information used in selection of subprojects
WR01	• Information about 66 screened projects (location, type: FC/FCD/FCDI, project area, benefited area: irrigation/drainage/flood control, project components: length of embankment/crest level of embankment/earth work/ location and dimension of regulator/pipe sluice/culvert/sluice/clouser/ navigation lock/inlet/cross dam/pump number/tube-well number/low lift pump number/location of public cut/length and type of protection work, etc.) • WMIP outputs ▪ Drainage condition of existing khals and reason of congestion, ▪ Water logging area identification in pre-monsoon and post-monsoon , ▪ Functionality of existing structures, ▪ Functionality of water management groups, ▪ Requirement of re-section of embankment, location of public cut and reasons, ▪ River ban erosion, etc. • Outcomes of PCMs
WR02	• Outcomes of PCMs • DEM for delineation of project area boundaries
WR03	• North East Water Management Plan (FAP6) • Satellite image (Landsat, IRS, Google images)
WR05	• Satellite image (IRS, Cartoset) • Wave action (intensity, duration, magnitude, erosion-prone areas) • Outcomes of PCMs

Source: Technical papers prepared by CEGIS (April 2013)

Besides, land use data and past serious flood records, which have been analyzed and compiled as referred to in the **Figures 3.2.1** to **3.2.4**, were used in the subproject selection:

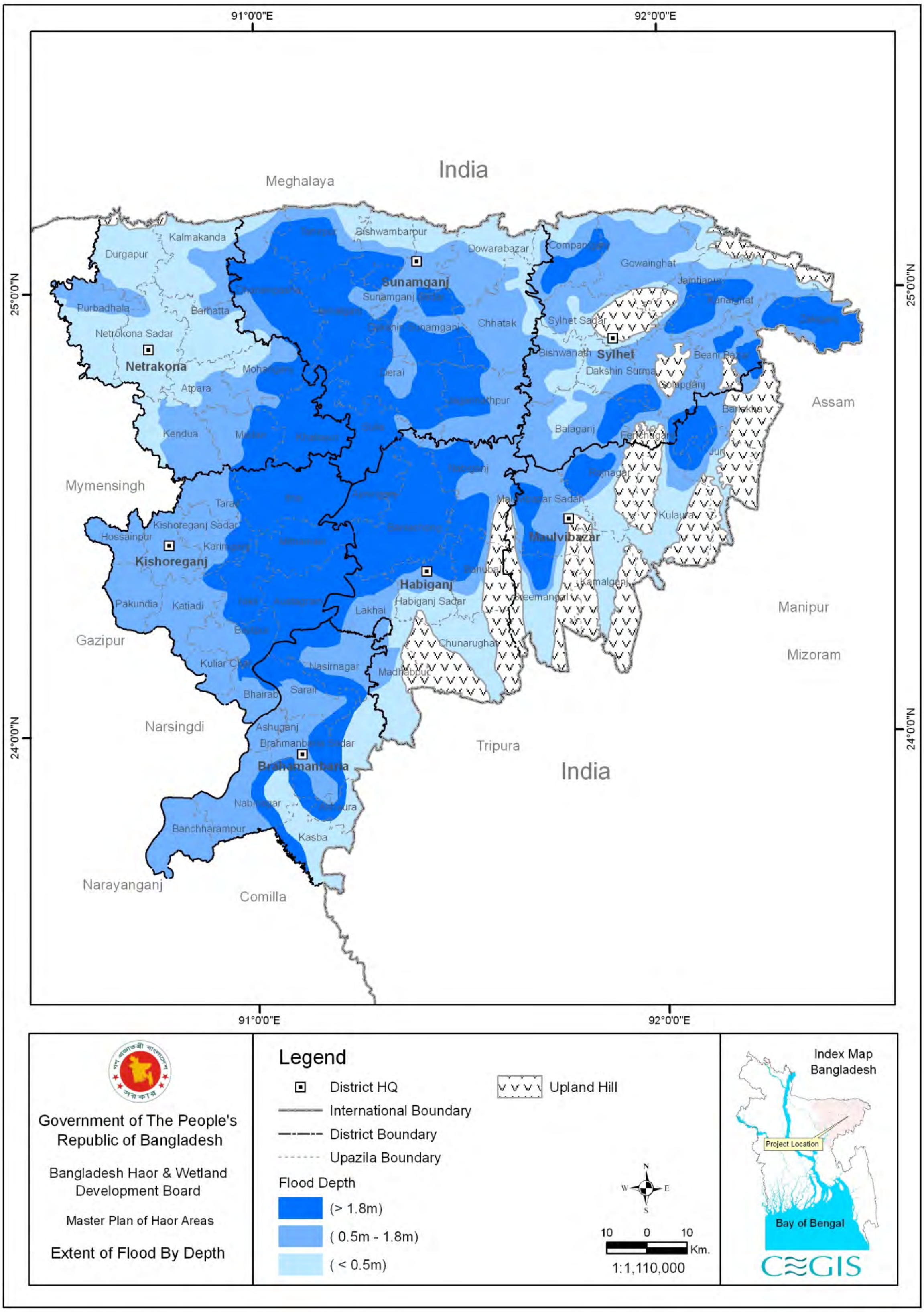
1) Figure 3.2.1 Extent of Flood by Depth (Oct. 1998 Flood)
2) Figure 3.2.2 Hazard Map, Flash Flood
3) Figure 3.2.3 Cropping Pattern
4) Figure 3.2.4 Land Zone

After the selection, the M/P formulation process worked out design of subprojects at a master plan level. The design work was carried out referring to:

1) Available design of major project structures adopted in existing similar water-related projects, and
2) Past experiences and lessons learned by senior ex-officials of BWDB and renowned water experts.

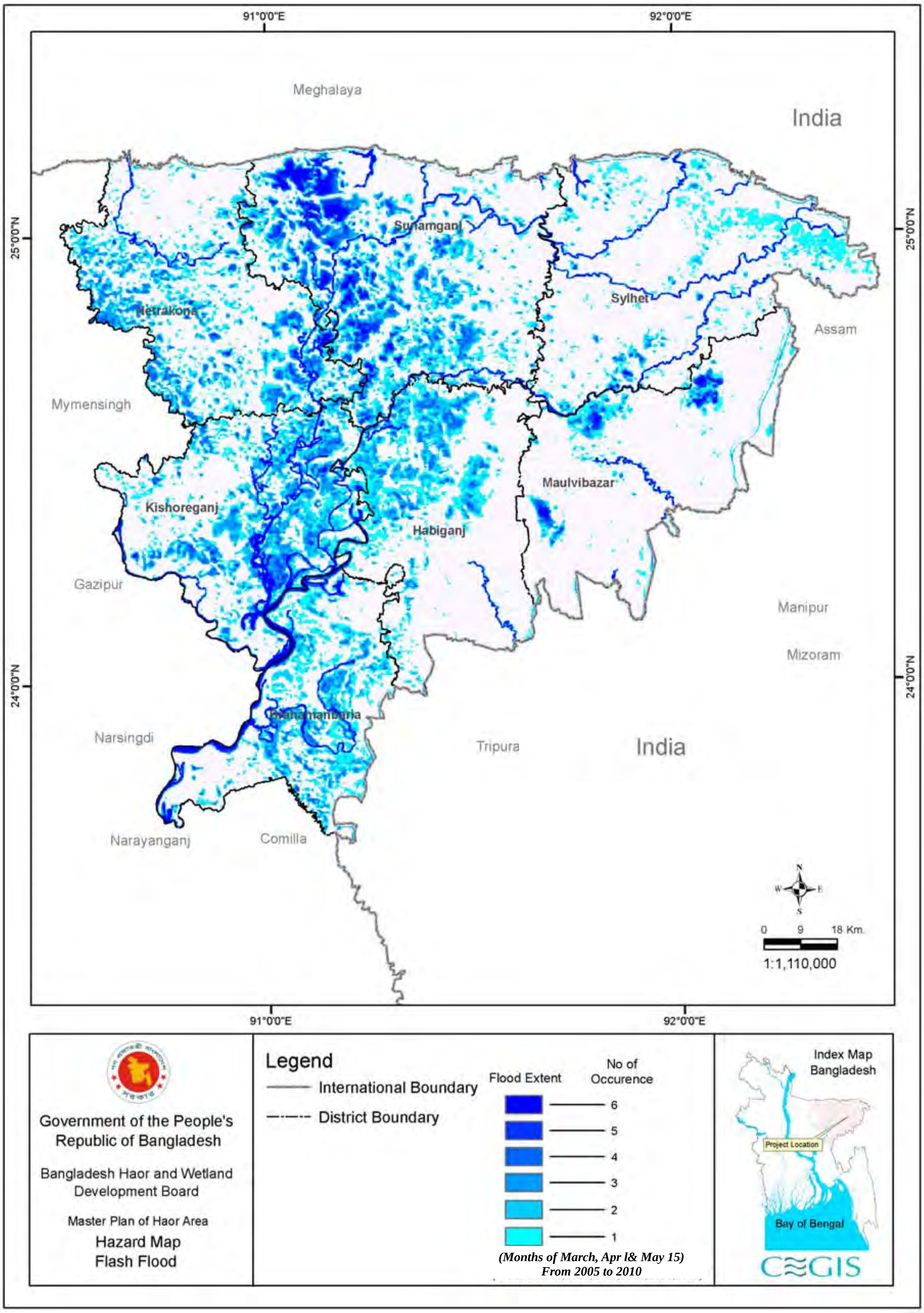
Therefore, it is pointed out that no latest data/information about relevant river cross-sections and foundation soil of planned structure sites was incorporated into the subproject design and no verification of subproject design through flood inundation and riverbed movement analyses was conducted.

In due consideration of the above, it is essential for the Study to examine and/or confirm the soundness and necessity of project through basic study, in particular from a technical point of view, based not only on latest river, topography and foundation soil data to be obtained through the river/topographic survey and geotechnical investigation, but also on hydraulic analysis of flood inundation and riverbed movement, all of which are currently in progress in the Study, in order to successfully achieve the objectives of the Study.



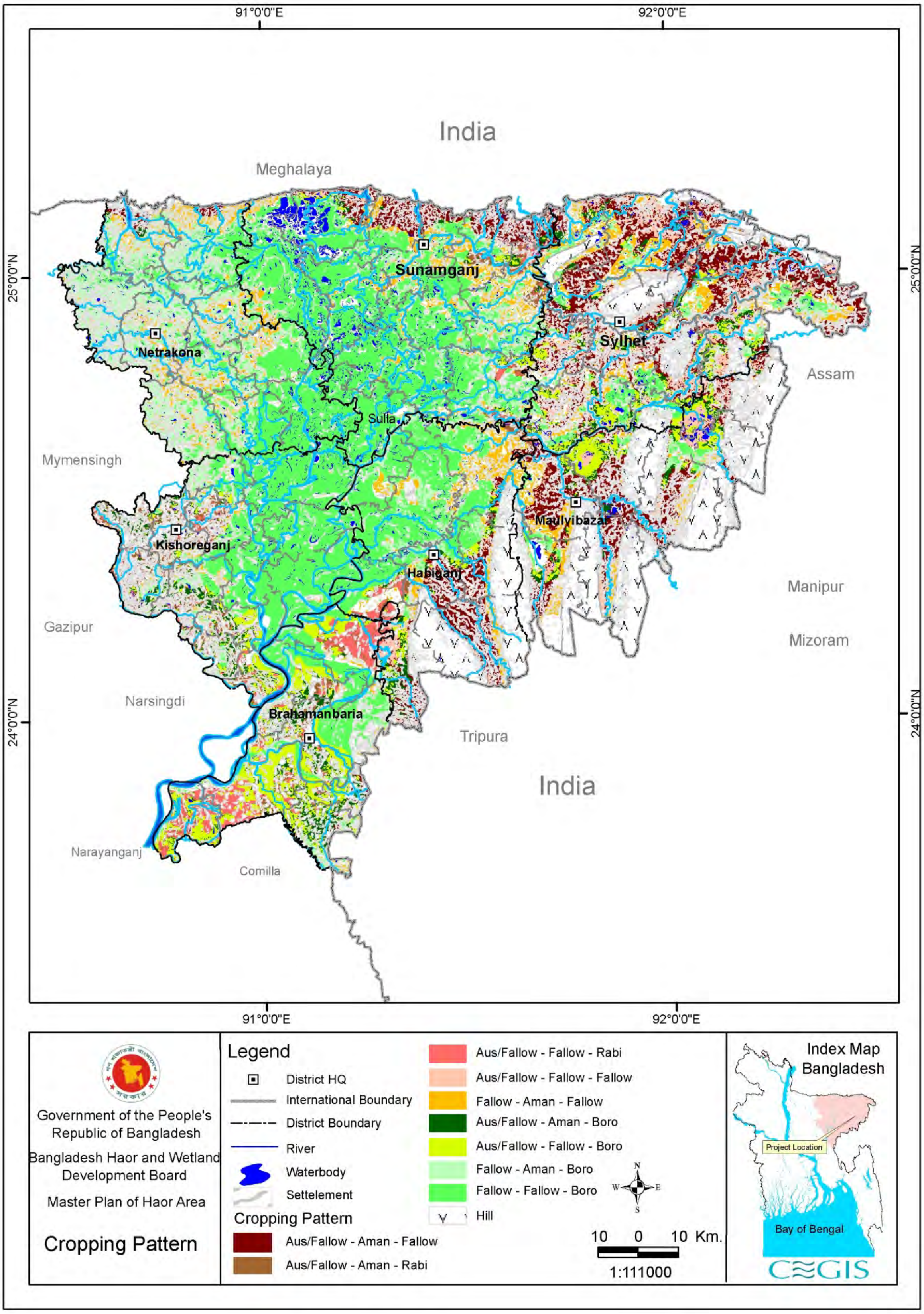
Source: Master Plan of Haor Areas, April 2012
Note: October 1998 Flood

Figure 3.2.1 Extent of Flood by Depth



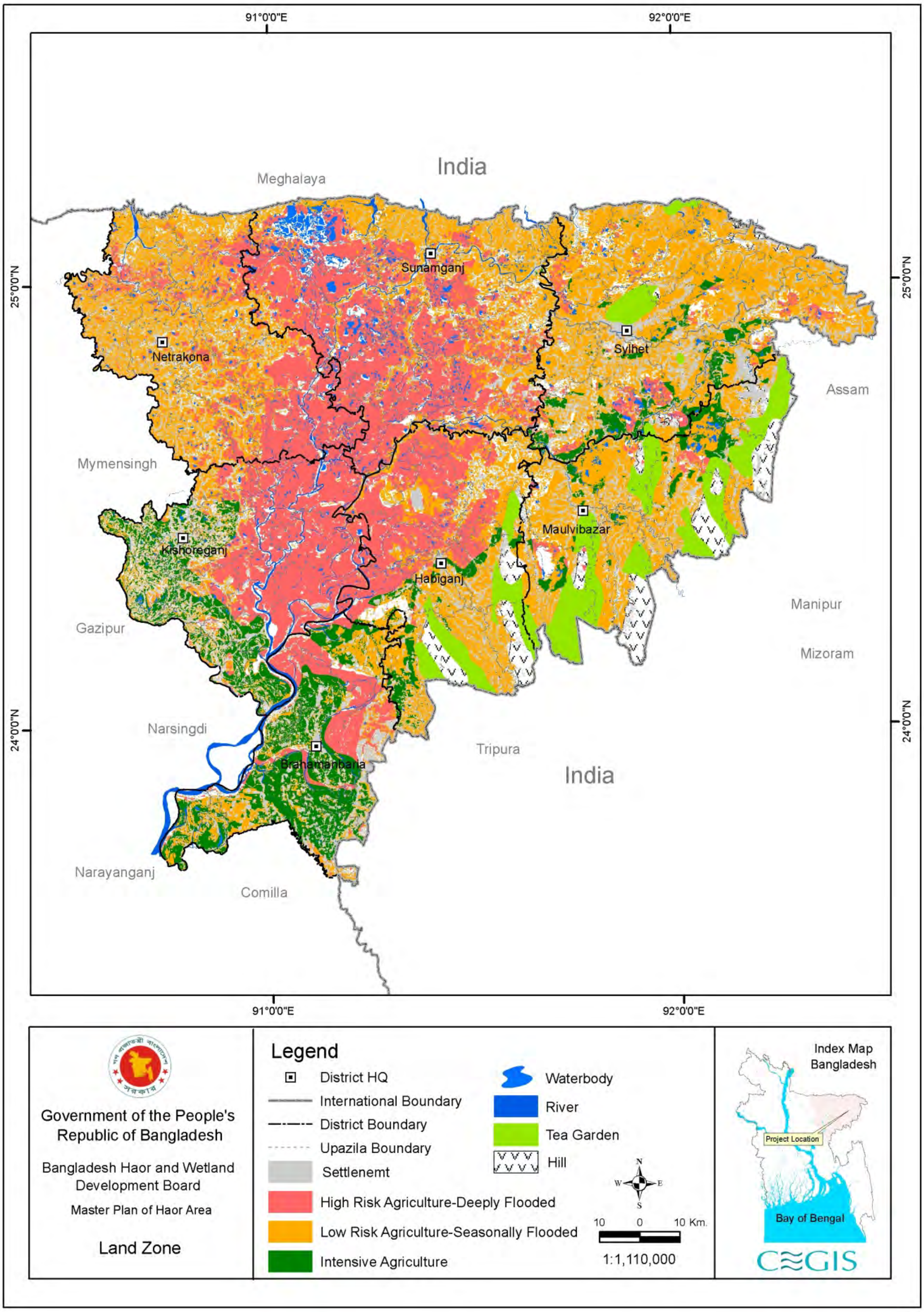
Source: Master Plan of Haor Areas, April 2012

Figure 3.2.2 Hazard Map, Flash Flood



Source: Master Plan of Haor Areas, April 2012

Figure 3.2.3 Cropping Pattern



Source: Master Plan of Haor Areas, April 2012

Figure 3.2.4 Land Zone

CHAPTER 4 FIELD SURVEY AND INVESTIGATION

4.1 River Profile and Cross Section Survey

The river cross sections are required to deal with the following issues in the Study:

1) Flood run-off and inundation analyses,

2) Sediment balance study and riverbed movement analysis, and

3) Structural measures, such as embankment, river bank protection, and dredging.

4.1.1 Data Collection and Review

The relevant information and river cross section survey data were collected from Bangladesh Water Development Board (BWDB) under the Ministry of Water Resources and the Institute of Water Modeling (IWM).

(1) BWDB Data

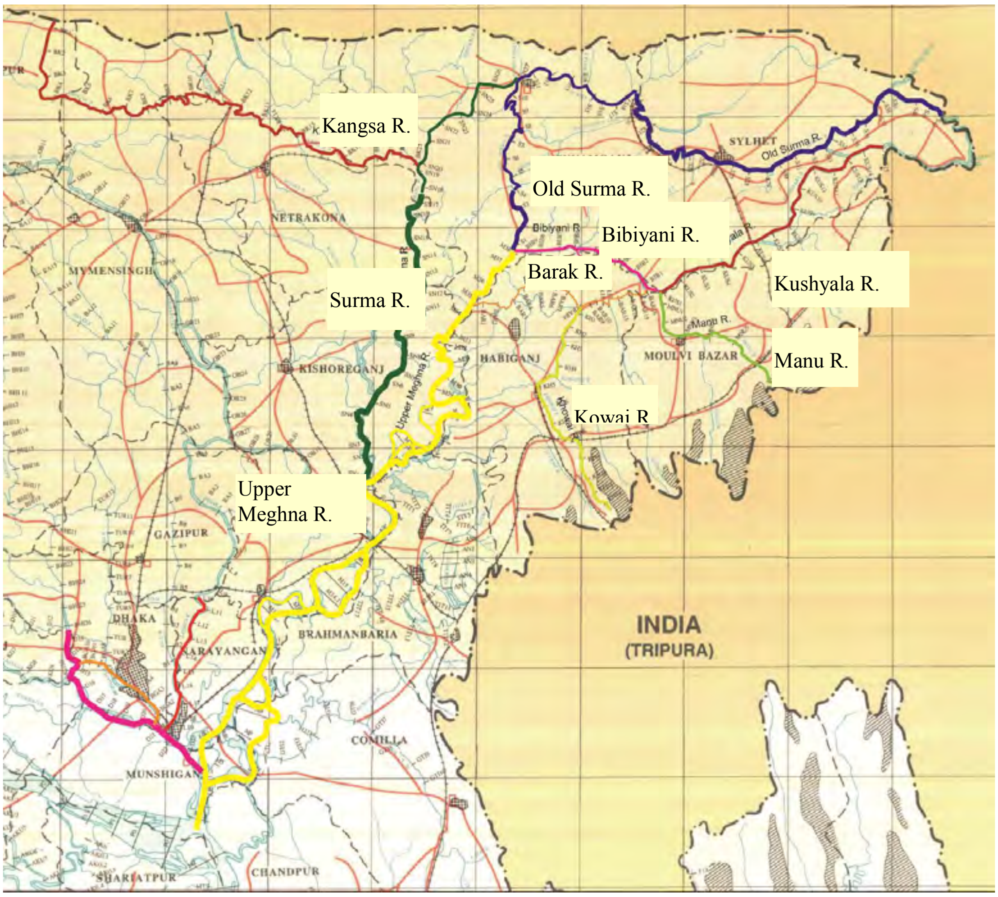
The River Morphology Circle, which belongs to BWDB carries out the river cross section survey of 30 rivers in Bangladesh. The river cross section survey results are checked by the River Morphology Section under the Flood Forecasting and Processing Circle (FFPC), which also belong to BWDB. Finally, the river cross section data are stored in the database of FFPC.

The river cross section data having been surveyed in the Study area by BWDB are listed in **Table 4.1.1** below and the locations of rivers are shown in **Figure 4.1.1**.

Table 4.1.1 River Cross Section Data in Study Area (BWDB)

River Name	Number of Sections	Average River Width	Survey Year
Surma-Baulai River and its tributaries			
Old Surma River	42	600m	S-1~34, 2003, 2005, 2009 S-35~42, 2000, 2003, 2005
Surma R.	27	750m	SN1-19 No Data SN-20~27, 2005, 2007, 2009
Boghai Kangsher River	21	460m	BK-1~5, 2001, 2008 BK-6~21, 2001, 2006, 2008
Meghna River			
Upper Meghna River	21	4,360m	1999, 2000, 2002, 2003, 2005, 2006, 2008, 2009
Kalni-Kushyara River and its tributaries			
Kushyara River	15	600m	2004, 2006, 2008
Bibiyana River	9	820m	2002, 2006, 2008
Monu River	7	260m	2002, 2005

Source: JICA Study Team



Source: Flood Forecasting and Processing Circle under the BWDB

Figure 4.1.1 Target Rivers in the Study Area to Undertake River Cross Section Survey by BWDB

These river cross sections related to the hydraulic analysis are compared for chronological change. As a result, the sections of each river listed below can be applied from the historical data. The river cross sections of the Old Surma River and the Kangsa River are shown in **Annex 4.1**.

- Old Surma River 6 sections. S-3, -24, -25, -27,-32,-34
- Kangsa River 7 sections. BK-2, -10, -11, -15,-18,-19, -20

On the other hand, coordination of both bank pillars of cross sections is collected from the River Morphology Circle of BWDB and these data are plotted in the map. Many pillars data are not located at both banks of the rivers.

Finally, the river cross section data in the Study area surveyed by BWDB are not applied to hydraulic analysis due to low reliability.

(2) IWM Data

Data availability of river cross sections in the Study area is confirmed by the IWM. The existing cross section data in the Study area are available from the following studies;

1) Calibration stage of the North East Region Model (NERM) in 2007
2) “Dredging of Surma-Baulai River System, improvement of existing embankments and drainage channel by using mathematical model and state of the art survey technique” in 2012.

The river cross section data that were applied for the calibration of NERM in 2007 are summarized in **Table 4.1.2** as follows:

Table 4.1.2 Applied River Cross Section Data for the Calibration of NERM in 2007

River Name	Survey Year	River Name	Survey Year
Surma River	1991, 1999-2000	Dhanu River	1991-92
Baulai River	2005	Jadukata River	2005
Tributaries of the Surma - Baulai River	2005	Upper Meghna River	2005
Kangsha River	Unknown	Kalkhal Channel	Unknown

Source: IWM

Moreover, IWM has carried out the river cross section survey and preparation of the simulation model in a part of the haor area. The river cross section survey results partly cover the Study area. The numbers of river cross sections that overlapped with the Study area are summarized in **Table 4.1.3**.

Table 4.1.3 Number of River Cross Sections Surveyed by IWM in 2011-12

River Name	Number of Sections
Surma River	17
Baulai River	40
Old Surma River	31
Jadugata River	11

Source: IWM

The area covered by the river cross section survey and the locations of the survey lines are confirmed. It is judged that the survey data are suitable from the above items.

4.1.2 River Profile and Cross Section Survey

The river cross section survey was executed by a local contractor. Al-Mayeda Survey Consultants was selected through the tender process according to the JICA's guidelines.

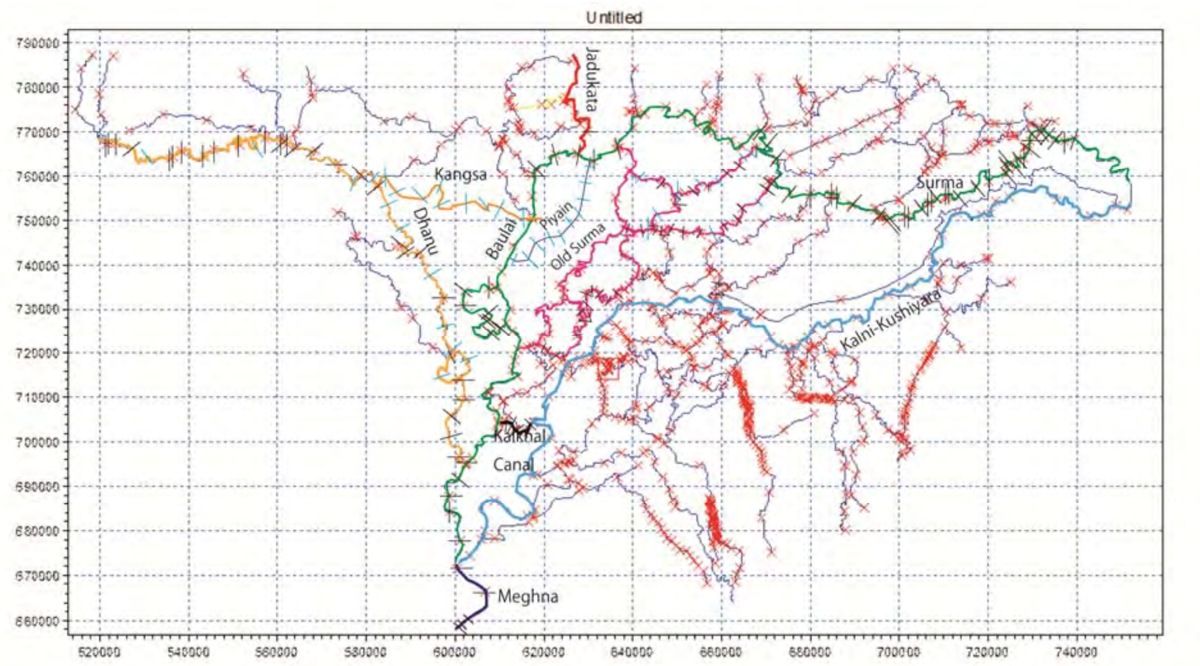
The number of river cross sections to be survey is summarized in **Table 4.1.4**. And location map of rivers to carry out survey work is shown in **Figure 4.1.2**.

Table 4.1.4 Number of River Cross Section to Each River

River Name	Number of Sections	River Name	Number of Sections
Surma-Baulai River	58	Kalkhal Channel	5
Piyain River	10	Upper Meghna River	
Other Tributaries of Surma-Baulai River	40	-Upstream of Bhairab*	5 1)
Kangsha-Dhanu River	50	Total	168

Note:* Bhairab Bazar is located at lower boundary of NERM. Therefore, the upper Meghna River is divided to upper and lower reaches at Bhairab Bazar.

Source: JICA Study Team



Note: Black line is the almost same location of previous survey. Blue line indicates new survey location
Source: JICA Study Team

Figure4.1.2 Survey Location of River Cross Sections

The result of the river cross section survey is shown in Drawings.

4.2 Topographic Survey and Geotechnical Investigation

4.2.1 Topographic Survey

Normally a topographic survey is carried out after the selection of project sites. However, the fieldworks of the topographic survey have to be finished before the rainy season because the project areas are located within the hoar area. Therefore, the topographic survey needs to be started before the selection of priority project sites.

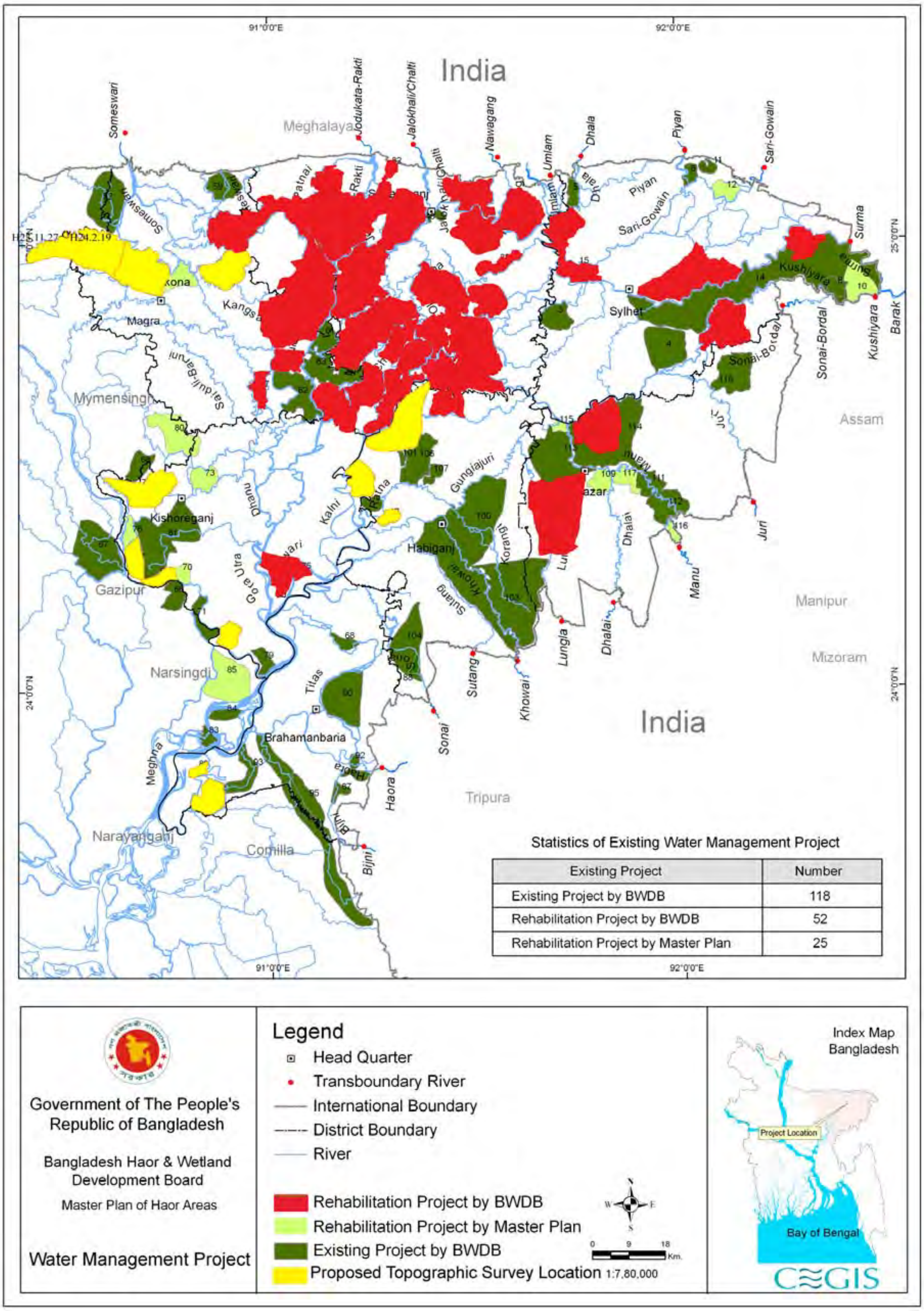
There are 118 haor projects in the Study area, out of which 52 haor projects were decided to carry out rehabilitation works with GOB funding. The remaining haor projects are 66. In the M/P, 25 haor projects are proposed to carry out rehabilitation works. **Table 4.2.1** shows the number of haor projects by category and **Figure 4.2.1** shows the location of each haor project.

Table4.2.1 Number of Haor Projects

Category of Haor Projects	Number
Existing Haor Projects by BWDB	118
Rehabilitation Projects by BWDB	52
Rehabilitation Projects proposed in the M/P	25
Remaining Projects (Not Considered for Rehabilitation)	41

Source: Haor Master Plan

In the M/P, the elevation and dimensions of the existing submergible embankment, regulators, canals, etc. were not investigated. BWDB in Dhaka have no detailed information on the structural drawings and data of damaged structures.



Source: Haor Master Plan,2012

Figure4.2.1 Location Map of Haor Projects

(1) Target Haor Projects of the Topographic Survey

The land use data and past serious flood records were used in the selection of sub-projects. According to **Figures 3.2.1** to **3.2.4**, high frequency of flash flood and only boro crop production areas are widely distributed in Sunamganj, Habiganj, Netrakona, Kishoreganj, and Brhamanbaria districts. When flash flood damage occurs only in the boro crop production areas, it is a serious impact to the farmers in this area as compared with other districts, such as Sylhet and Moulvibazar districts, since there is no crop production. Therefore, the above five districts are given priority and the topographic survey for 16 projects proposed in the M/P were carried out.

On the other hand, the World Bank-financed Water Management Improvement Project (WMIP) is carrying out rehabilitation works in the surrounding area of the haor area. Four projects in the M/P are carried out in WMIP.

Therefore, there are 12 target haor projects for topographic survey as listed in **Table 4.2.2** and the locations of these target haor projects are shown in **Figure 4.2.1**.

Table 4.2.2 Target Haor Projects for Topographic Survey

Name of Haor Project	Selection	Remarks
1. Dampara Water Management Scheme	O	
2. Kangsa River Scheme	O	
3. Takurakona Scheme	X	Under rehabilitation by WMIP
4. Singer Beel Scheme	O	
5. Gazaria Beel Scheme	X	Under rehabilitation by WMIP
6. Baraikhali Khal Scheme	O	
7. Charfaradee-Jangalia Scheme	X	Under rehabilitation by WMIP
8. Alalia-Bahadia Scheme	O	
9. Modkhola Bhairagirchar sub-project Scheme	O	
10. Adampur Scheme	X	Under rehabilitation by WMIP
11. Ganakkhalli Sub-scheme	O	
12. Kairdhala Ratna Scheme	O	
13. Bahira River Scheme	O	
14. Aralia Khal Scheme	O	
15. Chandal Beel Scheme	O	
16. Satdona Beel Scheme	O	

Note: O: Execution of survey works, X: Not execution of survey works
Source: JICA Study Team

(3) New Haor Projects

The problems related to water resources and management in the new haor projects proposed in the M/P were discussed and considered during the public consultation meetings (PCMs) in 66 upazilas. The new haor projects were selected through discussions with the field offices and central office of BWDB. Then, 26 new haor projects were selected as listed in **Table 4.2.3**.

Table 4.2.3 List of New Haor Projects

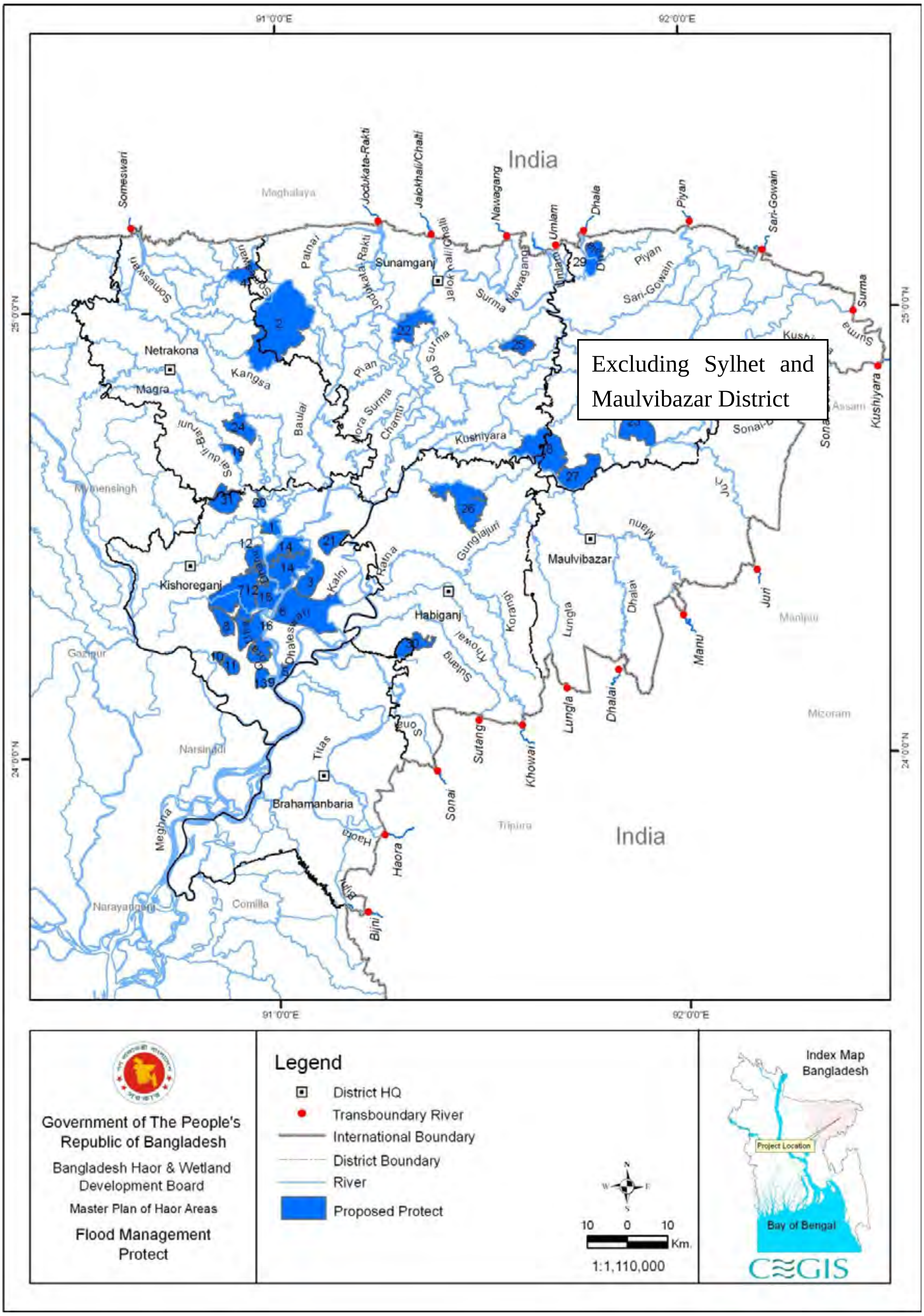
No.	Project Name	No.	Project Name
1	Badla Haor Project (Kishoreganj)	14	Naogaon Haor Project (Kishorganj)
2	Dharmapasha Rui Beel Project (Sunamganj & Netrokona)	15	Noapara Haor Project (Kishorganj)
3	Charigram Haor Project (Kishorganj)	16	Nunnir Haor Project (Kishorgang)
4	Bara Haor (Kamlakanda) (Netrokona)	17	Sarishapur Haor Project (Kishorganj)
5	Ayner Gupi Haor (Kishorganj)	18	Bansharir Haor Project (Netrokona)
6	Bara Haor Sub Project (Austagram) (Kishorganj)	19	Chatal Haor Project (Kishorganj)
7	Boro Haor Project (Nikli) (Kishorganj)	20	Dakhshiner Haor Project (Kishorganj)
8	Chandpur Haor Project (Kishorganj)	21	Dhakua Haor Project (Sunamganj)
9	Dulapur Haor Project (Kishorganj)	22	Ganesh Haor Project (Netrokona)
10	Golaimara Haor Project (Kishorganj)	23	Jaliar Haor Project (Sunamganj)
11	Joyariya Haor Project (Kishorganj)	24	Mokhar Haor Project (Habiganj)
12	Korati Haor Project (Kishorganj)	25	Shelnir Haor Project (Habiganj & Bramanbaria)
13	Kuniarbandh Haor Project (Kishorganj)	26	Suniar Haor Project (Kishorganj & Netrokona)

Note: Closed in parenthesis is the district name
Source: JICA Study Team

The topographic survey of the new haor projects was carried out. The topographic survey includes spot elevation survey along the envisaged alignment of submergible embankment. The location map of the new haor projects is shown in **Figure 4.2.2**.

(4) Topographic Survey

The topographic survey was carried out based on the subcontract with a selected local contractor. Al-mayeda Survey Consultants was selected through the tender process according to JICA's guidelines.



Source: Haor Master Plan, 2012

Figure4.2.2 Location Map of New Projects for Topographic Survey

4.2.2 Geotechnical Investigation

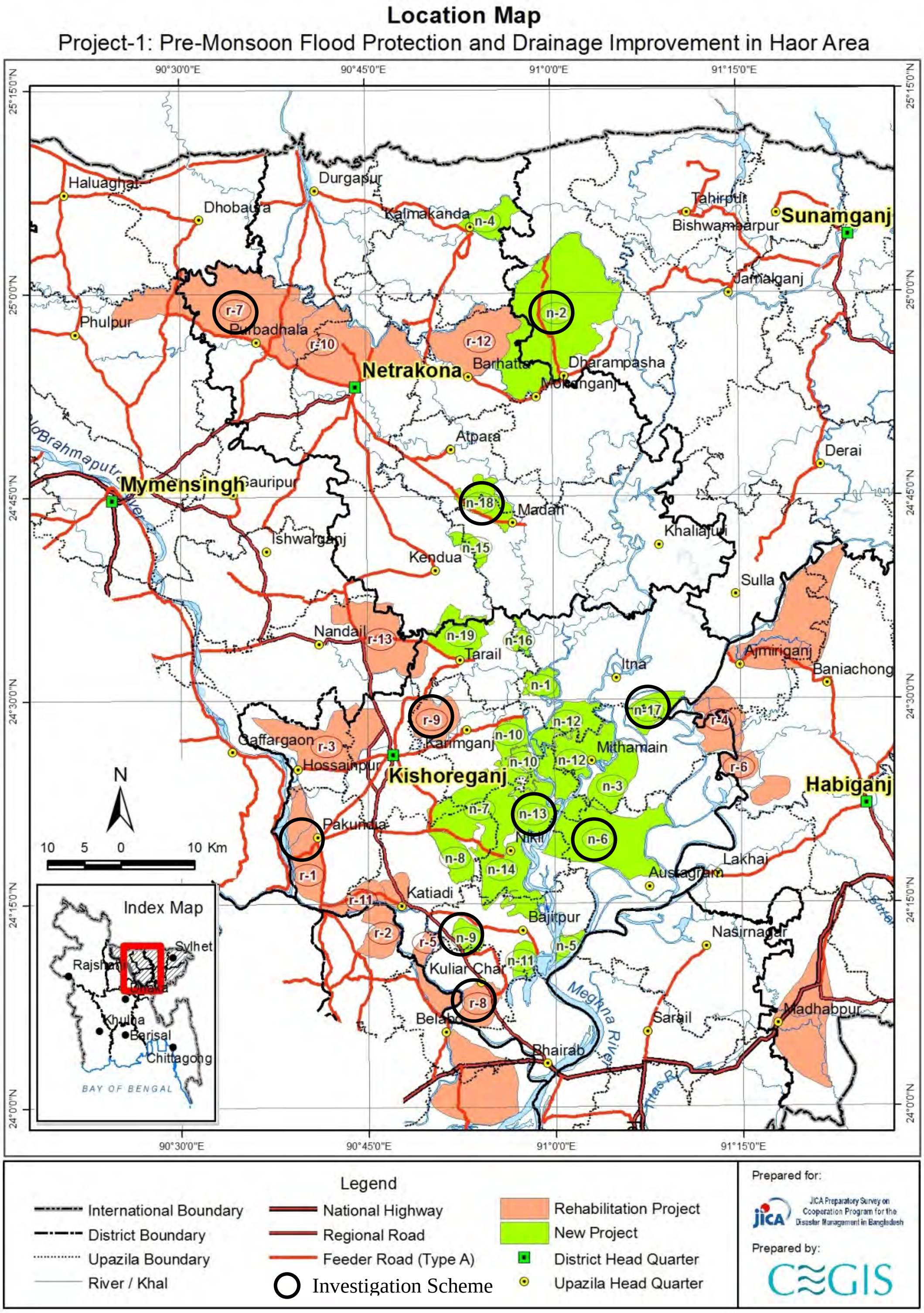
Geotechnical investigation was conducted under the sub-contract of ten haor projects, consisting of four rehabilitation projects and six new projects presented in **Figure 4.2.3**.

The locations of the geotechnical investigation were selected considering the following ideas:

1) The locations were selected in the target haor project area excluding 52 rehabilitation projects to be implemented by BWDB.
2) The locations were selected in the priority new and rehabilitation project area extracted in the M/P.
3) The locations were selected with geotechnical representativeness of all target project areas.

The major work items of the geotechnical investigation are the follwings:

1) Core Drilling: 300 m (30 m/ hole, 1 hole/ project)
2) Dutch Cone Test: 360 m (20 m/ hole, 3 holes/ new project)
3) Laboratory Test for Undisturbed Samples (core drilling sites)
4) Laboratory Test for Embankment Materials (3 samples/ new projects)
5) Dry-Wet Cycle Test (1 new project)
6) Riverbed Material Survey (10 locations)



Source: JICA Study Team

Figure 4.2.3 Location Map of Geotechnical Investigation

(1) Data Collection and Review

During the first work in Bangladesh, the following data and information related to soil and geology in the Study area were collected:

1) ”Geological Map of Bangladesh, 1:1,000,000”, Geological Survey of Bangladesh, 2001
2) Soil laboratory test results (physical, consolidation and strength tests) at two locations in the haor area near the northern international border with India (each at one location in Netrokona and Sunamganj Districts) which has been described in “the Report on the Feasibility Study for Capacity-Building Project for Sustainable Development of Water-Related Infrastructure (Part-1), January 2012, JICA Technical Cooperation Project”.
3) Standard Penetration Test (SPT) results at several gate structures constructed in the haor projects which are being operated and maintained by BWDB.

The findings from the review of data and information collected, are as follows:

1) The geological map of Bangladesh indicates the existence of soft silt and clay including peat in the Study area. According to 2) above, some parts of soil samples include about 2% to7% organic materials.
2) Besides, according to 2) above, the laboratory data for foundation shows the following soil parameters:

   Netrakona: Grain size; silt100% wn*=19.57% qu*=1.57(kg/cm^2),

   Sunamganj: Grain size; silt70%, clay30% wn*=34.57% qu*=0.65 (kg/cm^2),

   (*: wn=Moisture content, qu=Unconfined compression strength)
3) Some drilling data from BWDB suggest that soft cohesive soils are distributed universally over the floodplains in the haor area.

(2) Necessity of the Work

The existing source materials/data on (i) foundation soil of structures such as embankment and sluices, and (ii) embankment construction materials which are available in the Study are as enumerated in (1) above.

It was clarified through the M/P review that the M/P had no conducted any geotechnical investigation for the formulation of the structural plan, and the structural measures, such as embankment and sluices proposed in the M/P were drawn out, referring to the existing haor projects, without any data from the survey of the foundation soil and embankment materials in the project sites.

In view of the above, it was concluded that the Study needs geotechnical investigation, excluding the areas of the 52 haor projects which have been incorporated in the BWDB Rehabilitation Project, with the aim of assessing the following technical points:

(a) Stability of foundation for embankment and sluices against settlement and piping,
(b) Soil materials available for embankment construction, and
(c) Durability of submergible embankment which is subject to repeated submergence and drying.

(3) Scope of Work

The survey items and locations are as tabulated in **Table 4.2.4** under the sub-contract with Development Design Consultant Ltd. (DDC).

Table 4.2.4 Survey Items and Locations

Survey Items		Locations			Remarks
		Existing Haor Projects	New Haor Projects	Total	
Ground survey	Core drilling	4 schemes*1	6 schemes*1	10	Sluice site
	Dutch cone test	-	6 schemes*2	6	Submergible embankment
Soil test					
Foundation	Physical test	4 schemes*3	6 schemes*2	10	
	Consolidation test				
	Strength test				
Embankment Materials	Compaction test	-	5 schemes*4	5	
	Strength test				
	Dry-Wet cycle test	-	1 scheme*4	1	

Notes: Survey locations are selected from the haor project areas as follows:
*1 See Figure4.2.3
*2 6 core drilling survey schemes
*3 4 core drilling survey schemes
*4 Selected from 6 core drilling survey schemes

(4) Preparation of Technical Specifications

The technical specifications of the geotechnical investigation were prepared for the sub-contract work as part of the contract documents. The planned and completed main survey items and quantities are summarized in **Table 4.2.5**.

The dry-wet cycle test was conducted to identify the adequate degree of compaction so that the durability of the new submergible embankment would increase against repeated submergence during the monsoon season.

The geotechnical investigation results are explained in **Chapter 8** and **Annex 4-2**.

Table 4.2.5 Planned and Completed Main Survey Items and Quantities

Survey Item	Planned Quantity	Details	Completed Quantity	Reason for Amendment
I Foundation Investigation				
I-1 Core Drilling	300 m	30m/hole, 1hole/site, 10 sites	300 m	
I-2 Standard Penetration Test	300 nr.		300 nr.	
I-3 Undisturbed Sampling	50 nr.	Every 1.0m in principle	**14 nr.**	Reason-1
I-4 Field Permeability Test	60 times	5 samples/hole, 10 sites	**46 times**	Reason-2
I-5 Dutch Cone Test	360 m	10 holes x 6 depths (5m pitch)	**274 m**	Reason-3
I-6 Laboratory Test				
(1) Physical Test*1	1 LS	20m/hole, 3 holes/sites, 6sites	1 LS	
(2) Mechanical Test*2	1 LS		1 LS	
II Embankment Material				

Survey Item	Planned Quantity	Details	Completed Quantity	Reason for Amendment
Survey II-1 Sampling II-2 Laboratory Test (1) Physical Test*1 (2) Mechanical Test*3 II-3 Dry-Wet Cycle Test (1) Test Peace Preparation (2) Unconfined Compression Test	15 nr. 1 LS 1 LS 36 nr. 36 nr.	3 points/site, 5 sites D=80,90,98%, 6 cycle, 2 pieces -ditto-	15 nr. 1 LS 1 LS 36 nr. 36 nr.	
III Riverbed Material Survey III-1 Sampling III-2 Laboratory Test (1) Physical Test	30 nr. 1 LS	3samples/site, 10 sites	30 nr. 1 LS	
IV Report	5 copy		5 copy	

*1 Physical test includes grain size analysis, liquid/plastic limit, specific gravity, moisture content and unit weight.

*2 Mechanical test for foundation investigation includes consolidation test and unconfined compression test for undisturbed sample.

*3 Mechanical test for embankment material includes compaction test, unconfined compression test, tri-axial compression test.

Reason-1: Undisturbed sampling was planned to conduct mechanical test for clay and peat layer of which strength was difficult to estimate by only SPT. However, the foundation ground was mainly consisted of non-plastic silt and fine sand, therefore clay and peat as the target of undisturbed sampling was less than supposed.

Reason-2: Permeability test for clay was omitted, since clay was obviously impermeable and the test would need much time. Some tests at silt and sand depths test could not be conducted due to collapse of the borehole.

Reason-3: A large size DCT machine was applied to complete the test by 20 m depth, however the large machine could not be transported to 9 sites due to issues of access and a smaller machine was applied for these sites. The smaller machine could not reach to 20 m depth and completed by just 10 to 20 m. It was confirmed by the large machine that deeper soil than 10 m had enough cone resistance more than expected.

Source: JICA Study Team

(5) Site Inspection for Selection of Core Drilling Points

Site inspection was carried out from 4 to 12 February 2013 to select specific core drilling points (ten haor project sites) as well as to assess the site conditions in the dry season for the geotechnical investigation.

One drilling point for each haor project has been selected out of the locations of the structures such as regulators/sluices, based on the general project map and also paying special attention to accessibility to the drilling site.

4.3 Survey of Existing River and Agricultural Facilities

4.3.1 Data Collection and Review

The existing river and agricultural facilities are mainly river dike called “full embankment” in Bangladesh, revetment, submergible embankment, regulators, pipe sluices and drainage and irrigation canals. There are 118 haor projects implemented and operated by BWDB in the haor area. These projects were composed of the submergible embankment to protect paddy fields from the flash floods during the pre-monsoon season and regulators, drainage and/or irrigation canals. Bridges were also included in some haor projects.

On the other hand, flood control and drainage projects were also carried out at the Surma River, Manu River, Khowai River, etc. in the haor area.

(1) Results of the Data Collection in Dhaka and BWDB Site Offices

Data collection works related to haor projects and flood control projects and drainage projects in the haor area, were carried out by BWDB and concerned agencies.

1) Detailed Information of Structures

In the M/P, the rehabilitation works of the existing haor projects are classified in **Table 4.3.1**.

Table 4.3.1 Rehabilitation Works of Existing Haor Projects

Haor Project	Number of Project	Remarks
1.Rehabilitation Works planned by BWDB	52	
Feasibility Study (F/S) was finished (2007)	37	Table 4.3.2 shows information on rehabilitation works. Some project offices requested the Design Circle to carry out the detailed design (D/D)
F/S is ongoing	15	Data cannot be collected.
2.Proposed by the M/P	25	To check the dimensions of structures, BWDB site offices were requested to collect as built drawings. However, these drawings were not collected because nobody knows where the drawings have been stored.
3.Remaining Project	41	No information from BWDB

Note: Number of haor projects includes seven districts.
Source: Haor Master Plan, DPP, JICA Study Team

Information related to the facilities of the haor projects were collected in Dhaka and from the site offices. However, the information on the facilities in the 37 haor projects, which are funded by the GOB, were collected. **Table 4.3.2** shows information on the existing 37 haor projects.

During the site reconnaissance, the JICA Study Team tried to collect as-built drawings of the existing haor projects. However, such drawings were not obtained because the staffs from the BWDB site offices have no knowledge of their location.

In addition, the facilities and work volume of the proposed rehabilitation works were mentioned in the M/P. But the locations and areas for rehabilitation were not mentioned. Information on the type of facilities, dimensions, and damaged areas should be collected.

Therefore, a river facility survey is needed to check the present conditions.

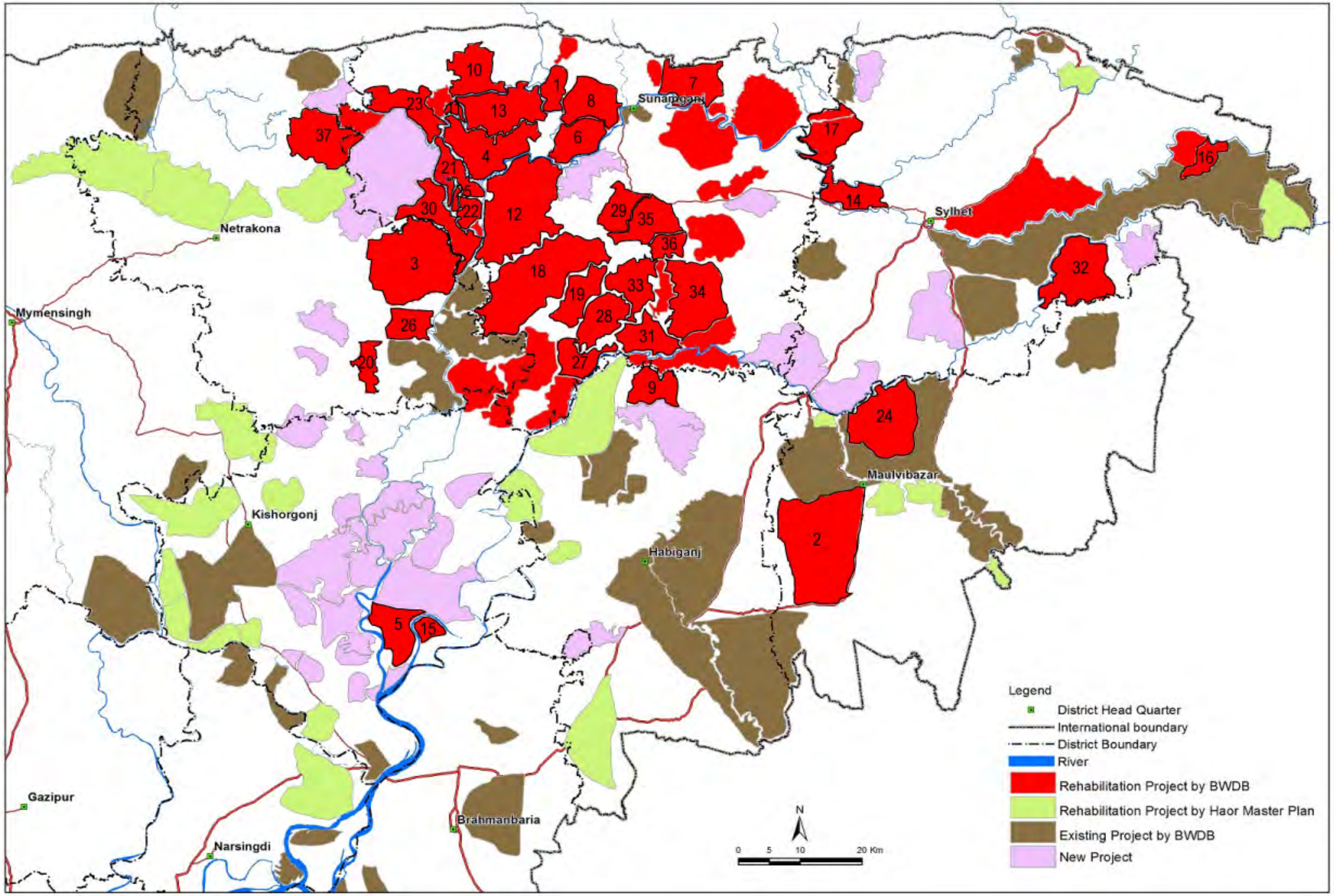
Table 4.3.2 Part of the Rehabilitation Project by BWDB (37 Projects)

No.	Name of Haor with Area (ha)	Proposed Rehabilitation Works Along with the New Projects						
		Embankment/ Dike in km		No. of Regulators/Sluice Gates and Bridges/Culverts			River Excavation/ Dredging	Other Interventions
		Existing	Rehabilitation	Existing	Rehabilitation	New		
1	Angurali Haor 2,630ha	26.71km (Submergible)	26.71km	1 (Regulator)	None	2 (Sluice) 1 (irrigation Pipe Outlet)	Rokti, Jadhukata	
2	Hail Haor 24,370ha	68km (Submergible) 23 km (Internal Dike)		4 (Bridge)	None	None		
3	Haizda Embankment project 16,880ha	47.4km (Submergible)	47.4km (Submersible)	10 (Regulator)	7 (Regulator)		Baulai	
4	Halir Haor 10,000ha	58.46km (Submersible) 9.95km (Compartmental Dike)	58.46km (Submersible) 9.95km (Compartmental dyke)	2 (Regulator)			Surma, Baulai	
5	Humpaipur Haor 5,270ha	34.27km (Submergible)	34.27km (Submergible)	5 (regulator)	4 (regulator)			
6	Joalbhanga Haor 4,370ha	60.59km (Submergible)	33.55km (Submergible)	1 (Bridge) 1 (Pipe Sluice) 4 (Regulator)				
7	Kalner Haor 6,828ha	64.15km (Submergible)	30.76km (Submergible)	2 (Regulator)			Surma	
8	Karchar Haor 5,513ha	35.8km (Submergible)	16.82km (Submergible)	3 (Bridges) 2 (Culvert) 2 (Pipe sluice) 1 (Regulator)		3 (Bridges convert into WCS)		1 (Causeway)
9	Makalkandi Haor 4,200ha	41.47km (Submergible)	41.47km (Submergible)	3 (Bridge) 3 (Pipe Sluice) 1 (Regulator)	3 (Pipe Sluice)	2 (Regulator)	Baulai	
10	Matian Haor 7,761ha	48.57km (Submergible) 10.14km (Internal Dike)	48.57km (Submergible)	1 (Regulator)			Baulai	
11	Mohalia Haor 645ha	14.75km (Submergible)	14.75km (Submergible)	1 (Regulator)			Baulai	
12	Panger Haor 19,075ha	78.87km (Submergible) 9.9km (Internal Dike)	75.42km (Submergible)	2 (Regulator)	1 (Regulator)		Baulai	1 (Causeway)
13	Shanir Haor 7,761ha	48.20km (Submergible) 23.88km (Internal Dike)	48.20km (Submergible)	5 (Regulator)	2 (Regulator)		Baulai	
14	Zilker Haor 5,263ha	14.74km (Submergible) 4.62km(Compartment	8.88km (Submergible) 4.62km (Flood Control	2 (Bridge) 5(Box	4(Culvert) 4(Pipe Sluice)	4 (Regulator)		1 (Causeway)

No.	Name of Haor with Area (ha)	Proposed Rehabilitation Works Along with the New Projects						
		Embankment/ Dike in km		No. of Regulators/Sluice Gates and Bridges/Culverts			River Excavation/ Dredging	Other Interventions
		Existing	Rehabilitation	Existing	Rehabilitation	New		
		Dike) 5.3km (Flood Control Embankment)	Embankment)	Culvert) 6(Pipe Sluice) 3(Regulator)				
15	Dewghat Haor 1,220ha	4.46km (Submergible)	4.43km (Submergible)	3(Pipe Sluice) 3(Regulator)	3(Regulator)			1 (Causeway)
16	Shafique Haor 2,380ha	15.92km(Submergible) 2.64km(Internal Dike)	15.92km(Submergible) 2.64km(Internal Dike)	4(Bridge) 2(Pipe Sluice) 1(Regulator)	1(Regulator)	4(Regulator)		
17	Patharchauly 5,466ha	33.63km(Submergible)	33.63km(Submergible)	2(Pipe Sluice) 2(Regulator)	1(Pipe Sluice) 1(Regulator)	4(Regulator)		
18	Kalikota Haor 17,610ha	84.48km(Submergible) 34.34km(Compartmental Dike)	71.22km(Submergible)	5(Bridge) 2(Pipe Sluice) 2(Regulator)		17(Box Culvert) 2(Bridge) 2(Regulator)		3 (Causeway)
19	Udgal beel Haor 5,900ha	33.55km(Submergible) 21.58km(Compartmental Dike) 4.67km(Flood Control Embankment)	33.55km(Submergible) 4.67km(Flood Control Embankment)	8(Bridge) 1(Regulator)	1(Regulator)			1(Causeway)
20	Balali-Padamsree 2,398ha	13.14km(Submergible)	13.14km(Submergible)	1(Bridge) 1(Culvert) 2(Regulator)	2(Regulator)			
21	Sonamoral 3,275ha	45.58km(Submergible) 3.8km(Compartmental Dike)	45.58km(Submergible)	4(Regulator)	3(Regulator)			
22	Dhankunia Haor 1,692ha	18.44km(Submergible)	18.44km(Submergible)	1(Regulator)		2(Regulator)	Baulai	
23	Gurmar Haor 5,360ha	51.59km(Submergible)	51.59km(Submergible)	14(Irrigation Pipe) 5(Regulator)	5(Regulator)			
24	Kawadhighi Haor 22,672 ha	57.9km (Flood Control Embankment)	28km (Flood Control Embankment)	1(Bridge) 2(Regulator)	1(Regulator)			1(Barrage)
25	Joydhona Haor 355ha	11.3km (Submergible)	11.3km (Submergible)			2(Regulator)		

No.	Name of Haor with Area (ha)	Proposed Rehabilitation Works Along with the New Projects						
		Embankment/ Dike in km		No. of Regulators/Sluice Gates and Bridges/Culverts			River Excavation/ Dredging	Other Interventions
		Existing	Rehabilitation	Existing	Rehabilitation	New		
26	Nawatana 3,020ha	7.7km(Submergible)	7.7km(Submergible)	2(Pipe Outlet) 1(Regulator)	1(Regulator)			2(Cross Dam)
27	Bhanda Beel Haor 4,000ha	31.45km(Submergible) 9.10km(Compartmental Dike)	31.45km(Submergible)	6(Pipe Sluice) 1(Regulator)	5(Pipe Sluice) 1(Regulator)	2(Pipe Sluice) 1(Regulator)		
28	Baram Haor 5,500ha	33.12km(Submergible)	33.12km(Submergible)	3(Pipe Sluice) 3(Regulator)	3(Pipe Sluice) 2(Regulator)		Mara Chamti Nadi, Chamti Nadi	
29	Shangair Haor 5,000ha	28.95km(Submergible) 7.39km(Internal Dike)	28.95km(Submergible) 7.39km(Internal Dike)	3(Regulator)	1(Regulator)			
30	Chandra Sonar Thal 5,714ha	62.74km(Submergible)	48.17km(Submergible)	5(Pipe Sluice) 3(Regulator)	5(Pipe Sluice) 3(Regulator)			
31	Tanguar Haor 5,000ha	40.91km(Submergible)	36.51km(Submergible)	4(Pipe Sluice) 2(Regulator)	3(Pipe Sluice) 2(Regulator)	1(Regulator)		2(Cross Dam)
32	Kushiara Bradhal Haor 7,500ha	41.26km(Submergible)	41.26km(Submergible)			7(Regulator)		
33	Chaptir Haor 4,553ha	40.64km(Submergible)	37.62km(Submergible)	1(Bridge) 8(Pipe Sluice) 3(Regulator)	4(Pipe Sluice) 3(Regulator)			1(Causeway)
34	Naluar Haor 12,140ha	79.78km(Submergible) 8.6km(Internal Dike)	67.55km(Submergible)	6(Bridge) 6(Regulator)	4(Regulator)			2(Loop cut)
35	Khai Haor 4,800ha	28.16km(Submergible)	17.00km(Submergible)	6(Bridge) 4(Pipe Sluice) 2(Regulator)	4(Pipe Sluice) 2(Regulator)			
36	Jamkhola Haor 2,000ha	22.47km(Submergible)	22.47km(Submergible)			4(Regulator)		1(Causeway)
37	Updakhali Haor 7,220ha	33.23km(Submergible)	33.23km(Submergible)	11(Bridge) 5(Regulator)	4(Regulator)			

Note: Existing means Existing Structure, Rehabilitation means Rehabilitation structures, New means new construction in the rehabilitation project
Source: DPP for Pre-Monsoon Flood Protection and Drainage Improvement in Haor Areas, Original May, 2010, Recast May, 2011, BWDB



Source: JICA Study Team

Figure 4.3.1 Location Map of 37 Rehabilitation Project planned by BWDB

The flood control projects and drainage projects were also executed in the haor area. In these projects, full embankments, regulators, barrages, and pump stations were constructed.

- Full Embankment

Upstream of Surma River	about 110 km
Kushiyara River	about 120 km
Manu River (tributary of the Kushiyara River)	about 140 km
Khowai River(tributary of the Kushiyara River)	about 90 km

- Barrage

Manu Barrage	8 vertical roller gates	2nos. x 9.15m (W) x5.34m(H)
		6nos. x 9.15m(W)x5.03m(H)

Manu Barrage

Irrigation Intake (Right Bank)

Roller Gate (Manu Barrage)

Hoisting Equipments (Roller Gate)

Note) Refer to Figure 4.3.2

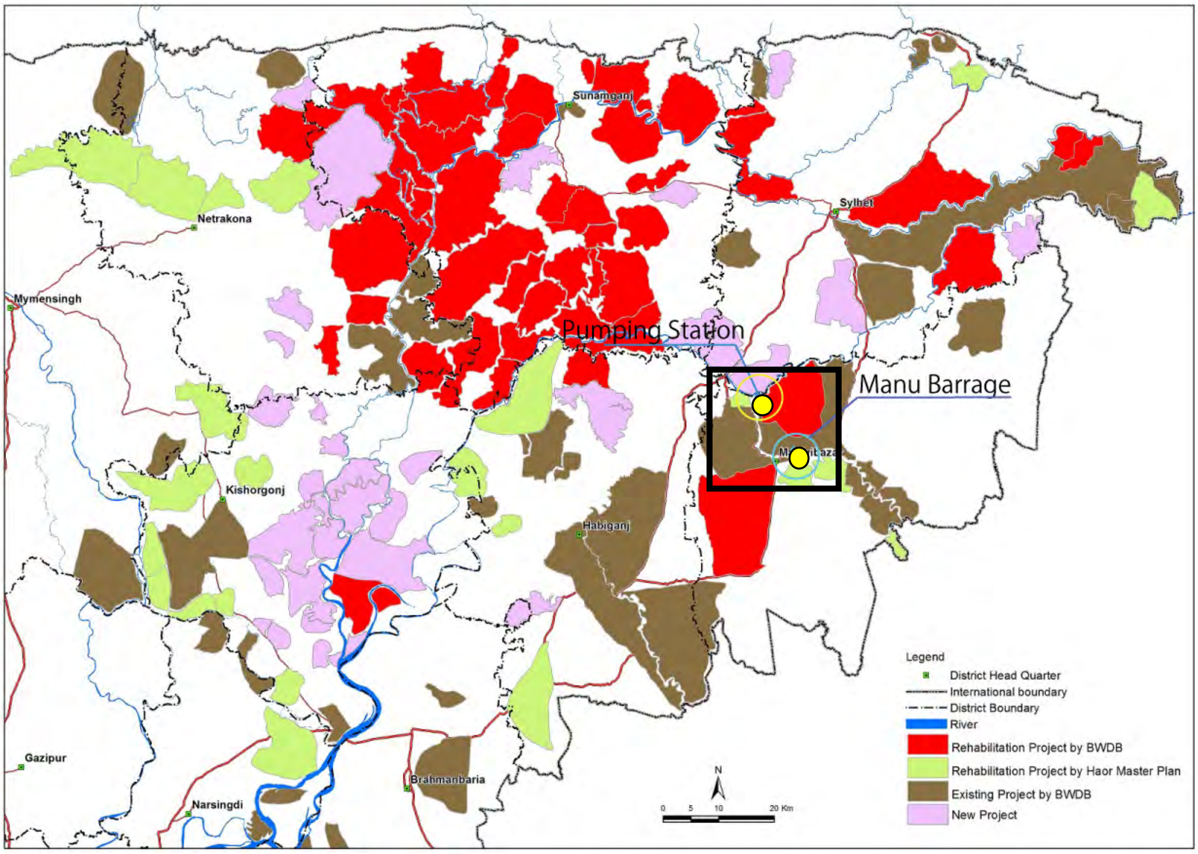
- Pump Station

Rahimpur Pump Station (Right bank of Kshiyara River) It is under construction as a replacement facility of the existing regulator. 4units (1.88m^3/s/unit)

Kashempur Pump Station (Left bank of Manu River) 8units (4.25m^3/s/unit)

	
Pumping Stataion	Panel
Note) Refer to Figure 4.3.2	

The location map of the Manu Barrage and Pumping Station is shown in **Figure 4.3.2**.



Source: JICA Study Team

Figure 4.3.2 Location Map of the Manu Barrage and Pumping Station

2) Flood Damage

The flood damage on the river facilities was surveyed. The data on flood damage on the structures were taken only from the flood damage survey by BWDB in 2007. Two floods occurred in 2007, one in June and the other in September.

Flood in June

Nilphamari and Kurigram districts, which are located along the Jamuna River in the northern region, were damaged. Also, Sylhet and Sunamganj districts along the Surma River were damaged.

Flood in September

The inundation ratio along the Jamuna River changed from 60% to 80%. The inundation ratio in Sunamganj District was 15% to 30%, while the inundation ratio in other districts along the Surma River was 0% to 15%.

Table 4.3.3 shows the flood damage on river structures in 2007.

3) Operation and Maintenance

The facilities constructed under the BWDB projects in the haor area, are BWDB assets, and the operation of regulators is carried out by the sluice committee. In 1999, the Ministry of Water Resources published the "Guideline for Participatory Water Management"; however, new organizations following such guideline were not established yet.

The sluice committee was established to discuss between the executive engineer of the BWDB site office and stakeholders, such as the upazila chairman and ward members. The sluice committee has the key to the regulator. The operation of the regulator is instructed by BWDB staffs. The sluice committee operates the regulator under the instruction of BWDB.

On the other hand, the regulators along the river which are not included in the haor projects have no established committee. Therefore, the BWDB site office requests the operation of such regulators to respective ward members. In this case, the BWDB site office directly requests the ward members to operate the gates.

Water users groups for irrigation were established under the Manu River Project because water supply from the Manu River is controlled by the Manu Barrage.

Table 4.3.3 Flood Damage of River Structure in 2007 (BWDB)

(Unit: 100,000)

District	Project Name	Embankment (km)			Irrigation Canal/ Drainage Channel (km)			Water Control Structure (Nos.)			Bank Protection (km)		Groyne (Nos.)	Spur/ Hard Protect		Others		Damage (BDT)
		Full	Part	BDT	Full	Part	BDT	Full	Part	BDT	Full	Part	Part	Part	BDT	QTY	BDT	
B. Baria	Kondagokama FCD	0.040	1.000	15.0								0.09			5.0			20.0
B. Baria	Protection of the Meghna River Bank										0.09	0.08			50.0			50.0
B. Baria	Joydarkandi Village Protection											0.20			10.0			10.0
B.Baria	Howra River Project	0.634	6.000	25.0														25.0
B.Baria	Protection of the Buri River Project		0.120	10.0														10.0
Habiganj	Kusheria Left bank	0.333	0.460	10.0														10.0
Habiganj	Madofpur FCD	1.850	1.641	85.0														85.0
Habiganj	Goinggazun FCD	0.740	1.590	23.4														23.4
Habiganj	Khowai River Left and Right Bank Protection	2.000	16.300	175.0								0.317			100.0			275.0
Habiganj	Debnath school and bazar project											0.060			5.0			5.0
Habiganj	Makalkandi Haor	1.250		20.0														20.0
Habiganj	Markuli Bazar Protected Project											0.100			3.5			3.5
Moulavibazar	Manu River Project	0.300	0.840	20.0		1.000	7.0									1	26.0	53.0
Moulavibazar	Manu River FCD Project, ph-1	0.180	1.380	40.0														40.0
Moulavibazar	Dhalai River Project	1.770	1.400	50.0														50.0
Moulavibazar	Tarapasha-Prammagar FCD Project	0.250	0.515	17.0														17.0
Moulavibazar	Manu River FCD Project, ph-2	0.650	1.400	30.0								0.250			40.0			70.0
Moulavibazar	Manu Soyjun Protective Work		0.150	2.0														2.0
Moulavibazar	Manu Left Flood Embankment	0.040	0.035	14.0														14.0
Moulavibazar	Dewrachar FCD Project	0.140		2.0														2.0
Moulavibazar	Hamhamichara FCD		0.300	3.0														3.0
Moulavibazar	Baria Haor Sub-project							2		7.0								7.0
Moulavibazar	Hail Haor Project		1.500	15.0														15.0
Moulavibazar	Manu River Project															1	40.0	40.0

District	Project Name	Embankment (km)			Irrigation Canal/ Drainage Channel (km)			Water Control Structure (Nos.)			Bank Protection (km)		Groyne (Nos.)	Spur/ Hard Protect		Others		Damage (BDT)
		Full	Part	BDT	Full	Part	BDT	Full	Part	BDT	Full	Part	Part	Part	BDT	QTY	BDT	
	(Mechanical)																	
Sylhet	Kushiara Dike		20.700	63.0														63.0
Sylhet	Surma River System	0.015	1.780	20.0														20.0
Sylhet	Kushiyara River Right Bank Embankment Project		1.900	12.0					2	20.0								32.0
Sylhet	Dhaleshwan Cross Dam		0.965	12.0								0.200			4.0			16.0
Syhlet	Sari-Goyain Project	2.500	0.780	37.0														37.0
Syhlet	Khoshara Bardal Project		1.500	8.0														8.0
Syhlet	Surma Right Bank		2.291	12.0														12.0
Syhlet	Goinaghal Project	2.500		25.0														25.0
Syhlet	Jneelkar haor project	0.620		20.0														20.0
Syhlet	Pathor Chowfee Haor Project	0.820		20.0														20.0
Syhlet	Embankment from Balagonj to Kalanichar		19.000	12.0														12.0
Syhlet	Safiq Haor Project	0.950		8.0														8.0
Syhlet	Barr Haor Project	1.000		5.0														5.0
Sunamganj	Karchar Haor, Kalpanar, Angraly, Sanir, Mathian, Mohallia, Zoal	25.861	134.050	732.5					28	12.5		0.470			54.0			799.0
Keshoreganj	Charparadi-Janggalia Project											0.100			1.0			1.0
Netrokona	Someswari River Hazard Management Project		0.200	5.0														5.0
Netrokona	Updakhali Sub-project	0.500		8.0					5	4.0								12.0
Netrokona	Kongsho River Sub-projects		3.000	9.0					2	1.5								10.5
Netrokona	Dampara Water Management Project		6.000	10.0					2	1.5								11.5
Netrokona	Thakurakona Sub-project		5.000	8.0					5	1.5								9.5
Netrokona	Singer Beel Sub-project	0.390		6.0		3	6.0	4	2	4.5								16.5

District	Project Name	Embankment (km)			Irrigation Canal/ Drainage Channel (km)			Water Control Structure (Nos.)			Bank Protection (km)		Groyne (Nos.)	Spur/ Hard Protect		Others		Damage (BDT)
		Full	Part	BDT	Full	Part	BDT	Full	Part	BDT	Full	Part	Part	Part	BDT	QTY	BDT	
Netrokona	Netrokona Town Protection Project											0.300			20.0			20.0
Netrokona	Hayjada Haor	4.290		20.0														20.0
Netrokona	Notan Haor	0.150		1.0					3	1.0								2.0
Netrokona	Deferent Khal Close in the Haor Area	5.880	3.000	70.0								0.100			6.0			76.0
Netrokona	Mahananda River Embankment Project		5.000	10.0				2		2.5								12.5
Netrokona	Balai Padasri Sub-project		0.400	2.0														2.0

Note: The damaged costs by 2007 flood in each project are estimated from full and partial damaged length for the embankment and canal/channel , and number of full and partial damaged location for water control structures. .

Source: BWDB

4.3.2 Targets of Field Survey

The targets of the field survey are 1) the existing haor projects, and 2) the river facilities because existing facilities related to water management are located in the existing haor areas and along/across the rivers.

(1) Existing Haor Projects

The target areas of the haor projects for this survey are also decided based on the same reasons for the topographic survey. The targets of this survey include the existing haor projects in the five districts except the haor projects to be rehabilitated by BWDB. **Figure 4.3.3** and **Table 4.3.4** show the target haor projects of the facility survey.

Table 4.3.4 Number of Haor Projects for Facility Survey

	District	Number
1	Sunamganj	1
2	Habiganj	7
3	Netrakona	8
4	Kishoreganj	10
5	Brahamanbaria	4
	Total	30

Source: JICA Study Team

(2) River Facilities

Many full and submergible embankments in Sunamganj, Netrakona, Kishoreganj, Brahamanbaria districts were constructed under the haor project. These structures have been surveyed in the haor project. Therefore, the river facility survey is carried out for Sylhet, Maulvibazar and Habiganj districts.

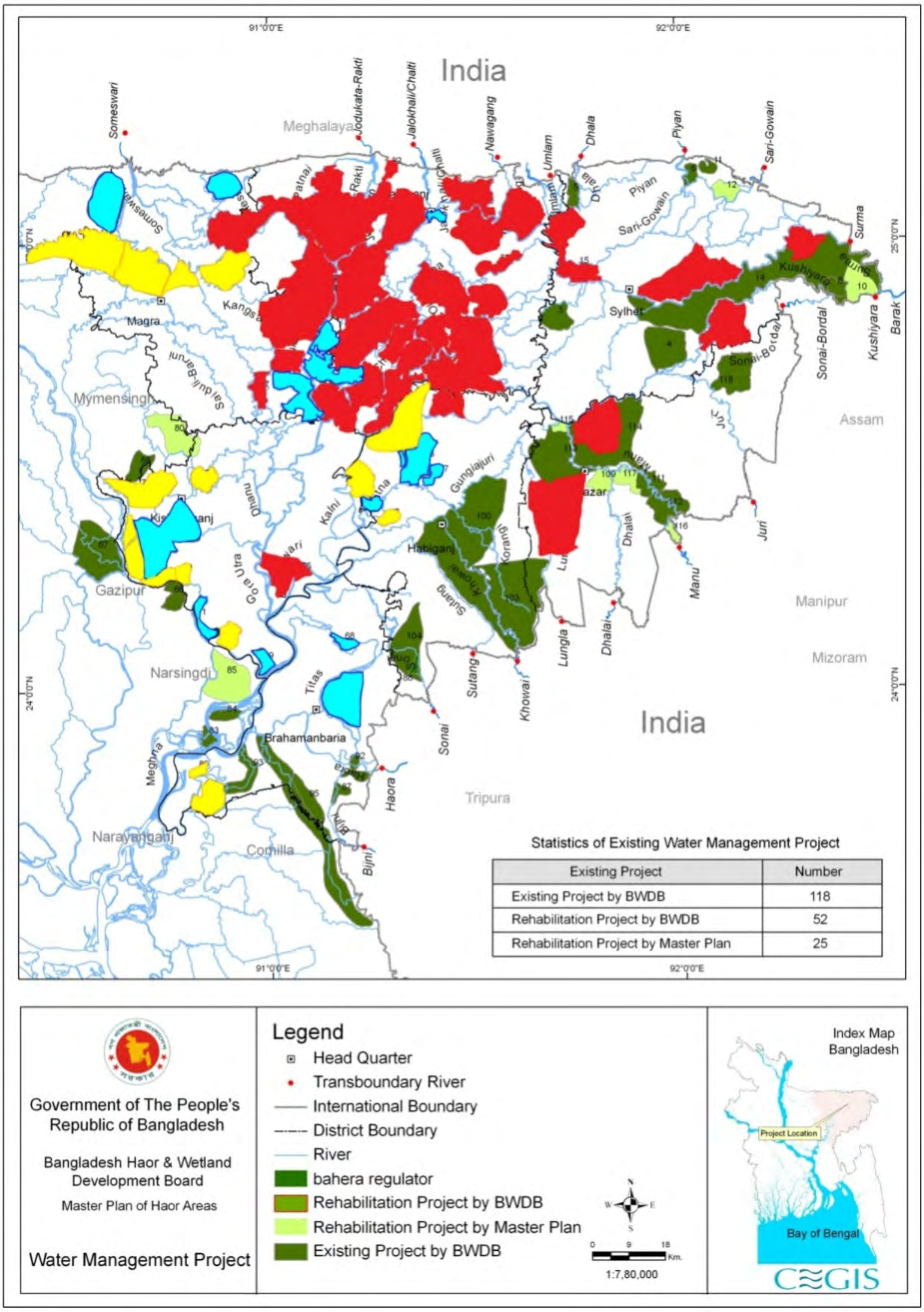
(3) Schedule of Field Survey

The field survey is divided to two steps. The first step consists of the existing haor projects, and the second step consists of the river facilities. The first step was conducted from early February to early March and second step was planned from the middle of March to early April. However, the second step was shifted to the beginning of May because many hartar occurred in March and April.

4.3.3 Survey Items

The field survey shall include the following items:

1) Collection and review of design drawings and design conditions/criteria,
2) Past flood overtopping and damage of submergible embankment, and types and problems of drainage facilities,
3) Major causes of facility damage and malfunction,
4) State of O&M,
5) Function of haor areas (method for securing irrigation water, supply of nutritive salt due to farm land sedimentation, freshwater fishing in farm land, etc.)



Note: Red color; Rehabilitation project by BWDB, Yellow color; Rehabilitation project by Master Plan, Blue color; No rehabilitation project in haor area, Green; No rehabilitation project out of deep haor area

The field survey is carried out to yellow and blue color hoar projects.
Source: Haor Master Plan

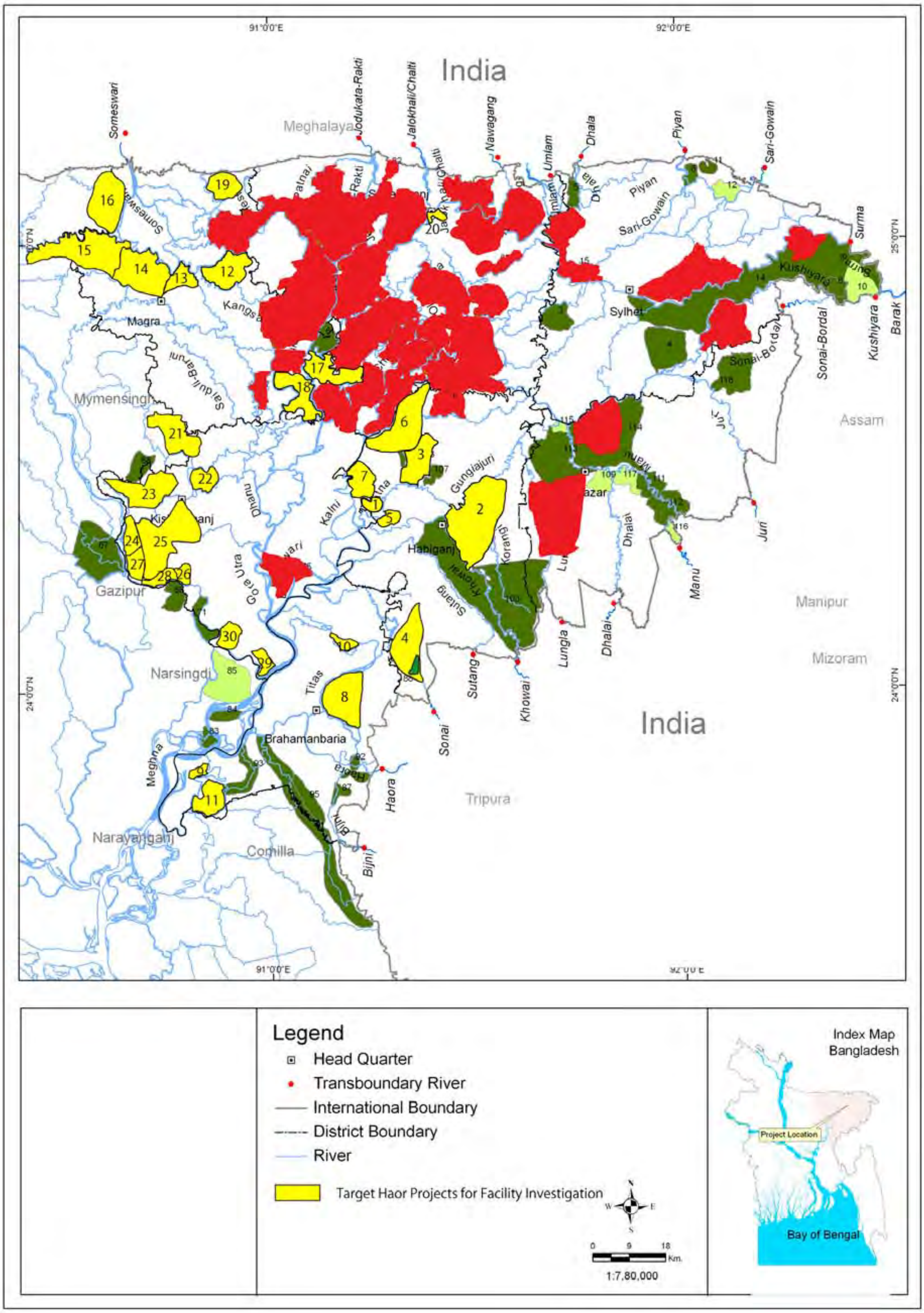
Figure 4.3.3 Location Map of Haor Projects for Field Survey

Table 4.3.5 Inventory Survey Results

No.	Haor Project Name	District	Embankment (km)		Canal	Regulator				Others	Remarks
			Submergible	Full	(km)	No.	Vent	Width(m)	Height (m)		
1	Cheghaia Khal Scheme	Habiganj	2.5	0	2	1	1	1.5	1.8		Embankment: Total damage is 130m. Artificial cutting, about 35m, is carried out due to boat transportation and inland fishing. Canal: Sedimentation problem Regulator: Gate has not been operated since 2011 due to gearbox problem.
2	Gangajuri FCD Sub-scheme	Habiganj	0	46	4.5	2 2 1 2	7 5 2 1	1.5 1.5 1.5 1.5	1.8 1.8 1.8 1.8	5-pipe sluice 2-1.02 dia 3-0.64m dia.	Embankment: Damage is occurred about 600m due erosion and partial artificial cutting . Canal: sedimentation problem Regulator: one 7 vent regulator is not operated from 2012 due to damage of gearbox and hoist rod. Othe 7 vent is operated even 2 gates are not function.
3	Sukti River Embankment	Habiganj	20	0	11.5	0					Embankment:Repaire work was carried out by BWDB Canal: Sedimentation problem
4	Madhabpur Scheme	Habiganj	0	38	38	0					Embankment: Damage is occurred about 1,260m due erosion and partial artificial cutting .
5	Aralia Khal Scheme	Habiganj	0	0	2.4	2	2	1.5	1.8		Canal: Sedimentation problem Regulator: 2regulators were not operated since 2011 due to gearbox problems (stolen & broken)
6	Kairdhala Ratna Scheme	Habiganj	26	0	40	1 2	5 2	1.5 1.5	1.8 1.8		Embankment: Damage is occurred about 60m due to erosion. Regulator: 5vents are operated but 2 gates are damaged from 2011. Other regulators are not operated from 2010 due to gearbox damage
7	Bashira River Re-excavation	Habiganj	15	0	20	2	3	1.5	1.8		Embankment: Damage is occurred about 6000m due to erosion. Canal: Sedimentation problem Regulator: 2 regulators were not operated from 1997 and 1998, respectively due to damage of stoplogs.
8	Datta khola & adjoing beel	Bramanbaria	0	0	73.5	0					Canal: Sedimentation problem
9	Chandal Beel Scheme	Bramanbaria	0	2.8	1.5	1	2	1.5	1.8		Embankment: Damage is occurred about 100m due to erosion. Canal: Sedimentation problem Regulator: 2vent regulator was not operated from 1998 due to gate slot problem
10	Akashi & Shapla Beel Scheme	Bramanbaria	0	5.5	6.5	0					Embankment: Damage is occuerd about 150m due to erosion and artificial cutting. Canal: Sedimrntation Problem
11	Satodana Beel Scheme	Bramanbaria	0	0	0	2	2	1.5	1.8		Regulator: Stoplog type regulator was not operated from 2006 due to damage of stoplogs. Gate type regulator was also not operated from2004 due to grabox problem.
12	Singer Beel Scheme	Netrakona	3.5	13.2	55	2 2	3 1	1.5 1.5	1.8 1.8	2-Pipe sluice 2-0.33m Dia 2-Culvert 2-1.5mx1.8m	Embankment: Full embankment is damaged about 100m due to erosion, and submergible embankment is damaged about 125m due to erosion and artificial cutting. Canal: Sedimentation problem. Regulator 2-3vent and 1-1vent regulators are operated. 1-1vent was not operated from 2010 due to gearbox problem.
13	Thakurakona Scheme	Netrakona	0	13.2	N/A	2 1	3 2	1.5 1.5	1.8 1.8		Embankment: Reparing work is on going by WMIP. Canal: Excavation work is on going by WMIP. Regulator: 1-3vent regulator is operated but 2 gates were damagedfrom 2009. Other regulators are not operated. Repare works are planned in WMIP.
14	Kangsha River Scheme	Netrakona	0	20	0	1 3 3	4 3 1	1.5 1.5 1.5	1.8 1.8 1.8	3-Pipe culvert 3-0.33m Dia.	Embankment: Damage is occurred about 40m due to erosion. Regulator: 4vent regulator was not operated from 2009 due to gearbox problem for 2 gates. 3-3vent regulator was not operated from 2009due to gearbox problems. 2-1 vent regulators were not operated from 1999 and 2009, respectively due to gearbox problem.
15	Dampara Water Management	Netrakona	27	20	12	1 1	10 5	1.5 1.5	1.8 1.8	Pipe culvert 1no. 2vent-0.33mDia 43nos.1vent-0.33mDia 1no.-1vent-0.64mDia Box culvert 1no.-1.5mx1.8m	Embankment: Submergible embankment is damaged about 460m and full embankment is about 200m due to erosion. Regulator: 10-vent regulator is operaated but 2 gates are damaged from 2008. 5vent regulator was not operated from 2010 due to gearbox problem Canal: Sedimentation problems, some parts of canal are re-excavated by upzila. Culvert: 7 culverts were not funtion due to clogging by sediment material.

No.	Haor Project Name	District	Embankment (km)		Canal	Regulator				Others	Remarks
			Submergible	Full	(km)	No.	Vent	Width(m)	Height (m)		
16	Someswari River sub-scheme	Netrakona	0	6	0	0				Box culvert 2nos. 1mx0.5m	Embankment: Damage is ocured about 1,970m due to erosion.
17	Khaliajuri FCD Polder #2	Netrakona	52.1	0	0	2 1 2 5	4 3 2 1	1.5 1.5 1.5 1.5	1.8 1.8 1.8 1.8	4nos. Pipe inlet 4-0.75m Dia 2nos. Box culvert 0.75mx0.75m	Embankment: Damage is occurred about 810m due to erosion and artificial cutting. Regulator: 2-4vent regulators are under construction. 3vent regulator is not operated from 2009 due to gearbox problem. 2-2vent tregulators are operated even both gates are damaged. 3-1 vent regulators are notoperated due to gearbox problem.
18	Kaliajuri FCD Polder #4	Netrakona	47	0	0	1 1 3	4 3 1	1.5 1.5 1.5	1.8 1.8 1.8	5nos. Pipe inlet 5nos. 0.50m Dia Box culvert 1no. 0.5mx1.0m 4nos. 0.66mx0.66m Pipeculvert 1no. 0.3m Dia 2 Causeway	Embankment: Damage id occurred about 630m due to erosion and artificial cutting Regulator: 4vent and 3 vent regulatores are under constructios. 1 vent regulators are damaged due to gear box problem.
19	Mohadao Nadii Embankment	Netrakona	3	7.5	0	0				3nos. Box Culvert 1.32m x 0.67m	Embankment: Full embankment is damaged about 420m due to erosion, artifical cutting and lower than the design crest elevation, and submergible embankment is damaged about 120m due to erosion and artificial cutting.
20	Sunamganj Town Protection	Sunamganj	0	1.6	0	0					Embankment: Damage is about 300m due to erosion.
21	Sukhaijuri Bathai sub-project	Kishoreganj	0	20.9	0	1 1	6 1	1.5 1.5	1.8 1.8	3nos. Pipe sluice 3-0.9m Dia	Embankment: Full embankment is damaged about 70m. Regulator: 6vent regulator is not operated from 1993 due to conflict between fishers committee and farmers committee. 1vent regulator is not operated due to gearbox problem.
22	Gazaria Beel sub-project	Kishoreganj	0	0	0	1 1	2 1	1.5 1.5	1.8 1.8	3nos. Pipe sluice 3-0.9m Dia	Regulator: 1 vent regulator is not operated due to gearbox problem. All pipe sluice are not function due to siltation and lost of gate
23	Boraikhali Khal sub-project	Kishoreganj	0	5.3	24.5	1	6	1.5	1.8	2nos. Pipe Sluice 2-0.9m Dia.	Embankment: Damage is about 10m due to erosion. Canal: Sedimentation problem. All pipe sluices are not function due to siltation.
24	Char Ferradee-Jangalia sub-project	Kishoreganj	0	11.6	0	1	5	1.5	1.8	1no. Pipe Sluice 0.9m Dia.	Embankmnt: Rehabilitaion works are carried out by WMIP. Regulator is operated. Pipe sluice is not funtion due to siltation.
25	Singua River Re-excavation sub-project	Kishoreganj	0	0	55	0					Canal: Riverbed aggradation in Singua River is occurred due to sedimentation.
26	Adampur sub-project	Kishoreganj	0	0	9.4	1	2	1.5	1.8		Regulator is good condition. Canal: Sedimentation problem
27	Alalia Bahadia sub-project	Kishoreganj	0	0	8	1	2	1.5	1.8		Regulator is good condition. Canal: Sedimentation problem
28	Motkhola-Bairagir Char sub-project	Kishoreganj	0	10.8	0	1	2	1.5	1.8		Embankment: Damage is about 50m due to erosion. Regulator is good condition.
29	Bhairab Bazar Erosion Protection sub-project	Kishoreganj	0	0	0	0				Bank Protection 3km	Bank erosion: Damage is about 3000m due to erosion. Some protection works was carried out near abatment by railway authority.
30	Ganakkali sub-project	Kishoreganj	0	0	0	1 1	2 1	1.5 1.5	1.8 1.8		2vent regulator is not operated because the gate, hoisting rod, gear box was stolen just after construction. 1vent regulator is not operated due to gearbox problem.

Source: JICA Study Team



Source: JICA Study Team

Figure 4.3.4 Location Map of Filed Survey

4.3.4 Survey Results

(1) Design Drawings of the Haor Projects

The availability of drawings related to the existing haor projects has been looked into. Therefore, the JICA Study Team tried to collect existing as-built and design drawings from the BWDB field offices. However, the JICA Study Team was not able to obtain such drawings.

Only some index maps, such as the general plan, were collected. The index maps are attached in Annex 4-3.

The design standard of BWDB has been collected already from the BWDB Design Circle I. Its standard is applied to the design works in the Study.

(2) Problems in Haor Projects

Major structures in the haor projects include embankment (full and submergible), regulators and canals. **Table 4.3.5** shows the components of structures and the problems faced by each haor project. **Figure 4.3.4** shows the location map of the filed survey.

1) Regulator

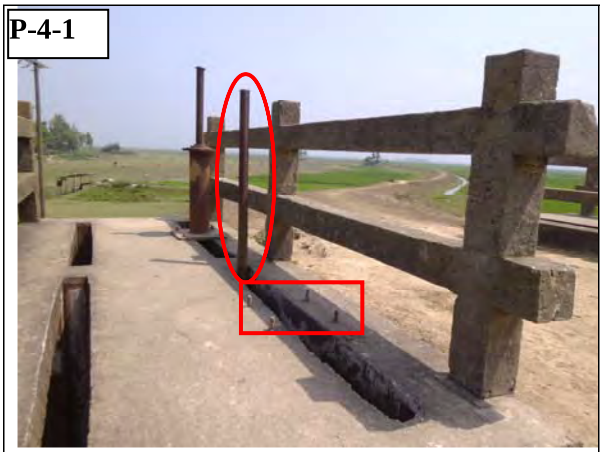
Many regulators are not operated due to maintenance problems. The responsibility of maintenance of regulators rests upon the BWDB field office; however, they don't have enough budgets for regular maintenance. Therefore, the metal structures deteriorate year by year. Finally, metal structures, such as gate leaves, spindles, and gear boxes are broken or cannot be operated manually. The survey team found out that gearbox is damaged because no grease has been provided on the gearbox and that there is damage to the anchor bolt of the lifting device.

There are 60 regulators in the survey area, in which 31 regulators are completely not operated and 6 regulators are partially damaged.

On the other hand, the regulator cannot be operated due to conflicts between farmers and fishery committees.

The damage to the regulators is as shown in the photographs below;

P-4-1



No lifting device

P-4-2

Corrosion of gate leaf is occurred.

P-4-3

① No gearbox ② Gate leaves are not painted.

Note: Location of the photograph is referred in Annex-4-4

On the other hand, the responsibility of the operation of the regulator lies with the sluice committee which is organized by the stakeholders. The sluice committee coordinates with BWDB for operation of the regulator. Such operation is based on the instruction from BWDB. The sluice committee or union committee functions as operator of the regulator.

2) Embankment

Full embankment and submergible embankment in the survey area was respectively constructed for 258 km and 175km, respectively, in haor area. These structures are mainly damaged for about a few meters to 10s m. Damage of several hundred meters is a few. A part of the haor project located in the floodplain area has been rehabilitated by WMIP. However, the rehabilitation works for the damaged structures were not carried out thorough the GOB funding.

Damage to the embankments is classified into two cases, namely, erosion due to flood over-topping and/or river flow velocity and direction, and artificial cutting. According to interviews with the village people and the BWDB site office staffs, the reasons for artificial cutting are to create entrances for boat, to create drainage outlets and inlets of irrigation water and for inland fishery purposes.

3) Canal

The canal in the survey area, which has a total length 241 km, is connected to the river. Generally the regulator is provided near the connection point. The farmers operate regulators as follows:

Rainy season: Gate open (water level is almost the same as the river water level)

Beginning of planting season: Gate close (to store water in the canal and pond)

After planting season: Gate open (drainage purpose) or Gate close (to keep store water)

Harvesting season: Gate close (Protection from pre-monsoon floods)

Many canals suffer from sedimentation problems, thus, resulting to lack of irrigation water and drainage problems. The present condition of canal is shown in the photograph below.

P-4-4	P-4-5
	
Re-excavation of canal (WMIP) due to sedimentation problem	Present situation of drainage canal According to interviews with village people, canal bed aggradation was already occurred. Re-excavation of canal is required.
Note: Location of the photograph is referred in Annex-4-4	

4) Problems

(a) Operation and Maintenance (O&M)

As explained above, the most important problem is the lack of O&M budget. The BWDB site offices requested to the BWDB head office for their O&M budget as estimated based on the repair works cost of the damaged structures. According to the interview with the BWDB site office, the actual budget is given about 20% to 30% only of the required cost. It is impossible to carry out all repair works and maintenance works with such budget. Therefore, they consider the priority of the repair works and only high priority structures undergo repair works, thus low priority structures are not rehabilitated.

On the other hand, LGED hands over the facilities constructed in the project to the stakeholders, such as the village people. The stakeholders then established a committee to carry out O&M. But BWDB does not have experience to establish the same type of O&M organization of LGED.

The JICA Study Team carried out hearing to the BWDB site offices regarding to the problem of the lack of the O&M budget and the participatory O&M approach. As a result of the interview, the BWDB site offices want to hand over to the water management group (WMG) established based on "Guideline for Participatory Water Management". They think that the WMG will be established under the new project, but it is difficult to establish the WMG in the existing project. The following issues shall be settled:

1) Establishment of new O&M organization (WMG) by stakeholder, and
2) Preparation of a system, such as to function facilities in the long term.

(b) Rehabilitation of Embankment

As a result of the interview with the village people, the embankment materials for rehabilitation works are collected near the river and canal. The embankment materials are to be compacted by use of a rammer, however, the compaction works have not been carried out.

It is unknown that the actual embankment materials satisfy the design value. There is no control of the compaction and water content during the construction. Therefore, it is expected that the strength of the structure is low.

(c) Regulator

Many regulators are not operated because the gearboxes were not greased. Some regulators are operated except gearboxes. On the other hand, the gearboxes and spindles for gates at some regulators have been stolen and sold. In the Ganakali Project, the gearbox and hoist were stolen just after completion of the construction.

Regarding the regulators, O&M and improvement of public awareness on the significance and necessity of regulators are important.

(3) River Facilities

River facilities were surveyed in Shylet, Maulvibazar and Habiganj districts. Many facilities, such as full embankments, submergible embankments and regulators, in other four districts have already been surveyed in the existing haor projects. **Table 4.3.6** shows the target rivers.

Table 4.3.6 Target Rivers for River Facility Survey

District	Target River
Shylet	Surma River, Kshiyara River
Maulvibazar	Manu River, Kshiyara River
Habiganj	Khowai River

1) Full Embankment

(a) Surma River

Full embankment was basically constructed at both banks and the maximum height of embankment is about 3 m. The left bank and right bank were constructed from the boarder to Shylet city and the boarder to Golabganj town, respectively. The river course is meandering and erosion has occurred outside of the meandering portion. Concrete panels were provided at these locations but were not sufficient due to budget limitation.

Sliding of the full embankment was found out outside of the meandering portion. It is expected that erosion at the toe of the slope would occur. The sliding portion is presently at only one location in the Surma River.

P-4-6

Crest of Full Embankment (Height between the crest and the land-side is about 2m, maximum height is about 3m.)

P-4-7

River bank protection by concrete panel

Sliding occurred at the beginning of the meandering portion.

Impact of bank erosion

Bank erosion

Note: Location of the photograph is referred in Annex-4-4

(b) Kushiyara River

The right bank is located in Bangladesh and the left bank is located in India at the upstream of the Kushiyara River. Therefore, full embankment and revetment on the right bank were constructed. The Rahimpur Pump Station is under construction instead of the regulator.

According to interview with the village people, the height of some parts of the full embankment is lower than the design crest elevation as flood water often enters into the land-side.

The full embankment at the left bank of the Kushiyara River was constructed for about 30km in Moulvibazar. The crest of the full embankment is utilized as a community road. Erosion of the meandering portion has occurred.

(c) Manu River

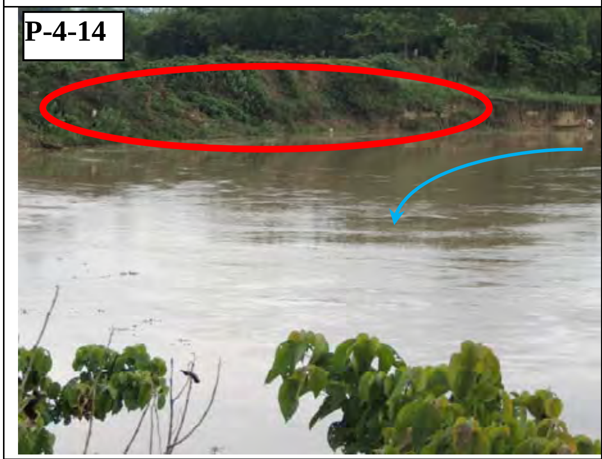
The Manu River is a tributary of the Kushiyara River and originates from the Tripula area in the Indian territory. The Manu Barrage is located on the Manu River and is the only barrage in the haor area. The existing full embankment along the Manu River suffers a serious damage due to erosion at water colliding fronts. The total length of the existing full embankment is 140 km and about 50 km long portions have been damaged. The total length of the existing full embankment along the Dhalai River, a left tributary of the

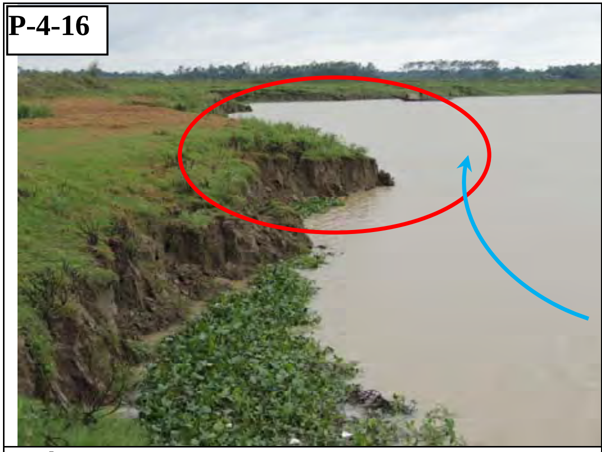
Manu River, is 130 km, of which about 60 km long embankments are damaged.

(d) Khowai River.

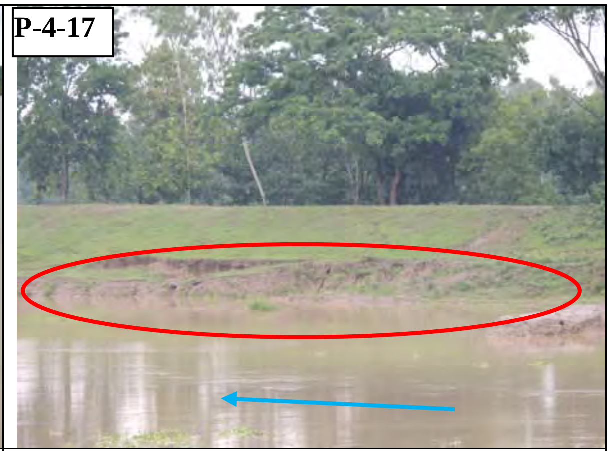
The Khowai River is also a tributary of the Kushiyara River and originates from the Tripula area in the Indian territory.

A total of 84 km long embankments had been constructed in the Khowai River Project, Phase 1, out of which 34km long embankments were rehabilitated in Khowai River Project, Phase2. Since the rehabilitation, 10 years have passed and some locations are partially eroded. However, the damage of embankment in the Khowai River is less serious compared with that of other rivers owing to the execution of rehabilitation.

P-4-12 	P-4-13 
Full embankment in the Kushiyara River The crest of the full embankment is utilized as a community road.	Full embankment of the Kushiyra River (hundreds meter upstream from the left side photo.) The crest elevation is lower than the design crest elevation. Thus, flood water often enters the mosque area. The overflow water depth is about 10 cm to 20cm.
P-4-14 	P-4-15 
Manu River (near the boundary) The river bank protection was constructed in this area in 2006/07. However, the eroded area was partially provided with concrete block type revetment due to budget shortage; therefore, the meandering portion was eroded.	Erosion at the meandering portion of the Dhalai River



Kshiyara River
Bank erosion of the low water channel at the meandering portion



Khowai River
Bank erosion at the toe of the slope

Note: Location of the photograph is referred in Annex-4-4

2) Regulator

Many regulators completed after 2009 are still functioning. Two regulators near the Kashempur Pump Station are still functioning even if they have been constructed for more than 30 years. This is because the operators of the pump station carry out maintenance works for these two regulators.

On the other hand, the Mori regulator completed in 2010 was already broken because a group of fishermen forcibly operated to open a gate of the regulator. At present, the spindle is broken.

3) Barrage

The Manu Barrage is the only structure in the haor area. It is located about 22 km upstream from the confluence of the Kshiyara River and the Manu River. The barrage was constructed and completed in 1982/83 using fund from the Government of Kuwait. The barrage has a width of 86 m and has eight roller gates. The power source for the operation of the barrage is a commercial source and there is a buck-up generator which can be used for emergency purpose. When the commercial power source is shut down and the buck-up generator cannot be used, manual operation can be applied. The civil works were carried out by a general contractor in Bangladesh, and the hydromechanical works were executed by SHIMCO from India.

The civil structures are still in good condition, while the hydromechanical structures are also under good maintenance.

The BWDB site office wants to replace the motor for the gates and the buck-up generator.

(3) Flood Mark

The JICA Study Team collected flood information from the village people and the BWDB officer in the existing haor project area. The highest flood water depth from the paddy field was confirmed by the village people for the 29 haor projects during river facility survey. The flood water depth in the haor project is summarized in **Table 4.3.7**. The minimum water depth is 1.5m and the maximum is 4.0m. The water depths varies in each location of the haor projects.

Table 4.3.7 Maximum Water Depth at 29 Haor Projects

No.	Scheme		Max. Depth from paddy field
1	Sukaijuri Bathai	Kishoreganj	2.8m
2	Gazaria Beel	Kishoreganj	2.8m
3	Boraikhali Khal	Kishoreganj	2.5m
4	Char Ferradee-Jangalia	Kishorganj	2.8m
5	Gingua River Re-excavation	Kishorganj	2.5m
6	Adampur	Kishorganj	2.5m
7	Alalia-Bahadia	Kishorganj	2.3m
8	Motokhola-Bairagir Char	Kishorganj	2.5m
9	Bhairab Bazar Erosion Protection	Kishorganj	2.8m
10	Ganakkhali	Kishorganj	2.5m
11	Binnabaid	Kishorganj	2.8m
12	Akashi & Shapla Beel	Brannabaria	3.5m
13	Datta Khola	Brannabaria	3.8m
14	Satdona Beel	Brannabaria	3.5m
15	Chandal Beel	Brannabaria	2.8m
16	Kair Dhala Ratna	Habiganj	1.5m
17	Shutki River Embankment	Habiganj	4.0m
18	Madhabpur FCD	Habiganj	3.0m
19	Cheghaia Khal	Habiganj	4.0m
20	Aralia Khal	Habiganj	1.5m
21	Ganajuri FCD	Habiganj	3.0m
22	Singer Beel	Netrakona	2.8m
23	Thakurakona	Netrakona	2.9m
24	Kangsha River	Netrakona	3.0m
25	Dampara water management	Netrakona	3.2m
26	Someswari River	Netrakona	3.2m
27	Khaliajuri FCD Polder#2	Netrakona	3.5m
28	Khaliajuri FCD Polder#4	Netrakona	3.7m
29	Sunamganj Town Protection	Sunamganj	2.4m

Note: Data are collected from interview survey
Source: JICA Study Team

(4) Function of Haor Area

1) Flood Reservoir and Desilting Basin

The haor area receives huge flashy inflows from the adjacent Indian states of Tripura and Meghalaya, which lies tin the south and north, respectively. It also receives the substantial outflow from the Barak River basin, which lies in the east and occupies parts of the Indian states of Assam, Mizoram and Manipur. The haor area floods early and drains late. The floodwater levels rise very quickly in the pre-monsoon season. Generally the rise starts in late April and shoots up to 2 m to 3 m at fortnight and rarely comes down afterwards with much of the haor area being flooded to a depth of up to 6 m to 8 m in the monsoon season. Drainage of this floodwater is to the north to south and southwest via Surma, Kushiyra, Baulai and Kalni Rivers into the Meghna River and the Bay of Bengal. Drainage after the wet season ends and typically takes up to three months.

2) Method for Securing Irrigation Water

There are substantial volumes of (post monsoon) residual surface water available for irrigation. Surface water in rivers and haors is extensively used for rice production in the dry season. About two-thirds of the total rice growing area is irrigated by surface water compared to the national average of 20%. According to the survey conducted by the Ministry of Agriculture 52% of 1.35 million irrigation water users or farmers in the haor area irrigate surface water compared to 18% throughout the country (Minor Irrigation Survey Report 2011-12, Bangladesh Agriculture Development Corporation, according to the survey by the Ministry of Agriculture). Furthermore, diesel operated equipments, such as (deep tube wells (DTWs), shallow tube wells (STWs) and low-lift pumps (LLPs)) cover about 78% of the total irrigated area (groundwater and surface water combined) compared to the national average of 69%. Surface water irrigation by diesel operated LLPs accounts for about 87% of the total irrigated area. About 98% of the surface water users irrigate their land by diesel operated LLPs. Water users who irrigate their land by electricity operated LLPs account for 2% of the total water users. Water charge in the diesel operated LLP irrigated area is two to three times higher than in electricity operated LLP irrigated area. Surface water for irrigation is mostly obtained from the beels as well as from the channels and rivers using LLPs. The regulators on the channels are closed before land drainage is complete so that sufficient water is regained in the beels for irrigation. The water management plan that will ensure irrigation water supply and contribute to food production in the haor area should include as follows:

- Increasing of the effectiveness of the existing irrigation infrastructure through improvements of operation and maintenance systems.
- Provision of irrigation infrastructure in the areas of existing and potential high agricultural productivity.
- Improvement of water distribution by development of irrigation infrastructure. Such as construction of lined canal and buried pipe system, and supply of flexible pipe.
- Dredging of rivers and re-excavation of channels and beels to conserve adequate water for irrigation in dry season.
- Provision of cross dams on rivers, channels and hilly streams for water conservation for irrigation.
- Excavation of hilly streams in order to improve flow.
- Electricity supply for irrigation to reduce crop production.
- Support farmers for solar powered irrigation pumping.

3) Soil Nutrient Supply

Soils in the haor area are relatively uniform, developed in non-calcareous alluvium and productive. Grey, heavy, silty clay loams predominate on the ridges; while clay in the haor centers. Small areas of loamy soils occur alongside rivers, together with mixed sandy and silty alluvium. Peats occupy some wet haor centers. The cultivated layer is lighter in texture except in haor centers. Most soils have dark grey to black topsoil and between slightly to strongly acid and moderately alkaline in reaction. Fertility level is medium to high with low P and high in Zn and S content while that of other essential nutrients is themedium. The levels of N and P_2O_5 are medium. Organic matter content ranges between 0.5% to 2.0% in ridge soils and 2.0% to 4.0% in haor centers. Permeability is generally slow, except in some loamy ridge soils. Moisture-holding capacity is moderate to low. The soils are better suited for rice cultivation with irrigation in the dry season. Silty clay and loamy soils on intermediate positions are suitable for both irrigated boro rice and non-rice crops. Deep floods in haor area damage crops or restrict land use for crop production. However, the floods may actually benefit deepwater aman rice grown after the harvest of boro rice in the pre-monsoon season. The deepwater rice provides shelter for fish and their food in the form of periphyton on submerged stems and leaves, refuge for wildlife, and base of food chain through decomposition of plant material.

The soil nutrients in the haor area are affected by many factors. These include flooding, elevation of the soils relative to the local flood levels, sediments content of the flood water, types of crop grown, and nature and rate of fertilizers application on the land. The floodwater running off upstream carries silt and clay. The fertility associated with flooding comes from various sources including nitrogen-fixing organism living in floodwater, decomposition of organic matter, release of nitrogen from soil micro organic matter by microbial activity after soil is submerged and phosphorous and some minor elements released by changes in soil chemistry which occur between dry and submerged conditions. Flood protection and drainage which reduce the depth and duration of flooding may reduce the fertility. This needs to be compensated by increased fertilizer use.

In the hill lands upstream there have been extensive and indiscriminate cleaning of the forest over large tracts of areas, followed by use of the land for cropping. The numerous rivers rising in these hills carry huge volume of sediments of which some are flashed out. The reminder is deposited mainly on the river beds, cultivated lands and depressions. These sediments are characterized by coarser fraction in the upstream and final materials in the downstream. There are significant changes in soil productivity with the increase in severity and frequency of flooding, burial of land by raw sandy sediments and depletion of soil fertility level. The increasing degradation of vegetation and soils in the Indian states of Assam Hills and in some Bangladesh's hills areas too will increase runoff into the rivers. This seems likely to increase the amounts of sediments including more sands carried by floodwater in the haor area (Agricultural Development Possibilities in Bangladesh by Hugh Brammer, 1997, University Press Limited, Bangladesh).

4) Freshwater Fishing in Farm Land

Freshwater fisheries are comprised of floodplain (77%), beels (9%), channels (11%) and ponds and ditches (3%). The floodplain covers about 324,000 ha, beels 37,000 ha, channel 45,000 ha and ponds 4,300 ha. Floodplain landscapes are not absolutely flat. They comprise higher parts (river banks, ridges) and lower parts (old river-channels, basins). Virtually every floodplain includes both ridge and basin land which are seasonally flooded. The ridge soils are better suited for non-rice corps and heavier soils on the lower part are for boro rice in the winter season. In floodplain areas subsistence fishing occurs mainly during the flooding period and large-scale beel fishing occurs in the winter season on an annual basis.

There are two types of fishermen - traditional and non-traditional, who catch for generating an income. Traditional fishermen live on fishing and have been engaged in the profession since generations. There are an estimated 12,000 to 18,000 traditional fisherman households settled mostly in the haor area. The jalmohals (water bodies which are registered for revenue collection as a fishery) are generally leased out to them through cooperatives. The non-traditional fishermen are mainly an emerging group from landless and poor farmers. They fish in open water especially during monsoon season and sell the catch. Such non-traditional fishermen are increasing in number and nearly 30-40 percent of the total households in haor area are reportedly engaged in catching fish. According to the Bangladesh Bureau of Statistics (2011) the number of subsistence fisheries households in the haor area is 1.6 million (2010 Yearbook of Agricultural Statistics). Annually, each household catches 115 kg of fish in floodplain. Accordingly the total annual catch from the floodplain is about 184,000 tons. The semi-closed seasonal water bodies on cultivated floodplain covers about 2,900 ha where the fish production is about 6,350 tons annually.

CHAPTER 5 HYDROLOGICAL AND HYDRAULIC STUDY

5.1 Data Collection and Review

Most of the data were obtained from BWDB, IWM and CEGIS. Some of the information obtained can only be used in conjunction with these institutions.

(1) Existing Data Availability

1) Water Level

Water level data is very important information for the Study because it is the reference in the definition of the water surface elevation to define the height of submerged embankment planned in the M/P for the protection of agricultural land during the pre-monsoon season.

Measurements exist for 46 stations in the Northeast Region. The IWM study used data series from 1986 (mostly from April) to 1993 (mostly up to March). While updating the previous models the data was updated up to November 2006. These data are still available from BWDB and updated data up to March 2012 could be readily accessed; while data prior to 1986 are also available with BWDB. However, they might not be necessary as 25 years data, 1986-2011, is quite a long series for any hydrological analysis, and the river channel dynamic or morphological changes have occurred after 1986. Hence, the existing NERM has been updated through calibration using hydrological data from 1986. The list of the water level measurement stations is provided in **Table 5.1.1**.

The frequency of water elevation measurement is not continuous as it can be seen in the NERM. The water elevation measurements at most of the gauges have been conducted manually every 3 hours for a total of 5 measurements a day from 6:00 a.m. to 6:00 p.m. using a staff gauge. There are no automatic gauging stations present in the Northeast Region.

2) Flow

There are 27 flow/discharge measurement stations located in the Northeast Region. BWDB maintains these measurement stations. Data until 2001 are available from BWDB. Flow/discharge measurements have been carried out with a bucket-type current meter. The list of flow/discharge measurements is provided in **Table 5.1.2.** Flow measurements are less frequent than water elevation records due to budget constraint and other difficulties and issues. There have been 16 to 18 measurements conducted annually at Sylhet, Sunamganj and Bhairab Bazar along the Surma-Baulai Rivers.

3) Rainfall

There are 45 rainfall measurement stations in the Northeast Region, which are being maintained by BWDB. Rainfall is measured on a daily basis (24 hour rainfall from 7:00 a.m.) with a manual rain gauge and its data are updated up to March 2012. The measured daily rainfall data are sent and stored in BWDB/Dhaka through the following process:

i) The measured daily rainfall is entered into a prescribed monthly rainfall statement form, and the monthly rainfall statement is sent by a field engineer of “Hydrology Sub-division (BWDB)” to the Executive Engineer of “Surface Water Processing Branch (BWDB/Dhaka)” after the statement is checked and signed by the field engineer.

ii) After the monthly rainfall statement is checked and compiled by the Executive Engineer of "Surface Water Processing Branch", the compiled data are stored into a computer in BWDB/Dhaka under the supervision of the Director of "Processing and Flood Forecasting Circle (BWDB/Dhaka)". And

iii) The measured daily rainfall is also sent directly from a rain gauge station to "Flood Forecasting and Warning Centre (BWDB)" during the months of April to October by mobile phone.

Data from 1986 to 2006 have been used by IWM. The list of rainfall stations is provided in **Table 5.1.3**.

4) Evaporation

There are only 3 evaporation measurement stations in the Northeast Region as listed in **Table 5.1.4**. BWDB maintains these stations. Evaporation is measured on a daily basis (24 hour evaporation from 7:00 a.m.) with an evaporation pan and its data are updated up to March 2012. Data from 1986 to 2006 have been used by IWM in connection with regional hydrologic modeling. The frequency for evaporation measurements is once a day.

5) Temperature

There are 4 temperature measurement stations in the Northeast Region. The Bangladesh Meteorological Department (BMD) maintains these stations. Air temperature is measured twice a day (7:00 a.m. and 6:00 p.m.) with a maximum-minimum thermometer, and its data are available from January 1948 to March 2012. Data from the remaining period of 2012 is also available. These data have been used in the M/P. The list of temperature stations is provided in **Table 5.1.5**. Temperature measurements are generally continuous or at several times a day, depending on locations and objectives of the record.

Table 5.1.1 List of Water Level Data Available from DWDB

Sl	District	RiverName	StationID	StationName	Data Available with BWDB		Remarks
					From	To	
1	Mymensingh	Banar	SW8	Basuri	April 1986	March 2012	More data prior to April 1986 are also available for most of the stations, but it might not be required in consideration of length of data series and in consideration of updating existing NAM and HD Model as data from 1986 has been used in the models
2	Mymensingh	Banar	SW9.5	Trimohini	April 1986	March 2012	
3	Mymensingh	Bhogai-Kangsa	SW35.5	Sarchapur_ Mymensingh	April 1986	March 2012	
4	Mymensingh	Old Brahmaputra	SW227	Offtake of Suti	April 1986	March 2012	
5	Mymensingh	Old Brahmaputra	SW228.5	Mymensingh	April 1986	March 2012	
6	Mymensingh	Nitai	SW314	Ghosegaon	April 1986	March 2012	
7	Kishoreganj	Mogra	SW311.4	Chamraghat	April 1986	March 2012	
8	Sylhet	Kushiara	SW172.5	Amalshid	April 1986	March 2012	
9	Sylhet	Kushiara	SW173	Sheola	April 1986	March 2012	
10	Sylhet	Kushiara	SW174	Fenchuganj	April 1986	March 2012	
11	Sylhet	Kushiara	SW175.5	Sherpur	April 1986	March 2012	
12	Sylhet	Piyan	SW233	Protappur_Piyan gang	April 1986	March 2012	
13	Sylhet	Piyan	SW233A	Jaflong_Spill	April 1986	March 2012	
14	Sylhet	Piyan	SW234	Companiganj	April 1986	March 2012	
15	Sylhet	Sari-Gowain	SW251	Sarighat	April 1986	March 2012	
16	Sylhet	Sari-Gowain	SW252	Gowainghat	April 1986	March 2012	
17	Sylhet	Sari-Gowain	SW252.1	Salutikar	April 1986	March 2012	
18	Sylhet	Sonai-Bardal	SW265	Jaldhup	April 1986	March 2012	
19	Sylhet	Surma-Meghna	SW266	Kanairghat	April 1986	March 2012	
20	Sylhet	Surma-Meghna	SW267	Sylhet	April 1986	March 2012	
21	Sylhet	Surma-Noya	SW345	Durlavpur	April 1986	March 2012	
22	Sylhet	Lubachara	SW326	Lubachara	April 1986	March 2012	
23	Sylhet	Dhala	SW332	Islampur	April 1986	March 2012	
24	Sylhet	Jhalukhali	SW333A	Dulura	April 1986	March 2012	
25	Habiganj	Korangi	SW138	Sofiabad	April 1986	March 2012	
26	Habiganj	Khowai	SW157	Ballah	April 1986	March 2012	
27	Habiganj	Khowai	SW158	Chunarghat	April 1986	March 2012	
28	Habiganj	Khowai	SW158.1	Shaistaganj	April 1986	March 2012	
29	Habiganj	Khowai	SW159	Habiganj	April 1986	March 2012	
30	Habiganj	Sonai	SW264A	Montala	April 1986	March 2012	
31	Habiganj	Sutang	SW280	Sutang Rly.Brid	April 1986	March 2012	
32	Sunamganj	Dhanu-Baulai-Gh orautra	SW72B	Sukdebpur	April 1986	March 2012	
33	Sunamganj	Jadukata	SW131.5	Laurergarh Saktiarkhola	April 1986	March 2012	
34	Sunamganj	Surma-Meghna	SW268	Chhatak	April 1986	March 2012	
35	Sunamganj	Surma-Meghna	SW269	Sunamganj	April 1986	March 2012	
36	Sunamganj	Surma-Meghna	SW269.5	Dirai_on Kalni	April 1986	March 2012	
37	Sunamganj	Lubachara	SW326A	Borogram	April 1986	March 2012	
38	Sunamganj	Jhalukhali	SW333	Muslimpur	April 1986	March 2012	
39	Sunamganj	Noyagang	SW337	Urargaon	April 1986	March 2012	
40	Sunamganj	Omayan Chella	SW341	Chella Sonapur	April 1986	March 2012	
41	Moulvi Bazar	Dhalai	SW67	Kamalganj	April 1986	March 2012	
42	Moulvi Bazar	Juri	SW135A	JuriCont_Silghat	April 1986	March 2012	
43	Moulvi Bazar	Lungla	SW192	Motiganj	April 1986	March 2012	
44	Moulvi Bazar	Monu	SW201A	Chatalaghat	April 1986	March 2012	
45	Moulvi Bazar	Monu	SW201	Monu Rly.Bridge	April 1986	March 2012	
46	Moulvi Bazar	Monu	SW202	Moulvi Bazar	April 1986	March 2012	

Source: BWDB

Table 5.1.2 List of Flow/Discharge Data Available from BWDB

Sl	District	River Name	Station ID	Station Name	Data Available with BWDB		Remarks
					From	To	
1	Sunamganj	Omayun Chella	SW341	Chella Sonapur	April 1986	March 2012	More data prior to April 1986 are also available for most of the stations, but it might not be required in consideration of length of data series and in consideration of updating existing NAM and HD Model as data from 1986 has been used in the models
2	Sunamganj	Noyagang	SW337	Urargaon	April 1986	March 2012	
3	Sunamganj	Jhalukhali	SW333	Muslimpur	April 1986	March 2012	
4	Sunamganj	Surma-Meghna	SW269	Sunamganj	April 1986	March 2012	
5	Sunamganj	Jadukata	SW131.5	Laurergarh Saktiarkhola	April 1986	March 2012	
6	Netrokona	Someswari	SW262	Bijoypur	April 1986	March 2012	
7	Netrokona	Bhogai-Kangsa	SW36	Jaria-Jhanjail	April 1986	March 2012	
8	Moulvi Bazar	Monu	SW201	Monu Rly.Bridge	April 1986	March 2012	
9	Moulvi Bazar	Lungla	SW192	Motiganj	April 1986	March 2012	
10	Moulvi Bazar	Juri	SW135A	JuriCont_Silghat	April 1986	March 2012	
11	Moulvi Bazar	Dhalai	SW67	Kamalganj	April 1986	March 2012	
12	Mymensingh	Nitai	SW314	Ghosegaon	April 1986	March 2012	
13	Mymensingh	Old Brahmaputra	SW228.5	Mymensingh	April 1986	March 2012	
14	Kishoreganj	Surma-Meghna	SW273	Bhairab Bazar	April 1986	March 2012	
15	Kishoreganj	Old Brahmaputra	SW230.1	Bhairab Bazar R	April 1986	March 2012	
16	Sylhet	Jhalukhali	SW333A	Dulura	April 1986	March 2012	
17	Sylhet	Dhala	SW332	Islampur	April 1986	March 2012	
18	Sylhet	Lubachara	SW326	Lubachara	April 1986	March 2012	
19	Sylhet	Surma-Meghna	SW267	Sylhet	April 1986	March 2012	
20	Sylhet	Surma-Meghna	SW266	Kanairghat	April 1986	March 2012	
21	Sylhet	Sonai-Bardal	SW265	Jaldhup	April 1986	March 2012	
22	Sylhet	Sari-Gowain	SW251	Sarighat	April 1986	March 2012	
23	Sylhet	Piyan	SW233A	Jaflong_Spill	April 1986	March 2012	
24	Sylhet	Piyan	SW233	Protappur_ Piyan gang	April 1986	March 2012	
25	Sylhet	Kushiara	SW175.5	Sherpur	April 1986	March 2012	
26	Sylhet	Kushiara	SW173	Sheola	April 1986	March 2012	
27	Sylhet	Kushiara	SW172.5	Amalshid	April 1986	March 2012	

Source: BWDB

Table 5.1.3 List of Rainfall Data Available from BWDB

Sl	District	Station ID	Station Name	Data Available with BWDB		Remarks
				From	To	
1	Sylhet	CL102	Companyganj Bholaganj	April 1986	March 2012	More data prior to April 1986 are also available for most of the stations. But it might not be required in consideration of length of data series and in consideration of updating existing NAM and HD Model as data from 1986 has been used in the models
2	Sylhet	CL116	Lallakhal	April 1986	March 2012	
3	Sylhet	CL125	Sheola	April 1986	March 2012	
4	Sylhet	CL128	Sylhet	April 1986	March 2012	
5	Sylhet	CL129	Tajpur	April 1986	March 2012	
6	Sylhet	CL130	Zakiganj	April 1986	March 2012	
7	Sylhet	CL228	Kanairghat	April 1986	March 2012	
8	Sunamganj	CL107	Chhatak	April 1986	March 2012	
9	Sunamganj	CL109	Gobindaganj	April 1986	March 2012	
10	Sunamganj	CL127	Sunamganj	April 1986	March 2012	
11	Sunamganj	CL44	Moheshkhola	April 1986	March 2012	
12	Sunamganj	CL49	Laurergarh	April 1986	March 2012	
13	Moulvi Bazar	CL104	Chandbagh	April 1986	March 2012	
14	Moulvi Bazar	CL108	Dakhinbagh	April 1986	March 2012	
15	Moulvi Bazar	CL114	Kamalganj	April 1986	March 2012	
16	Moulvi Bazar	CL117	Langla	April 1986	March 2012	
17	Moulvi Bazar	CL118	Latu	April 1986	March 2012	
18	Moulvi Bazar	CL119	Monumukh	April 1986	March 2012	
19	Moulvi Bazar	CL122	Moulvi Bazar	April 1986	March 2012	

Sl	District	Station ID	Station Name	Data Available with BWDB		Remarks
				From	To	
20	Moulvi Bazar	CL126	Srimangal	April 1986	March 2012	
21	Moulvi Bazar	CL229	Monu Rly. Br.	April 1986	March 2012	
22	Habiganj	CL105	Chandpur Bagan	April 1986	March 2012	
23	Habiganj	CL110	Habiganj	April 1986	March 2012	
24	Habiganj	CL111	Itakhola(Baikuntha)	April 1986	March 2012	
25	Habiganj	CL120	Markuli	April 1986	March 2012	
26	Mymensingh	CL27	Phulbaria	April 1986	March 2012	
27	Mymensingh	CL45	Ghosegaon	April 1986	March 2012	
28	Mymensingh	CL46	Rasulpur	April 1986	March 2012	
29	Mymensingh	CL5	Bhaluka	April 1986	March 2012	
30	Mymensingh	CL64	Gafargaon	April 1986	March 2012	
31	Mymensingh	CL65	Gauripur	April 1986	March 2012	
32	Mymensingh	CL72	Muktagacha	April 1986	March 2012	
33	Mymensingh	CL73	Mymensingh	April 1986	March 2012	
34	Mymensingh	CL75	Nandail	April 1986	March 2012	
35	Mymensingh	CL77	Phulpur	April 1986	March 2012	
36	Kishoreganj	CL101	Bhairab Bazar	April 1986	March 2012	
37	Kishoreganj	CL112	Itna	April 1986	March 2012	
38	Kishoreganj	CL113	Khaliajuri	April 1986	March 2012	
39	Kishoreganj	CL61	Bajitpur	April 1986	March 2012	
40	Kishoreganj	CL71	Kishoreganj	April 1986	March 2012	
41	Netrokona	CL115	Kendua	April 1986	March 2012	
42	Netrokona	CL121	Mohanganj	April 1986	March 2012	
43	Netrokona	CL123	Netrokona	April 1986	March 2012	
44	Netrokona	CL63	Durgapur	April 1986	March 2012	
45	Netrokona	CL68	Jaria-jhanjail	April 1986	March 2012	

Source: BWDB

Table 5.1.4 List of Evaporation Data Available from BWDB

Sl	District	Station ID	Station Name	Data Available with BWDB		Remarks
				From	To	
1	Mymensingh	E024	Mymensingh	April 1986	March 2012	More data prior to April 1986 are also available for most of the stations, but it might not be required in consideration of length of data series and in consideration of updating existing NAM and HD Model as data from 1986 has been used in the models
2	Sreemangal	E036	Sreemangal	April 1986	March 2012	
3	Sunamganj	E037	Sunamganj	April 1986	March 2012	

Source: BWDB

Table 5.1.5 List of Temperature Data Available from BMD

Sl	District	Station ID	Station Name	Data Available	
				From	To
1	Comilla	11313	Comilla	April 1986	March 2012
2	Mymensingh	10609	Mymensingh	April 1986	March 2012
3	Moulvi Bazar	10724	Sreemangal	April 1986	March 2012
4	Sylhet	10705	Sylhet	April 1986	March 2012

Source: BMD

(2) Data Consistency and Resolution

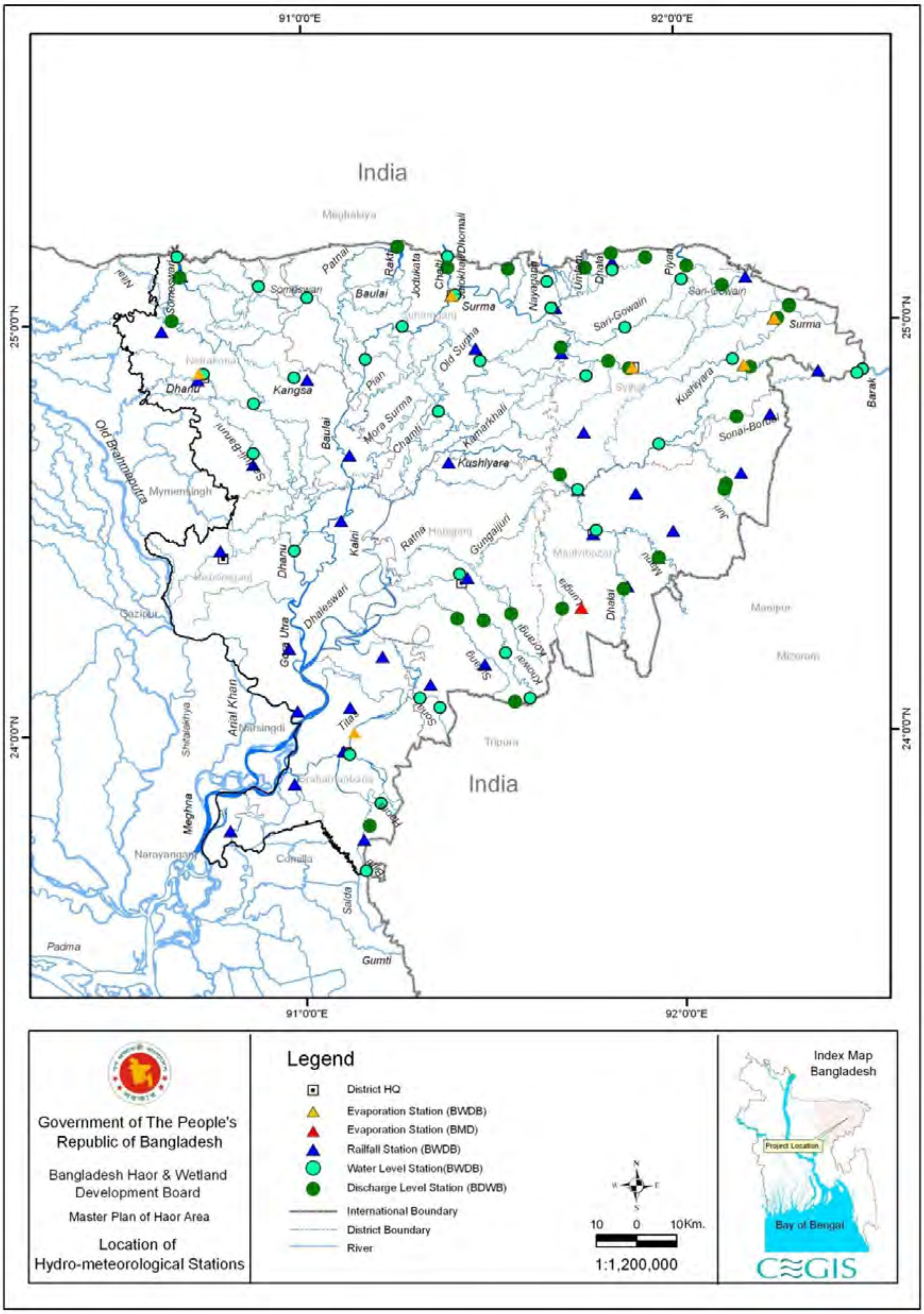
The data series available from BWDB and BMD are quite long and are considered sufficient. However, the number of stations of evaporation measurement appears less, but the variation of evaporation rate in the haor area is negligible.

Rainfall data seem to be inadequate for hydrologic modeling. Rainfall is measured only thrice a day and the spacing does not cover major geographic or climatic region throughout the watershed.

For watersheds without rainfall and/or rating curves at their outlets, flood hydrographs were estimated by transposing the results from nearby watersheds considering the precipitation, watershed vegetation cover, soil, physical characteristics, and area sizes. Rainfall data are recoded and collected daily at several locations in the watershed. However, the data are sparse and manually registered thrice a day. To account for the flow at the trans- boundary locations, water level (WL) stations are operated at these locations and rating curves are developed.

No automatic rain gauging stations have been operated. In a region with intense precipitation, the rainfall needs to be registered with more details in order to have a precipitation run-off model within an acceptable degree of certainty. The precipitation at the foothill in India, which is one of the highest areas in the world, results in high flood run off during the monsoon season.

Figure 5.1.1 locates the hydro meteorological stations in the Northeast Region.



Source: Master Plan of Haor Area, April, 2012

Figure 5.1.1 Location Map of Hydro Meteorological Stations

5.2 Hydrologic Model

IWM preserves "General Model" and the six "Regional Models" developed under Surface Water Simulation Modeling Programme Phase-II (SWSMP II, 1992 - 1996).

The North East Regional Model (NERM), which is one of the "Regional Models", covered the same study area. Attempts were thus made to have an overview of the NERM available in IWM. The development of NERM was initiated in early 1991. The model comprised a hydrological (rainfall-runoff) model and a hydro-dynamic (river, channel, and flood plain) model. The hydrological model was originally calibrated from April 1986 to December 1992. The model was subsequently validated for the period from April 1992 to March 2003. This model provided runoff discharges as the input data to the hydrodynamic model.

The hydrologic analysis was centered on two topics: hydrologic modeling to provide input flow data to the hydrodynamics model, and statistical analysis to extrapolate precipitations, water surface elevation, and flows at several locations throughout the Northeast Region.

(1) Model Description and Analysis

The mathematical model with MIKE 11 was utilized to route the rainfall-runoff from several watersheds within the North and Southeast regions by CEGIS and IWM. CEGIS calibrated the model for watersheds situated within the Bangladesh-India border, while IWM extrapolated the model over the Indian border in order to incorporate the whole watershed.

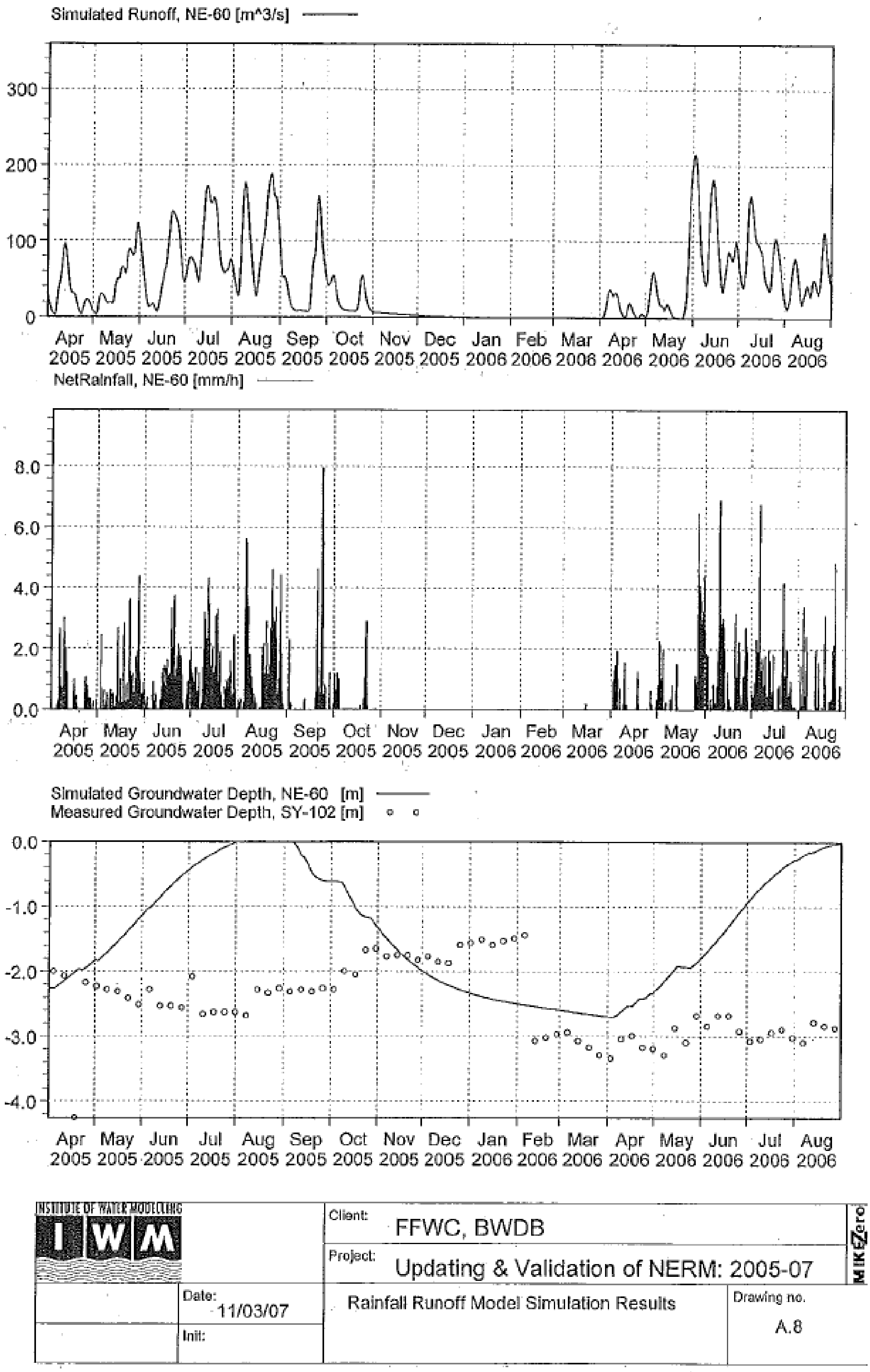
The models settled the output to a 3 hour time step which is the input time interval for the NERM. Annex 5-1 shows the division of the inland and transboundary catchments in the NERM.

(2) Models Reliability

The WL-discharge rating curves and the discharge hydrographs at the sub-watershed outlets are not reliable. These outlets have been frequently under the effect of backwater formed at the confluence of major tributaries and also large portion of flow spillovers or inflows exchanging volumes of water with flood plain before reaching the WL stations. In addition, wherever the rating curves were not available, the calibration of the model was tried utilizing the variation of ground water table as reference. Considering the lag time between the surface runoff flow and the ground water table variation, the hydrologic calibration at most of the time is unreliable.

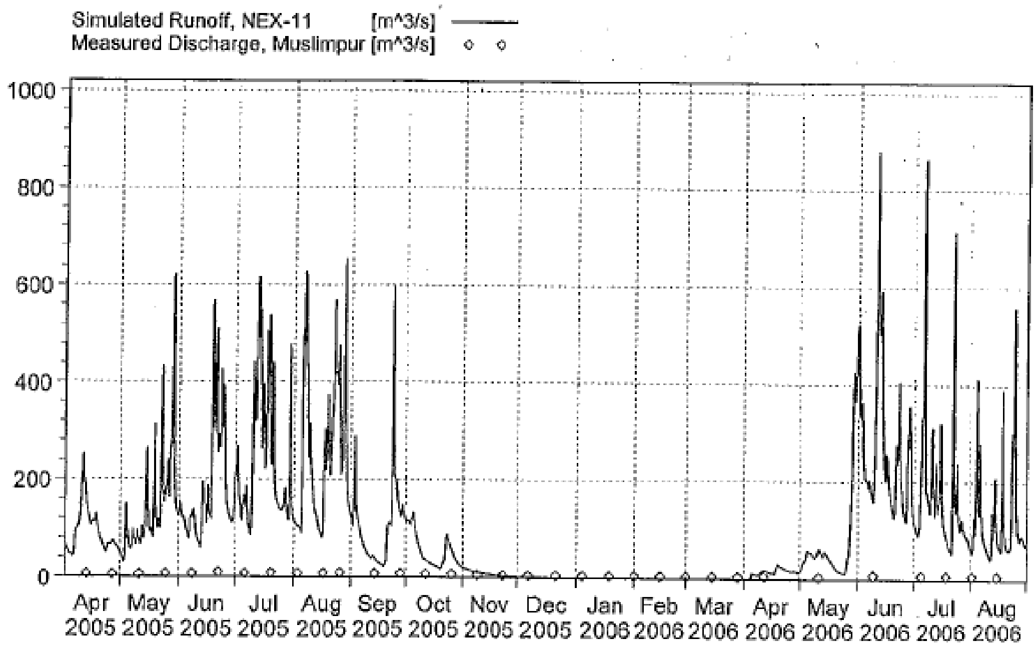
The watershed physiographic characteristics and data quality jeopardizes the hydrologic model calibration, while the estimated hydrographs are indeed questionable. To improve the water yield from the upstream sub-watershed data, additional studies are thus necessary.

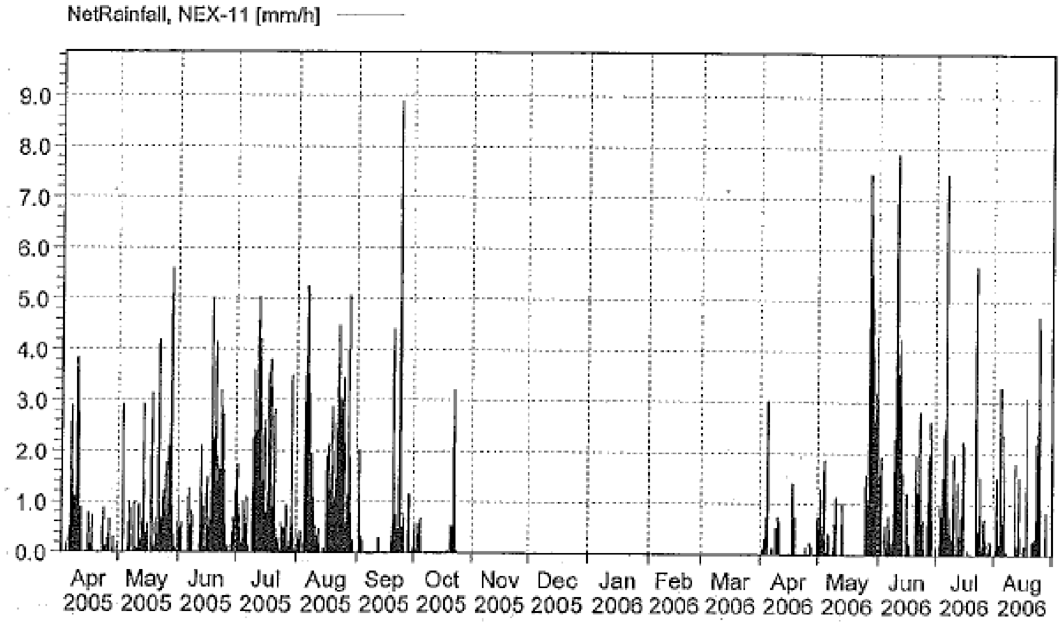
The verification of the IWM and CEGIS model calibration shows that the data available are poor in quality, thus resulting in unsatisfactory prediction of input flows for the hydrodynamic model. **Figure 5.2.1**, exemplifying some of the calibration results in the IWM Validation Report, clearly shows that the model calibration needs improvement.



Source: IWM

Figure 5.2.1 Hydrologic Model (NAM-IWM) Calibration Results (1/2)





INSTITUTE OF WATER MODELLING IWM		Client: FFWC, BWDB	MIKE Zero
		Project: Updating & Validation of NERM: 2005-07	
	Date: 11/03/07	Rainfall Runoff Model Simulation Results	Drawing no. A.36
	Init:		

Source: IWM

Figure 5.2.1 Hydrologic Model (NAM-IWM) Calibration Results (2/2)

Certainly, the data sampling locations and quality for precipitation over the watershed and/or flows at the watershed outlets must be greatly improved. These goals can only be achieved with a long term strategy plan and a continuous commitment from the GOB and agencies in charge of collecting hydro-meteorological information.

5.3 Flood Runoff Analysis

5.3.1 General

(1) Pre-monsoon Season

The pre-monsoon season usually extends from April to May in Bangladesh. This season is characterized by powerful short-duration thunderstorms with heavy rainfall which yield intense runoff from the hills across the border in India. This intense flood runoff and the runoff due to the direct precipitation in the haor area combine, and accumulate as inundation occurs over the haor area.

The most important impact caused by rainfall during this season is the occurrence of flash floods that frequently overtop river banks and natural levees. Flash floods cause devastating damage to the agricultural product, mainly boro rice in the harvest season.

(2) Monsoon Season

The monsoon season starts just after the end of the pre-monsoon season and continues to September through October. During this period, most agricultural activities cease because a large part of the haor area is inundated; for example the water depths in several regions reach up to 5 m. The economic activities in this area is mostly reduced, and the local population relay on fishing as a source of livelihood.

During the monsoon season, the precipitation is not as intense as that of the pre-monsoon season, but the rainfall continues over the larger watershed with a longer duration. The runoff due to this rainfall drains over the haor area. A large volume of flood also originates from the area across the Indian border where one of the largest average annual precipitations in the world occurs.

The hydrographs throughout the steeper valleys in the Indian side of the border attenuate when they reach the flat topography in the Northeast Region. The reduced slope of the terrain just downstream of the border frequently causes floods which spread over the flood plains and lakes reducing the peak discharge, resulting in attenuation of hydrographs.

Over the haor area, the floodplain topography is very shallow with reduced landscape slope. This physiography is the product of the sediment deposition due to erosion of overland soil in the Indian hills of the watershed, geological subsidence in the Sylhet basin, and morphological alterations caused by the channel migration of the Brahmaputra River. As a consequence, flow conditions of most of the haor area behave like a reservoir during the monsoon season, controlled by the back-water of the downstream, the Padma River.

5.3.2 Dynamic Hydraulic Modeling

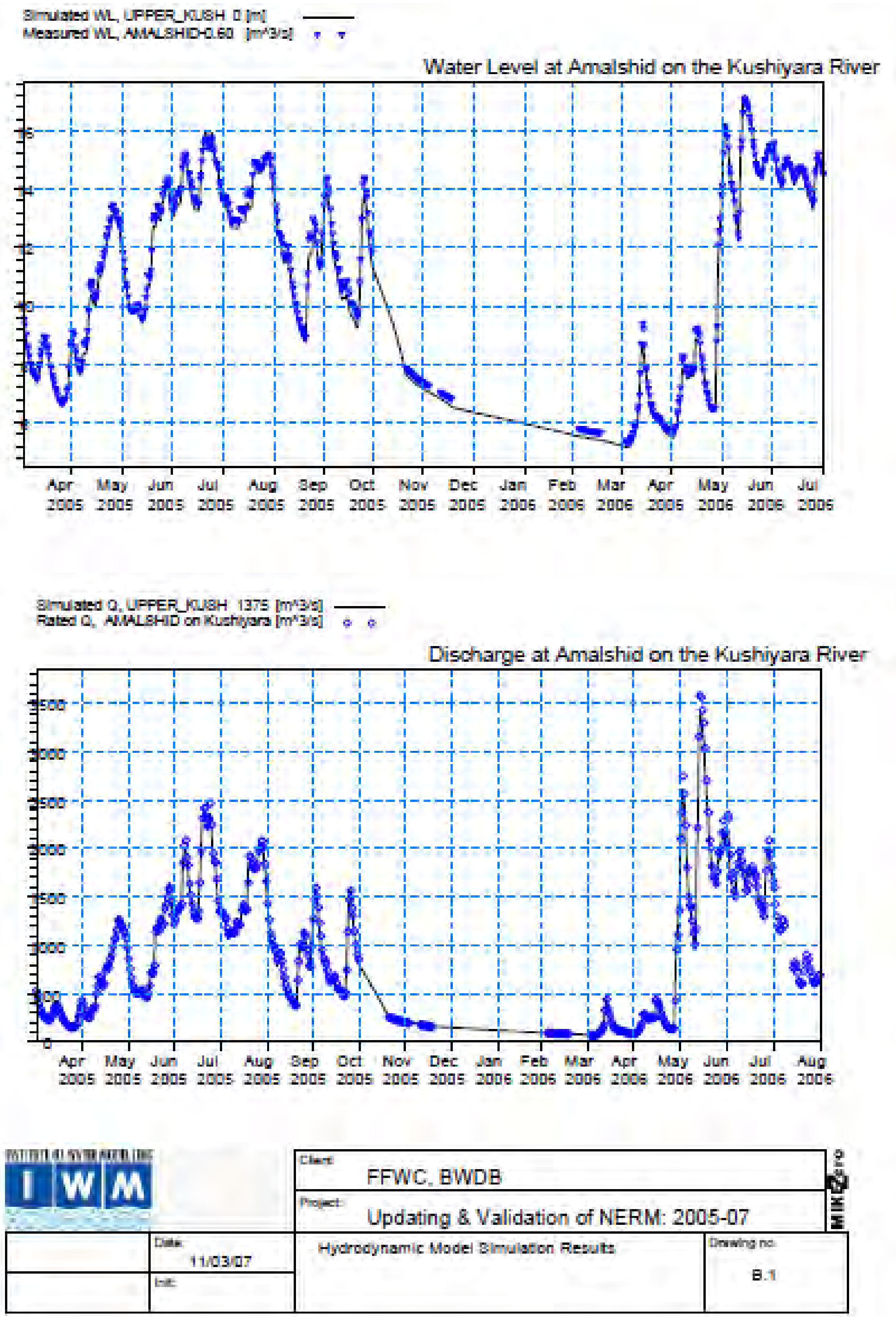
(1) NERM

IWM developed a dynamic hydraulic model utilizing the MIKE11 software. This model utilizes to make a network of the rivers, virtual channels and overflow points. The overflow to and return flow from inundation area and flow in the inundation area can be represented the overflow points, and the virtual channel, respectively. The model utilizes hydrographs from the transboundary tributaries, intermediate gauging stations and downstream boundary site conditions (the Bhairab Bazar WL Station) as input data.

The dynamic hydraulic model was calibrated based mainly on hydraulic roughness and overbank spill coefficients from April 1991 to March 1993, and was validated from April 1993 to July 2003. The NERM was used in the FAP6 study, and feedback from the FAP6 model was incorporated into the model. The NERM was also used for water resources management planning in the National Water Management Plan (NWMP). The NERM was revalidated using the hydrological data from April 2005 to July 2006 and recent topographic information under the BWDB project “Real Time Data Collection for Flood Forecasting and Warning Centre (July 2005 to December 2006) and Update & Validation of General/National & 6 Regional Models for 2003-06 Hydrological Year”.

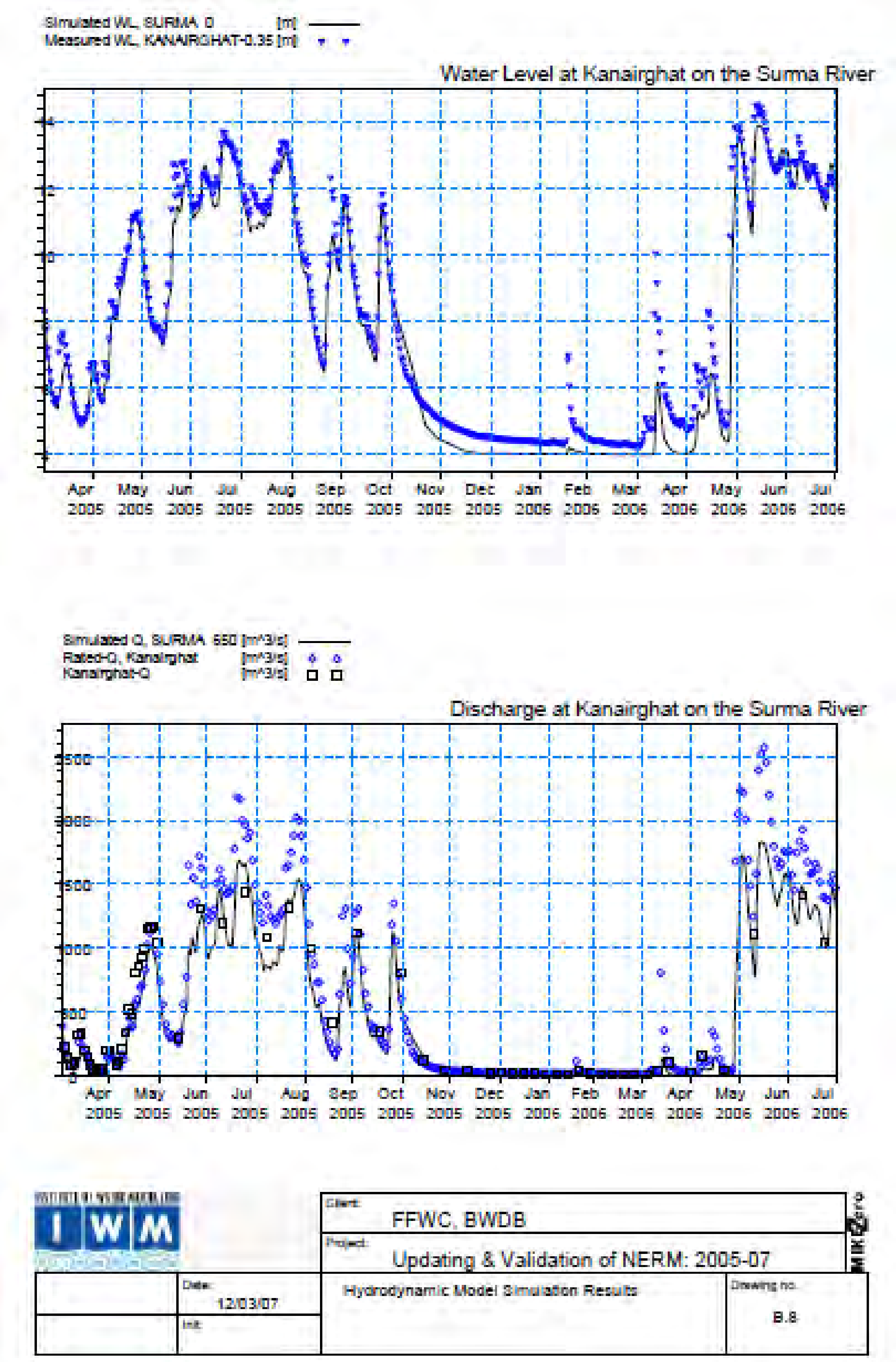
Even though the input information from the hydrological model and flow series from tributaries are not reliable, the results of NERM are rather good. The possible reason is that the model filters the uncertainties by adjusting flows and water surface elevations throughout the intermediate WL stations localized in the main river system.

As a result of the NERM calibration verification, the model seems to be reliable, but the reason why it simulates well the measured data must be carefully verified. **Figure 5.3.1** shows the good calibration results for water surface elevation and flows. Furthermore, the verification on goodness of fit of NERM is discussed in “Sub-section 5.3.2 (2)”.



Source: IWM

Figure 5.3.1 Water Surface Elevation and Flow Calibration Results (1/2)



Source: IWM

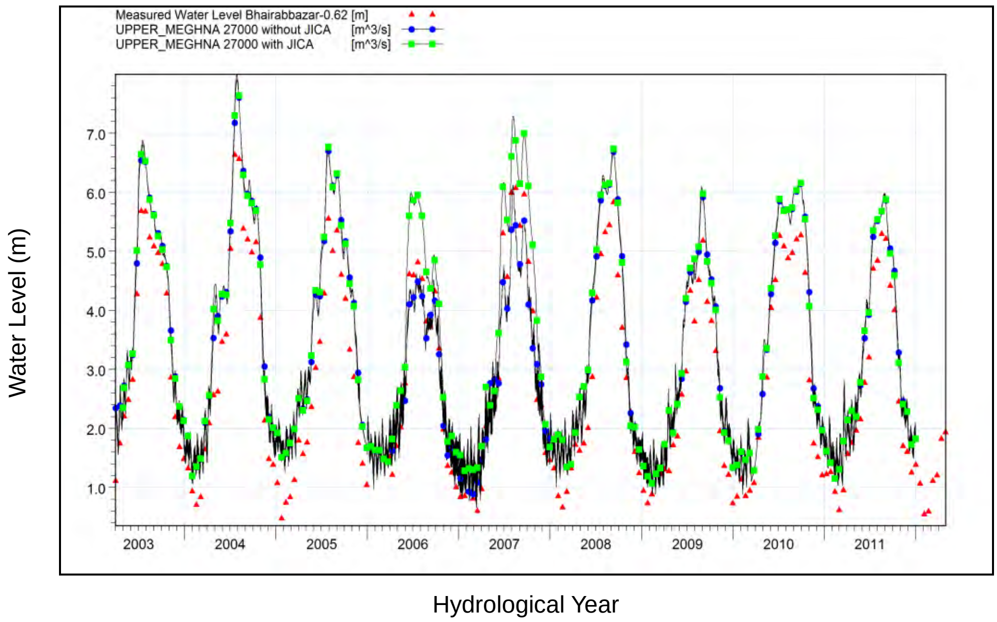
Figure 5.3.1 Water Surface Elevation and Flow Calibration Results (2/2)

It is difficult to estimate a probable flood water level by the conventional method, which is a process of rainfall–runoff analysis, runoff-flood inundation level relation, and frequency analysis of rainfall and flood water level. This is because inundation in the haor area is developed by the combination of runoff from the upstream Indian border side area and direct runoff in the haor area as described in the foregoing sections. In this section, probable flood water levels are estimated by the use of a set of flood water levels simulated by the simulation model calibrated with input of recorded water levels.

Figures 5.3.2 to 5.3.5 show the measured water level variation during the pre-monsoon and monsoon seasons from 2003 to 2011 at four representative water level gauging stations along the Surma-Baulai River System. The water level records were observed by BWDB local staff 5 times a day (every 3 hours from 6:00 a.m. to 6:00 p.m.).

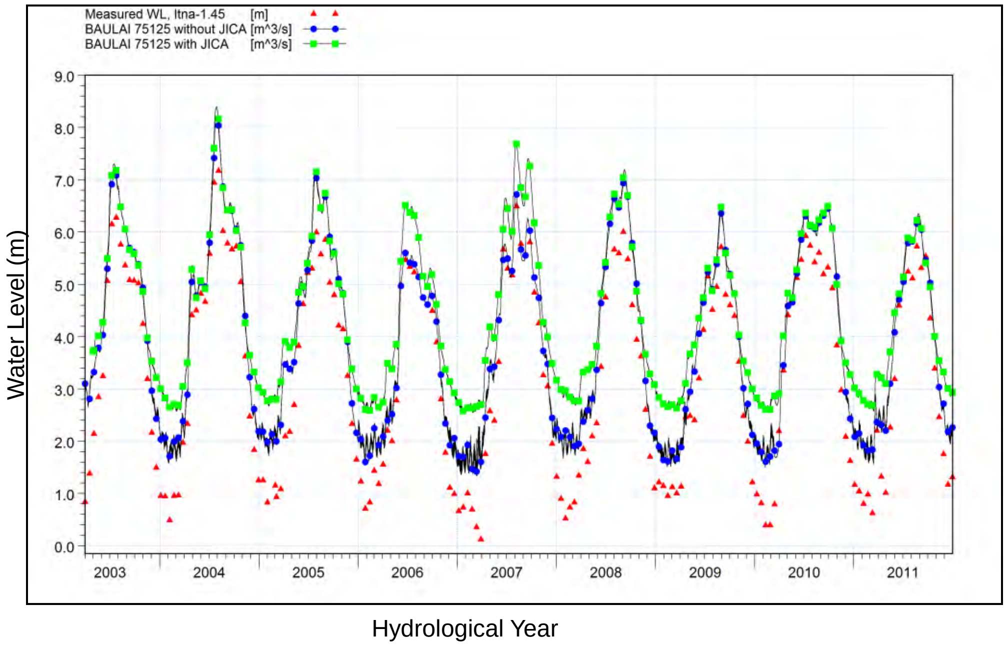
The abovementioned figures present the observed water level records, several simulation results using the 2005/2006 calibrated NERM, and simulation results using the NERM modified with the river cross sections surveyed in the Study.

The four water level gauging stations used are Bhairab Bazar, Itna, Sunamaganj and Sylhet.



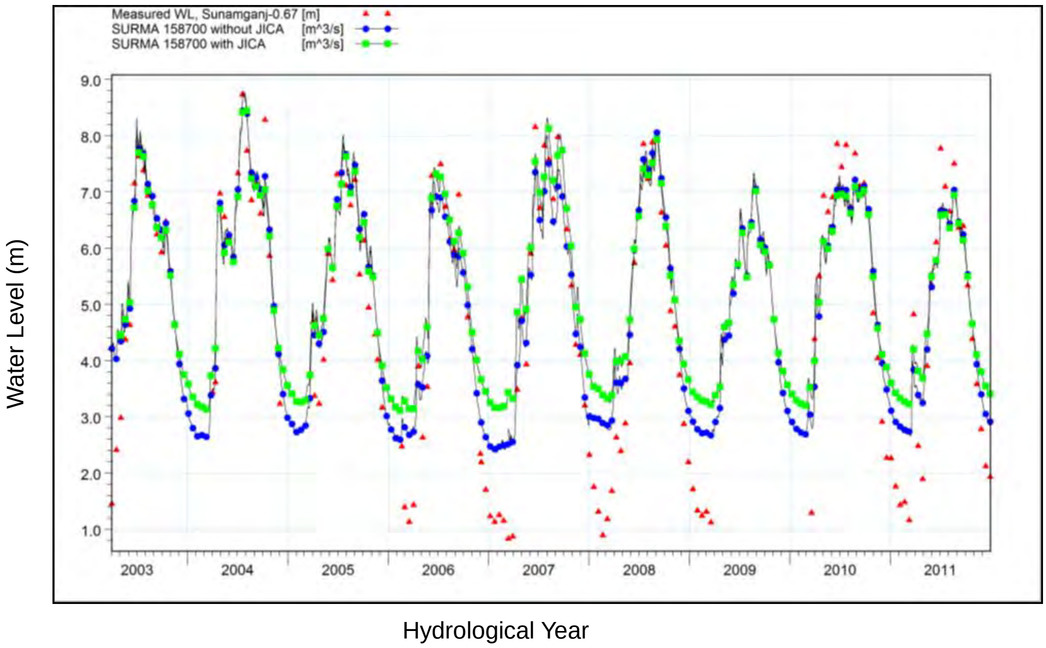
Source: IWM/JICA Study Team

Figure 5.3.2 Measured and Simulated Water Levels at Bhairab Bazar Gauging Station



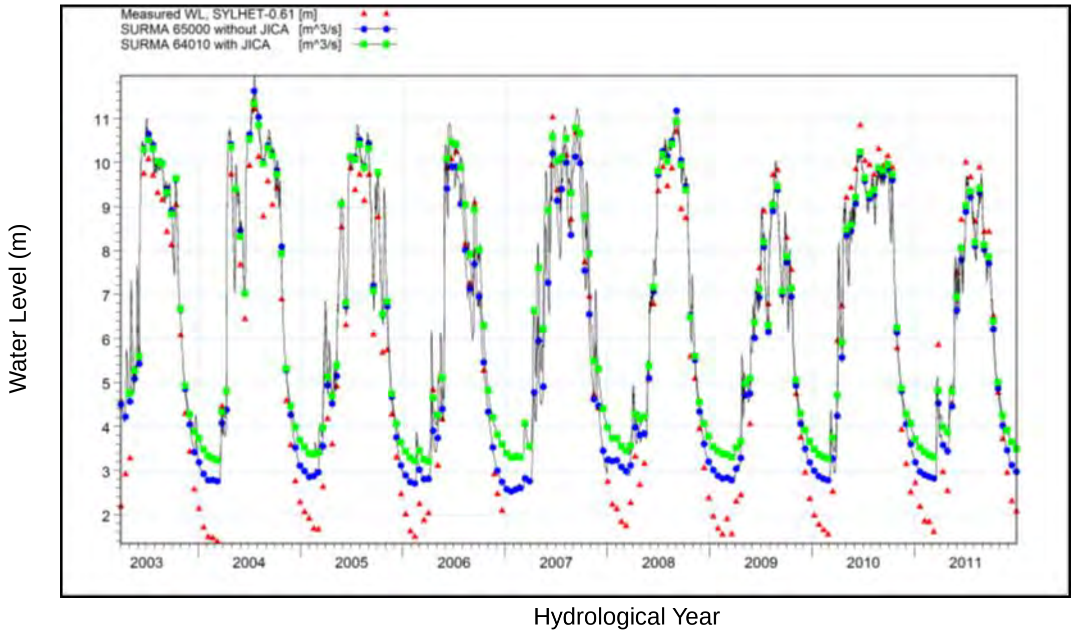
Source: IWM/JICA Study Team

Figure 5.3.3 Measured and Simulated Water Levels at Itna Gauging Station



Source: IWM/JICA Study Team

Figure 5.3.4 Measured and Simulated Water Levels at Sunamganj Gauging Station

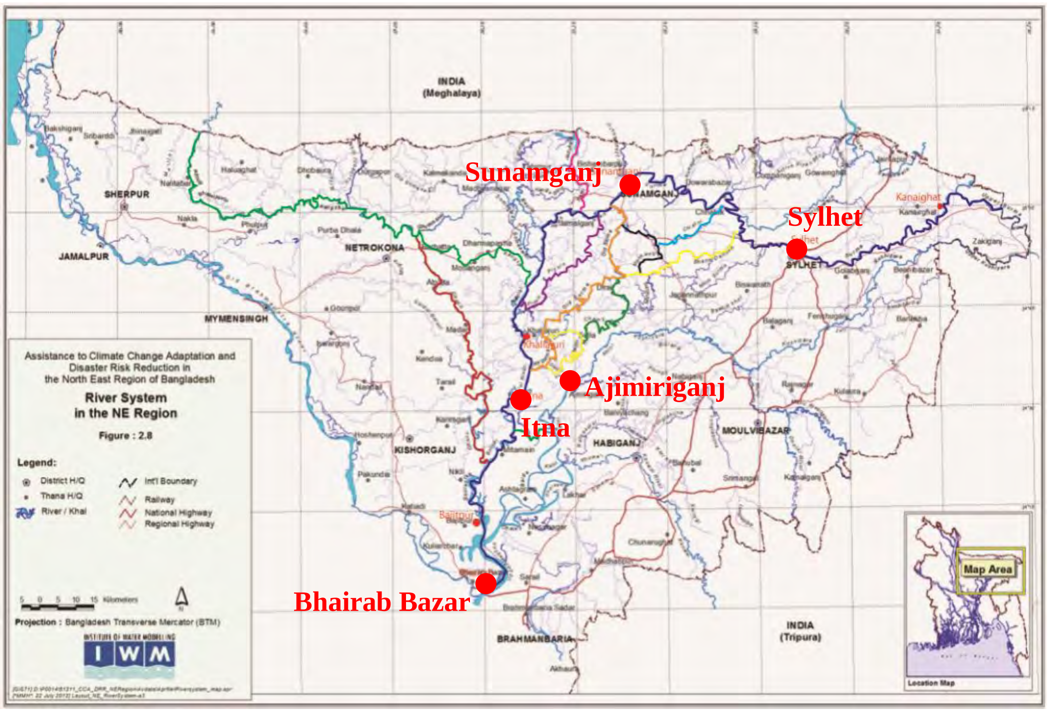


Source: IWM/JICA Study Team

Figure 5.3.5 Measured and Simulated Water Levels at Sylhet Gauging Station

(2) Verification of NERM

The design water level of the submergible embankment and full embankment for the rehabilitation project and new project are determined from the analysis results of NERM. Therefore, the verification of NERM is carried out to check the relation of the highest pre-monsoon and monsoon water levels between the simulated output and observed data. **Figure 5.3.6** shows the verification points in the haor area.



Source: JICA Study Team

Figure 5.3.6 Verification Points of NERM

Figure 5.3.7 shows the relation between the observed data and simulated data at five locations, namely, Bhairab Bazar, Itna, Ajimirganj, Sunamganj, and Sylhet. **Table 5.3.1** shows the comparison between the simulated water level and the expected observed water level from the regression equation under the pre-monsoon 10-year flood condition.

Table 5.3.1 Comparison between Simulated Water Level and Expected Observed Water Level under Pre-monsoon 10-year Flood Condition

Location	Simulation (EL.m)	Observed (EL.m)	Difference	
	A	B	|A-B|	A/B
Bhairab Bazar	2.86	2.45	0.41m	1.17
Itna	4.52	3.86	0.66m	1.17
Sunamganj	6.95	7.30	0.35m	0.95
Sylhet	9.92	10.20	0.28m	0.97

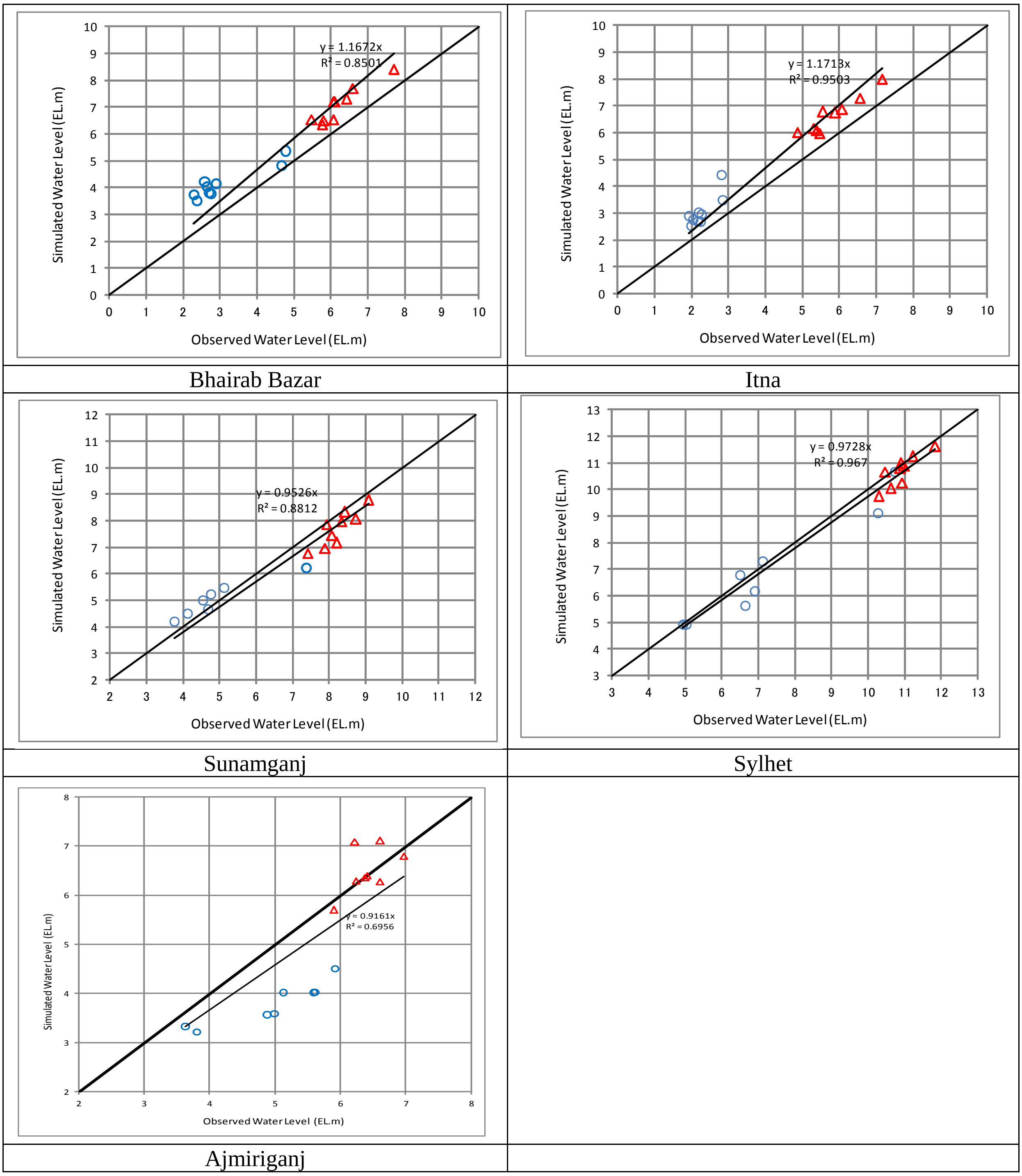
Note: Observed water level is estimated from the regression equation shown in Figure 5.3.7.
Source: JICA Study Team

The simulated water level at Sunamganj and Sylhet is 3% to 5 % lower than the observed one. On the other hand, the difference between the simulated and observed water level at Bhairab Bazar is 17%. The reason for this is that Bhairab Bazar is vulnerable to the impact of the Padma River and old Brahmaputra River, and the hydraulic phenomenon surrounding Bhairab Bazar is complicated. However, the simulated water level is higher than the observed one. It means that the design water level is set with the safety side.

The difference of simulated and observed water level at Itna is also 17%, with the former higher than the latter value. Itna is hydraulically affected by Bhairab Bazar, and hydraulic phenomenon in the flood plain is complicated.

For the planar verification, the relation between observed and simulated water level at Ajimiriganj which is located at the Kalni-Kushiyara River, is studied. The difference between the observed and simulated high water level is only 9%.

Therefore, NERM adapts well with the design high water level in the haor area.



Note: ○Highest water level during pre-monsoon, △Highest water level during monsoon
Source: JICA Study Team

Figure 5.3.7 Relation between Observed Water Level and Simulated Water Level at Five Locations

5.3.3 Water Levels for Return Periods

Water level hydrographs are simulated for 31 years from 1980 to 2010 for the Sylhet, Sunamganj, Itna and Bhairab Bazar water level gauging stations along the Surma-Baulai River by use of the recorded hydrologic data and the calibrated NERM. The simulation results of the annual maximum 3-hour water level in the pre-monsoon season and monsoon season are shown in **Tables 5.3.2** and **5.3.3**, respectively.

(1) Plotting Position

The plotting position of the frequent analysis applied in Bangladesh is the Chegadayev plotting position as it has been used in FAP-25. Therefore, the Chegadayev plotting position is applied in this Study. The formulation of the Chegadayev plotting position is as follows:

$Pi=(i-0.3)/(N+0.4)$

P: Exceedance probability of i^{th} sample

N: Total number of data

(2) Distribution Function

The distribution function is applied to the three parameter log normal distribution and modified maximum likelihood method as the "Flood Hydrology Study in FAP25, 1992" recommended to apply the log normal distribution regarding to the statistical analysis of hydrology data. The distribution is as follows:

$$P_{LN}(X) = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left(\frac{Y-\mu_Y}{\sqrt{2}\sigma_Y}\right)$$

$$\mathrm{erf}(z) = \frac{2}{\sqrt{\pi}}\int_0^z \exp(-u^2)du$$

where, $Y=\ln(X-X_0)$

μ_Y=mean of Y

σ_Y=standard deviation of Y

X_0=location parameter, conditioned by (X_0<X)

Table 5.3.2 Simulation Results of Annual Maximum 3-hour Water Level at Four Stations during the Pre-monsoon Season

Year	Annual Maximum of Daily Simulated Pre-monsoon Water Level (m)			
	Bhairab Bazar	Itna	Sunamganj	Sylhet
1980	2.78	4.15	6.16	8.60
1981	2.15	3.04	4.67	5.69
1982	2.26	3.92	5.66	7.31
1983	2.81	4.70	6.76	9.88
1984	2.89	3.67	5.79	7.45
1985	2.42	3.40	5.59	7.86
1986	2.25	3.32	5.02	6.74
1987	1.92	3.22	5.01	6.40
1988	2.30	3.54	5.65	7.80
1989	2.33	3.86	6.27	9.01
1990	2.52	4.24	6.33	9.34
1991	3.27	4.79	7.52	10.57
1992	1.81	2.39	3.78	4.24
1993	2.66	4.29	6.55	9.81
1994	2.38	3.70	5.65	8.01
1995	2.51	2.71	4.51	4.98
1996	2.71	3.80	6.17	9.02
1997	1.91	2.06	2.52	2.88

Year	Annual Maximum of Daily Simulated Pre-monsoon Water Level (m)			
	Bhairab Bazar	Itna	Sunamganj	Sylhet
1998	2.19	2.88	4.30	5.27
1999	2.44	3.35	5.45	6.29
2000	2.69	4.60	6.75	9.76
2001	2.19	3.33	5.68	8.05
2002	2.56	4.37	5.93	7.10
2003	2.47	3.11	4.75	6.24
2004	2.86	4.76	7.39	10.51
2005	2.23	3.22	4.96	5.93
2006	2.24	2.80	4.30	4.89
2007	2.41	3.45	5.52	7.42
2008	2.40	2.71	3.87	4.25
2009	2.04	2.84	4.66	5.73
2010	2.86	4.61	7.37	10.04

Source: IWM/JICA Study Team

Table 5.3.3 Simulation Results of Annual Maximum 3-hour Water Level at Four Stations during the Monsoon Season

Year	Annual Maximum of Daily Simulated Monsoon Water Level (m)			
	Bhairab Bazar	Itna	Sunamganj	Sylhet
1980	5.79	6.14	7.42	9.71
1981	5.85	6.43	7.98	10.31
1982	5.82	6.49	7.77	10.11
1983	6.18	6.74	8.21	10.70
1984	6.28	6.76	8.12	10.28
1985	5.77	6.38	7.99	10.60
1986	5.06	5.69	7.23	9.29
1987	6.29	6.85	8.27	10.49
1988	7.05	7.49	8.53	10.94
1989	5.80	6.45	7.78	10.42
1990	5.43	6.00	8.01	10.59
1991	5.80	6.27	8.12	10.67
1992	4.94	5.80	7.75	10.10
1993	6.32	6.86	8.00	10.70
1994	5.05	5.60	7.25	10.01
1995	6.08	6.62	7.90	10.49
1996	5.88	6.24	7.69	9.96
1997	5.71	6.26	7.91	10.41
1998	6.72	6.96	8.08	10.51
1999	5.82	6.37	7.91	10.51
2000	5.91	6.34	7.59	10.03
2001	5.52	5.95	7.46	10.34
2002	6.10	6.59	8.01	10.32
2003	6.08	6.59	8.48	10.65
2004	7.18	7.63	8.74	11.50
2005	5.57	6.34	8.10	10.40
2006	4.87	5.78	7.88	10.83
2007	6.57	7.08	8.51	10.97
2008	5.90	6.47	8.10	10.70
2009	5.41	6.19	8.01	10.44
2010	6.12	6.47	7.91	10.63

Source: IWM/JICA Study Team

(3) Goodness of Fit-test

The goodness of fit-test is carried out by using the Kolmogorov-Smirnov (K-S) test. The K-S test is a nonparametric test for the equality of continuous, one-dimensional probability distribution that can be used to compare a sample with a reference probability distribution. The null distribution of this statistic is calculated under the null hypothesis that the sample is drawn from the reference distribution. In addition, the goodness of fit-test is carried out to apply Standard Least Squares Criterion (SLSC) which is proposed in the Technical Criteria for River Works prepared by the Ministry of Land, Infrastructure, Transport and Tourism of Japan.

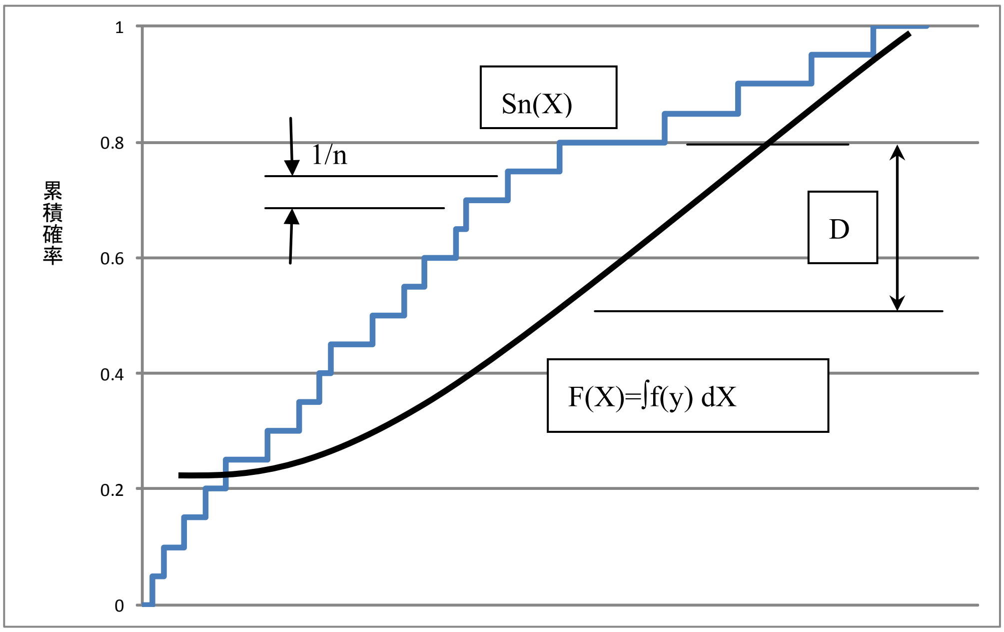
Kolmogorov-SmirnovTest

Null hypothesis: "Sample X occurs from the three parameter log-normal distribution."

Cumulative probability distribution of sample X S(X): Empirical Distribution Function

Sn(X)=1/n x ΣXi(x)

Where, Xi(x) =1 (xi≤x), =0 (xi>x)



Source: JICA Study Team

Figure 5.3.8 Illustration for Cumulative Distribution of Sample X and Cumulative Distribution of Probability Distribution Function of Sample X

Standard Least Squares Criterion (SLSC)

The SLSC value (Sc) is calculated from the following formula:

$$Sc = \frac{\sqrt{\xi_{min}^2}}{|s_q - s_{1-q}|}$$

$$\xi_{min}^2 = \frac{1}{N}\sum_{i=1}^{N}(s_{(i)} - s_{(i)}^*)^2$$

$$s_{(i)} = \frac{x_{(i)} - \hat{\mu}}{\hat{\sigma}}$$

where,
- Sc: SLSC value
- N: number of data
- x(i): ordered statistics which arranged sample data xi (i=1,2,3,…,N) in ascending order
- $\hat{\mu}$: estimated location parameter
- $\hat{\sigma}$: estimated scale parameter
- s(i): standard variable
- s(i)*: expected value of standard variable which arranged sample data in small order (The sample data obey the frequent analysis model with zero and one of location parameter and scale parameter)

(4) Estimation of Probable Water Level

1) Probable Water Level

The probable water level at each station is evaluated by using three parameter log-normal distribution. **Tables 5.3.4** and **5.3.5** show the probable water level at each station.

Table 5.3.4 Probable Water Level at Four Stations in Pre-monsoon Season

(Unit: EL.m)

Year	Bhairab Bazar	Itna	Sunamganj	Sylhet
2	2.42	3.56	5.49	7.30
5	2.70	4.18	6.45	9.01
10	2.86	4.52	6.95	9.92
20	3.00	4.85	7.23	10.50

Source: JICA Study Team

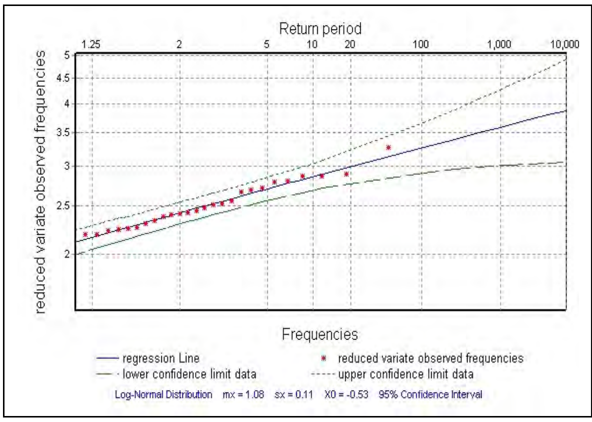
Table 5.3.5 Probable Water Level at Four Stations in Monsoon Season

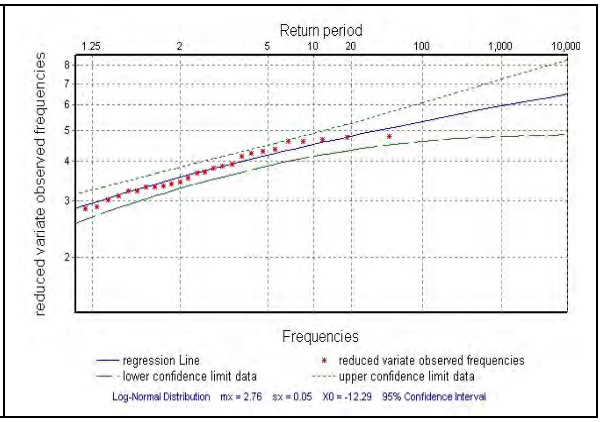
(Unit: EL.m)

Year	Bhairab Bazar	Itna	Sunamganj	Sylhet
2	5.88	6.41	7.96	10.44
5	6.34	6.82	8.25	10.77
10	6.60	7.05	8.40	10.95
20	6.80	7.30	8.55	11.11

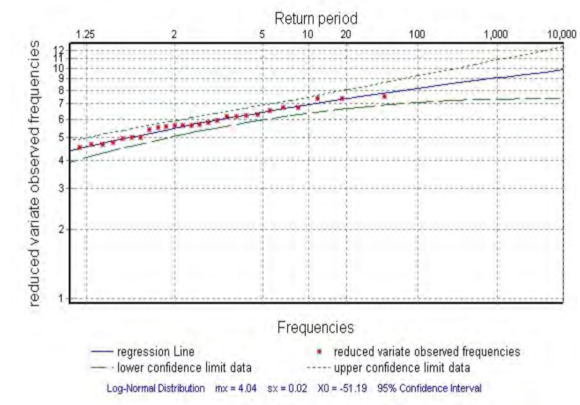
Source: JICA Study Team

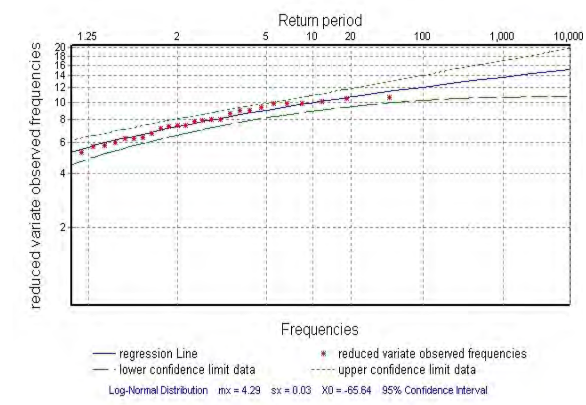
Figures 5.3.9 and **5.3.10** show the relation between the water level and return period at the four stations during the pre-monsoon and monsoon seasons, respectively.





Bhairab Bazar	Itna

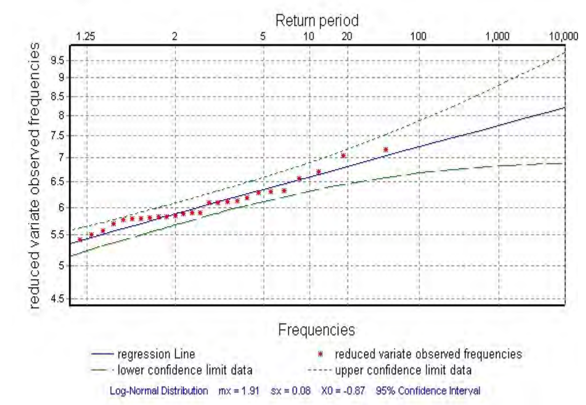


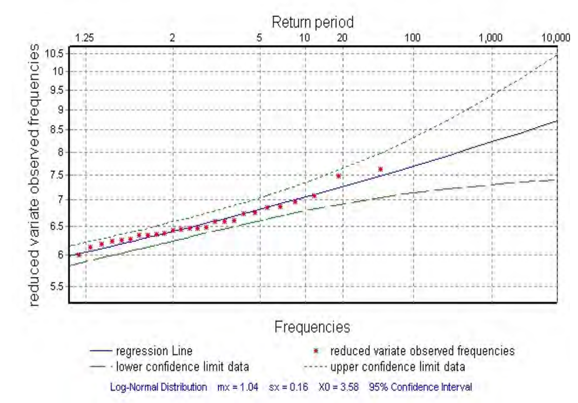


Sunamganj	Sylhet

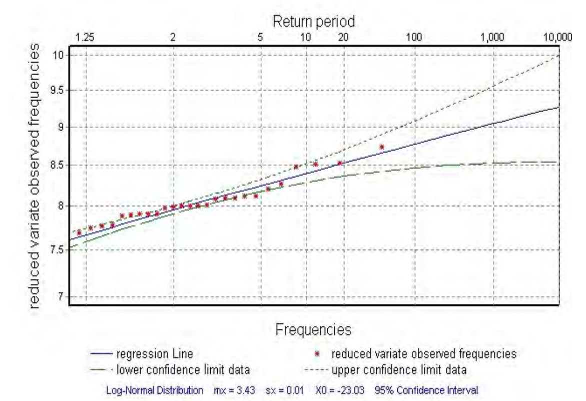
Source: JICA Study Team

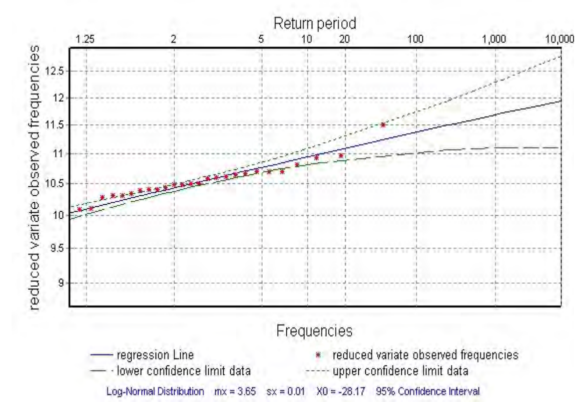
Figure 5.3.9 Frequency Analysis Result of Pre-monsoon Seasons at the Four Stations





Bhairab Bazar	Itna





Sunamganj	Sylhet

Source: JICA Study Team

Figure 5.3.10 Frequency Analysis Result of Monsoon Seasons at the Four Stations

2) Goodness of Fit-Test

Cumulative probability distribution of sample X F(X): three parameter log-normal distribution

D=Max(|Sn(X)-F(X)|)

Significant probability of D: $Pr(D\sqrt{n}>z)=2\Sigma(-1)^{j-1}\exp(-2j^2z^2)$ (approximate formula, where n>20)

Significant level =5%; z=1.36

Judgment of the null hypothesis

If the value of D√n is greater than1.36, the null hypothesis is rejected. (The assumed distribution cannot be applied to the sample data.)

If the value of D√n is smaller than1.36, the null hypothesis is accepted. (The assumed distribution can be applied to the sample data.)

The goodness of fit-test results of log-normal distribution in the pre-monsoon and monsoon periods are shown in **Tables 5.3.6** and **5.3.7**, respectively.

Table 5.3.6 Goodness of Fit-Test Results of Log-Normal Distribution (Pre-monsoon Period)

	Bhairab Bazar	Itna	Sunamganj	Sylhet
(1) Kolmogorov-Sminov				
D√n	0.30	0.44	0.37	0.34
Z	1.36	1.36	1.36	1.36
(2) SLSC	0.029	0.033	0.034	0.031

Source: JICA Study Team

Table 5.3.7 Goodness of Fit-Test Results of Log-Normal Distribution (Monsoon Period)

	Bhairab Bazar	Itna	Sunamganj	Sylhet
(1) Kolmogorov-Sminov				
D√n	0.54	0.41	0.71	0.71
Z	1.36	1.36	1.36	1.36
(2) SLSC	0.039	0.034	0.043	0.058

Source: JICA Study Team

5.4 Sediment Balance and Riverbed Movement Analysis

5.4.1 Data Collection and Review

(1) Existing Data Availability

In connection with the Study, the availability of sedimentation data of BWDB and IWM has been investigated. The current status is given in **Table 5.4.1**. Additional information about the sediment characteristics are provided in **Tables 5.4.2** and **5.4.3**.

Table 5.4.1 Summary of Sediment Analysis Report of SWSMP for the Northeast Region

River Name	Locations	D_{50} (mm) of Bed materials
Upper Meghna	Bahirab Bazar	0.20 – 0.12
Surma	Kanair Ghat	0.26 – 0.02
Kushiyara	Sheola	0.226 – 0.037
Jadukata	Lourergar	0.151-0.10
Someswari	Durgapur	0.114 – 0.011
Khowai	Shaistaganj	0.245-0.012

Source: CEGIS

Table 5.4.2 Median Grain Size (D50) of Collected Samples

Sl.	Station	Location	River	D50 (mm)	Date of Sampling
1	Badhyanathpur	Centre	Karangi	0.032	12/06/2010
2	Badhyanathpur	Right Bank	Karangi	0.047	12/06/2010
3	Shankarpur	Left Bank	Lunglabijna	0.051	12/06/2010
4	Shankarpur	Centre	Lunglabijna	0.039	12/06/2010
5	Shankarpur	Right Bank	Lunglabijna	0.044	12/06/2010
6	Balikhal	Left Bank	Karangi-Lunglabijna Confluence	0.028	13/06/2010
7	Balikhal	Centre	Karangi-Lunglabijna Confluence	0.022	13/06/2010
8	Balikhal	Right Bank	Karangi-Lunglabijna Confluence	0.036	13/06/2010

Source: CEGIS

Table 5.4.3 Locations of Suspended Sediment Sampling by FAP-6

Location	River	District	Upazila
Markuli	Kushiyara	Hobiganj	SullaBalaganj
Sherpur	do	Sylhet	Beani Bazar
Sheola	do	do	
Ajmiriganj	Kalni	Hobiganj	Ajmiriganj
Shantipur	do	Kishorganj	Mithamine
Kadam Chal	do	do	do
Shaistaganj	do	Moulvi Baza	Chunarughat
Monu Railway Bridge	Monu	do	Kamalganj
Sylhet	Surma	Sylhet	Sylhet Sadar

Source: CEGIS

The sediment data so far collected in the Northeast Region is sparse and of poor quality to be utilized for a comprehensive sediment study. Most of the information related to sediments is available from the FAP-6 study. Additional sediment samples were collected for specific morphological studies or sediment modeling done by CEGIS and IWM but have limited scope and spatial distribution. The sediment data is mostly riverbed material, with sparse suspended sediment but no bed load samples.

(2) Rating Curve Analysis

The available sediment load rating curves were sampled only for the suspended portion of the total load. The plot of the data indicates a disperse cloud of suspended load with most of the sizes smaller than sand.

The diffuse suspended sediment measurements are common in the geomorphological study. These are the results of sampling techniques, uncertainty inherent to the computation, variability of characteristics of the sub-watersheds, which includes but are not limited to soil, topography, vegetation cover, and variability in the precipitation intensity.

5.4.2 Sediment Balance

The Northeast Region is tectonically the most active in Bangladesh. The Sylhet basin tectonic subsidence plays an important role on the geo-morphological process of this region. It is a tub-shaped north-south aligned basin with a length of 100 km (see **Figure 1.3.1**).

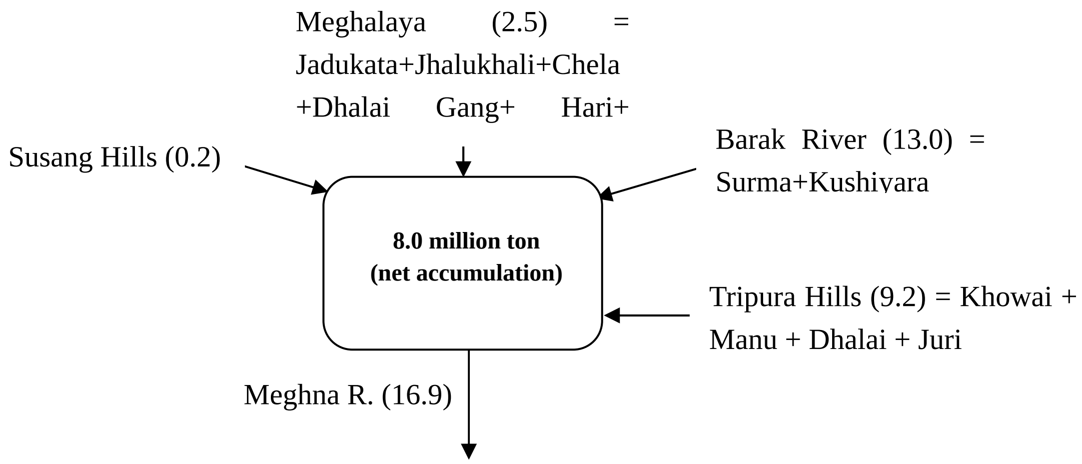
Every monsoon season, the Sylhet basin is flooded with inundation depths of 1-2m. The annual extent of inundation is more than 8,000 km^2. All the rivers in the basin become hydro-morphologically inert during the monsoon season compared to its activities during the pre- and post-monsoon periods.

The exercise on sediment balance in the Northeast Region is mainly based on the sediment analysis made by FAP 6. FAP 6 used the sediment concentration and bed material data from BWDB and the Surface Water Modelling Centre (SWMC) including the primary data collected in the said study. The River Survey Project under FAP 24 measured the flow and sediment in the Upper Meghna River at Bhairab Bazaar from 1994 to 1996. The quality of the data measured by FAP 24 is considered better compared with those measured by other agencies. The present exercise in the Study includes the analysis of FAP 24 data for comparing the sediment balance made by FAP 6 using the measured data of BWDB and SWMC.

In FAP 6, the sediment budget (see **Figure 5.4.1**) for the Northeast Region was estimated by summing up the sediment yields of the Barak River, Tripura Hills streams and Meghalaya Hills streams with the deduction of yields of the Meghna River. The total sediment accumulation or depletion was estimated, as follows.

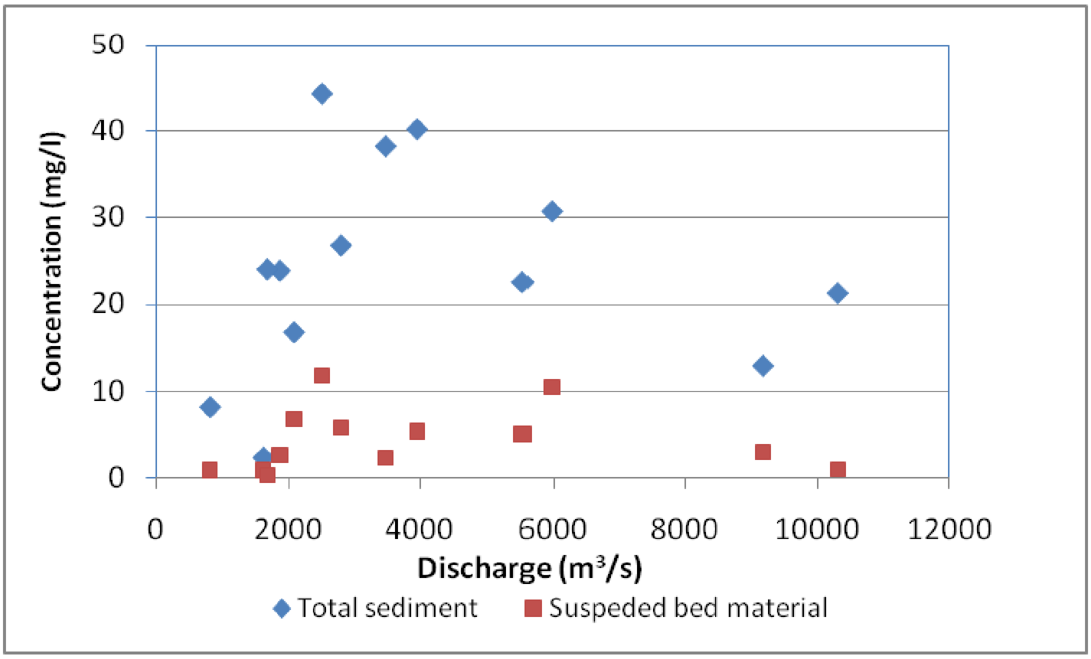
The measurement period at Bhairab Bazar in FAP6 was from 1994 to 1995. The suspended sediment concentration was very low, and the maximum suspended sediment concentration (section-average) was 40 mg/l. The concentration of suspended bed material was as low as 10 mg/l. The maximum measured flow velocity (section-average) at Bhairab Bazaar was 0.7 m/s, when the discharge in the Upper Meghna River was more than 10,000 m^3/s.

The concentrations of total sediment and suspended bed materials increase with discharge, but when the discharge exceeds 4,000 m^3/s, the concentration starts to drop rapidly (Figure 5.4.2). This characteristic of suspended sediment concentration is a likely process at the outlet of a heavily flooded subsiding basin.



Source: Master Plan of Haor Area, April, 2012

Figure 5.4.1 Sediment Budget for the Northeast Region



Source: JICA Study Team and CEGIS

Figure 5.4.2 Suspended Sediment Concentration in the Upper Meghna River at Bhairab Bazaar Measured in River Survey Project (FAP 24) during 1994-1995

The annual average suspended sediment load at Bhairab Bazaar was 5 million ton, which is at least 3 times less than the estimation of FAP6. Out of the 5 million tons, 80% is wash load, while the rest is suspended bed material. It is assumed that the sediment load estimated based on the FAP 24 sediment measurement is representative at Bhairab Bazaar and the total sediment generated by all other rivers in the Northeast Region remained the same as the estimate by FAP 6. Thus, the net deposition of sediment in the Sylhet basin would be about 20 million ton/year, which is 2.5 times higher than the FAP6 estimated magnitude of FAP 6.

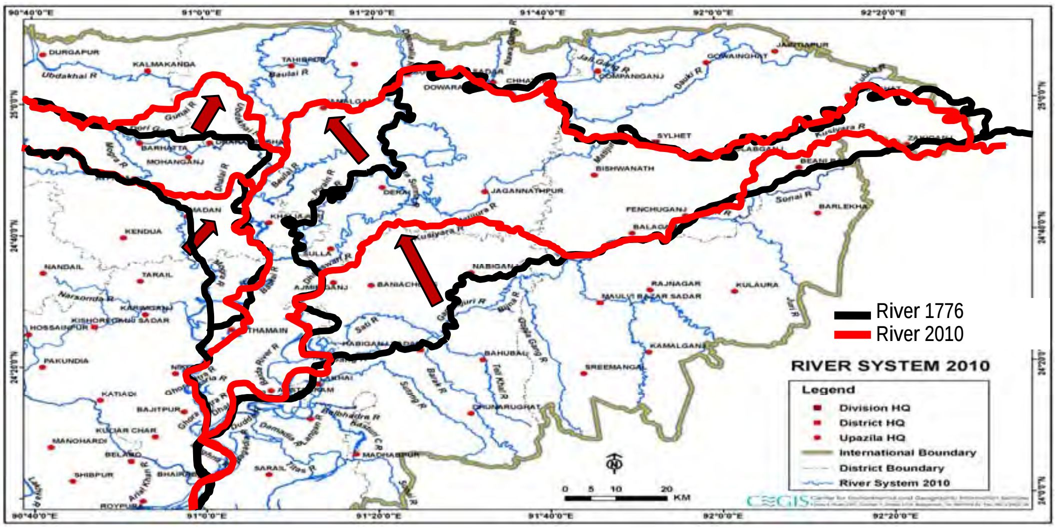
5.4.3 Riverbed Movement Analysis

As a result of the delta development process, the Brahmaputra has shifted its course several times between the east and west sides of the Madhupur Tract. The avulsion of the Brahmaputra River had occurred every 2,000-3,000 years during the Holocene. Through this continual process, the Brahmaputra shifted from the east side of the Madhupur Tract to the present course of the Jamuna about 200 years ago after feeding sediment to the subsiding Sylhet basin.

It is recognized that a major part of the Brahmaputra sediment was used to balance the subsidence of the Sylhet basin. After the avulsion of the Brahmaputra, the Sylhet basin became a sediment starved basin having a pronounced effect on the shifting processes of rivers such as the Surma and Kushiyara. The depressed Sylhet basin attracts the rivers from both the east and west sides. Presently, all the rivers, namely, the Surma, the Kushiyara, the Kangsha, and the Someswari Rivers fall into the depressed basin, before they flow south to meet with the Meghna River.

Over the past centuries, the rivers have shifted their courses several times. Historical changes of the Surma and the Kushiyara Rivers are described below based on the old maps available in CEGIS, the cartographic surveys conducted from 1910 to 1930, and river network extracted from the 2010 satellite image.

Different studies reveal that there is net subsidence in the Sylhet basin, which shows a higher rate at the northern part of the basin. The estimated rate of maximum subsidence would be about 1 m during the last 200 years after avulsion of the Brahmaputra River. The shifting of the courses of the Kushiyara, Surma, Someswari and Kangsha Rivers in the last 240 years followed a particular direction, towards the north, where the rate of subsidence is at maximum (see **Figure 5.4.3**).

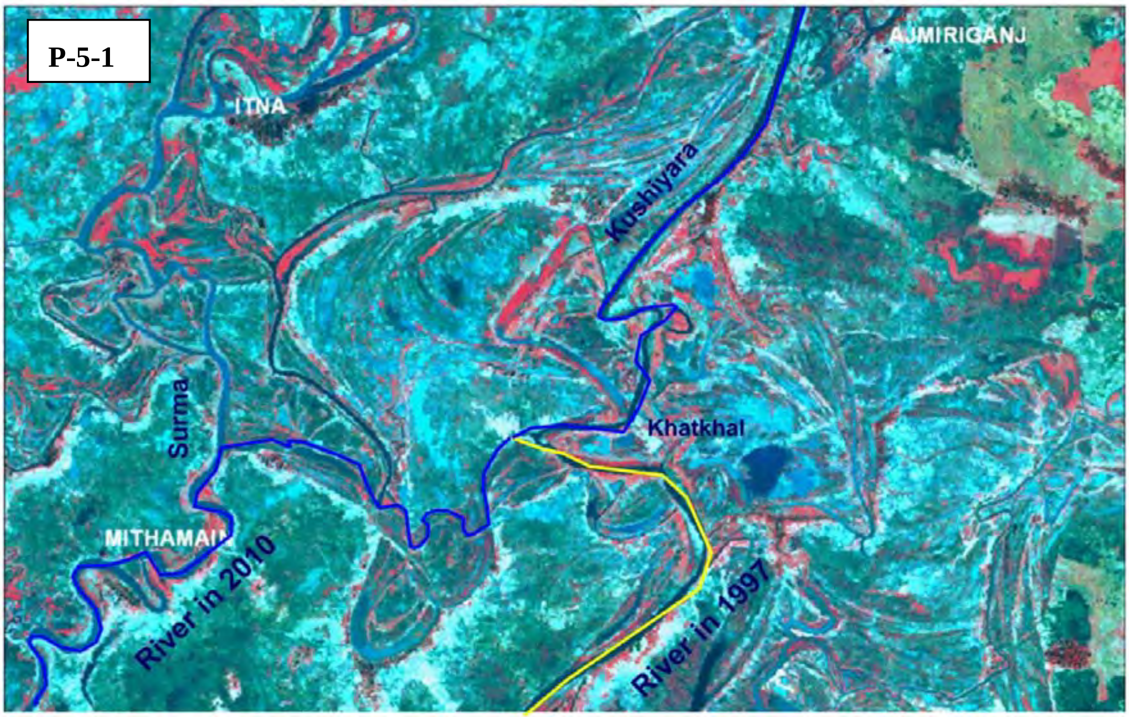


Source: CEGIS

Figure 5.4.3 Major Rivers Moving towards Deepest Part of the Basin

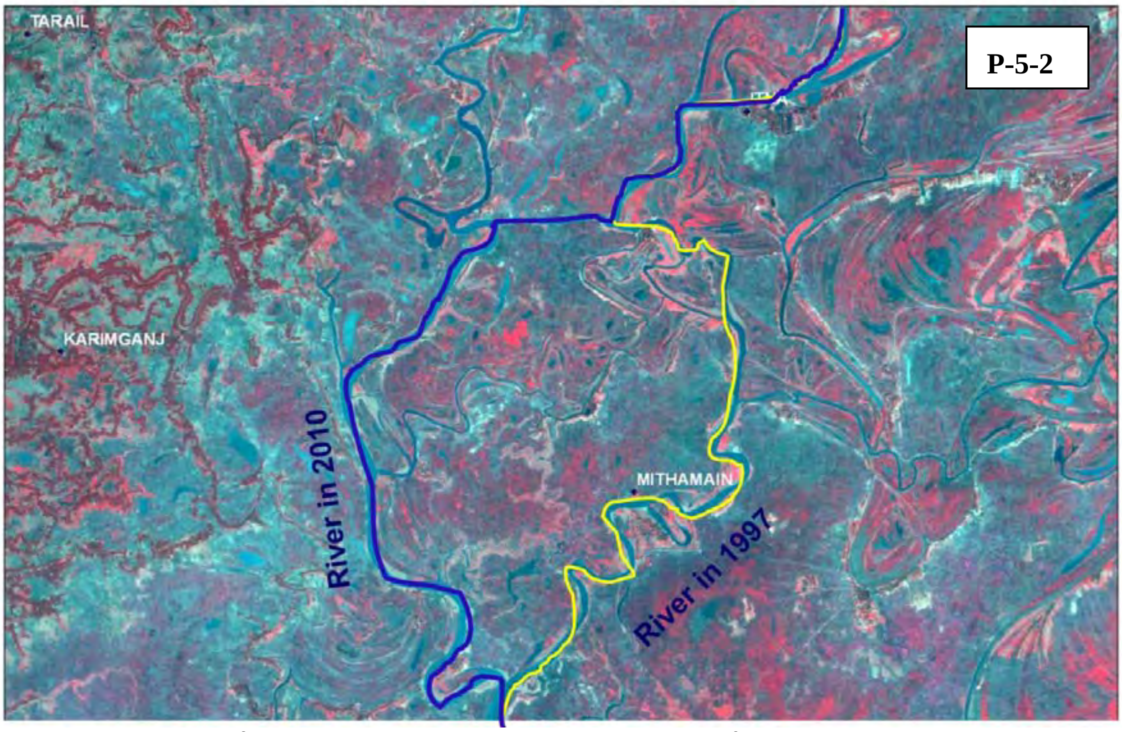
These rivers shifted their courses from an upper level to a lower level and from south to north, while the ultimate flow direction of these rivers are north to south at the bottom of the Sylhet basin. The analysis showed that the topographical slope of the Sylhet basin is not in line with the flow direction of the rivers, i.e. the elevation in the north is about 2m lower than in the south. The process of river development after shifting of their courses and the topography is reverse from the direction of the flow.

Changes in the river courses in the Northeast Region did not only occur in a century scale, but also in a decade scale. Two such changes have been identified using recent satellite images. One of these changes has occurred in the Kushiyara River downstream of Ajmiriganj (see **Photo 5.4.1**). That diversion of flow in the Kushiyara River caused the water level in the Surma River to rise, which may have triggered the development of a new diversion channel from this river to further west to the Ghorautra River (see **Photo 5.4.2**). The process of development of these two channels was almost simultaneous. The development of these two channels appears to have been the result of the two individual but related events of local morphology.



Source："Master Plan of Haor Area, Annex 1: Water Resources, Ministry of Water Resources, April 2012"

Photo 5.4.1 Changes of Kushiyara River Courses (Downstream of Ajmirganj)



Source："Master Plan of Haor Area, Annex 1: Water Resources, Ministry of Water Resources, April 2012"

Photo 5.4.2 Changes of Surma River Courses (East of Karimganj)

5.4.4 Dredging in the Surma-Baulai River System

The FAP6 and other relevant documents were reviewed to identify the potential rivers in the haor area for dredging. In FAP6, 20 river systems were proposed for dredging.

A total of 125 km of river that stretches from the Surma, Rakti, Bauli and Katakhal Rivers has been selected for dredging based on the following criteria, and as compiled in **Table 5.4.4**:

- Navigational purpose,
- Flood reduction,
- Creation of new or vertical/lateral extension of village platform, and
- Expediting the avulsion process of the river systems.

Table 5.4.4 Proposed Dredging Plan in Master Plan of Haor Area

Sl no	River Name	District	Upazila	Length (km)	Selection Criteria
1	Surma	Sunamganj	Dowarabazar	5.1	Navigational purpose
				3.8	
				5.9	
			Sunamganj Sadar	9.5	
		Sylhet	Kanaighat	5.8	Dry season flow diversion
				4.5	
				6.5	
				41.1	
2	Rakti	Sunamganj	Jamalganj	8	Navigational purpose
				8	
3	Baulai	Sunamganj	Dharampasha	4.3	Navigational purpose
		Netrakona	Khaliajuri	18.7	Navigational purpose Flood reduction Creation of new or vertical and lateral extension of village platform
				4.4	
				4.4	
			Itna	4.7	
				8.5	
			Mithamain	6	
				4.5	
				7	
				62.5	
4	Katkhal channel	Kishoreganj	Mithamain	12.79	Navigational purpose Flood reduction Creation of new or vertical and lateral extension of village platform Expediting the avulsion process of the river systems
				12.79	
	Grand Total (Surma+Baulai+Katkhal)			**124.39**	

Source: CEGIS

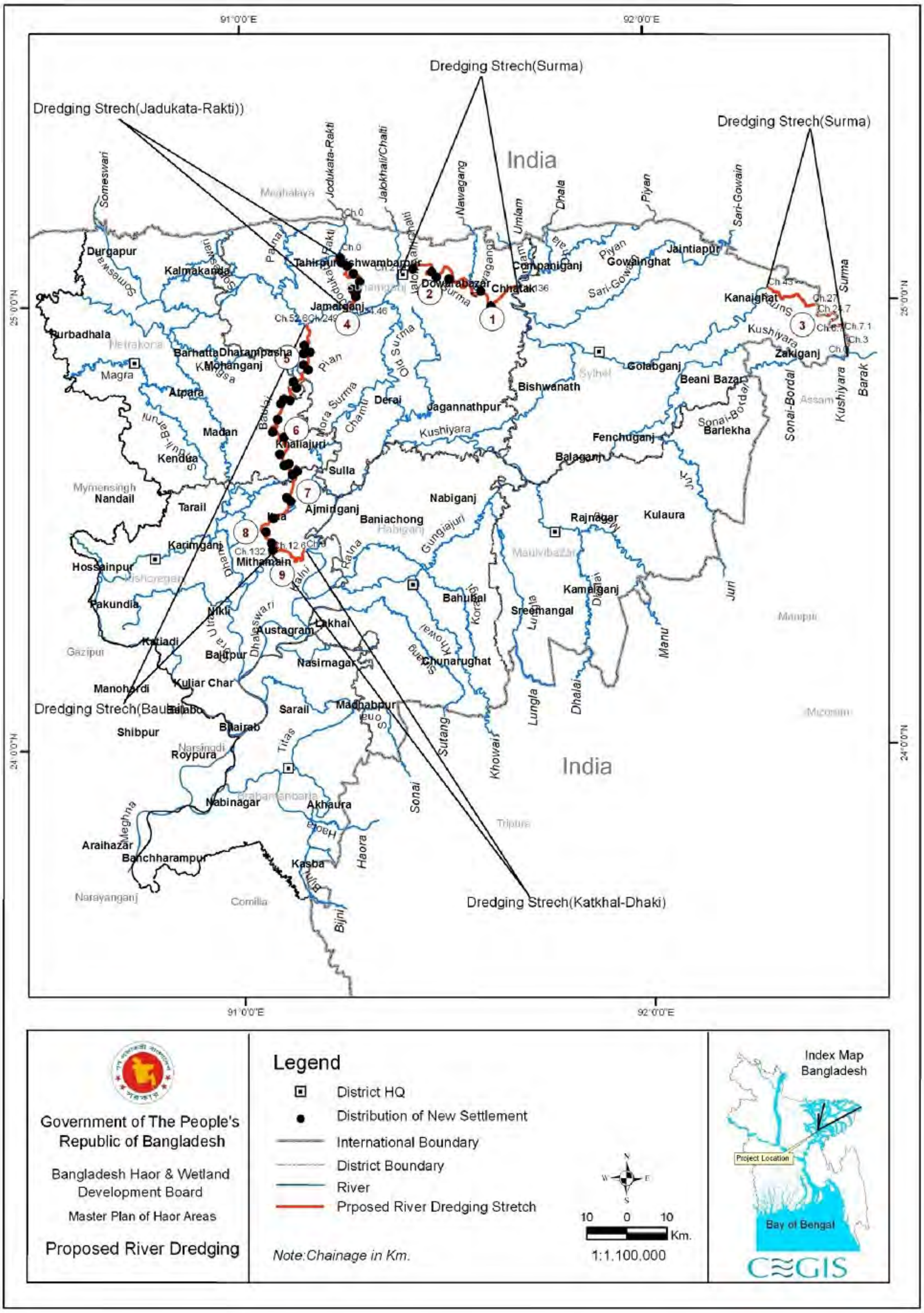
Several dredging layouts have been planned in Bangladesh at several times. The location of the dredging is presented in the following figures:

Figure 5.4.4 shows the dredging distribution included in the M/P, which focuses on the Surma-Baulay river system. **Figure 5.4.5** presents the plan proposed in the FAP 6 study. **Figure 5.4.6** includes the proposed dredging configuration for navigation.

The required dredging volume has been preliminarily estimated in the Study, using hydrographic survey charts of BIWTA surveyed in 2008. The survey in 2008 covered the downstream reaches at Chatak to Bhairab Bazar. Dredging volume calculation is based on the BIWTA requirements for least available depth (LAD) in the Bhairab-Chatak navigation route and the minimum required width of fairways. The LAD is 3.7 m, while the width of fairways is 60 m. **Figures 5.4.7** and **5.4.8** show the thalweg riverbed profiles from Chatak to Sunamganj and from Jamalganj to Bhairab Bazar, the formation level at 3.7 m and locations of dredging for navigability improvement.

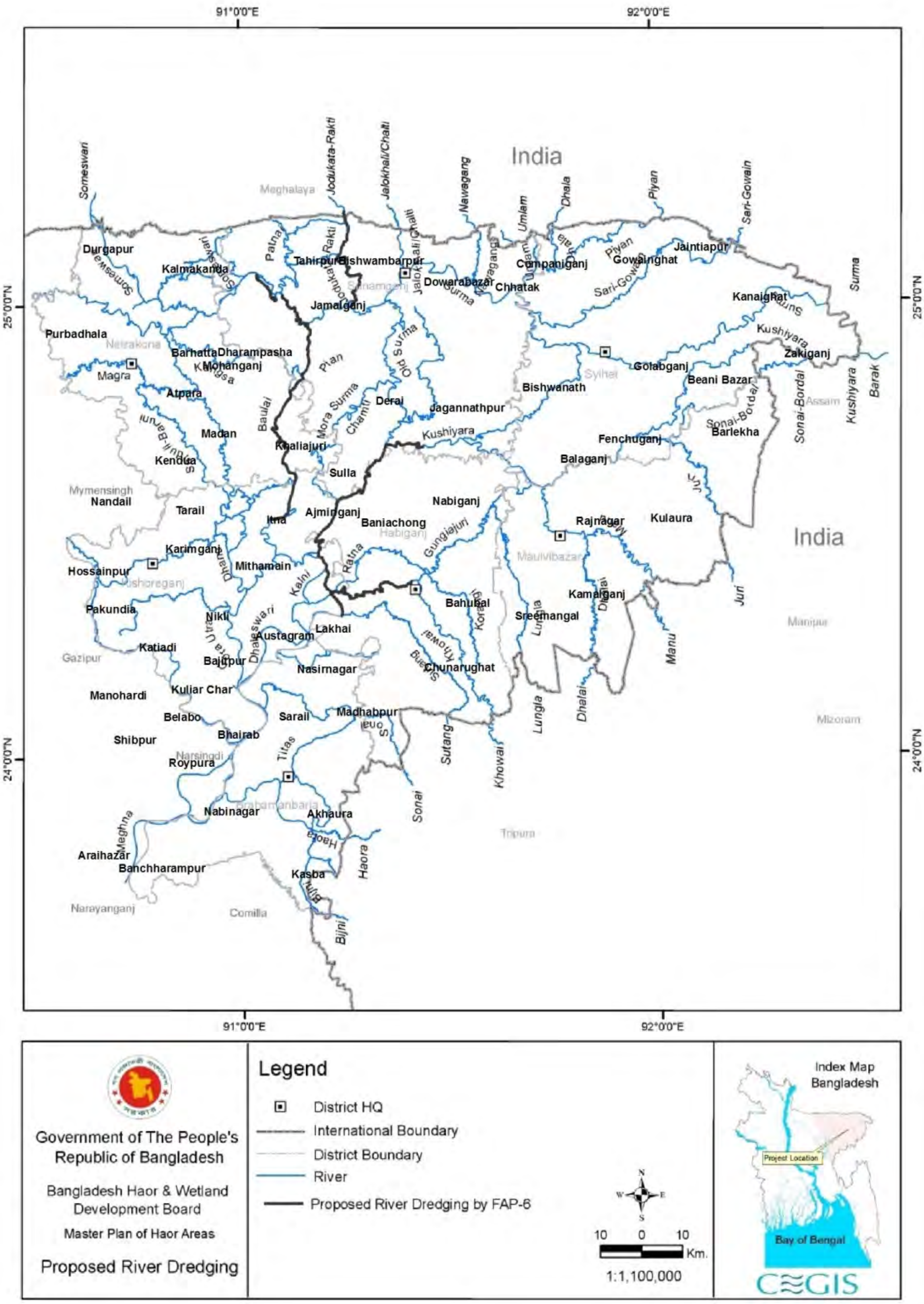
From Chatak to Sunamganj, the length of the reach was found to be 44 km. Four locations have been identified for dredging where the thalweg level is above the formation level. The total dredging volume has been calculated at 130,640 m^3.

From Jamalganj to Bhairab Bazar, the length of the reach was found to be 156 km. About 17 locations have been selected for dredging. The total dredging volume has been estimated at 532,960 m^3.



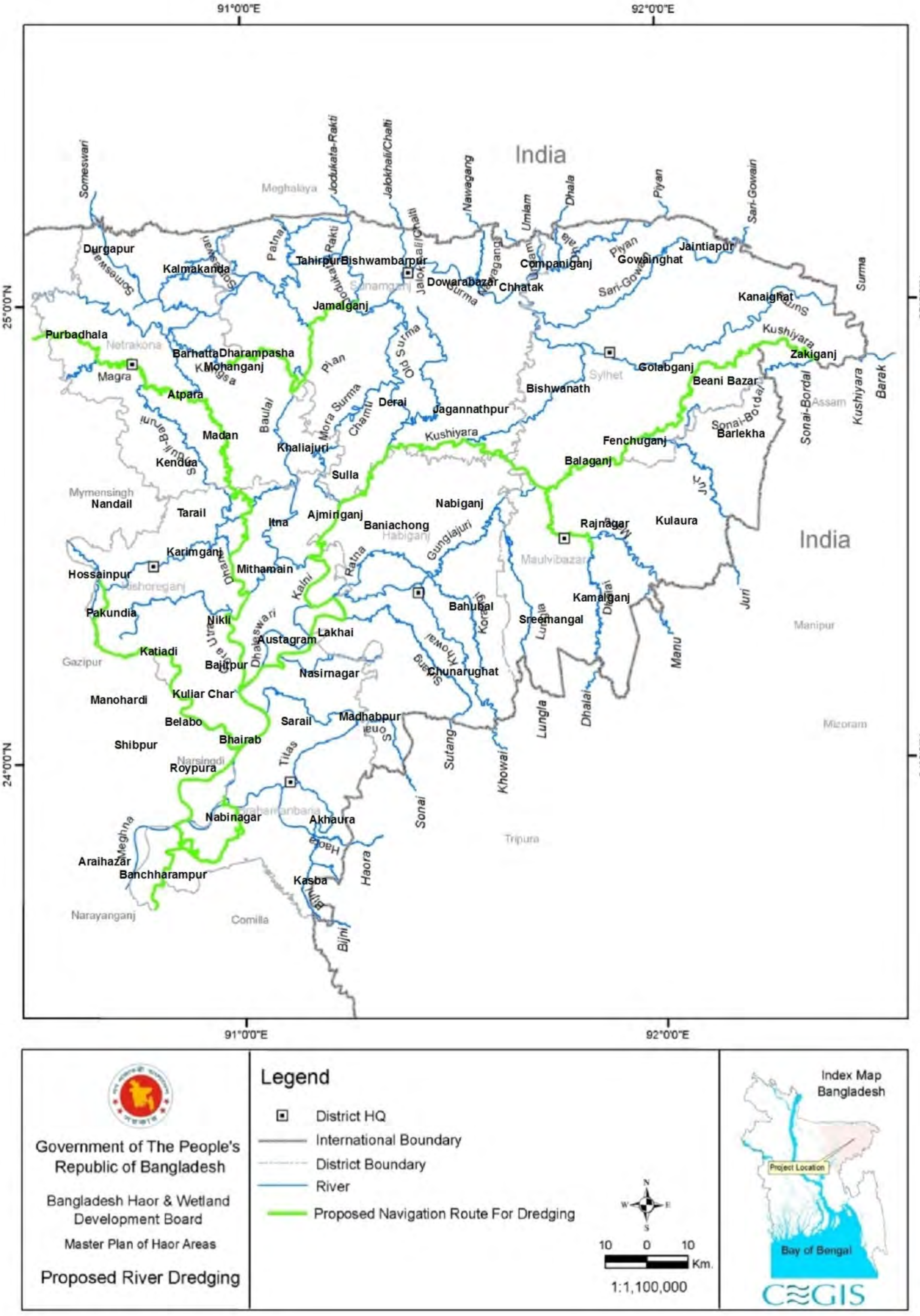
Source: CEGIS

Figure 5.4.4 Proposed River Dredging in the Haor Area Master Plan



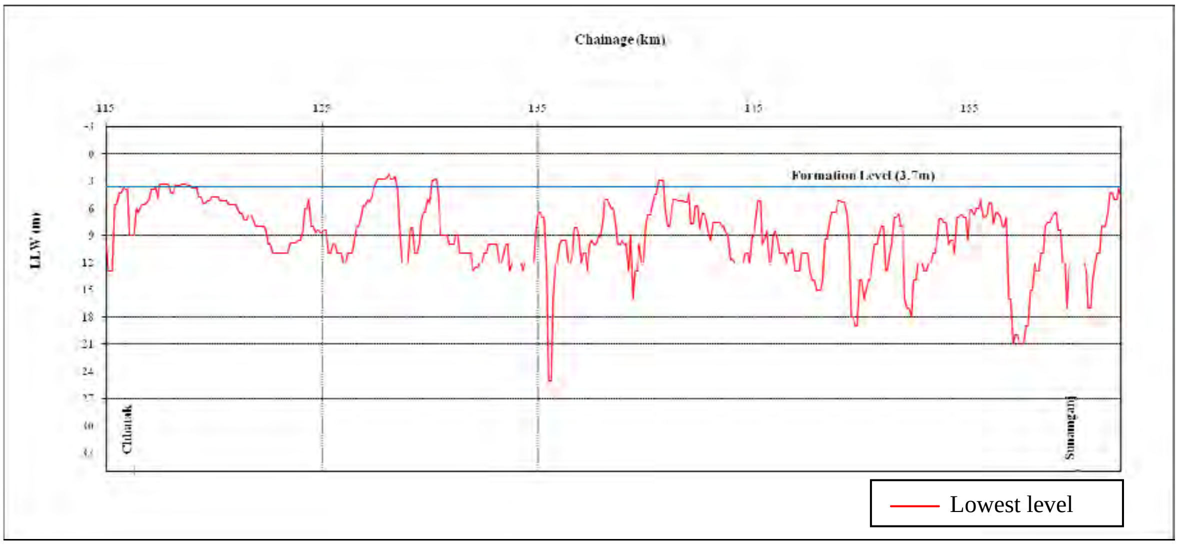
Source: FAP 6

Figure 5.4.5 Proposed River Dredging in FAP6



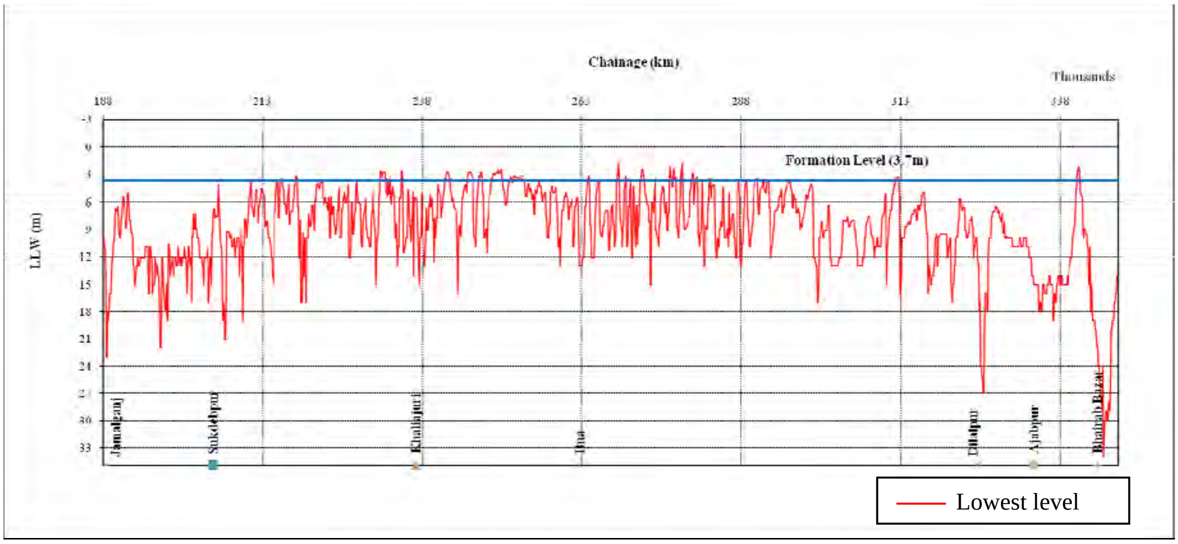
Source: Master Plan of Haor Area, April 2012

Figure 5.4.6 Proposed River Dredging for Navigation Route



Source: JICA Study Team and CEGIS

Figure 5.4.7 Long Profile of Surma River 2008 from Chatak to Sunamganj Showing Formation of Level and Locations of Dredging for Maintaining Navigability



Source: JICA Study Team and CEGIS

Figure 5.4.8 Long Profile of Surma-Baulai-Upper Meghna Rivers 2008 from Jamalganj to Bhairab Bazar Showing Formation of Level and Locations of Dredging for Maintaining Navigability

CHAPTER 6 REVIEW OF FLOOD MEASURES AND RIVER MANAGEMENT

6.1 Flood Protection Level and Design Rainfall in Flood Measures

6.1.1 Flood Protection Level

The standard design manual was prepared by BWDB in 1995. The flood protection level is explained in this manual.

(*Excerpts from BWDB Design Standard Manual*)

7.0 DESIGN CRITERIA OF EMBANKMENT

7.5 Design Crest Level

7.5.2 Selection of Design Flood Frequency

The frequency of occurrence of floods that needs to be selected for the design of a particular embankment depends on the acceptable extent of damage by inundation in the locality. Considering likely agricultural damage, damage to important installations and loss of human lives, the following flood frequencies may be adopted:

- <u>1 in 20 years flood</u> where agricultural damage is predominant
- <u>1 in 100 years flood</u> where loss of human lives, properties and installations are predominant. In general, embankment along the Jamuna, Padma and Meghna rivers shall be designed with this return period.

7.5.3 Design Flood Levels

Having selected the flood frequency the design flood levels need to be assessed separately in two cases, as follows, depending upon whether embankments are to be provided on one bank or on both banks.

i) Embankment on one bank

Where an embankment needs to be constructed on one bank only, the design flood levels may be computed by frequency analysis of available annual maximum river level data for full flood protection embankments, and by frequency analysis of maximum river level data before some specified time during the year, e.g. 31 May, for submersible embankment.

ii) Embankments on both banks

Where embankments are to be constructed on both banks, the computation of design flood levels by frequency analysis of historical river level data at a particular location is not a logical approach as the recorded river levels are measured with overbank flow conditions. Accordingly, the design flood levels need to be computed from the design flood discharge under confined conditions. A model study may required to be taken up to determine the confinement effect.

7.12 Submersible Embankments

7.12.1 General

The Haor submersible embankments are designed to restrict flood waters from entering the sub-project until 31 May. The delay in flooding would enable farmers to harvest boro rice without the risk of crop damage.

7.12.2 Crest Level

Submersible embankments in haor areas are designed for a **1 in 10 year pre-monsoon flood expected to occur before 31 May**. In addition, a nominal height of freeboard of about 0.30m is provided. The freeboard is provided to account for possible increases in the pre-monsoon flood levels due to embankment confinement effect. To ensure access at any time, the operating decks of the regulators are designed above the 1 in 20 year annual flood. The embankment crest should be gradually raised to the regulator deck level over a 50 m length on each side of the structure. This will prevent washout of the embankments adjacent to the structures.

(1) Actual Application of Standard Design Manual

The JICA Study Team visited and discussed the Design Circle-I under BWDB as stated below.

According to the standard design manual, the design flood water level will be decided based on a ten year pre-monsoon flood before 31 May. However, the Design Circle-I adopts that before 15 May for the following reasons:

- Farmers recently cultivated high yield variety (HYV) boro rice, and the harvesting season is until 15 May. To avoid flash flood damage to boro rice, the calculation period of flood water level is considered until 15 May.
- The agricultural and fishery sides have agreed to bring flood water into paddy fields after 15 May.
- Even if the calculation period is set up to 31 May, fishermen will still break the submergible embankment after 15 May.
- Farmers also expect to bring water to paddy field as soon as possible after harvesting because farmers want to use rivers/channels in transporting boro rice by boat.

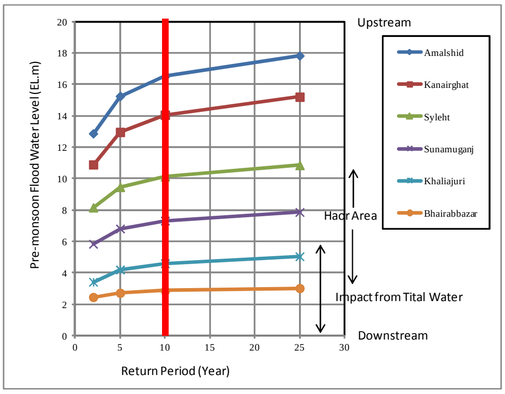
The design flood water level is decided based on a simulated water level by IWM.

(2) Technical Review of Flood Protection Level for Submergible Embankment

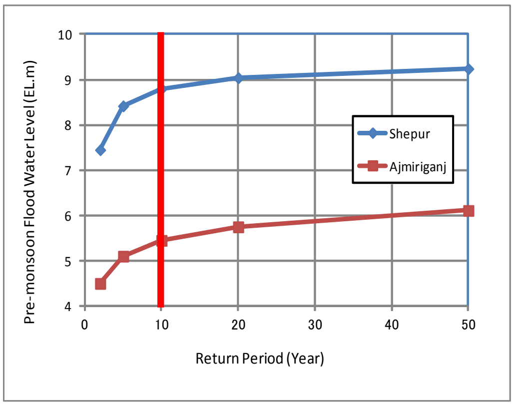
Main damage caused by flash floods in the haor area falls towards boro rice production. Therefore, major factor in deciding the flood protection level can affect boro rice production.

On the other hand, drought level of irrigation water supply is generally applied 5-year drought level. If drought occurs, boro rice production and farmer’s income also decrease. Flood and drought together can cause serious damage on crop production. Therefore, the flood protection level of submergible embankment shall be the same level or higher compared with the drought level of water use.

On the other hand, several probable water levels at some water level gauging stations in the Surma-Baulai and Kalni-Kushiyara Rivers were evaluated in the “Mathematical Modeling along with Hydrological Studies and Terrestrial Survey under the Haor Rehabilitation Scheme, March 2007, IWM”. The relation between water levels and return periods before the implementation of rehabilitation work is shown in **Figure 6.1.1**. **Table 6.1.1** shows water level difference between15-year and 10-year return periods, and 10-year and 5-year return perioda in the Surma-Baulai and Kalni-Kushiyara Rivers.



Surma-Baulai River



Kalni-Keshiyara River

Data Source: Mathematical Modelling along with Hydrlogical Studies and Terrestrial Survey under the Haor Rehabilitation Scheme, March 2007, IWM

Figure 6.1.1 Relationship between Return Periods and Pre-monsoon Flood Water Levels

Table 6.1.1 Water Level Rising Regarding Return Period

Difference	Amalshid	Kanairghat	Syhlet	Sunamganj	Khaliajuri	Bhairab Bazar
1)10-yr and 5yr	1.25m	1.09m	0.67m	0.50m	0.40m	0.14m
2)15-yr and 10-yr	0.44m	0.38m	0.24m	0.18m	0.15m	0.05m
2)/1)	0.35	0.35	0.36	0.36	0.38	0.36

Note: 15-year probable water level is expected from interpolation method.

Data Source: Mathematical Modelling along with Hydrological Studies and Terrestrial Survey under the Haor Rehabilitation Scheme, March 2007, IWM

The slopes of the curves in **Figure 6.1.1** change from steep to gentle the 10-year return period. The water rising ratio between 15-year to 10-year and 10-year and 5-year is about 36%. The water rising ratio around 10-year return period slows down.

In addition, the submergible embankment functions as flood protection during the pre-monsoon season, which is a very short period. The flood protection level is less than the full embankment.

It is judged to be appropriate design flood protection level of the submergible embankment considering the 10-year probable water level of pre-monsoon flood.

(3) Flood Protection Level for Full Embankment

The flood protection level of full embankment in Bangladesh basically follows the BWDB's standard design manual. However, special cases such as land acquisition limitations and small rivers have used smaller protection level in due consideration of actual field conditions. Such decisions for the special cases, which are also based on political judgment of the GOB, are considered reasonable. In this Study, a 20-year flood protection level is employed for the design of full embankment according to the design standard manual.

(4) Estimation Method of Design Water Level

The design water level is estimated through frequent analysis by using the water level data. There are two kinds of water level considered if the run-off model and/or the inundation model is available for the target area. One is the observed water level and the other is a simulated water level. The JICA Study Team confirmed with the Design Circle, which applies the following approach at the present:

Case 1: Run-off model and/or Inundation model is available

The design water level is decided from the simulated water level.

Case 2: No model

The observed water level data is applied to estimate the design water level.

There is a NERM for the project area. Therefore, the simulated water level is applied in estimating the design water level.

6.1.2 Design Rainfall

The availability of data and information about rainfall distribution in sub-watersheds and flow at their respective outlets is rather poor in the Northeast Region. No rainfall record is available inside and upstream of the border areas with India, where a large amount of rainfall occurs. In addition, due to the topographic conditions at the watershed outlets, the rating curves and hydrographs have not been satisfactorily recorded yet.

The hydrologic model study of the NERM clearly demonstrates that the estimate of river flow based on rainfall data is not reliable with the currently available data set.

Therefore, the rainfall data cannot be applied to define the design rainfall in flood measures planning to provide probable water levels for structural design.

The alternative to design rainfall is to use records of river discharge or water surface, such as annual peak discharges and flood water levels at representative locations in watersheds and extrapolate the values using well-known statistical methods. Though the topography of the haor areas has a gentle 2 m to 3 m undulation, the height of submergible embankment is relatively low at almost 1 m to 2 m. It should be adequate to use statistical water levels from the measured values of design water level of submergible embankment in hydraulically sensitive area.

The rainfall frequency analysis method, however, can be safely used to compute the probable rainfalls falling directly over the areas to be protected by submergible embankments. The estimation of rainwater volume inside these areas is important to work out drainage plan of agriculture land, etc.

In due consideration of the above, the procedures recommended are as follows:

1) For the design of submersible embankment (crest elevation), water level statistical analysis and model analysis should be used; and
2) For the determination of rainwater volume inside the areas protected by submersible embankment, statistical analysis of local rainfalls in Bangladesh should be applied.

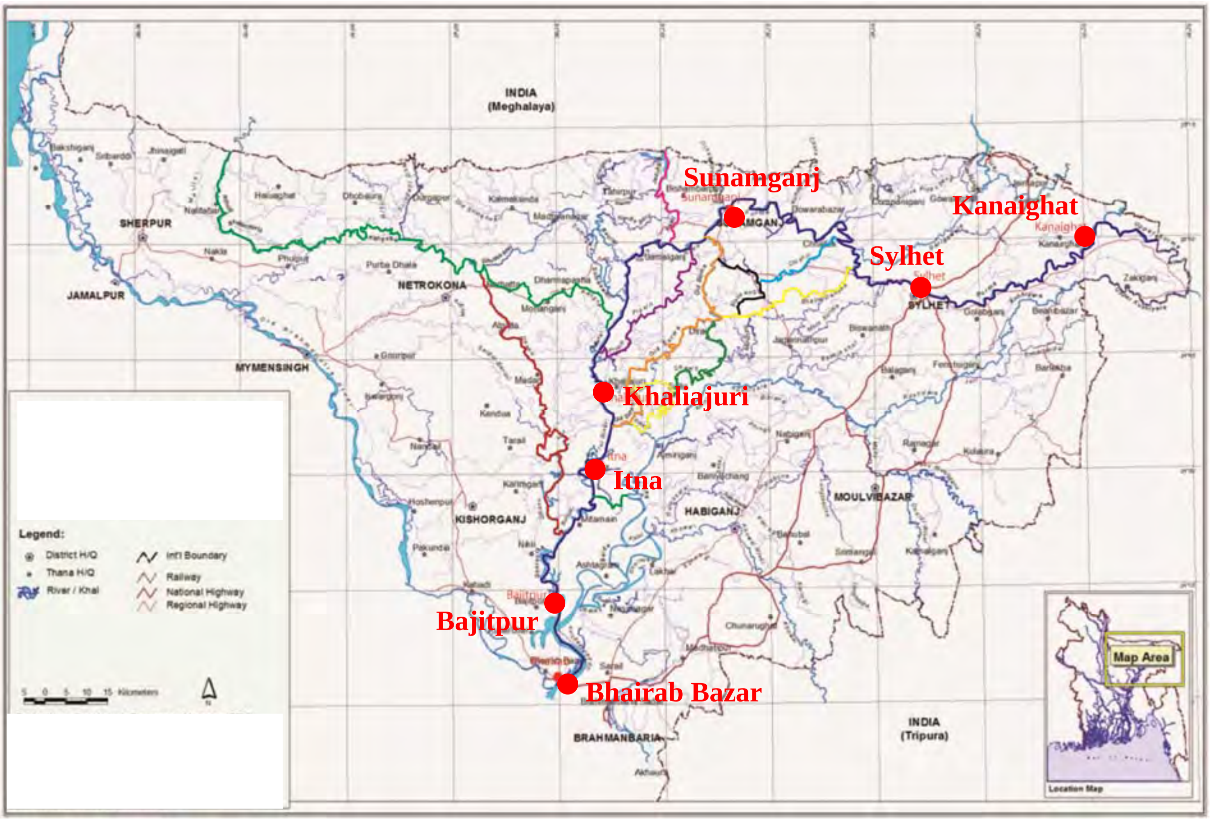
6.2 Flood Management in Bangladesh

The danger level at some water level gauging stations along rivers was decided and flood management has been carried out based on the danger level in Bangladesh. Danger level is defined as a level above where flood may likely cause damages to crops and homesteads. If there is no embankment along the river, the danger level is set close to the annual average flood water level. If there is a continuous embankment along the river, the danger level is set slightly lower of the design flood water level for the embankment. **Table 6.2.1** shows the danger levels and their setting locations, while **Figure 6.2.1** shows the location map of danger level setting points.

Table 6.2.1 Danger Level

Setting Points	Danger Level (PWD)
Surma-Baulai River	
Kanaighat	13.80m
Sylhet	11.25m
Sunamganj	8.25m
Khaliajuri	7.01m
Itna	7.01m
Dilalpur (Bajitpur)	6.09m
Meghna River	
Bhairab Bazar	6.55m

Source: Interview from BWDB



Note: Red circles are the danger level setting points.
Source: Interview with BWDB

Figure 6.2.1 Location Map of Danger Level Setting Points

6.3 Strategy of Flood Measures and River Management Plan in M/P

The strategies of flood measures and river management in the M/P were explained in Section 9.3 of Annex-1 Water Resources. The proposed strategies are 1) flood management, 2) drainage improvement, 3) riverbank erosion protection, and 4) operation and maintenance (O&M) for the existing scheme. Each strategy is explained below:

1) Flood Management

Flood management has two objectives, mainly as follows:

i) Protection from sudden intrusion of flood water is required to save agricultural production (especially boro rice production), and

ii) Allowance of flood water during the monsoon is crucial to maintain the aquatic ecosystem.

To achieve the flood management strategy, the following issues are proposed:

i) Construction of intake structure to divert water to protected land after the harvesting of boro crops (15 May),

ii) Construction of new and rehabilitation of existing submergible embankments against a 10-year pre-monsoon probable flood,

iii) Construction of new and rehabilitation of existing full embankments near the boundary of the inundation and deep haor area against a 20-year annual probable flood,

iv) Construction of bypass channel,

v) Mechanized construction, and

vi) Establishment of flood forecasting model of flash flood (non-structural measure).

2) Drainage Improvement

Post-monsoon drainage is essential for rabi (including boro) cultivation. Timely and quick recession of flood water allows cultivars to go for crop culture in the haor areas. Therefore, the following measures are proposed:

i) Dredging of mainstream rivers, and

ii) Drainage improvement of distributaries to reestablish the drainage connectivity of the haor areas.

3) Riverbank Erosion Protection

The Government has recognized river bank erosion as a disaster. River bank erosion is observed on all the rivers in Bangladesh including those in the haor areas.

River bank erosion is considered as one of the major reasons of pauperization. To elevate poverty and protect life and property of the people, river banks should be protected against erosion according to the government policy and directives, which is to attach priority to protect towns, Government installations, structures of high economic value and national heritage.

4) Operation and Maintenance (O&M) of Existing Scheme

Problems for O&M of existing scheme are i) budget shortage, ii) inadequate equipment supports, iii) inadequate manpower, iv) poor quality of O&M works, v) inadequate monitoring, and vi) non-availability of O&M manual. Therefore, the M/P has proposed following measures;

i) The line agency has to ensure adequate fund,

ii) Adequate equipment supports have to be ensured, and

iii) Adequate manpower for proper O & M activities has to be ensured.

The protection level and projects for flood measures were proposed in the M/P, but the control points, defined as important location to plan river management, and indicators such as the discharge, water level, etc. for river management plan are not cleared. These shall be decided to manage flood control.

6.4 Applicability of River Planning Method in Japan

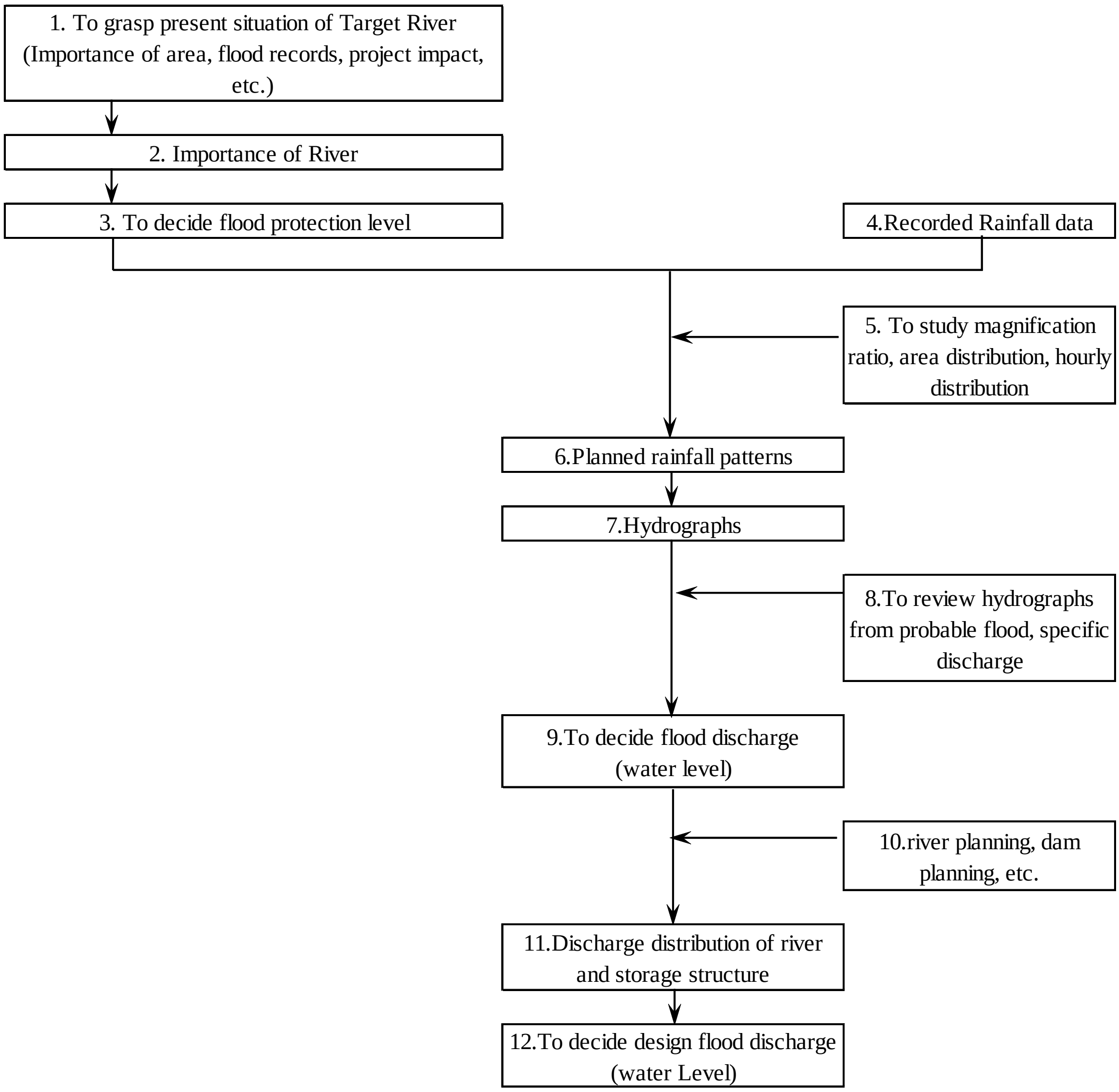
The river planning method used in Japan was studied to examine its applicability to the river planning in Bangladesh. **Figure 6.4.1** shows the flow chart of ordinary flood control plan. The applicability of the Japanese method of river management plan for haor area was studied based on **Figure 6.4.1**. The study results are shown in **Table 6.4.1**.

Table 6.4.1 Applicability of Japanese River Management Method

Items	Applicability
1) To grasp the present situation of the target river	The river management is carried out based on the danger level of control points. Data collection of water level is executed at these control points of danger level. These control points are set at upper, middle, and lower reaches of the Surma-Baulai River. Japanese selection criteria of control points are as follows; ➢ Existing hydraulic and hydrological data are sufficiently stored, ➢ It is a base point for hydraulic and hydrological analysis, and ➢ It is closely related to overall plan. Therefore, it is possible that the control points of river management plan in Surma-Baulai River are selected from the existing danger level of control points.
2) Importance of river and setting of flood protection level	In determining the planning scale of the Japanese technical criteria, the importance of the subject river should be emphasized, and the actual damage caused by past floods, economic effects, and other factors should all be taken into consideration. On the other hand, the planning scale of full embankment is determined from the design standard in Bangladesh. The planning scale is applied considering 20- or 100-year return periods. In this Study, the planning scale is applied based on the design standard of Bangladesh.
3) Selection and application of recorded rainfall(s) and planned rainfall(s)	Section 6.1.2 mentions; "The available data and information on rainfall distribution in sub-watersheds and flow at their respective outlets are rather poor in the Northeast Region. The hydrologic model study of NERM clearly demonstrates that the estimated river flow based on rainfall data is not reliable with the currently available set of data. Therefore, the rainfall data cannot be applied to define the design rainfall in the flood measures planning to provide probable water levels for structural design." Therefore, it is not possible to apply recorded rainfall(s) and planned rainfall(s).
4) Hydrograph(s)	Hydrograph is not applicable because 3) is not applied.
5) Flood Discharge	In the project area, the measurement of the water level is carried out five times per day from 1980. Recently, discharge measurement is also carried out about twenty times per year. However, there are no old data of the discharge measurement. It is difficult to grasp past discharge because there are no records on the past observed discharge. The flood management plan based on the discharge was not prepared. Therefore, flood discharge will be based on the water level at each control point. There are two kinds of water level, i.e., observed and simulated water level. According to the Design Circle, the simulated water level is applied to estimate the design water level, if the run-off model and/or the inundation model are available. NERM exists for the project area. Therefore, the simulated water

Items	Applicability
	level is applied.
6) Design Flood Discharge	In the flood control plan, the peak discharge to be used as basis for river channel and dam planning for major locations should be determined by rationally routing the design flood through river channels, dams, etc. The design flood water level is estimated from the simulated water level.
7)Planning of Facility Installation	<u>Deep haor area</u> It is difficult to apply the layout planning that is used in Japan because of the following reasons: ➢ The river course of Surma-Baurai River in the deep haor area is not stable, and ➢ A large lake appears during the monsoon season. On the other hand, the river course at the upper and lower reaches of deep haor area does not significantly move. Therefore, full embankment can be constructed. In this case, the layout planning used in Japan is applicable. However, the existing full embankment shall be considered when the layout plan of the full embankment alignment is studied. The design standard in Bangladesh is applied in planning of submergible embankment because this kind of embankment is not applied in Japan. The planned river profile and typical cross section are decided from the present flow capacity, river profile, riverbed aggradation and degradation, existing full embankment and original ground elevation.

Source: JICA Study Team



Source: JICA Study Team prepared based on the "Technical Criteria for River Works in Japan"

Figure 6.4.1 Flow Chart of Flood Control Plan in Japan

CHAPTER 7 STRUCTURAL MEASURES FOR FLOOD MEASURES AND RIVER MANAGEMENT PLAN IN HAOR AREA

7.1 Basic Conditions for Flood Measures and River Management Plan

In the M/P, flood control measures are proposed, particularly the construction of a full embankment and submergible embankment in the deep haor area. The proposed measures for the deep haor area corresponded with the people's concept of "living with flood".

Flood control planning methods in Japan can be partly applied to the flood control plan in the Surma-Baulai River. Therefore, method for flood control and river management plans shall be studied considering the present situation and design guidelines applied in Bangladesh and Japan.

(1) Target River

Major rivers in the study area are the Surma-Baulai River and the Kalni-Kshiyara River. Both rivers branch off from the Barak River at the border between India and Bangladesh. The Surma-Baulai River flows through Slyhet City, Sunamganj and Itna town areas. The Kalni-Kshiyara River flows through Fenchuganj, Ajimirigang and Austagram town areas. Both rivers join near Bajitpur.

The dredging works in the Kalni-Kushiyara River are being studied. Therefore, the Surma-Baulai River is selected as the target river for planning of the dredging works.

(2) Control Points of Flood Control Measure

The control points of flood control measure have not been established yet, but the control points of danger level are determined. It is considered that some of the control point of danger level will become candidate control points for flood control measure because they are applicable for hydraulic and hydrological analysis.

The control points of flood control measure are considered in each of the pre-monsoon and monsoon seasons because the circumstances in the haor area drastically change between these seasons.

<u>Pre-monsoon season</u>

The control points for danger level in the upper reach from Sunamganj Town were set at: 1) Kanaighat, 2) Slyhet, and 3) Sunamganj. The crucial areas of flood control are Sylhet City and Sunamganj Town due to prefectural capital status and the concentration of assets in this area. On the other hand, Kanaighat is located near the international border. This is important in confirming the water level at the most upstream point. The water level at Kanaighat is used mainly for: 1) flood warning in and around Kanaighat and 2) examination of water level at Sylhet City. Therefore, Kanaighat is not applied as a control point of flood control but shall still be a control point for danger level. Sylhet and Sunamganji are used as control points of flood control considering the protection of assets and sufficient data for hydraulic and hydrological analysis.

In addition, Bairab Bazar is also a control point of flood control in consideration of its downstream impact. And Itna Town is also determined to be a control point because many river facilities against pre-monsoon floods are planned in and around this area.

Monsoon season

The deep haor area becomes a huge-sized lake during the monsoon season due to its low land elevation. People in this area are considered to be “living with flood”. Flood control measures in the deep haor area are not applied. The Itna control point is canceled during the monsoon season.

The control points of flood control selected during the monsoon season are 1) Sylhet, 2) Sunamganj, and 3) Bairab Bazar.

Table 7.1.1 Control Points of Flood Control Measure

Location	Pre-monsoon	Monsoon
Sylhet	O	O
Sunamganj	O	O
Itna	O	X
Bhairab Bazar	O	O

Source: JICA Study Team

(3) Importance of River and Planning Scale

According to the Technical Criteria for River Works Practical Guide for Planning, “in determining the planning scale, the importance of rivers should be emphasized, and the actual damage caused by past floods, economic effects, and other factors should be taken into consideration”. The importance of river is classified into several classes from A to E. The planning scale of each class is indicated as referred to in **Table 7.1.2**.

Table 7.1.2 Importance of River and Planning Scale

Importance of River	Planning Scale (Return period in year) *
Class A	Over 200
Class B	100-200
Class C	50-100
Class D	10-50
Class E	Below 10

Note: * Inverse of the annual probability of excess

Source: Technical Criteria for River Works Practical Guide for Planning, Japan

In the standard design guideline of Bangladesh, the design flood water level of submergible embankments and full embankments are decided based on the following:

Submergible Embankment: 10-year probable flood during pre-monsoon season

(Pre-monsoon season is defined to 31 May in the standard design guideline, but its end date was proposed on 15 May based from the result of public consultation meetings in deep haor area. At present, the design circle in BWDB applies 15 May to be the end date of the pre-monsoon season.)

Full Embankment: 1:20 years flood where agricultural damage is predominant

1:100 years flood where loss of human lives, properties and installations is predominant. In general, embankment along Jamuna, Padma and Meghna Rivers shall be designed considering such return period.

The planning scale in the design standard is decided in consideration of not only technical and economic view points but also government policy decisions. Therefore, the planning scale in this study utilizes the one stipulated in the standard design guideline in Bangladesh.

The planning scale is set at:

Submergible Embankment: 10-year probable flood during pre-monsoon season

Full Embankment: 20-year probable flood

(4) Setting of Planned High Water Level at Control Points for Flood Control

The planned high water levels are estimated based from the run-off analysis and inundation analysis. **Table 7.1.3** shows the planned high water levels at the control points.

Table 7.1.3 Planned High Water Level at Control Points

Control Points	**Pre-monsoon (EL.m)**	**Monsoon (EL.m)**
Bairab Bazaar	EL. 2.88m	EL.6.80m
Itna	EL. 4.52m	-
Sunamganj	EL. 6.95m	EL.8.55m
Slyhet	EL. 9.92m	EL.11.11m

Source: JICA Study Team

Figure 7.1.1 shows the lowest riverbed profile, original ground elevation, dike crest elevation, and planned high water level during the pre-monsoon and monsoon seasons.

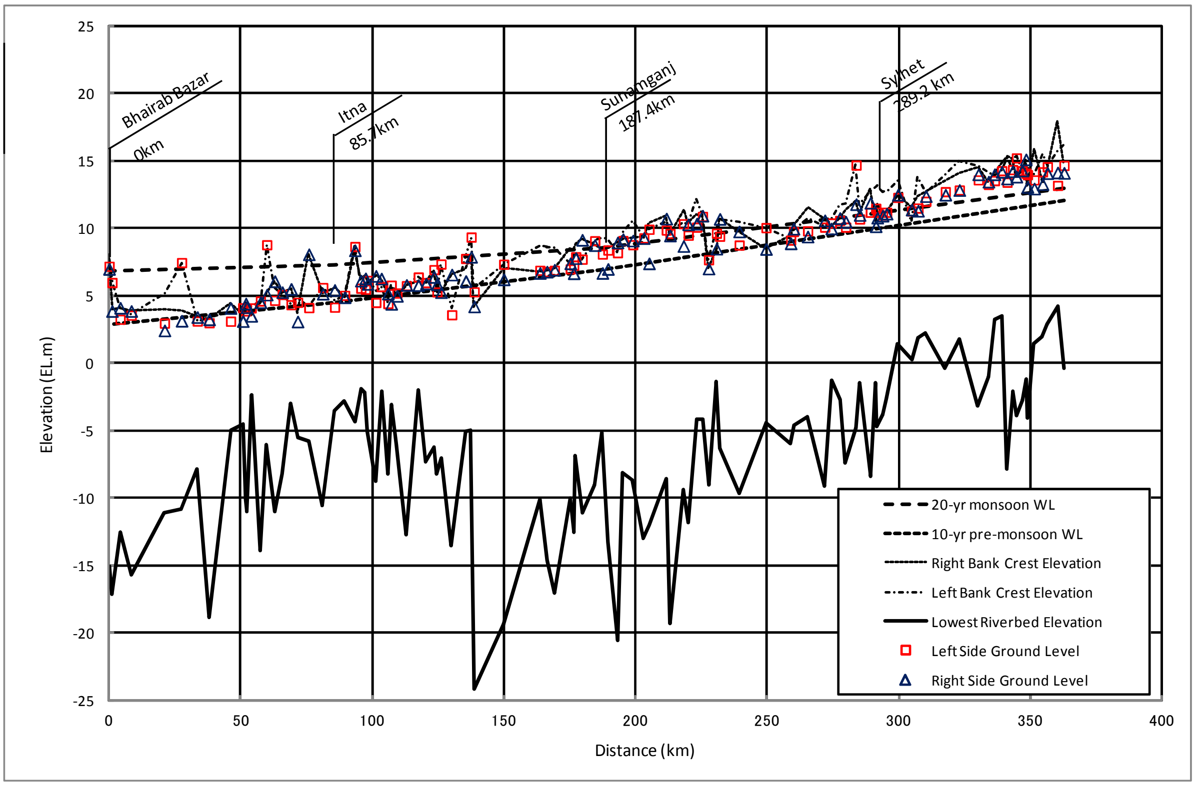
In Japan, the planned high water level is decided from collinear approximation to envelop the estimated water level from the planned discharge using non-uniform flow calculation and local water rising at each point. However, the planned discharge is not estimated in the haor area. The water level is directly estimated using the NERM. Therefore, the planned high water level line is directly connected at each control point. Flow capacity is shown in **Figure 7.1.2**.

<u>Flood Phenomena during Pre-monsoon Season</u>

It is conjectured that a flood phenomena during the pre-monsoon season begins at the upstream of Itna Town because the flow capacity upstream of the Itna station is small. This indicates that the lowest riverbed elevation surrounding the Itna station is higher.

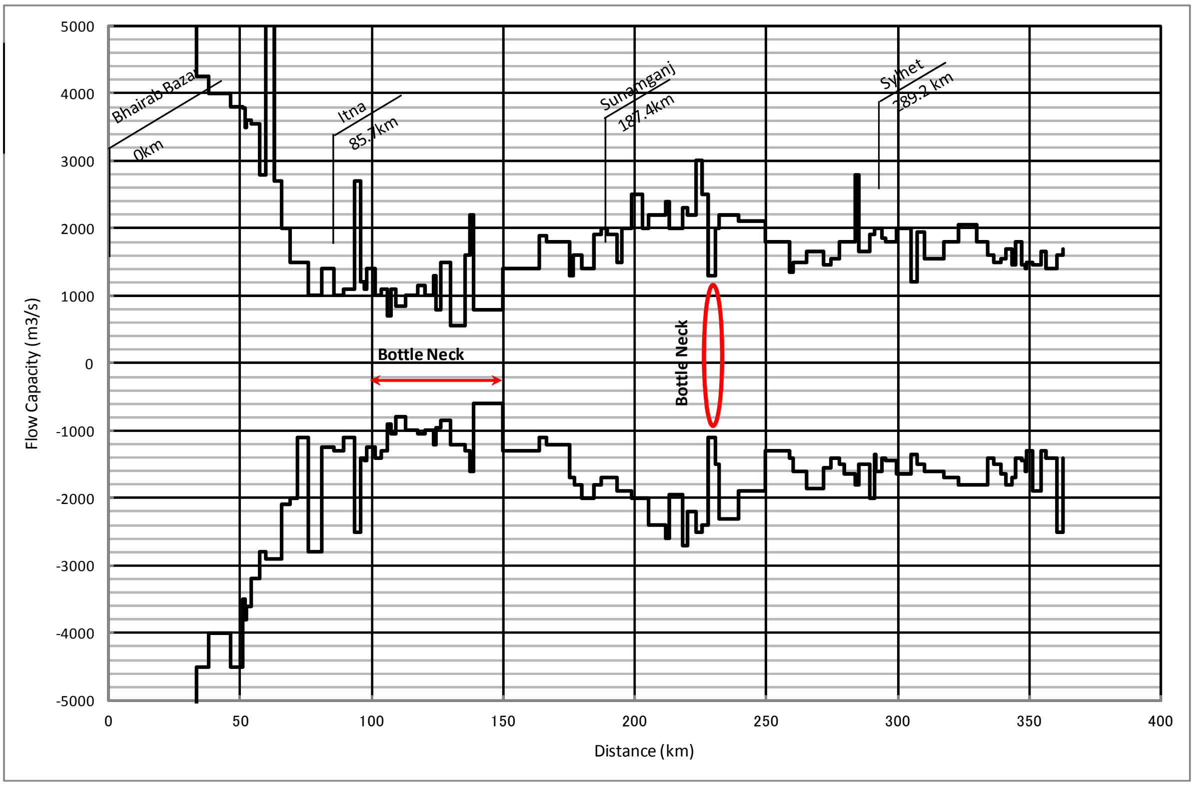
The planned high water level during the pre-monsoon season is lower than the original ground elevation at most places except the deep haor area. This means that many locations along the Surma-Baulai River are not inundated by the pre-monsoon floods. If inundation occurs in some places except in the deep haor area, tributary floods and/or local floods may occur due to drainage problem.

In addition, the flood impact at Dhaka from the upper Meghna River basin is reduced by the inundation phenomena in the deep haor area.



Source: JICA Study Team

Figure 7.1.1 Profile of the Surma-Baulai River



Source: JICA Study Team

Figure 7.1.2 Flow Capacity of the Surma-Baualai River

Flood Phenomena during Monsoon Season

The planned high water level during the monsoon season is about 2 m to 3 m higher than the original ground elevation in the deep haor area. The planned high water levels in many locations are the same as those of the crest elevation of the embankments. The levels may also be the same as the original ground or lower than the original ground. Therefore, most of the deep haor area will be inundated.

On the other hand, the planned high water level at several locations in the flood plain area is same or lower than the crest elevation of the embankment and the ground elevation. Then, it is conjectured that the flood phenomena at the flood plain area starts at the bottle neck sections.

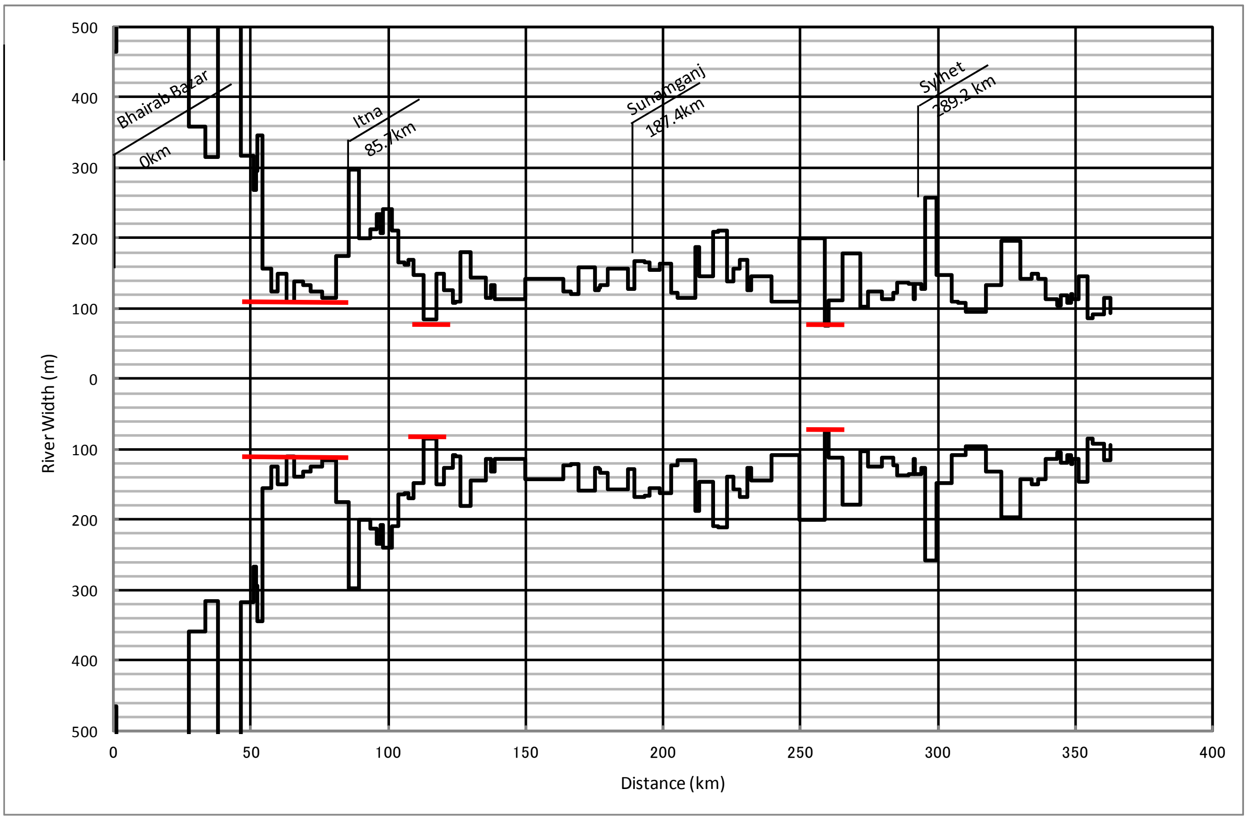
River Width

The river width is shown in **Figure 7.1.3** and the average river width at each section is shown in **Table 7.1.4**.

Table 7.1.4 Average River Width

Section	Average River Width (m)
Sylhetto Upstream stretch	270
Sunmganj to Sylhet	300
Sunamganj to Itna	320
Itna to Bhairab Bazar	920

Source: JICA Study Team



Source: JICA Study Team

Figure 7.1.3 River Width of Surma-Baulai River

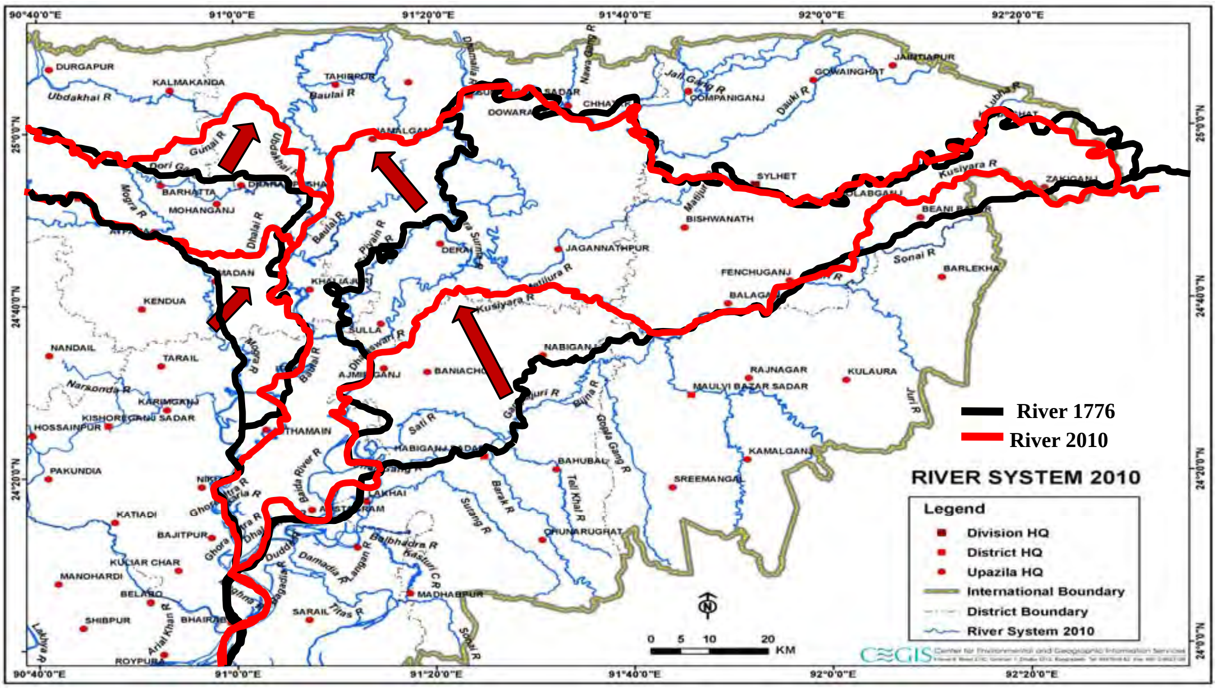
From a macro-perspective, the average river width widens from the upstream to the downstream of the river. However, river width of about 30km at the downstream stretch and about 40 km at the upstream stretch from Itna Town is narrow and the lowest riverbed elevation is higher. The flow capacity at the upstream stretch from Itna is also too small. Therefore, countermeasures shall be applied such as river widening and/or dredging.

7.2 Structural Measures for Flood Measures and River Management Plan

7.2.1 General

The facility plan of the Suruma-Baulai River is evaluated based on the planned high water level, historical changes of river and proposed projects in the M/P.

Historical changes of the Surma-Baulai River are shown in **Figure 7.2.1**. It is evaluated based on old maps that are available in the CEGIS, cartographic surveys conducted from 1910 to 1930, and river network extracted from the 2010 satellite image.



Source: CEGIS

Figure 7.2.1 Surma-Baulai River moving towards the Slyhet Basin

Based on the figure, these rivers shifted their courses from an upper level to a lower level and from south to north. The process of river development after shifting the courses and the topography reverses the direction of the flow. The river course of the Surma-Baulai River in the Sylhet basin still shifted. It is difficult to fix the river course by the river facilities.

On the other hand, the upstream of Sunamganj was constructed with a full embankment. Full embankment and river bank protection were provided under the town protection project in Slyhet and Sunamganj. The full embankment at the left bank of the Surma-Baulai River was constructed under the upper Surma River scheme. However, many locations with full embankment and river bank protection have been eroded. It is necessary to rehabilitate these full embankment and river bank protection.

7.2.2 Pre-monsoon Flood Protection and Drainage Improvement Project

(1) Proposed Facilities

The facility survey was carried out for the 30 existing haor projects in five districts, namely: Sunamganj, Netrakona, Habiganj, Kishorganj, and Brahamanbaria. Many locations in these districts are irrigated for one crop of boro rice. Four existing haor projects are rehabilitated in the Water Management Improvement Project (WMIP). Two projects, Sunamganj Town Protection Project and Bairab Erosion Protection Sub-project, were rejected due to the small amount for the rehabilitation works of river bank protections. Twenty four rehabilitation projects were selected. On the other hand, 26 new projects proposed in the M/P were also considered.

Full embankment has been constructed along the left bank between Sylhet City and the upstream border of the Suruma-Baulai River. The full embankment was damaged at many locations due to the lack of O&M budget. Rehabilitation works of the full embankment are important. However, the flow capacity of the upstream stretch of Sylhet City has become smaller compared to the originally designed capacity because the flow area has been reduced by riverbed aggradation due to sedimentation. If the rehabilitation works of the full embankment are decided, the dredging works shall be carried out at the same time. In this case, although maintenance dredging is important, it is difficult because of the lack of maintenance budget. Therefore, the rehabilitation works of the full embankment in the upper Surma River scheme are not proposed.

Table 7.2.1 shows the principal rehabilitation features and new constructed haor projects, while **Figures 7.2.2** and **7.2.3** show the location map of the projects.

Table 7.2.1 Principal Rehabilitation Features and New Constructed Haor Projects

No.	Sub-project Name	Location	Principal Features of Major Structures
i) Rehabilitation of existing haor projects			
1.	Dampara Water Management Scheme	Upazila : Purbodhola District: Netrakona	Resectioning of embankment = 200 m (full), 460 m (submergible) Replacement of gearbox = 4 nos. Replacement of rubber seal = 3 nos. Re-excavation of canal = 12 km (Kalihor Khal) Pipe cleaning = 3 locations Sluice gate (0.6 m x 0.6 m) = 23nos. Maintenance equipments = 1no.
2.	Kangsa River Scheme	Upazila : Sadar, Purbodhola District: Netrakona	Resectioning of embankment = 40 m (full) Fully replacement of gate with related mechanical equipments = 1 no. Replacement of gearbox = 10 nos. Replacement of rubber seal = 1 no. Maintenance equipments = 1 no.
3.	Singer Beel Scheme	Upazila : Barhatta District: Netrakona	Resectioning of embankment = 100 m (full),125 m (submergible) Replacement of gearbox = 2 nos. Re-excavation of canal = 2 km (1km+1km) Installation of sluice gate (1.5 m x 1.8 m) = 1 no. Pipe cleaning = 2 locations
4.	Baraikhali Khal Scheme	Upzila: Nandail, Hosenpur Kishoreganj Sadar District: Mymensingh, Nandail, Kishoreganj.	Resectioning of embankment = 10 m(full) Re-excavation of canal = 24.5 km Installation of flap gate (0.5 m x 0.5 m) = 2 nos. Pipe cleaning = 2 locations Maintenance equipments = 1 no.

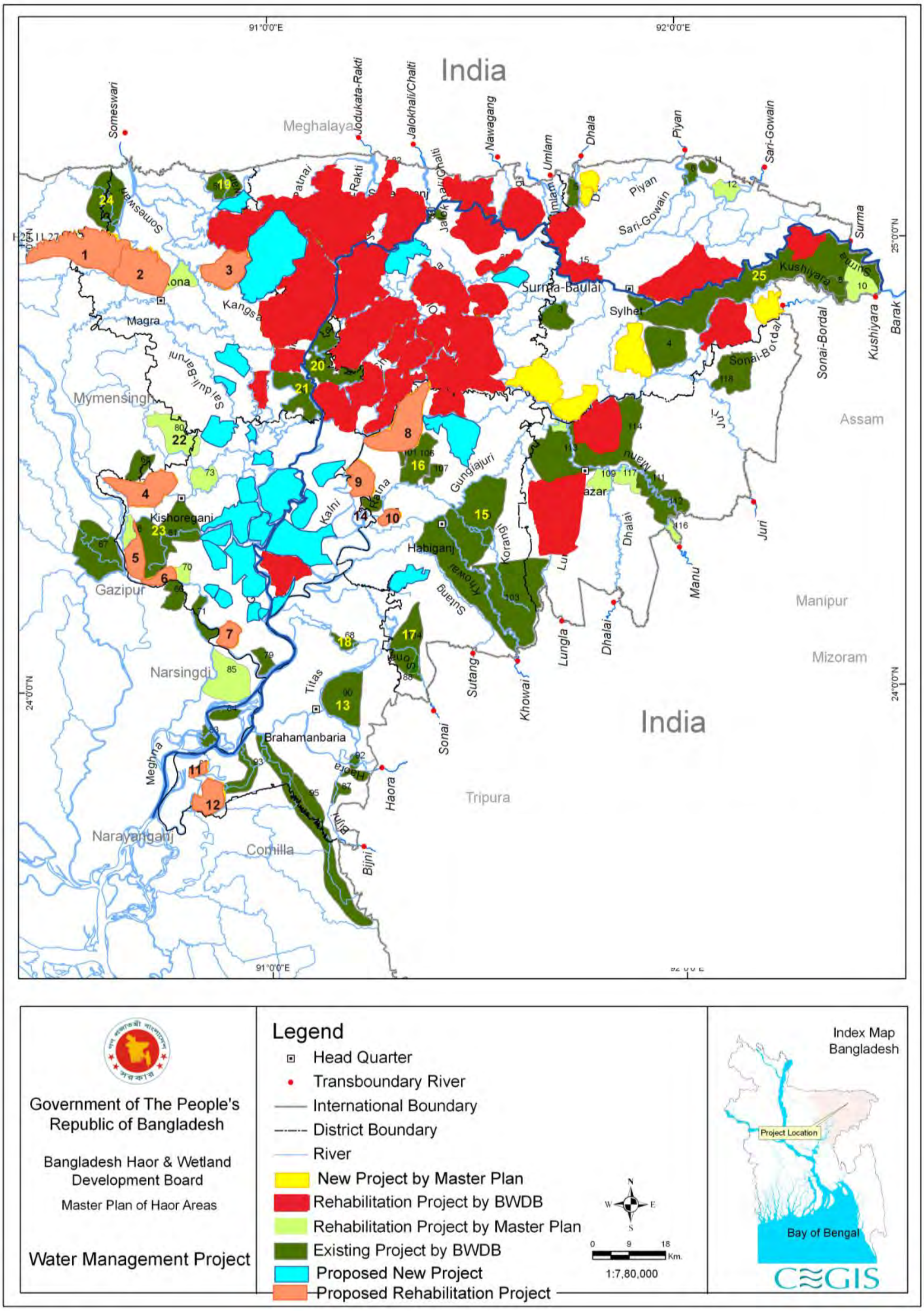
No.	Sub-project Name	Location	Principal Features of Major Structures
5.	Alalia-Bahadia Scheme	Upzila: Katiadi, Pakundia District: Kishoreganj	Re-excavation of canal = 8 km (5 km + 3 km)
6.	Modkhola Bhairagirchar Sub-project Scheme	Upzila: Pakundia, Katiadi District: Kishoreganj	Resectioning of embankment = 50 m (full)
7.	Ganakkhalli Sub-scheme	Upzila: Kuliarchar District: Kishoreganj	Fully replacement of gate (1.5 m x 1.8m) with mechanical equipments = 3 nos. Maintenance equipments = 1 no.
8.	Kairdhala Ratna Scheme	Upzila: Ajmiriganj, Baniachong District: Habiganj	Resectioning of embankment = 60 m (submergible) Replacement of gearbox = 5 nos. Replacement of rubber seal = 1 no. Maintenance equipments = 1 no.
9.	Bahira River Scheme	Upzila: Ajmiriganj, Baniachong District: Habiganj	Resectioning of embankment = 6,000m (submergible) Installation of gate (1.5 m x 1.8 m) with mechanical equipments = 4nos. Re-excavation of canal = 20 km Maintenance equipments = 1 no.
10.	Aralia Khal Scheme	Upzila: Baniachong District: Habiganj	Reinstallation of gearbox = 4 nos. Re-excavation of canal = 2.4 km Maintenance equipments = 1 no.
11.	Chandal Beel Scheme	Upzila: Bancharampur District: Brahmanbaria	Resectioning of embankment = 100 m (full) Fully replacement of gate with mechanical equipments = 2nos. Re-excavation of canal = 1.5 km Maintenance equipments = 1 no.
12.	Satdona Beel Scheme	Upzila: Bancharampur District: Brahmanbaria	Installation of stoplogs = 2 sets Fully replacement of gate with mechanical equipments = 2 nos. Maintenance equipments = 1 no.
13	Datta Khola and Adjoing Beel Scheme	Upazila: Sadar, Mojlishpur District: Brahmanbaria	Re-excavation of canal = 73.5 km (total canal length)
14	Cheghaia Khal Scheme	Upazila: Baniachong District: Habiganj	Embankment = 130 m Replacement of gearbox = 1 no. Re-excavation of canal = 4.5 km
15	Gangajuri FCD Sub-project	Upazila; Bahubol, Baniachong & Sadar District Habiganj	Embankment =600m (full) Replacement of gearbox = 19 nos. Replacement of hoist rod = 1 no. Re-excavation of canal = 4.5 km
16	Sukti River Embankment Project	Upazila; Ajmirigang, Baniachong District Habiganj	Repair works of submergible embankment are carried out by BWDB. Re-excavation of canal = 11.5 km
17	Madhapur Scheme	Upazila; Madhapur District Habiganj	Embankment = 1,260 m (full) Re-excavation of canal = 38 km
18	Akashi and Shapla Beel Scheme	Upazila; Nasirnagar, Sarail District: Brahmanbaria	Embankment = 150m (full) Re-excavation of canal = 6.5 km

No.	Sub-project Name	Location	Principal Features of Major Structures
19	Mohadao Nodi Embankment Scheme	Upazila; Kamlakanda District Netrakona	Embankment = 420 m (full) = 120 m (submergible)
20	Kaliajuri polder #02 Scheme	Upazila; Kaliajuri District Netrakona	Embankment = 810 m (submergible) Replacement of gearbox =19 nos.
21	Kaliakjuri Polder #04 Scheme	Upazila; Kaliajuri District Netrakona	Embankment = 630 m (submergible) Fully replacement of gate with mechanical equipments = 2 nos. Replacement of gearbox = 1 no.
22	Sukaijuri Bathai Sub-project	Upazila; Nandail, Tarail, Kendua District Mymensingh, Kishoreganj, Netrakona	Embankment = 70 m (full) Replacement of gearbox = 1 no. (This project was proposed in the M/P. However, it is mainly located in the Mymensingh District and was rejected from this study because Mymensingh District was excluded from the target area.)
23	Singua River Scheme	Upazila; Pakundia, Kishoreganj Sadar, Nikli District Kishoreganj,	Re-excavation of canal = 55 km
24	Someswari River Embankment Project	Upazila; Durgapur District Netrakona	Embankment = 1,970 m (full) Replacement of gearbox = 1no.
25	Surma River Scheme	Upazila: Beani Bazar , Dakshin Surma, Golapganj Sylhet Sadar Zakiganj District Sylhet	Full embankment = 60 km (It is assumed that 50% of embankment is damaged.) Dredging works shall be carried out together with rehabilitation works because the flow capacity becomes smaller due to riverbed aggradation. Maintenance dredging shall be carried out but the maintenance budget is limited. At present, the maintenance budget is not sufficient. The scheme was rejected from this Study because Sylhet District was excluded from the target area.
ii) Development of new haor projects			
26	Badla Haor Project	Upazila: Itna, Karimganj, Tarail Dstrict: Kishoreganj	Embankment = 10.8 km Re-excavation of canal = 2 km 2-vent regulator = 2 nos.
27.	Dharmapasha Rui Beel Project	Upazila: Dharmapasha, Kalmakanda, Barhatta, Mohanganj District: Sunamganj & Netrakona	Embankment = 57.1km Re-excavation of canal = 5 km 9-vent regulator = 3 nos. 8-vent regulator = 2 nos. 6-vent regulator = 1 no. 3-vent regulator = 1 no.
28.	Charigram Haor Project	Upazila: Mithamain, Austagram, Itna, Nikli District: Kishoreganj	Embankment = 25.7 km Re-excavation of canal = 3 km 4-vent regulator = 1no. 1-vent regulator = 1no.
29.	Bara Haor (Kamlakanda)	Upazila: Kamlakanda, Dharmapasha District: Netrakona	Embankment = 27.0 km Re-excavation of canal = 40 km 5-vent regulator = 1 no. 1-vent regulator = 1 no.
30.	Ayner Gupi Haor	Upazila: Austagram,	Embankment = 13.7 km 3-vent regulator = 1no.

No.	Sub-project Name	Location	Principal Features of Major Structures
		Bajitpur District: Kishoreganj	
31.	Bara Haor Sub Project (Austagram)	Upazila: Austagram, Mithamain, Nikli, Itna, Karimganj District: Kishoreganj	Embankment = 60.3 km Re-excavation of canal = 40 km 11-vent regulator = 2 nos. 4-vent regulator = 1no. 3-vent regulator = 1no.
32.	Boro Haor Project (Nikli)	Upazila: Karimganj, Katiadi, Kishoreganj Sadar, Nikli District: Kishoreganj	Embankment = 9.6 km Re-excavation of canal = 10 km 9-vent regulator = 2 nos. 3-vent regulator = 1 no.
33.	Chandpur Haor Project	Upazila: Katiadi, Nikli District: Kishoreganj	Embankment =2.1 km Re-excavation of canal = 5 km 4-vent regulator = 1no. 1-vent regulator = 1no.
34.	Dulapur Haor Project	Upazila: Bajitpur District: Kishoreganj	Embankment = 8.3 km Re-excavation of canal = 3 km 2-vent regulator = 1no.
35.	Golaimara Haor Project	Upazila: Bajitpur District: Kishoreganj	This project was rejected because the ground elevation is higher than 10-year probable pre-monsoon flood water level based on the spot elevation survey and hydraulic analysis results.
36.	Joyariya Haor Project	Upazila: Bajitpur, Kuriar Char District: Kishoreganj	This project was rejected because the ground elevation is higher than 10-year probable pre-monsoon flood water level based on the spot elevation survey and hydraulic analysis results.
37.	Korati Haor Project	Upazila: Kalimganj, Nikli District: Kishoreganj	Embankment = 40.4 km Re-excavation of canal = 4 km 4-vent regulator = 1 no. 1-vent regulator = 1 no.
38.	Kuniarbandh Haor Project	Upazila: Bajitpur, Kuliar Char District: Kishoreganj	Embankment = 8.3 km 1-vent regulator = 1 no.
39.	Naogaon Haor Project	Upazila: Itna, Karimganj, Mithamain, Nikli District: Kishoreganj	Embankment = 34.1 km Re-excavation of canal = 20 km 9-vent regulator = 2 nos. 8-vent regulator = 1 no. 4-vent regulator = 1 no.
40.	Noapara Haor Project	Upazila: Austagram, Karimganj, Nikli District: Kishoreganj	Embankment = 28.3 k m Re-excavation of canal = 7 km 3-vent regulator = 1no. 2-vent regulator = 1no. 1-vent regulator = 1no.
41.	Nunnir Haor Project	Upazila: Bajitpur, Kariadi, Nikli District: Kishoreganj	Embankment = 25.5 km Re-excavation of canal = 20 km 5-vent regulator = 1 no. 2-vent regulator = 2 nos.
42.	Sarishapur Haor Project	Upazila: Bajitpur District: Kishoreganj	Embankment= 7.1 km Re-excavation of canal = 5 km 1-vent regulator = 1 no.

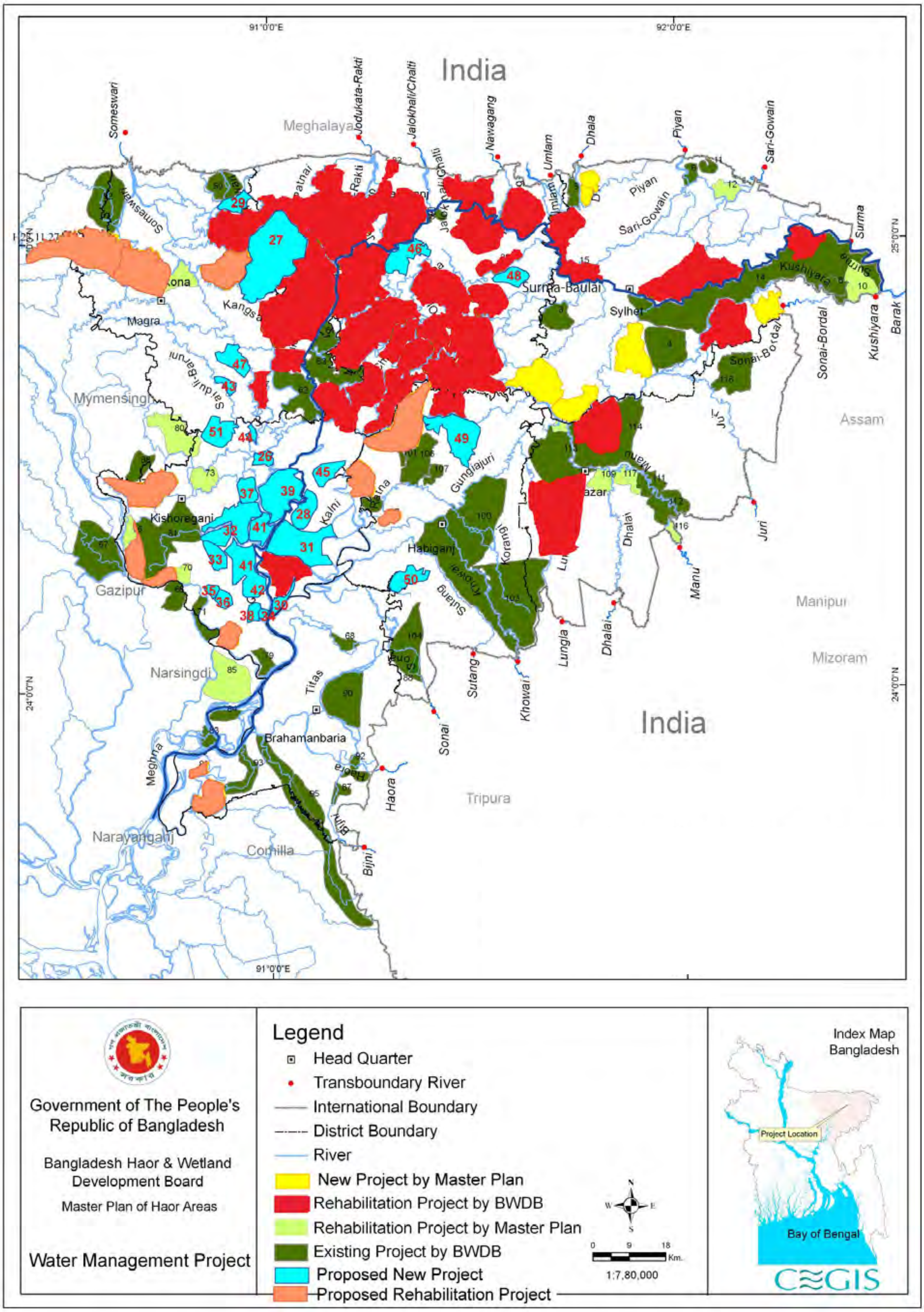
No.	Sub-project Name	Location	Principal Features of Major Structures
43.	Bansharir Haor Project	Upazila: Kendua, Madan District: Netrakona	Embankment =18.0 km 1-vent regulator = 2 nos.
44.	Chatal Haor Project	Upazila: Tarail, Itna, Madan District: Kishoreganj	Embankment = 5.7 km Re-excavation of canal = 11 km 1-vent regulator = 2 nos.
45.	Dakhshiner Haor Project	Upazila: Ajmirganj, Itna, Mithamain District: Kishoreganj	Embankment = 18.3 km Re-excavation of canal = 10 km 6-vent regulator = 1 no. 3-vent regulator = 1 no.
46.	Dhakua Haor Project	Upazila: Dakshin, Sunamganj, Jamalganj, Sunamganj Sadar District: Sunamganj	Embankment = 36.5 km Re-excavation of canal = 30 km 5-vent regulator = 1 no. 3-vent regulator = 1 no. 1-vent regulator = 1 no.
47.	Ganesh Haor Project	Upazila: Madan, Atpara District: Netrakona	Embankment = 22.5 km Re-excavation of canal = 3 km 3-vent regulator = 1 no. 2-vent regulator = 1 no.
48.	Jaliar Haor Project	Upazila: Chhatak District: Sunamganj	Embankment = 6.8 km Re-excavation of canal = 8 km 2-vent regulator = 1 no. 2-vent regulator = 1 no.
49.	Mokhar Haor Project	Upazila: Habiganj Sadar, Baniachanpur, Ajmirganj District: Habiganj	Embankment = 68.8 km Re-excavation of canal = 110 km 5-vent regulator = 1 no. 4-vent regulator = 2 nos. 3-vent regulator = 2 nos.
50.	Shelnir Haor Project	Upazila: Nasirnagar District: Habiganj & Brahmanbaria	Embankment = 30.1 km Re-excavation of canal = 2 km 1-vent regulator = 3 nos.
51.	Suniar Haor Project	Upazila: Tarail District: Kishoreganj & Netrakona	Embankment =16.2 km Re-excavation of canal = 25 km 4-vent regulator = 1 no. 1-vent regulator = 1 no.

Source: JICA Study Team



Source: JICA Study Team

Figure 7.2.2 Location Map of Proposed Haor Rehabilitation Projects



Source: JICA Study Team

Figure 7.2.3 Location Map of Proposed New Haor Projects

(2) Selection of Facilities

Fifty one projects have been proposed and divided into the rehabilitation and new projects. The proposed projects were selected from each group. Two rehabilitation projects and two new projects were rejected due to the reasons below,

The Sukajuri Bathai Sub-project was rejected because the main target area in this project is located in the Mymensingh District. In this case, the Mymensingh Office in BWDB would have handled this project if the district is located in the project area. The Upper Surma River Scheme was also rejected because the dredging work shall be carried out at the same time of the rehabilitation work. In this case, maintenance dredging is important but difficult to carry out due to the budget limitation.

It is confirmed that the ground elevation along the alignment of the proposed submergible embankment in the Golaimara Haor Project and the Joyariya Haor Project is higher than the design high water level of the submergible embankment as was determined in the spot elevation survey. Therefore, these projects do not require the construction of the submergible embankment.

The number of target projects became 47 projects. The prioritization of each group is determined from the economic viewpoint of the projects.

The following assumptions are applied to evaluate the ranking of each project:

- The crop yield (ton/ha) of the boro rice in the project area is assumed to be the same.
- The economic value of the boro rice in the project area is assumed to be the same.
- The beneficiary area is only cultivated for the boro rice.
- There is no example of the estimation method for the rice damaged cost using the relation between the flood depth and the period of inundation in Bangladesh. The damage ratio for each excess probability estimated in "Kalni-Kushyara River Improvement Project" is adopted because this project is located in the target area. **Table 7.2.2** shows damaged ratio of paddy.

Table7.2.2 Damage Ratio of Paddy

Excess Probability	Damaged Ratio (%)
2-year	6.4
5-year	26.4
10-year	36.1
20-year	55.5*

Note: * Damage ratio is determined by extrapolation, Detailed explanation of damage ration refers to Annex 7.3
Source：Kalni-Kushyara River Improvement Project

The damage cost is estimated from the following formula:

(Damage cost (BDT)) = (Unit price of boro rice (BDT/ton)) x (Crop yield (ton/ha)) x (Flooded area (ha)) x (Damage ratio (%))

The estimation of project ranking is a relative evaluation. Therefore, the following formula can be applied to evaluate the project ranking:

(Annualized damage of boro rice) =(Flooded area (ha)) x (Damage ratio (%))

The project ranking from an economic viewpoint is evaluated using the following formula:

(Economic efficiency) =(Annualized damage of boro rice) / (Direct construction cost)

- The crest of the existing submergible embankment is damaged due to erosion. The overtopping through the submergible embankment has occurred. Even the water level is now lower than the 10-year probable pre-monsoon flood water level. Many locations of the existing submergible embankment are damaged because of the BWDB field office's budget limitation. Therefore, it is assumed that the flood damage has occurred over a 2-year probable flood.
- The remaining existing haor projects that are not selected as rehabilitation projects in the M/P and by BWDB are also evaluated for economic efficiency. If the high priority projects are included in the remaining projects, they are also selected for rehabilitation.

Table 7.2.3 shows the prioritization result for each group.

1) Proposed Rehabilitation Works of Existing Haor Projects

Twenty three existing haor projects are selected. The proposed projects in M/P are 12 projects and the remaining projects that are not selected by BWDB are 11 projects.

Twelve projects are proposed because these projects are authorized by GOB. Also, three projects that are the Gangajuri FCD Project, Kaliajuri Polder #02 Scheme, and Kaliajuri Polder #04, are proposed from the remaining projects because they are high priority projects.

Therefore, a total of fifteen rehabilitation projects are proposed in this Study.

2) Proposed New Projects

Twenty four new haor projects are proposed because these projects are also authorized by GOB. In this Study, the prioritization of the new projects is evaluated.

Table 7.2.3 Project Prioritization for Each Group

(1) Rehabilitation Projects

No.	Name of Project	Annualized Benfit B	Cost (mil. BDT) C	B'/C	Rank	Remark
1	Dampara Water Management Scheme	1,167	32.0	36.5	9	Proposed Project in M/P
2	Kangsa River Scheme	1,149	4.6	248.2	3	Proposed Project in M/P
3	Singer Beel Scheme	360	7.9	45.8	7	Proposed Project in M/P
4	Baraikhali Khal Scheme	768	6.2	123.8	5	Proposed Project in M/P
5	Alalia-Bahadia Scheme	135	17.0	7.9	15	Proposed Project in M/P
6	Modkhola Bhairagirchar sub-project Scheme	167	16.3	10.2	13	Proposed Project in M/P
7	Ganakkhalli Sub-scheme	154	0.3	494.1	2	Proposed Project in M/P
8	Kairdhala Ratna Scheme	758	1.1	677.8	1	Proposed Project in M/P
9	Bahira River Scheme	273	113.6	2.4	23	Proposed Project in M/P
10	Aralia Khal Scheme	100	5.5	18.3	11	Proposed Project in M/P
11	Chandal Beel Scheme	104	25.8	4.0	22	Proposed Project in M/P
12	Satdona Beel Scheme	188	34.7	5.4	21	Proposed Project in M/P
13	Datta Khola and Adjoing Beel Scheme	1,044	154.4	6.8	17	
14	Cheghaia Khal scheme	82	14.9	5.5	20	
15	Gangajuri FCD sub-project	1,368	36.2	37.8	8	High ranking and high efficiency project
16	Sukti River Embankment Project	513	24.2	21.2	10	
17	Madhapur scheme	737	131.5	5.6	19	
18	Akashi and Shapla Beel scheme	154	19.8	7.8	16	
19	Mohadao Nodi Embankment scheme	158	17.7	8.9	14	
20	Kaliajuri polder #02 scheme	411	5.0	81.5	6	High ranking and high efficiency project
21	Kaliakjuri polder #04 scheme	399	2.7	148.2	4	High ranking and high efficiency project
22	Sukaijuri Bathai sub-project					Out of the project area
23	Singua River scheme(Drainage and Irrigation)	674	115.5	5.8	18	
24	Someswari River Embankment Project	851	81.0	10.5	12	
25	Upper Surma River Scheme					The dredging work shall be carried out at the same time of rehabilitation work. The maintenance dredging will be difficult due to budget limitation.

(2) New Projects

No.	Name of Project	Annualized Benfit B	Cost (mil. BDT) C	B'/C	Rank	Remark
26	Badla Haor Project	85	135.1	0.6	9	
27	Dharmapasha Rui Beel Project	1,286	1,119.5	1.1	5	
28	Charigram Haor Project	239	329.5	0.7	8	
29	Bara Haor (Kamlakanda)	164	1,001.6	0.2	17	
30	Ayner Gupi Haor	3	328.6	0.0	24	
31	Bara Haor Sub Project (Austagram)	755	1,025.7	0.7	7	
32	Boro Haor Project (Nikli)	479	236.9	2.0	1	
33	Chandpur Haor Project	70	58.5	1.2	4	
34	Dulapur Haor Project	29	197.9	0.1	18	
35	Korati Haor Project	123	962.4	0.1	19	
36	Kuniarbandh Haor Project	7	217.0	0.0	22	
37	Naogaon Haor Project	667	380.3	1.8	2	
38	Noapara Haor Project	141	565.7	0.3	16	
39	Nunnir Haor Project	207	349.8	0.6	11	
40	Sarishapur Haor Project	10	101.1	0.1	21	
41	Bansharir Haor Project	27	237.7	0.1	20	
42	Chatal Haor Project	43	111.1	0.4	12	
43	Dakhshiner Haor Project	180	288.6	0.6	10	
44	Dhakua Haor Project	228	620.3	0.4	14	
45	Ganesh Haor Project	117	312.0	0.4	13	
46	Jaliar Haor Project	114	95.4	1.2	3	
47	Mokhar Haor Project	451	1,444.2	0.3	15	
48	Shelnir Haor Project	10	323.9	0.0	23	
49	Suniar Haor Project	118	148.6	0.8	6	

Source: JICA Study Team

(3) Impact by New Haor Projects

1) Impact Study to Tanguar Haor after construction of new projects

Tanguar Haor that is registered in Ramsar Convention, is located at northern area of Sunamganj near the border of Indian territory. The western hill forms the watershed and the submergible embankment is constructed at southern area. The present condition of flow in and out the Tanguar Haor is explained below (reference **Figure 7.2.4**);

(i) Flow in the Tanguar Haor

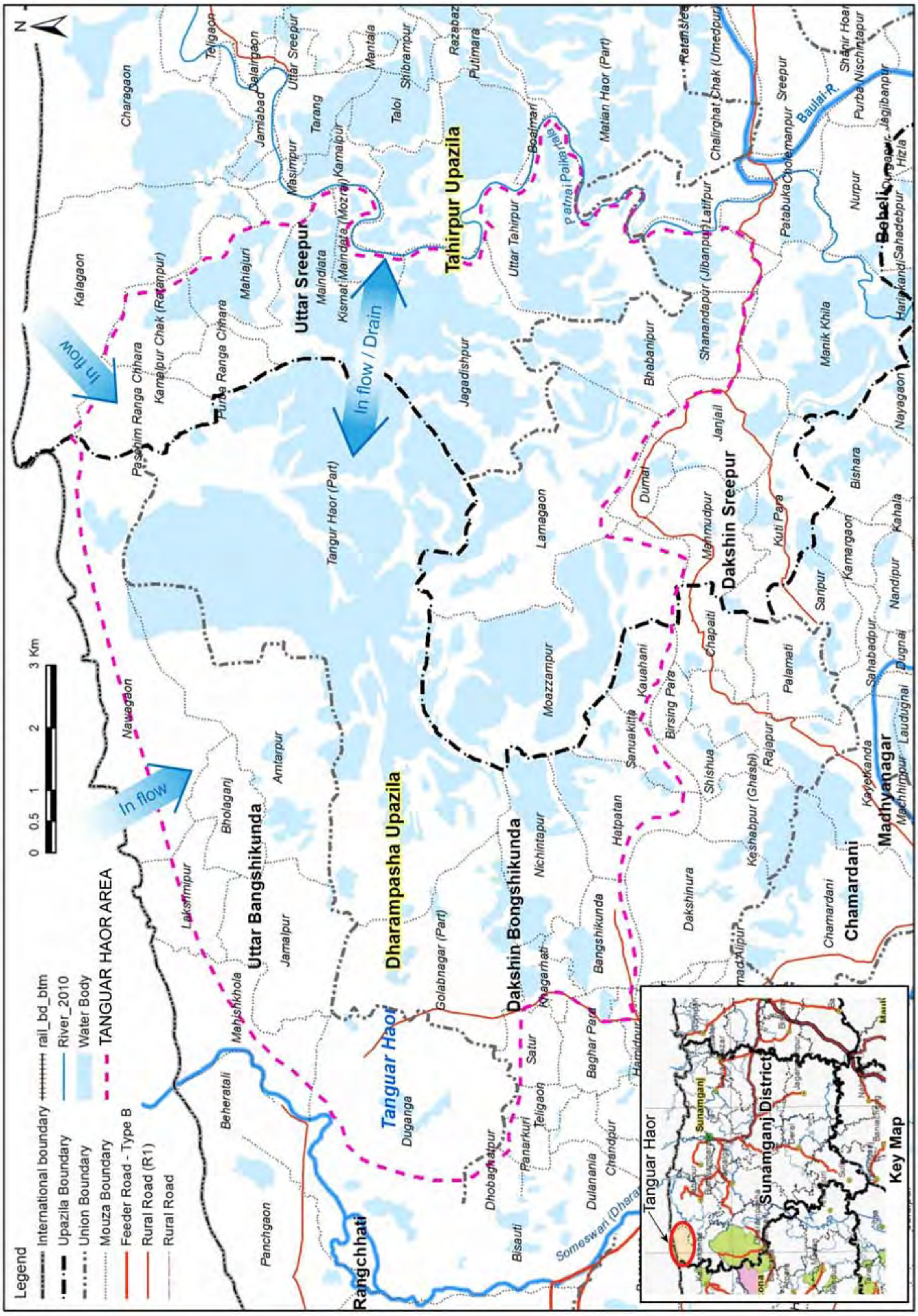
The water enters to the Tanguar Haor from the rivers through the northern hilly area at Indian border, the eastern adjoining river and the back water from the Baulai River.

- Inflow from the rivers through the hilly area at Uttar Bangshikunda Union and Uttar Sreepur Union,
- Inflow from Patnai Paikartala River that adjoin the east side of the Tanguar Haor, through the eroded and/or breaching portion of the submergible embankment and the road, and
- Back water from Baulai River through Patnai Paikartala River during pre-monsoon and monsoon period.

(ii) Outflow from the Tanguar Haor

The store water in the Tanguar Haor drains to Patnai Paikartala River thorough some small tributaries located in Uttar Sreepur Union during pre-monsoon and post-monsoon seasons.

The Pre-monsoon Flood Protection and Drainage Improvement Project is planned to consider no negative impact from hydraulic point of view near the confluence of Patnai Paikartala River and Baulai River. Therefore, it can be considered that the negative impact in the Tanguar Haor from the hydraulic viewpoint isn’t occurred after completion of the Project.



Source: JICA Study Team

Figure 7.2.4 Water Inflow and Drainage of Tanguar Haor

2) Impact to Dhaka

In the beginning of this Study, the dredging work was also considered as one component of the JICA cooperation project. The necessity of the dredging work was confirmed but it was identified as an inappropriate component of the JICA coopetation project. Therefore, the dredging work was rejected.

In this case, the outflow from the haor area has the same condition and its impact to Dhaka is controlled by the water level condition of the Padoma River. Therefore, there is no negative impact that will be caused by the Project.

3) Impact of the New projects on the Surroundings of Itna Town

New projects are planned at the downstream of Itna Town, but the area is inundated and is a flood plain area. If the submergible embankments of the new projects are constructed, the flood water flows in the river portion and the water level becomes higher than the present situation. The freeboard of existing haor projects located at the upstream area will be reduced. The negative impact on the upstream area was confirmed using HEC-RAS (refer to **Annex 7-1**). As a result of the hydraulic confirmation, the Charigram Haor Project causes water to rise in the upstream area (existing haor project near Itna Town: 10cm rise in water level). Therefore, countermeasures are required, if GOB wants to realize the Charigram Haor Project. The following measures will be considered:

a) Dredging works

b) Elevating the existing submergible embankment, and

c) Combination of a) and b)

It is expected that both flow direction between Surma-Baulai River and Kalni-Kushiyara River occurr during pre-monsoon and monsoon season. The Bara Haor Sub-project will hamper the water flow of both rivers. Therefore, countermeasures are required.

Two projects are rejected from the new haor projects. If GOB will carry out these projects, the countermeasure against the hydraulic impact shall be executed and the countermeasure will be decided through detailed model simulation and/or test.

(4) Proposed Project

As a result of the above study, 37 projects are proposed. These consist of 15 rehabilitation projects and 22 new projects. **Table 7.2.4** shows project list while **Figure 7.2.5** shows the location map of the proposed projects.

Table 7.2.4 Proposed Projects

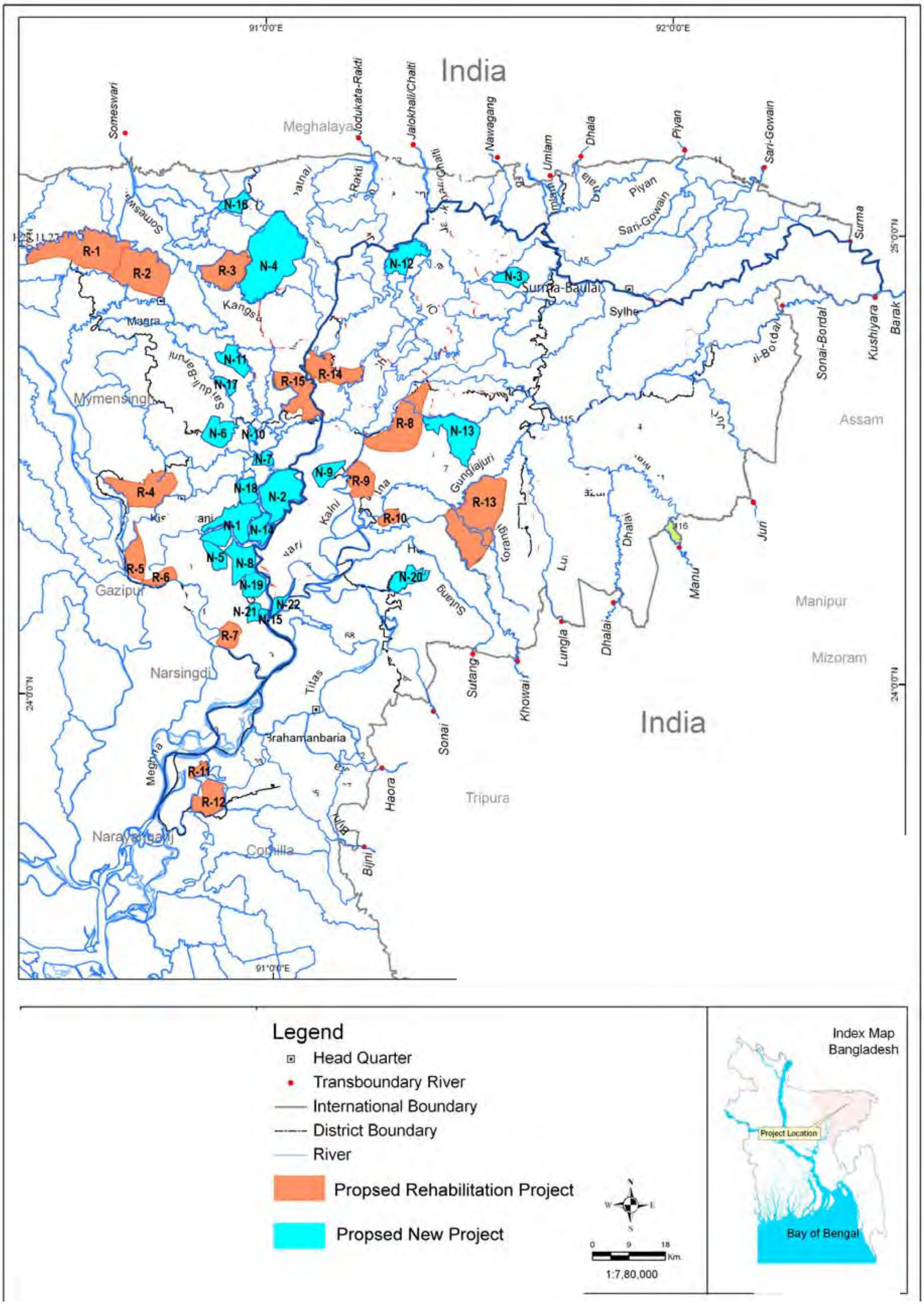
(1) Rehabilitation Projects

No.	Name of Project	Annualized Benfit B	Cost (mil. BDT) C	B'/C	Rank	Remark
R-1	Dampara Water Management Scheme	1,166.5	32.0	36.496	9	Proposed Project in M/P
R-2	Kangsa River Scheme	1,148.6	4.6	248.163	3	Proposed Project in M/P
R-3	Singer Beel Scheme	359.6	7.9	45.793	7	Proposed Project in M/P
R-4	Baraikhali Khal Scheme	767.8	6.2	123.842	5	Proposed Project in M/P
R-5	Alalia-Bahadia Scheme	134.6	17.0	7.912	12	Proposed Project in M/P
R-6	Modkhola Bhairagirchar sub-project Scheme	166.5	16.3	10.231	11	Proposed Project in M/P
R-7	Ganakkhalli Sub-scheme	154.1	0.3	494.123	2	Proposed Project in M/P
R-8	Kairdhala Ratna Scheme	757.9	1.1	677.758	1	Proposed Project in M/P
R-9	Bahira River Scheme	273.3	113.6	2.405	15	Proposed Project in M/P
R-10	Aralia Khal Scheme	99.8	5.5	18.295	10	Proposed Project in M/P
R-11	Chandal Beel Scheme	104.2	25.8	4.032	14	Proposed Project in M/P
R-12	Satdona Beel Scheme	187.6	34.7	5.413	13	Proposed Project in M/P
R-13	Gangajuri FCD sub-project	1,368.4	36.2	37.840	8	High ranking and high efficiency project
R-14	Kaliajuri polder #02 scheme	410.6	5.0	81.515	6	High ranking and high efficiency project
R-15	Kaliakjuri polder #04 scheme	399.3	2.7	148.241	4	High ranking and high efficiency project

(2) New Projects

No.	Name of Project	Annualized Benfit B'	Cost (mil. BDT) C	B'/C	Rank	Remark
N-1	Boro Haor Project (Nikli)	479	236.9	2.022	1	
N-2	Naogaon Haor Project	667	380.3	1.754	2	
N-3	Jaliar Haor Project	114	95.4	1.198	3	
N-4	Dharmapasha Rui Beel Project	1,286	1,119.5	1.148	5	
N-5	Chandpur Haor Project	70	58	1.191	4	
N-6	Suniar Haor Project	118	149	0.796	6	
N-7	Badla Haor Project	85	135	0.629	7	
N-8	Nunnir Haor Project	207	350	0.592	9	
N-9	Dakhshiner Haor Project	180	289	0.623	8	
N-10	Chatal Haor Project	43	111	0.387	10	
N-11	Ganesh Haor Project	117	312	0.375	11	
N-12	Dhakua Haor Project	228	620	0.367	12	
N-13	Mokhar Haor Project	451	1,444	0.313	13	
N-14	Noapara Haor Project	141	566	0.250	14	
N-15	Dulapur Haor Project	29	198	0.145	16	
N-16	Bara Haor (Kamlakanda)	164	1,002	0.164	15	
N-17	Bansharir Haor Project	27	238	0.115	18	
N-18	Korati Haor Project	123	962	0.128	17	
N-19	Sarishapur Haor Project	10	101	0.103	19	
N-20	Shelnir Haor Project	10	324	0.032	21	
N-21	Kuniarbandh Haor Project	7	217	0.033	20	
N-22	Ayner Gupi Haor	3	329	0.009	22	

Source: JICA Study Team



Source: JICA Study Team

Figure7.2.5 Location Map of Proposed Projects

7.2.3 River Dredging Project

The inundated water in the paddy field is drained in the direction of the river through channels/canals and regulators from the post-monsoon to the dry season due to boro rice planting. It is important to drain the inundated water quickly.

An adequate flow capacity is required to prevent the flood damage from small- or medium-scale floods in the flood plain area.

In addition, the minimum water depth for the navigation purpose shall be kept because the Suruma-Baulai River is important one for the navigation purpose.

Five stretches of dredging works were proposed in the M/P as shown in **Figure 5.4.4**.

1) Downstream Stretch from Dharmapasha in the Surma-Baulai River

The flow capacity at the downstream of Dharmapasaha is small while the lowest riverbed elevation at the upstream and downstream of Itna is high. It is highly possible to have negative impacts on the navigation aspect and flow capacity. However, the dredging works are not so efficient in improving the flow capacity of the river due to back water impact.

It is necessary to carry out the dredging works for navigation purposes. The improvement of the flow capacity is a secondary effect.

The required dredging volume in this stretch as estimated in the M/P, is shown in **Table 7.2.5**.

Table 7.2.5 Dredging Locations and Dredging Volumes

District	Upzila	Distance (km)	Width (m)	Depth (m)	Volume(10^3m^3)
i) Suruma-Baulai River (Downstream from Dharampasha)					
Sunamganj	Dharampasha	4.3	7	1.00	30.0
Netrakona	Khaliajuri	18.7	50	2.80	2,618.0
		4.4	6	2.58	68.0
		4.4	33	0.50	72.6
Kishoreganj	Itna	4.7	108	0.40	203.0
		8.5	101	0.21	176.0
	Mithamain	6.0	124	1.06	784.9
		4.5	168	2.35	1,776.6
		7.0	138	0.33	314.0
Total		62.5			6,043.1
ii) Katkhal Channel					
Kishoreganj	Mithamain	12.8	123	4.56	3,827.9

Source: Haor M/P

2) Katkhal Channel

The Katkhal Channel is important because connects the Surma-Baulai River and Kalni-Kushiyara River. However, this channel has also experienced bed aggradation due to sedimentation. It is required to carry out dredging on the channel for navigation and drainage purposes. **Table 7.2.5** shows the required dredging volume estimated in the M/P.

3) Stretch between Chatak and Sunamganj in the Surma-Baulai River

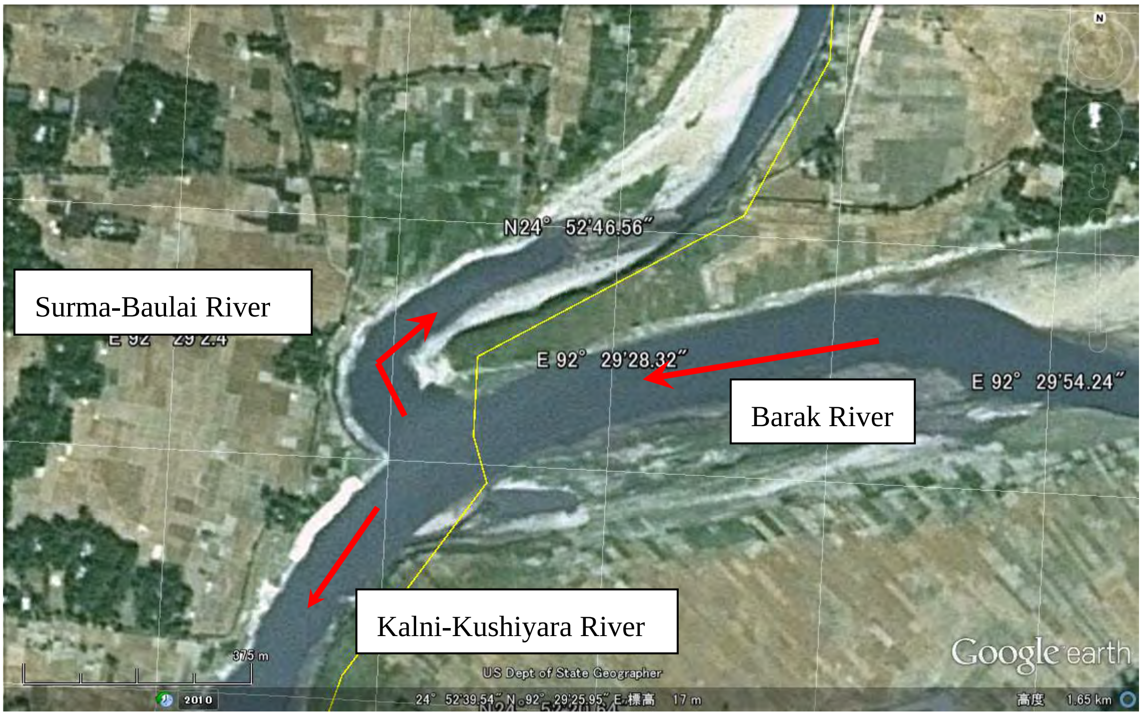
A part of the stretch between Chatak and Sunamganj has suffered from riverbed aggradation, and its flow capacity becomes small. The haor projects are located on the right bank between Chatak and Sunamganj with one project located at left side of the

Surma-Baulai River. The rehabilitation works of these haor projects are planned to be carried out by BWDB. During the monsoon season, the left bank area is the first to be inundated due to no flood control facilities. After that, right bank area is in inundation. The left bank area then becomes a natural retarding basin for the Sunamganj Town. The natural retarding basin located upstream of the Sunamganj is utilized as much as possible because the Sunamganj Town area is protected from inundation. However, riverbed aggradation has occurred between the Chatak and Sunamganj towns. If riverbed aggradation proceeds, the inundation in the natural retarding basin will start in the early stage of a flood event. The inundation risk in the Sunamganj becomes high.

Therefore, dredging is a useful measure in this stretch to keep or increase the flow capacity.

4) Stretch between Kanalghat and Border

The Barak River divides the Surma-Baulai River and the Kalini-Kushiyra River near the border as shown in **Figure 7.2.6**.



Source: Google earth

Figure 7.2.6 Location Map of Barak River, Surma-Baulai River and Kalni-Kushiyara River

The run-off volume of the Surma-Baulai River is smaller than the Kalni-Kushiyara River. On the other hand, GOB wants to increase the run-off volume in the Surma-Baulai River. However, it is impossible to change the alignment of the three rivers because the border line is located at the center of the rivers. Therefore, the M/P proposed to change the riverbed profile of the Surma-Baulai River.

At present, there is drainage problem between the Surma-Baulai River and the Kalni-Kushiyara River. To prevent inundation, it is required to increase the drainage capacity and flow capacity in the Surma-Baulai and the Kalni-Kushiyara Rivers.

Dredging is very useful to increase the flow capacity but it is not effective to increase run-off volume in the Surma-Baulai River.

5) Jadukata River

The Jadukata River has a large catchment area in the Indian territory. Large volumes of sediments are transported through this river. Because of sediment transportation, there is no water at the confluence of the Jadukata River and the Surma-Baulai River during the dry season. The water flow of the Jadukata River at the upstream has changed to the west direction and has entered the Surma-Baulai River. It is required to carry out dredging works for the maintenance of the river functions.

Based on the explanation of the necessity for dredging in the above five river stretches, the first three river stretches were finally selected due to the following reasons:

- The expectations of the dredging effect in Kanalgaht to the border in the Surma-Baulai River increase the run-off volume. However, the efficiency is very small.
- Frequent maintenance dredging will be required in the Jadukata River. It will be difficult to prepare the budget for maintenance dredging.

The following stretches are considered to carry out the dredging works.

1) Downstream stretch from Dharmapasha
2) Katkhal Channel
3) Stretch between Chatak and Sunamganj

<u>Possibility of JICA Cooperation Project</u>

The necessity of the dredging works is confirmed for the three river stretches. However, it is difficult to propose a JICA Cooperation Project due to the following reason.

- The budget for maintenance dredging has to be prepared by GOB. The budget preparation will be difficult considering the present maintenance situation. However, it is difficult to propose these dredging works for possible projects for JICA's cooperation due to the lack of the budget for maintenance dredging.

CHAPTER 8 PLAN AND DESIGN OF STRUCTURES FOR FLOOD MEASURES

8.1 Assessment of Present Situation and Appropriateness of Existing Structural Measures

8.1.1 Structural Measures during Pre-monsoon Season

(1) Present Situation of Existing Structures

The structural measures of flood control were not applied in the deep haor area during the monsoon season. The submergible embankment was constructed to protect against pre-monsoon floods. Channel/canal and regulators were also constructed for drainage improvement. The structural measures are being carried out in the deep haor area.

Submergible Embankment

At present, the submergible embankment does not function well due to partial damage by flood overtopping and artificial cutting.

P-8-1

Bashila River Sub-project（Total length of submergible embankment=15km The crest elevation becomes lower than the design crest elevation due to the overtopping.）

P-8-2

Singer Beel Project (Farmers demolished some parts of the submergible embankment to install a connection pipe between the river side and land side. However, they did not fill the embankment material up to the crest elevation of the submergible embankment.)

P-8-3

Chegaia Khal Scheme (The submergible embankment is cut for boat transportation by the people. This photograph shows the rehabilitation works at the artificial cutting location.)

P-8-4

Singer Beel Scheme (The farmers cut the submergible embankment to collect irrigation water.)

Note: Photograph location is shown in Annex-4-4.

Channel/Canal

Fertile soil is transported from the upstream during the monsoon season where it is deposited in the deep haor area. Erosion of channel/canal slope has occurred in which the eroded material is deposited in the channel/canal. Thus, the channel/canal is silted up by the fertile soil and eroded material. The flow capacity for drainage and the storage volume for water supply in the channel/canal are decreased.

P-8-5

Boraikali khal Sub-project (Sedimentation in the channel occurs every year. The drainage capacity and storage volume are decreased.)

P-8-6

Dampara Water Management Project (Sedimentation at the entrance of the Kalihor Khal occurrs every year. The drainage capacity and storage volume are decreased.)

Note: Photograph location is shown in Annex-4-4.

Regulator

The regulator was constructed near the confluence of the channel/canal and river. At present, about 50% of regulators have malfunctioned. Problems in drainage, water storage, and prevention of river water during flash flood have been encountered.

P-8-7

Dampara Water Management Project (This regulator has five gates. The gear boxes were damaged and removed. However, they have not been repaired yet. The gates are not operated.)

P-8-8

Khaliajuri-04 Project (The hoist deck, gear box, spindle, and guide wall concretes are damaged. The gate is not able to operate.)

Note: Photograph location is shown in Annex-4-4.

The flood control facilities in Bangladesh have an appropriate concept from the viewpoints of planning and design. However, following problems are found out:

- Operation and maintenance problem after completion of the structure,

- Low public morale, such as theft of gear box and artificial cutting of the submergible embankment,
- Lack of discussion among the stakeholders.

Causeway

The gate of regulator is manually opened to control river water levels and landside water levels before the start of the monsoon season. At present, the causeways are constructed in Kaliajuri Polder-4 to check ease of O&M.

P-8-9

P-8-10

Note: Photograph location is shown in Annex-4-4.

In addition, the causeway construction in the existing haor project is planned by BWDB as shown in **Table 8.1.1**.

Table 8.1.1 Planned Causeway in Haor Projects

No.	Name of Haor Project	Quantity (no.)	Total Cost (Lakh Tk)
1	Karchar Haor	6	325.74
2	Angurali Haor	2	108.58
3	Shanir Haor	1	54.29
4	Pagner Haor	5	271.45
5	Kalikota Haor	4	217.16
6	Udgal Beel	1	54.29
7	Naluar Haor	1	54.29
8	Chapitar Haor	1	54.29
9	Jamkhola Haor	1	54.29
10	Pathaechauli Haor	5	271.45
11	Shafique Haor	1	54.29
12	Nawtana Haor	2	108.58
13	Balali-Padmasri sub-project	1	54.29
14	Dewghar Haor	1	54.29
15	Humaipur Haor	2	108.58
16	Makalkandi Haor	1	54.29
	Total	35	1,900.00

Note: Unit price is BDT 54.29 *lakh* per one unit.
Source: BWDB

Local flood is drained through a causeway during the post-monsoon season. After the completion of the drainage in the landside area, the open space in the causeway will be closed with embankment material. Its embankment then becomes a part of the submergible embankment. In the beginning of the monsoon season, the embankment was taken out by the people. Then, the water levels in the river side and land side are kept at the same elevation and the overtopping from the crest of the submergible embankment is avoided.

If the final operation of the causeway shows good results, the causeway can be planned for flood control measures. However, the causeway is not proposed in this Study because BWDB has not obtain the result of effectiveness of the causeway at this stage.

(2) Evaluation of Existing Facilities

The evaluation of existing facilities is carried out from planning, design, construction and operation and maintenance points of view.

1) Planning

The submergible embankment was arranged against a 10-year probable pre-monsoon flood. The channel/canal and regulator were arranged to drain the landside water of the submergible embankment and to store water in the channel/canal. The planning concept is acceptable for the deep haor area.

However, there is no flood control plan from the upstream to the downstream of the river. It is necessary to prepare a plan in the Surma-Baulai River. The specification of each haor project in the deep haor area shall be decided considering the Surma-Baulalai River Management Plan.

2) Design

A standard design guideline is available. The flood protection level of the submergible embankment, grain size distribution, and stability analysis method of the embankment are included in the standard design guideline. The design guideline has been prepared to study by the BWDB’s senior engineers and the experts. However, it shall be improved regarding to the degree of compaction. The grain size of embankment material and the rammer to be used for the compaction are explained in the drawing, but the degree of compaction is not mentioned in the guideline and drawing.

The grain size distribution is decided during the design stage. The required materials for construction are not available at many sites. Material on-site is used for the embankment. It is necessary to carry out adequate material survey before design of the submergible embankment. The design circle in BWDB carries out the design works of the rehabilitation project, but the available embankment material at the site was not surveyed.

Therefore, the design modification will be carried out during the construction stage.

It is recommended material survey is carried out and the slope of embankment and the practicable grain size distribution shall be decided based on the material survey result.

3) Construction

Repair works for the embankment as shown in photograph of embankment in the Chegaia Khal Scheme, are carried out by BWDB. However, the labor collects the embankment material near the site and it is only put on the existing embankment. And there is no compaction of the embankment material. The deterioration of strength of the loose compacted embankment material under the submerged condition is faster than that of the good compacted material (refer to Section 8.1.3).

The design drawings indicate grain size distribution of the embankment material. However, the material from the design drawings were not followed at the site (it is difficult to collect the blend material.). The structures are not followed instruction of design stage, such as the grain size distribution, the water contents, and the compaction criteria, etc. Therefore, the strength of the structures may be weaker than the design stage.

Many haor projects have a problem of access to the project sites by the construction equipment because the construction budget is limited and the road network in the deep haor area is not developed.

It is recommended to carry out the control of water contents and the compaction, to execute mechanized construction. And the character of the embankment material collected through the mechanized construction has to be backed to the design modification. Then, it is possible to apply the embankment shape using the locally available material.

4) Operation and Maintenance

Regarding to O&M, lack of O&M budget is a serious problem in BWDB field offices. The LGED has applied a way where the constructed facilities are transferred to the stakeholders. The stakeholders then carry out O&M. The BWDB head office shall consider how to carry out O&M. In the facility survey, the staffs of BWDB site offices explained the difficulty of O&M activities because the O&M budget is only 10% to 20% of the initial budget requested to BWDB head office. Then, many facilities are not maintained and do not function.

At present, the O&M of the river facilities is not suitable. It is necessary to study how to improve these O&M activities.

For example, the approach in terms of the material and type of structure is studied, to minimize the life cycle cost. The O&M budget collection system is also studied which includes the collection of O&M budget cost from the beneficiaries.

It is understood that the O&M method was studied in preparing the “Preparatory Survey on Upper Meghna River Basin Watershed Management Improvement Project”.

If the O&M system is not improved, the same problems regarding O&M may occur for the rehabilitation projects and new projects after several years.

8.1.2 Structural Measures during the Monsoon Season

(1) Present Situation of Existing Structures

The existing haor projects are constructed not only in the deep haor area but also the flood plain area. Structural measures are composed of full embankment, submergible embankment, channel/canal, and regulators.

Full Embankment

The problems of the full embankment are: 1) erosion of embankment, 2) lack of extra embankment during the construction stage, and 3) artificial cut.

P-8-11

Singer Beel Scheme (Gully erosion)

P-8-12

Singer Beel Scheme (Artificial cut)

P-8-13

Mohadao Nodi Scheme (Bank erosion)

P-8-14

Madhabpur Scheme (Bank erosion)

Note: Photograph location is shown in Annex-4-4.

The channel/canal and regulators have the same conditions as in the deep haor area.

(2) Evaluation of Existing Facilities

1) Planning

The structural measures are not applicable in the deep haor area from the hydraulic, environmental, and social viewpoints ("life with flood").

In the flood plain, the construction of a full embankment is planned to cultivate two cropping. On the other hand, the area sandwiched between the Surma-Baulai River and the Kalni-Kushiyara River has drainage problems. To solve the problem, pumping station is under construction and regulators were constructed. The construction of the required facilities for flood control measures is an appropriate input. However, the concrete river management plan was not proposed in the M/P. It is necessary to prepare this plan in the Surma-Baulai River.

River facilities shall be planned based on the river management plan. At present, the flood control plan is considered based on the water level. The design water level will be changed due to river movement and riverbed aggradation. Therefore, planning based on discharge is better than the water level basis. It is required to have the following: discharge measurement on a regular basis, preparation/updating of the rating curve, expansion of rainfall gauging station, and changing the measurement system of the hydrologic data such as automatic recording system.

2) Design

The full embankment is designed based on the design flood water level of the 20-year probable flood. The calculation of the water level is carried out based on NERM. It is a normal approach to estimate the flood water level in Bangladesh.

However, the embankment material survey is not sufficient for design works.

3) Construction

The full embankment is constructed to protect the haor area located in the flood plain area. However, it is required to control the embankment material, water content, and compaction.

4) Operation and Maintenance

It is necessary to improve the O&M as in the case during the pre-monsoon season. If the O&M works of the BWDB field office are not improved, the river facility conditions will worsen.

8.1.3 Issues on Design, Construction and Maintenance of Existing Submergible Embankment in terms of Durability

The geotechnical investigation, interview survey with BWDB and site reconnaissance in the Study can point out three issues regarding the durability of existing submergible embankment, namely 1) low quality of embankment materials, 2) inferiority of embankment works and 3) lack of surface protection. "Durability" is defined as the resistance against local crack, deformation and erosion. It does not means resistance against shear deformation of embankment material.

(1) Low Quality of Embankment Materials

Too much fine silt and clay (under 0.075mm) soil materials of normal embankment may bring cracks causing erosion and deterioration easily through the dry and wet process. Shortage of fine soil materials (under 0.075mm in grain size) may bring comparatively high permeability with seepage. Embankment materials composed of 15 – 50 % silt and clay (under 0.075mm) are usually used to achieve the required durability and impermeability in Japan.

Soil materials for dykes in the haor areas are normally borrowed from adjacent ground of the embankment sites. According to the grain size investigations for embankment materials from 15 locations in five candidate haor projects, soil materials from each site are composed of more than 90 % silt and clay. These soil materials can induce cracks and erosion easily and low workability for compaction.

Table8.1.2 Results of Grain Size Investigation and Compaction Test for Embankment Materials

Site Name	Grain Size (<0.075mm) (%)	Maximum Dry Density (kN/m3)	Optimum Moisture Content (%)	Natural Moisture Content (%)
Dharmapasha Rui Beel	95 -98	15.9 – 17.1	16.9 – 19.0	13.4 – 30.9
Boro (Austagram)	95 -97	16.7 – 17.0	16.1 – 19.0	19.8 – 34.1
Joyariya	88 -92	15.9 – 17.9	14.2 – 19.2	16.6 – 21.6
Dhakshiner	98 -99	16.9 -17.8	16.0 – 18.0	18.7 – 29.7
Ganesh	96 -99	16.2 – 17.2	18.4 – 20.0	24.4 – 25.9

Source: JICA Study Team

(2) Inferiority of Embankment Works

The technical requirements for compaction works of submergible embankment are usually specified in the notes of bid drawings as 7.0 kg rammer compaction. However, no specification regarding the degree of compaction is stipulated in the drawings. Besides, according to the Design Circle of BWDB, many submergible embankments have been constructed by manual labor without complying with the technical specifications regarding compaction works. There is an opinion in the Design Circle that a 90 % degree of compaction should be required.

This idea is considered to be appropriate, as 90 % degrees are usually applied for river dykes as average limit degree of compaction, respectively, in Japan.

The natural moisture content is normally larger than the optimum moisture content in the haor area as indicated in **Table 8.1.2**. As the adjustment of moisture content is not also stipulated in any specification and drawing, it is one of the important issues for embankment works during the implementation stage.

In this study, the Dry-Wet cycle test was conducted to understand the relationship between the local durability of submergible embankment, which is influenced by the repeating submergence during the monsoon, and the degree of compaction. In this test: 1) specimens were compacted in PVC pipes (5cm diameter) by 80%, 90% and 98% degrees of compaction and covered by porous stone and filter paper on their upper and bottom face, 2) specimens were cured in the PVC pipes under the condition of dry-wet process for 10 days cycle (3 days submergence and 7 days drying), and 3) unconfined compression tests were carried out for 1, 2, 4, 8 and 16 cycles respectively to evaluate the reduction of local durability through the dry-wet process using unconfined compression strength as “indicators”, which is inferred to depend on the degree of compaction. The methodology of the dry-wet cycle test can be referred to in Annex 4.2.

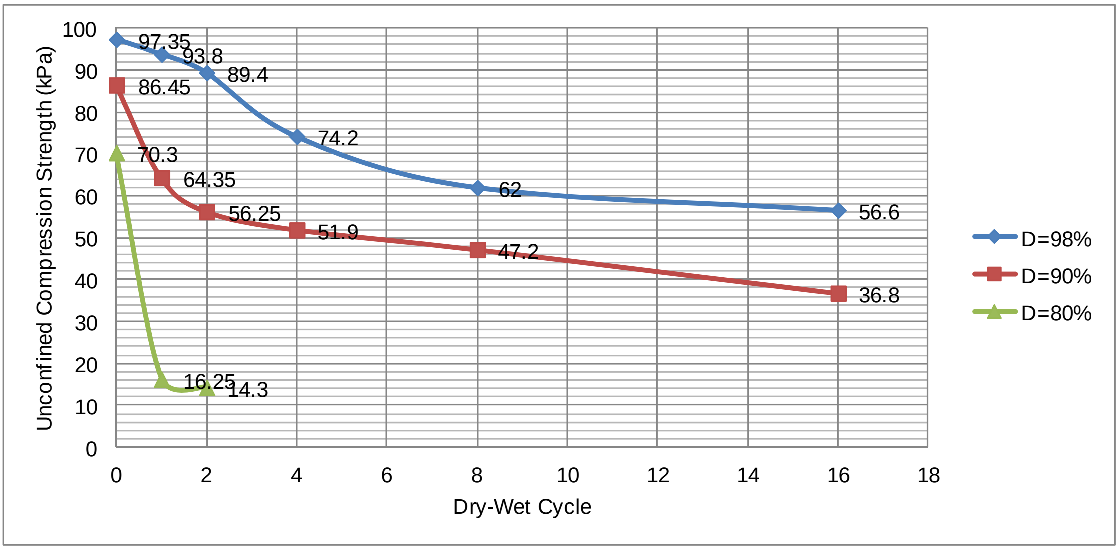
Figure 8.1.1 shows the result of the unconfined compression tests up to 16 cycles.

- In case of 80% degree of compaction, initial compression strength was found to be 70.3 kPa, however the compression strength rapidly decreases to 14.3 kPa after 2 cycles, the specimen cannot form the shape of itself at 4 cycles.

- In case of 90 % degree of compaction, the initial compression strength is 86.5 kPa, and the compression strength decreases to 36.8 kPa after 16 cycles (42 % of initial strength).

- In case of 98 % degree of compaction, initial compression strength is 97.4 kPa, and the compression strength decreases to 56.6 kPa after 16 cycles (58 % of initial strength).

The reduction of unconfined compression strength is considered to be caused by the deterioration on the upper and bottom of specimens where the dry-wet process has stronger influence. This means that local durability against the dry-wet process is inferred to be higher when higher degree of compaction is applied for submergible embankment, since the depth acted upon by infiltration and drying can be narrowed by applying a higher degree of compaction. Deterioration of submergible embankment which needs maintenance and repair works should be avoided as much as possible to reduce the maintenance cost. In this regards, a higher degree of compaction, such as 95% to 98%, is desirable.



Source: JICA Study Team

Figure 8.1.1 Decrease of Strength of Compacted Specimens by Dry-Wet Cycle Test for Three Degrees of Compaction

(3) Lack of Surface Protection

Pavement on the crest of submergible embankment and slope protection by turfing are obviously effective for increasing the long term durability of the surface of submergible embankment. Although the Design Circle of BWDB understands that slope protection and crest pavement of embankment increases its durability, especially crest pavement is not applied for any submergible embankment due to budget constraint at present.

Slope protection usually adopts a kind of turfing using local grass species called *dubra grass*. The *dubra grass* naturally grows in the haor area, and is used for slope protection by transplanting from the vicinity. The roots of the *dubra grass* survive even under monsoon flood, which will sprout up again after the monsoon season.

P-8-15

Brick pavement + turfing (slope: 1:3 approximately)
Construction period*: 1981 – 1987

P-8-16

Concrete cover + turfing (slope: 1:2 approximately)
Construction period: unknown

P-8-17	P-8-18
	
Turfing on slope without pavement (slope: 1:1.5 approximately) Construction period: 1997 - 2006	Brick pavement + turfing (slope: 1:3 approximately) Construction period*: 1981 – 1987
Note: Photograph location is shown in Annex-4-4.	

Photos: JICA Study Team

Surface Protection on Submergible Embankment and Road

***As the construction periods indicate those of the corresponding haor project, accurate completion years of the road and embankment in the above photos are unknown.**

(4) BWDB Design Manual regarding Embankment

BWDB has issueds "Standard Design Manual Volume-I: Standard Design Criteria". This issue describes the design criteria of embankment in "Section 7. Design Criteria for Embankment". However, issues such as standard grain size distribution of embankment materials, degree of compaction and adjustment of moisture content are not mentioned in the manual. As for compaction, although contract drawings instruct the use of a 7.0 kg rammer as notes, the degree of compaction is not mentioned.

The gradation of embankment materials is also mentioned in contract drawings as follows.

Clay > 30%

Silt 0 – 40 %

Sand 0 – 30%

The instruction above allows fine materials which include "0 %" of coarse material like sand and gravel. Practically, the ground adjacent to a submergible embankment site does not include sand and gravel. It means that most of the embankment materials may consist of silt and clay In effect, the repeated submergence in the area is feared to cause the deterioration of embankment due to cracking and erosion.

(5) Issues on Maintenance of Existing Submergible Embankment in Terms of Durability

Maintenance of existing submergible embankment is not carried out sufficiently due to the lack of budget. Lack of maintenance may bring small collapse and crack on the slope, baldness of turfing and wheel truck without any repair, which may result in the infiltration of the monsoon flood water into the depth of the submergible embankment as well as further deterioration.

Wheel trucks can be prevented by restricting traffic on the submergible embankment after the appearance of the crest of embankment in the beginning of the post-monsoon, or during/after heavy rain which makes the crest of embankment muddy.

Intentional excavation of submergible embankment by local people called “public cut” is frequently seen for local drainage inside the project area and navigation of fisheries.

Local organizations composed of beneficiaries for O&M of submergible embankment and regulators should be established to restrict traffic on the muddy crest of the submergible embankment and to prevent public cuts.

8.2 Proposal of Basic Standard Design of Structures for Flood Measures

8.2.1 Design Review of Existing Structural Measures

(1) Present Situation of Gate Equipment

A standard gate size (1.5 m wide x 1.8 m high) is usually used when installing regulators. Therefore the flow capacity of the regulator is determined from the number of its gates (number of vents). Gates are usually made of mild steel (yield strength: 40,000 psi = 280 MPa) with coating to prevent corrosion.

It was confirmed well through site reconnaissance during the Study that half of the gates on the existing regulators at present do not function well. Factors which caused the malfunctioning of these gates are robbery, loss of gate parts, corrosion and deterioration of gate equipment.

Maintenance work has not been carried out (neither greasing nor tightening of bolts). Nearby residents say that BWDB should be responsible for the gates even for its simple maintenance work such as greasing and bolt tightening. Any sense of ownership was not found among the residents.

P-8-19

Corroded Hoists (Chandal Beel Scheme)

P-8-20

Cut and stolen rod (Ghanakkali)

Note: Photograph location is shown in Annex-4-4.

Photos: JICA Study Team

Deteriorated Gate Equipment

(2) Present Situation of Concrete Structures

Alhough many sound concrete structures were confirmed during the site reconnaissance, some of these structures have serious problems like cracks and deterioration.

P-8-21

P-8-22

Note: Photograph location is shown in Annex-4-4.

Photos: JICA Study Team

Situation of Deterioration on the Existing Concrete Structure (Satdona Beel Scheme)

The left photo above (P-8-21) shows the present situation of the regulator with severe concrete crack. This crack seems to be caused not only from a structural factor like excess live loads but also from low quality of concrete.

The right photo (P-8-22) shows the concrete surface situation of the same regulator and indicates obviously that the gradation of the concrete aggregate is not adequate. The photograph also shows that the lack of mortar results in insufficient compaction.

According to the contract drawings, the required quality of concrete is described at a specified strength of 20 MPa. However, quality confirmation of the concrete through compression test might not have been undertaken because the concrete was mixed at the site by local people.

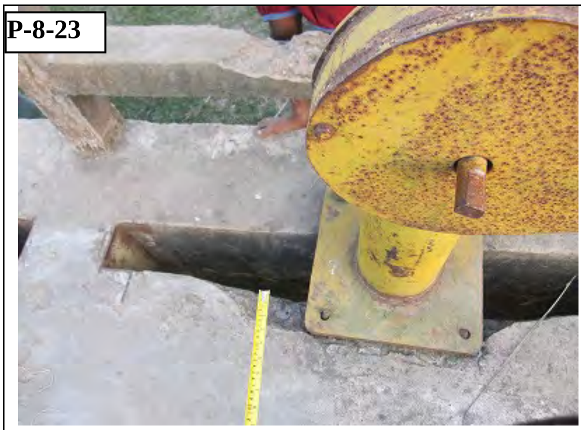
BWDB mentions that the standard mix proportion of concrete (water : sand : aggregate) is 1 : 2 : 4 or 1 : 1.5 : 3. The gradation of aggregate should follow ASTM standards, however it is practically difficult to control the concrete quality due to technical problem of the local people and lack of staff in BWDB field offices.

Standardization of mix proportion and method of quality control system need to be prepared.

Although the contract drawings of regulators usually instruct the clear cover of reinforcement bars, concrete exfoliation and exposure of corroded reinforcement bars were observed on some of the regulators. Instructions of contract drawings regarding clear cover are detailed below. The clear cover of operation decks is considered to be comparatively small against other portions.

Operating Deck:	25mm
Concrete Adjacent to Earth:	60mm
Concrete Adjacent to Water/Exposed or Others:	50mm

Concrete edges under the hoists chip on the deck slabs of some of the regulators. Shearing force might not be considered for the design of contact portion of deck slabs and a plates of hoists.

P-8-23	P-8-24
	
Kairdhala Ratna	Aralia Khal Scheme
Note: Photograph location is shown in Annex-4-4.	

Photos: JICA Study Team

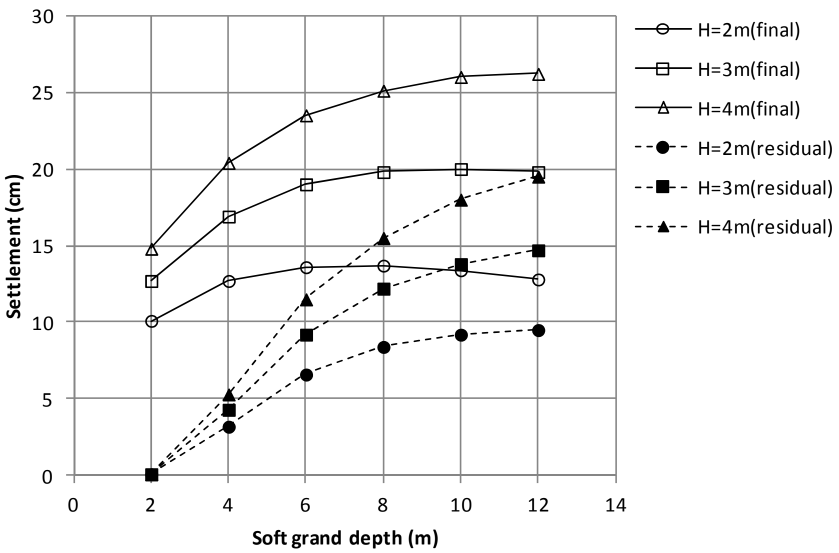
Chips on Deck Slab Concrete

8.2.2 Consideration for Structure Design

(1) Consideration for Design of Submergible Embankment

1) Basic Issue and Foundation Ground

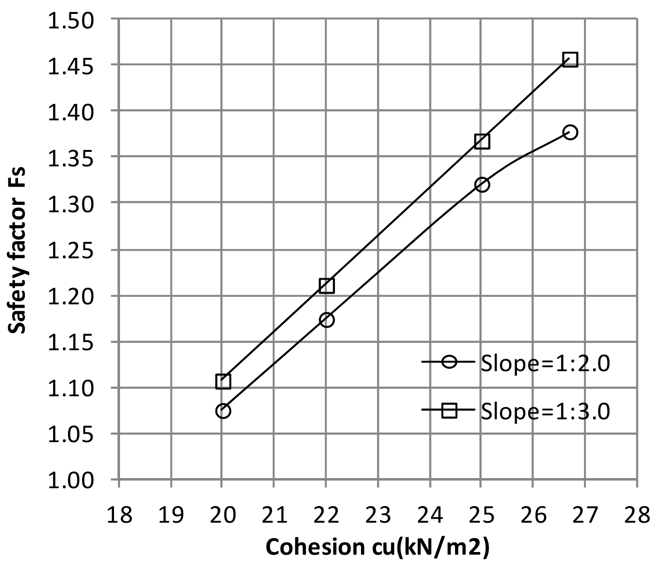
- The Standard Design Manual of BWDB stipulates that the crest elevation of submergible embankment shall be the 10-year probable water level during the pre-monsoon with a 0.3 m freeboard. The Study will follow this regulation.
- The manual stipulates that the crest width of the submergible embankment shall be a 4.3 m. However, the crest width of the submergible embankment is designed to be 3.6 m for cost reduction purpose in many cases. The crest width of 4.3 m is considered to be appropriate in terms of slope shoulder protection against traffic of vehicles during inspection and maintenance.
- The geotechnical investigation done by the Study shows that the thickness of soft ground (N-value < 4 in clay foundation) is usually less than 5 m in the haor area. Settlement calculations based on the consolidation tests showed that residual settlements have thickness less than 10 cm (soft ground depth < 5 m, height of submergible embankment < 4 m). The contract drawings of submergible embankment usually instruct an extra embankment of 15 cm, which seems to be enough in light of the result of the settlement analysis.



Source: JICA Study Team

Figure 8.2.1 Relationship between Settlement and Soft Ground Depth, Height of Embankment based on Consolidation Tests

- Dutch Cone Test (DCT) carried out in the Study shows that cone resistance is generally greater than 0.8 MPa, which is equivalent to 26.7 kPa in clay soil (except for the area with very soft ground sites). **Figure 8.2.2** below shows the result of circular slip analysis including also foundation ground, assuming 100% of residual pore water pressure. Embankment with a slope gradient of 1:2.0 satisfies the required safety factor (FS > 1.2) in the case of cohesion greater than 23 kPa (cone resistance > 0.7 MPa). In the case of very soft ground (cone resistance < 0.4 MPa), countermeasures like revision of embankment alignment are needed, if the height of the embankment is greater than 2.0 m. Boring survey is recommended during the implementation stage at maximum intervals of 500 m and at specific sites to be investigated from a topographic view point.



Source: JICA Study Team

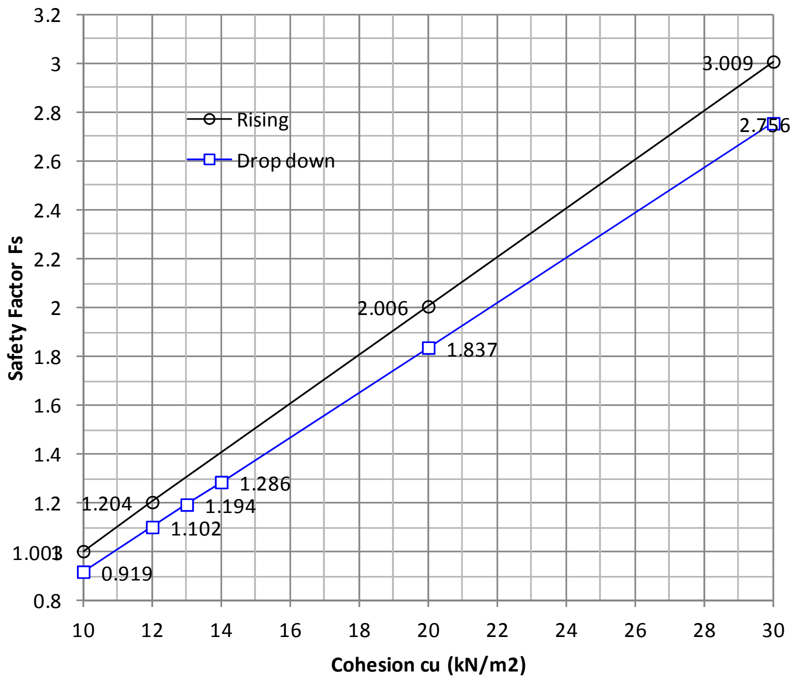
Figure 8.2.2 Relationship between Cohesion of Foundation Ground and Safety Factor of Circular Slip Analysis (Height of Embankment: 4.0 m)

2) Degree of Compaction for Embankment

Site soil materials consist of fine material with high moisture content. Coarse materials like sand and gravel are usually expensive and the improvement method of material grain size distribution by blending fine and coarse material is rather difficult in terms of cost and technical aspects. Moreover, as the site soil materials usually include high moisture contents, adjustment of moisture content is essentially needed for sufficient compaction.

Although the contract drawings of submergible embankment instruct the use of a 7.0 km rammer, no stipulation of quality control method like for the degree of compaction is mentioned in drawings and the manual. The degree of compaction should be stipulated to achieve the required strength from the stability analysis of embankment. The specification of embankment work and equipment must be determined by site test to achieve the degree of compaction.

Figure 8.2.3 presents the result of stability analysis of submergible embankment. The required cohesion to satisfy the safety factor of 1.2 is 14kPa (corresponding to 28kPa in unconfined compression strength). The degree of compaction must be determined to obtain the required cohesion, considering also the decrease of local durability through the dry-wet process presented in **Figure 8.1.1.**



Note: Rising: water level increasing, Drop down: water level decreasing
Source: JICA Study Team

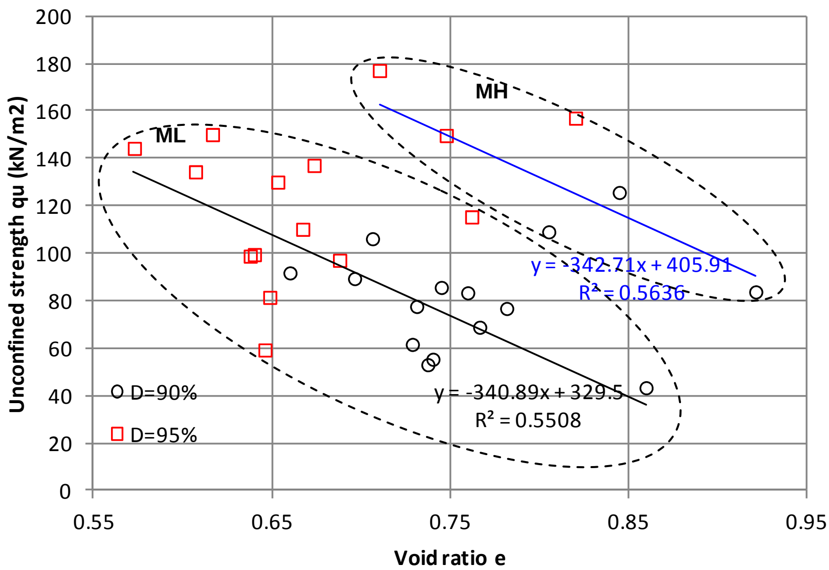
Figure 8.2.3 Relationship between Cohesion of Embankment Materials and Safety Factor of Circular Slip (Height of Embankment: 4.0m, Slope Gradient: 1:2)

Figure 8.2.4 presents the relationship between the unconfined compression strength and void ratio. Sample soil material is classified into ML (silt with low liquid limit) and MH (silt with high liquid limit) as separated by the dotted lines on the graph (**Figure 8.2.4**).

As for ML material, unconfined compression strength is in the range of 60 - 100kPa in case of 90% degree of compaction, and 100 to 140kPa in case of 95% degree of compaction except for some cases.

On the other hand, unconfined compression strength at 16 cycles in the dry-wet cycle test is 42% and 58% of the initial strength in case of 90% and 98% degree of compaction respectively.

More than 95% degree of compaction is desirable, considering the initial durability and decrease of durability through the dry-wet process for each degree of compaction. The dry-wet cycle test for 95% degree of compaction was not conducted in this survey, which should be conducted during the detail design stage. Therefore, another dry-wet cycle test for 95% degree of compaction should be carried out during the implementation stage to evaluate the decrease of the local durability.



Source: JICA Study Team

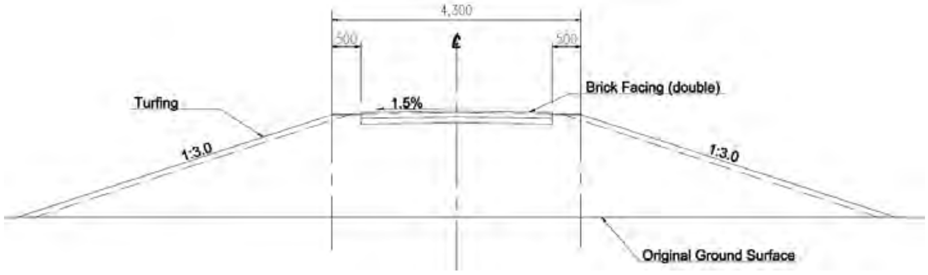
Figure 8.2.4 Unconfined Compression Test Using Embankment Material (Relationship between Unconfined Strength and Void Ratio)

3) Shape of Submergible Embankment

- The Standard Design Manual of BWDB mentions about that the shape of the submergible embankment should have a crest width of crest is 4.3 m, slope gradient of 1:3.0 for both sides, and freeboard of 30 cm. A slope gradient of 1:3.0 is recommended for stability against traffic loads when used as a road and for durability against submergence and overtopping. Slope is also expected to be protected by turfing based on the manual. Besides, the crest of embankment should be covered by pavement to prevent deterioration due to wheel trucks.
- Embankment material must be borrowed from adjacent area even if the grain size distribution is not suitable for the embankment because of the cost and technical aspects. However, 95 % degree of compaction is expected as the target degree to avoid the decrease of local durability and reduce the frequency of maintenance. Compaction of embankment should be carried out using bulldozers and rollers to achieve 95% degree

of compaction.

Quantity calculation and cost estimation in this study assume the following typical section of embankment considering the above situation. The height and length of embankment for new projects are mentioned in **Table 8.3.2**.



(2) Consideration for Design of Regulator

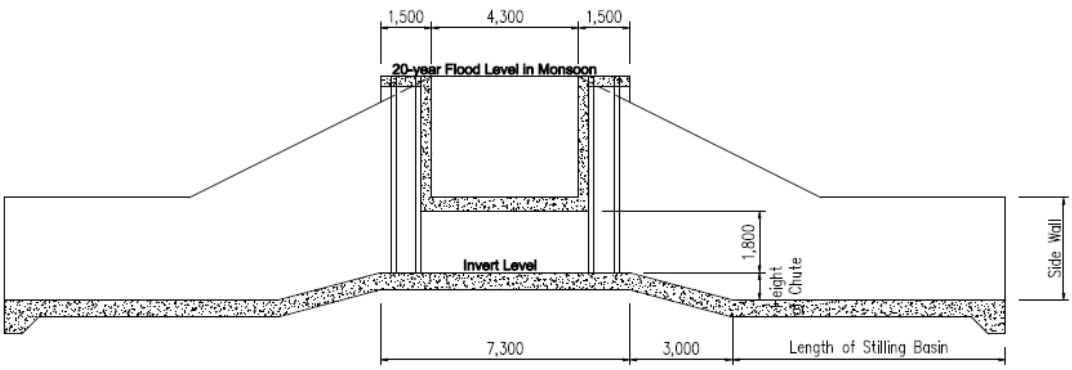
Present standard regulators are usually sluice way type structures with lift gates. As shown in **Figures 8.2.5** and **8.2.6**, the regulator has some gates with a height of 1.8 m and width of 1.5 m.

Regulator gates are opened on May 15 after harvesting of boro rice to induce flood water into the project area and make the water level in the project area almost equal to the river water level outside the project area. This operation reduces the damage due to overtopping of flood on the submergible embankment

The Standard Design Manual of BWDB mentions that flow capacity of the regulator should be defined so that the difference of water level between inside and outside of the project area will be less than 0.3 m when overtopping of flood starts over the submergible embankment.

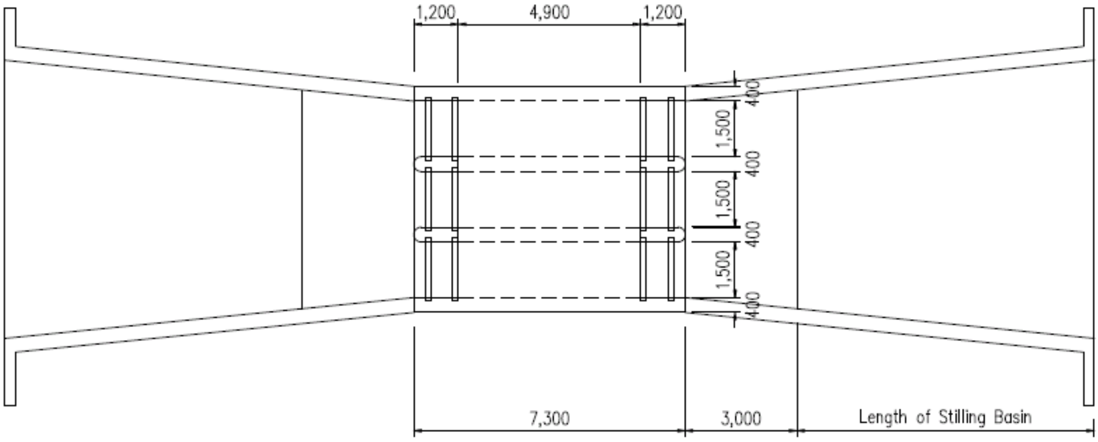
The manual also mentions that the elevation of the operation deck should be higher than the 20-year water level during the monsoon season so that gates can be operated even after the submergence of the regulator. Actual deck levels of some regulators are lower than the monsoon flood level and are submerged during the monsoon season.

The culvert type water ways for regulator are installed under the embankment. Aprons for stilling basin in the upstream and downstream stretches of the culverts are constructed to prevent scouring on both side of the embankment. The length of the stilling basin will be determined so as to be generally three times of the sequent depth of hydraulic jump.



Source: JICA Study Team

Figure 8.2.5 Typical Longitudinal Profile of Regulator



Source: JICA Study Team

Figure 8.2.6 Typical Plan of Regulator

The number of gates and basic feature of the regulator in each project were planned as presented in **Table 8.2.1** below. This was calculated from the divided catchment area using DEM from BWDB.

Table 8.2.1 Basic Features of Regulator for New Projects

Project Name	Regulator	Catchment (ha)	Design WL (m PWD)	Number of Gate	Invert Level (m PWD)	Deck Level (m PWD)	Stilling Basin	
							Length (m)	Wall Height (m)
Badla Project	No.1	763	4.9	2	3.5	7.9	6.0	3.0
Badla Project	No.2	513	4.9	2	3.5	7.9	6.0	3.0
Dharmapasha Rui Beel	No.1	6860	6.1	17	2.0	8.5	10.0	4.0
Dharmapasha Rui Beel	No.2	2404	6.1	6	2.0	8.5	10.0	4.0
Dharmapasha Rui Beel	No.3	3184	6.1	8	2.0	8.5	10.0	4.0
Dharmapasha Rui Beel	No.4	1033	6.1	3	2.0	8.5	10.0	4.0
Dharmapasha Rui Beel	No.5	6923	6.1	18	2.0	8.5	10.0	4.0
Charigram Project	No.1	2089	4.5	4	3.0	7.7	6.0	3.0
Charigram Project	No.2	708	4.5	1	3.0	7.7	6.0	3.0
Bara Haor	No.1	1961	6.0	5	3.0	8.6	9.0	4.0
Bara Haor	No.2	507	6.0	1	3.0	8.6	9.0	4.0
Ayner Gupi Haor	No.1	809	4.0	3	2.5	7.6	6.0	3.0
Boro Haor(Austagram)	No.1	4167	4.4	11	2.5	7.8	7.0	3.0
Boro Haor(Austagram)	No.2	1291	4.4	4	2.5	7.8	7.0	3.0
Boro Haor(Austagram)	No.3	4028	4.4	11	2.5	7.8	7.0	3.0
Boro Haor(Austagram)	No.4	823	4.4	3	2.5	7.8	7.0	3.0
Boro Haor(Nikli)	No.1	8053	5.0	18	3.0	8.4	7.0	3.0
Boro Haor(Nikli)	No.2	1096	5.0	3	3.0	8.4	7.0	3.0
Chandpur Haor	No.1	1573	4.9	4	4.0	9.2	5.0	3.0
Chandpur Haor	No.2	677	4.9	1	4.0	9.2	5.0	3.0
Dulalpur	No.1	355	4.0	2	1.5	7.6	8.0	3.0
Korati Beel Haor	No.1	726	4.8	1	2.8	8.1	7.0	3.0
Korati Beel Haor	No.2	2061	4.8	4	2.8	8.1	7.0	3.0
Kuniarbandh Haor	No.1	1327	4.0	1	3.5	7.6	3.0	4.0
Naogaon Haor	No.1	2394	4.9	9	2.0	8.2	8.0	4.0
Naogaon Haor	No.2	4760	4.9	17	2.0	8.2	8.0	4.0
Naogaon Haor	No.3	1125	4.9	4	2.0	8.2	8.0	4.0
Noapara Haor	No.1	783	4.5	2	2.8	8.0	6.0	3.0
Noapara Haor	No.2	586	4.5	1	2.8	8.0	6.0	3.0
Noapara Haor	No.3	1496	4.5	3	2.8	8.0	6.0	3.0
Nunnir Haor	No.1	2993	4.3	5	2.8	7.9	6.0	3.0
Nunnir Haor	No.2	1460	4.3	2	2.8	7.9	6.0	3.0
Nunnir Haor	No.3	894	4.3	2	2.8	7.9	6.0	3.0
Sarishapur Haor	No.1	1004	4.2	1	3.5	7.8	4.0	4.0
Bansharir Haor	No.1	333	5.8	1	4.5	8.1	6.0	3.0
Bansharir Haor	No.2	844	5.8	1	4.5	8.1	6.0	3.0

Chatal Haor	No.1	680	5.4	1	2.8	8.1	8.0	3.0
Chatal Haor	No.2	137	5.4	1	2.8	8.1	8.0	3.0
Dakhshiner Haor	No.1	1694	4.8	6	2.3	7.9	8.0	3.0
Dakhshiner Haor	No.2	789	4.8	3	2.3	7.9	8.0	3.0
Dhakua Haor	No.1	3430	6.0	5	3.8	8.2	7.0	3.0
Dhakua Haor	No.2	877	6.0	1	3.8	8.2	7.0	3.0
Dhakua Haor	No.3	1655	6.0	3	3.8	8.2	7.0	3.0
Ganesh Haor	No.1	984	6.1	2	3.8	7.7	8.0	3.0
Ganesh Haor	No.2	1944	6.1	3	3.8	7.7	8.0	3.0
Jaliar Haor	No.1	914	7.3	2	6.0	8.6	6.0	3.0
Jaliar Haor	No.2	1297	7.3	2	6.0	8.6	6.0	3.0
Mokhar Haor	No.1	3983	5.6	3	3.5	8.2	7.0	3.0
Mokhar Haor	No.2	3388	5.6	3	3.5	8.2	7.0	3.0
Mokhar Haor	No.3	5473	5.6	5	3.5	8.2	7.0	3.0
Mokhar Haor	No.4	4496	5.6	4	3.5	8.2	7.0	3.0
Mokhar Haor	No.5	4087	5.6	4	3.5	8.2	7.0	3.0
Shelnir Haor	No.1	1972	5.2	1	4.8	5.7	3.0	5.0
Shelnir Haor	No.2	469	5.2	1	4.8	5.7	3.0	5.0
Shelnir Haor	No.3	589	5.2	1	4.8	5.7	3.0	5.0
Sunair Haor	No.1	3197	5.7	4	4.0	8.4	6.0	3.0
Sunair Haor	No.2	697	5.7	1	4.0	8.4	6.0	3.0

Source: JICA Study Team

Some of existing regulators are not functioning due to corrosion, deterioration and damage of the structures and gates as mentioned in the previous sub-section. Therefore, the following issues should be considered.

- Enhancement of design and quality control of concrete structure
- Implementation of continuous maintenance

Table 8.2.2 Proposal for Improvement of Quality Control and Maintenance of Regulator

Item	Proposal
Enhancement of Design and Quality Control	- Standardization of maximum coarse aggregate, classification of aggregate, standard gradation of coarse and fine aggregate - Standardization of mix proportion (aggregate, cement and water) - Stipulation of slump value - Establishment of quality control method during construction stage (quality control by aggregate physical test and slump test) - Revision of clear cover according to the size of aggregate - Execution of structural calculation using hoist load - Proposal for maintenance method and budget in the design stage (reflecting to DPP)
Execution of Maintenance	- Operation and maintenance system with user participation - Clarification of demarcation and responsibility between user and BWDB - Preparation of O&M manual - Providing stoplog for gate maintenance - Pavement on crest of submergible embankment for inspection and maintenance work - Establishment of budget preparation by the user and BWDB - Establishment of countermeasures against robbery and vandalism (installing fence, fermenting residents ownership)

Although the gates of the regulator are made of mild steel (fy=280MPa) with coating against corrosion, most of the gates have deteriorated terribly due to the lack of periodic maintenance.

Periodic maintenance is expected, however the use of stainless steel can be also considered to save on the frequency of maintenance. In Bangladesh, stainless steel is used in the coastal area, where steel can be corroded easily, for mainly the gate slot which is difficult to replace.

Although stainless steel is not manufactured in Bangladesh, simple processing is possible. It is not practical to use stainless steel for the whole gate structure (the required stainless steel is approximately one ton), however it is worth considering to use it for one gate slot.

Supposing the price of stainless steel in Bangladesh is the same as in Japan (because it must be imported), the price must be around 610 JPY/kg = 740 BDT/kg. The weight of the steel gate slot for both left and right sides is supposed to total to around 200 kg, with an estimated price of BDT 148,000.

On the other hand, the general price of a gate with slot and hoist etc is BDT 98,400 including manufacturing and installation according to the schedule of rate from BWDB. This means that the price of a gate slot made of stainless steel is more expensive than that of a whole gate structure made of mild steel.

Considering the above, corrosion should not be prevented by using stainless steel, but periodic maintenance in the haor area, where is far from the coastal area.

8.3 Preliminary Work Quantity and Cost Estimation

The required rehabilitation works were identified through site inventory and interview survey under the Study. The rehabilitation cost was estimated based on the required works.

As for the new projects, design water levels and embankment crest levels were set through hydraulic analysis. Locations of regulators were determined from the existing DEM. The number of gates was calculated following the method mentioned in the BWDB Standard Design Manual. The calculation were done, supposing that the gates are to be opened on May 15 and that the water level difference between the river and land sides of the submergible embankment is less than 30 cm when flood overflows through the submergible embankment.

Table 8.3.1 Preliminary Work Quantity and Direct Cost for Rehabilitation Project

No.	Name of Haor Project	Re-sectioning of Embankment	Replace of Gate and Regulator	Re-excavation of Canal	Others	Direct Cost (BDT million)
r-1	1. Dampara Water Management Scheme	Full 200 m Sub 400 m	Gate 15 nos	12km	Pipe cleaning Pipe sluice	30.4
r-2	2. Kangsa River Scheme	Full 40 m	Gate 16 nos			4.4
r-3	3. Singer Beel Scheme	Full 100 m Sub 125 m	Gate 1 nos	2 km		7.5
r-4	4. Baraikhali Khal Sub-Project	Full 10 m	Gate 6 nos	24.5 km		5.9
r-5	5. Aladia-Bahadia Scheme		Gate 2 nos	8 km		16.2
r-6	6. Modkhola Bairagirchar Scheme	Full 500 m				15.5
r-7	7. Ganakkahali Scheme		Gate 3 nos			0.3
r-8	8. Kairdhala Ratna	Sub 60 m	Gate 9 nos			1.1
r-9	9. Bashira River Re-excavation Schme	Sub 6,000 m	2vent reg. 2 nos	20 km		108.2
r-10	10. Aralia Khal Scheme		Gate 4 nos	2.4 km		5.2
r-11	11. Chandal Beel Scheme	Full 100 m	2vent reg. 1 nos	2 km		24.6

r-12	12. Satdona Beel Scheme		2vent reg. 2 nos			33.0
	13. Datta Khola and Adjoining Scheme			73.5 km		147.0
	14. Cheghaia Khal Scheme	Sub 130 m	Gate 1 nos	4.5 km		14.2
r-13	15. Gangajuri FCD	Full 600 m	Gate 20 nos	4.5 km		34.4
	16. Sukti River Embankment			11.5 km		23.0
	17. Madhapur Scheme	Full 1,260 m		38 km		125.3
	18. Akashi and Shapla Beel Scheme	Full 150 m		6.5 km		18.9
	19. Mohadao Nodi Embankment	Full 420 m Sub 120 m				16.9
r-14	20. Kaliajuri Polder #02	Sub 810 m	Gate 19 nos			4.8
r-15	21. Kaliajuri Polder #04	Sub 630 m	Gate 3 nos			2.6
	22. Sukaijuri Bathai	Full 70 m	Gate 1 no			2.8
	23. Singua River			55 km		110.0
	24. Someswari River	Full 1,970m	Gate 1no			77.1
	Total					829.2

Source: JICA Study Team

1. r-1 to r-15 are prioritized projects.
2. Cost of embankment is estimated based on the Schedule of Rate of BWDB. Quantity of embankment is estimated from cross section survey on damaged portion.
3. Gate replacement cost is based on the Schedule of Rate of BWDB, Cost of regulator is based on the interview with BWDB.
4. Unit price of re-excavation of canal per km is referred from the Haor Master Plan. The length of re-excavation portion is based on the interview survey with the BWDB district office.

Table 8.3.2 Preliminary Work Quantity and Direct Cost for New Project

	Name of Haor Project	Crest Level (height) of embankment	Volume of Embankment	Re-excavation of Canal	Regulator	Direct Cost (BDT million)
n-1	Boro Haor (Nikli)	5.4m (0 – 3.2 m)	9.6 km	10 km	9-vent: 2nos 3-vent: 1nos	146.1 230.1
n-2	Naogaon Haor	5.3m (0 – 1.7 m)	34.1 km	20 km	9-vent: 2nos 8-vent: 1nos 4-vent: 1nos	208.2 370.2
n-3	Jaliar Haor	7.6m (0 – 1.6 m)	6.8 km	8 km	2-vent: 1nos 2-vent: 1nos	60.2 92.2
n-4	Dharmapasha Rui Beel	6.4m (0 – 2.7m)	57.1 km	5 km	9-vent: 3nos 8-vent: 2nos 6-vent: 1nos 3-vent: 1nos	632.2 1,088.2
n-5	Chandpur Haor	5.2m (0 – 0.6 m)	2.1 km	5 km	4-vent: 1nos 1-vent: 1nos	46.2 56.2
n-6	Sunair Haor	5.9m (0 – 0.4 m)	16.2 km	25 km	4-vent: 1nos 1-vent: 1nos	85.0 144.0
n-7	Badla Project	5.2m (0 – 1.8m)	10.8 km	2 km	2-vent: 2nos	68.8 131.8
n-8	Nunnir Haor	4.7m (0 – 2.5 m)	25.5 km	20 km	5-vent: 1nos 2-vent: 2nos	183.1 341.1
n-9	Dakhshiner Haor	5.1m (0 – 2.3 m)	18.3 km	10 km	6-vent: 1nos 3-vent: 1nos	160.9 280.9
n-10	Chatal Haor	5.7m (0 – 2.3 m)	5.7 km	11 km	1-vent: 2nos	72.3 107.3
n-11	Ganesh Haor	6.4m (0 – 2.2 m)	22.5 km	3 km	3-vent: 1nos 2-vent: 1nos	157.0 304.0
n-12	Dhakua Haor	6.3m (0 – 3.2 m)	36.5 km	30 km	5-vent: 1nos 3-vent: 1nos 1-vent: 1nos	325.9 603.9
n-13	Mokhar Haor	5.5 – 6.2m (0 – 5.8 m)	68.8 km	110 km	5-vent: 1nos 4-vent: 2nos 3-vent: 2nos	805.4 1,404.4
n-14	Noapara Haor	4.9m (0 – 3.5 m)	28.3 km	7 km	3-vent: 1nos 2-vent:1nos 1-vent: 1nos	304.3 550.3

n-15	Dulalpur Haor	4.3m (0 – 2.9 m)	8.3 km	3 km	2-vent: 1nos	111.1 192.1
n-16	Bara Haor	6.3m (0 – 4.6 m)	27.0 km	40 km	5-vent: 1nos 1-vent: 1nos	637.6 969.6
n-17	Bansharir Haor	6.1m (0 – 2.8 m)	18.0 km		1-vent: 2nos	114.2 232.2
n-18	Korati Haor	5.2m (0 – 4.3 m)	40.4 km	4 km	4-vent: 1nos 1-vent: 1nos	526.4 936.4
n-19	Sarishapur Haor	4.6m (0 – 1.8 m)	7.1 km	5 km	1-vent: 1nos	52.0 98.0
n-20	Shelnir Haor	5.5m (0 – 1.6 m)	30.1 km	2 km	1-vent: 3nos	131.3 317.3
n-21	Kuniarbandh Haor	4.3m (0 – 3.0 m)	8.3 km		1-vent: 1nos	118.0 211.0
n-22	Ayner Gupi Haor	4.3m (0 – 3.0m)	13.7 km		3-vent: 1nos	180.6 319.6
	Charigram Project	4.9m (0 – 2.2m)	25.7 km	3 km	4-vent: 1nos 1-vent: 1nos	153.8 321.8
	Bara Haor (Austagram)	4.8m (0 – 2.2 m)	60.3 km	40 km	11-vent:2nos 4-vent: 1nos 3-vent: 1nos	559.9 997.9
	Golaimara Haor	4.2m (0 m)	-	-	-	-
	Joyariya Haor	4.2m (0 m)	-	-	-	-
	Total					5,841 10,301

Source: JICA Study Team

1. n-1 to n-22 are prioritized projects.
2. Upper cost does not include the land acquisition cost, lower cost includes the land acquisition cost.
3. Embankment cost is estimated based on the Schedule of Rate of BWDB, quantity of embankment is based on the spot elevation survey.
4. Cost of regulator is based on the interview with BWDB.
5. Work quantity and unit price for the re-excavation of canal per km were referred from the Haor Master Plan.
6. Land acquisition cost is supposed to be 600 Tk./sqm from the Upper Meghna River Basin Watershed Management Improvement Project.

CHAPTER 9 NON-STRUCTURAL FLOOD MEASURES IN HAOR AREA

9.1 Assessment of Present Situation and Appropriateness regarding Existing Non-Structural Measures

The extensive annual flooding of the haor area makes livelihoods extremely vulnerable and limits the potential for economic growth. Although the lifestyle of the haor people is well adapted to flood phenomena, damage due to drainage related inundation, pre-monsoon flash floods, severe monsoon floods, river bank erosion, failure of river structures, etc. still occurs. Due to monsoon inundation, in most haor areas, only one crop is possible. Unfortunately, pre-monsoon flash floods occurring before the harvesting damage the crops once in 3 or 4 years. Thus, among many natural hazards, pre-monsoon floods are particularly challenging for the communities of the haor area. Though the main tools of the damage reduction revolves around structural measures like embankment, river dredging, etc., non structural flood measures are also considered as means of damage reduction. This section has assessed the present non structural measures practiced in the haor area and to evaluate their appropriateness.

9.1.1 Relevance of Flood Damage Pattern with Non-Structural Measures

Analysis of area specific flood damage pattern is relevant as not all types of non structural measures are effective for all types of flood damage. For example, where the flash flood can cause life threatening situation, early warning and evacuation is most important. On the other hand, where major threat due to the flash flood is crop damage, crop diversification and alternate livelihood can be an effective measure.

Threat to human life is not a common damage in the haor area, because there is no habitat in the low lying areas and most habitats are raised above normal monsoon flood levels. On the other hand, among the various types of flood damage experienced in the haor areas, crop damage is the main issue of concern. Thus, more focus is given on asset loss reduction by government and non-government organizations.

The following flood damage patterns in the haor area are considered.

(1) Flash Flood Onslaught

1) Damage for Rice Cultivation

Flash floods generally occur in two seasons: pre-monsoon and monsoon. Flash flood in the pre-monsoon season (April to mid-May) is a major concern due to its effect to crop production/harvest but that in the monsoon season (mid-May to October) is not considerably important since no crops are planted.

The occurrence of flash floods in the pre-monsoon season damages boro rice (single crop) and other cereals in the area. This is considered one of the major disasters in the area, which affects the primary production sector (e.g., agriculture and fisheries) and thus, threatens the lives and livelihood of the people (mostly farmers).

If flash floods continue to damage the production of boro rice, people will remain in a stressful condition until the next year's harvest. Also, many farmers will be forced to sell their livestock because of fodder shortage.

2) River Bank Erosion

Many excavated rivers are located in the haor area, and river bank protection is not provided at most of haor area. Thus, these areas suffer river bank erosion. Riverbank erosion is significant in such middle scale rivers as the Manu, Dharai, and Khoai Rivers, as well as in major rivers such as the Surma and the Kushiyara Rivers. These resulted to washout of houses, cultivated lands, and other properties owned by the people residing along the rivers.

(2) Flood Damage during the monsoon season

Fertile soil is provided from the upstream area during the monsoon season. Therefore, the people consider the blessing. On the other hand, the people suffer the following damages.

1) Erosion due to Wave Action Induced on Haor Water Surface

The villages in the haors are formed on earthen mounds or man-made platforms to keep their houses and cultivated land above the water level during the monsoon season, which lasts for about five months (mid-May to October) in a year.

The mounds and platforms have been threatened by repeated erosion due to wave action induced on the haor water surface by winds. Although bamboo and tarja (local grass) fencing are used by the people for mound/platform protection from wave action, the protection works often proved ineffective. Therefore, the mounds/platforms remain exposed to erosion for about 5 months (the monsoon season), resulting sometimes in washout destroying houses, cultivated land, etc.

2) Sedimentation in Rivers, Haors, and Other Water Bodies

Sedimentation is a concern in the area because it plays a governing role in the morphology of rivers, i.e., the change in the river channels and flood plains. Furthermore, sedimentation in river channels has induced incomplete drainage, frequent overtopping of floods from rivers, and aggravation of riverbank erosion in the upstream reaches. Besides, sedimentation in some haor areas has resulted in negative impacts on fisheries and decrease in the flood-retarding capacity in the areas.

3) Drainage Congestion in Rivers and Channels

Drainage is mainly very important during the month of December since it is the planting time for boro rice. The usual time for planting boro is every mid-December. However, due to congestion or delayed drainage in rivers and channels, plantation of boro rice is always delayed. As a result, its harvesting is also delayed, which increases the risk of pre-monsoon flash flood.

Non-structural measures refer to any measure that does not involve physical construction (like retarding basins, embankment, dredging, diversions, etc.) but instead uses knowledge, practices and/or agreements to reduce the potential impacts of a flood. Non-structural approaches can be a cost-effective alternative to traditional engineering and ecological solutions. Typical measures include the installation of early warning systems, soil and land use management, insurance, awareness building and public information actions, all of which can help mitigate flood related damage. Nonetheless, not all non-structural measures are effective in all situations and it is always better to adopt multiple non-structural measures along with some structural measures for better flood risk management.

9.1.2 Appropriateness regarding Existing Non-Structural Measures

Different types of non-structural measures are practiced in the haor areas. In this section, each measure is analyzed briefly covering present situation, on-going and planned activities, and potential for further interventions.

(1) Regulation of Development in River Areas

Present situation: Development of river areas in the haors is not regulated. There are two main reasons for not having any development control in the river areas. First, people usually construct their establishments in relatively flood free areas, so these are less susceptible to flood loss; and second, local administrations have no legal framework and resources to ensure any development control.

On-going and planned activities: Currently there is no activity in this regard.

Assessment: It is not an effective flood damage reduction measure because development control may not bring any new benefit. Formulating a relevant legal framework will be time consuming and enforcement will be difficult.

Potential for further interventions: It may be proposed that local authorities can be given legal authority for development control in consultation with all concerned stakeholders including BWDB. However, considering the effectiveness and necessity, this has a low priority.

(2) Flood Forecasting and Warning System

Present situation: Flood Forecasting and Warning Center (FFWC) of BWDB prepares a 3-day flood forecasting for specific points using a mathematical model based on data from water level and rainfall stations. The warning is provided by the FFWC to all relevant government and non government organizations, and also posted on the FFWC's website.

On-going and planned activities: Many agencies are now carrying out various activities. These includes, (a) the ADB pilot study on satellite based weather/ flood forecast to be implemented by JAXA, (b) calibration of the JICA funded Maulvibazar doppler radar station, (c) project to increase the lead time from current 3 days to 5 days by CDMP II, (d) development of local FF model for the northeast area under CDMP II to make flash flood warning (A new northeast FF model has just been developed under CDMP II, and an experimental flash flood warning was issued this year), and (e) installation of water gauge stations under CDMP II.

Assessment: At present, there is no regular flash flood warning. The issued monsoon flood warning is not user friendly as the warning states only the anticipated river water level at some few locations, which is difficult for the residents to correlate to their localities. So, currently it is not a very effective measure for the haor areas.

Once the on-going projects complete, it is expected that effectiveness of this measure will increase.

Potential for further interventions: Before any further interventions, impacts of on-going activities should be observed.

(3) Warning Dissemination

Present situation: Under the present institutional mandate, FFWC is responsible to provide the flood warning only to district level authorities. Warning dissemination to the people is responsibility of local government. Also, there is no monitoring as to whether recipients can understand or use the flood warnings provided.

On-going and planned activities: Current activities include, (a) trial basis mobile phone Instant Voice Response (IVR) method under the CDMP II project, and (b) trial basis national inundation map and future plan to produce local level inundation maps.

Assessment: Dissemination of flood forecasts in the haor area is weak because no single organization has overall responsibility of disseminating flood forecasts to potential users. Thus, at present, it is not a very effective measure. Effectiveness should be assessed after completion of ongoing activities.

Potential for further interventions: Legal arrangements can be proposed to give one organization (like Union Council) overall responsibility for flood warning dissemination. However, before any further interventions, impact of on-going activities should be observed.

(4) Simplified Warning System

Simplified flood warning denotes the system that does not use computational mathematical simulation model. There can be various types of simplified warning system: (a) By using historical data employing statistical calculation, (b) Co-relating upstream water gauge levels and downstream floods, and (c) Simple visual inspection of upstream river through CCTV, etc.

Present situation: Some NGOs (as explained below) tried to apply such systems in the haor area, but without much success.

Example of Type (a): In 2009, one NGO, CNRS developed a simplified warning system based on rainfall-runoff relationship. The target areas were the haors in Tahirpur Upazila. However, it was not successful because of lack of regular and timely availability of rainfall information in the Meghalaya catchment.

Example of Type (b): Another NGO, Oxfam had some activities on early warning based on upstream water level information. But the flood damage reduction was not achieved well. Though they could issue an early warning but the lead time was short. That could not reduce the damage as enough labor force was not available for harvesting because of a short notice. It is generally considered that a 7 day lead time is required for effective crop damage reduction (ADB, 2006).

On-going and planned activities: Currently there is no activity in this regard.

Assessment: Though the simplified warning system has a lot of potential as it can be rolled out rather quickly and with a fraction of cost compared to the conventional warning system, the simplified warning system in the haor area is currently not an effective measure because all previous activities failed due to lack of proper planning, proper institutional arrangements and local people's participation.

Potential for further interventions: There are lots of potential to introduce these systems. If the lessons learned from the previous failures can be addressed with proper institutional arrangements, the simplified warning system can be a low cost and rapidly deployable option.

(5) Local Disaster Management Planning

This includes, (a) Evacuation Planning, (b) Hazard Mapping, (c) Flood Shelter, (d) Disaster Prevention Edification, (e) Seed and Food Bank, and (f) Crop Insurance.

Present situation: Response aspects of flood warning including evacuation planning are much neglected, but this can be attributed to lack of proper warning and its dissemination. However, many NGOs (like POPI, Concern, Oxfam, CNRS, etc,) are working on awareness building, local hazard mapping, seed banking and construction of multi use flood shelter. Many of their activities are funded by CDMP II. However, currently crop insurance is not available.

On-going and planned activities: Current activities include (a) simplified Community Risk Assessment (CRA) tool under CDMP II, (b) awareness building through communication materials, forming volunteer corps, inclusion of disaster management in school curricula, higher education on disaster management, training of government officials, distribution of life jackets, solar lanterns and radio sets, etc. under CDMP II, (c) planned ADB Pilot Project on Weather Index-Based Crop Insurance (Japan Fund), (d) “Multi-Hazard Risk and Vulnerability Assessments, Modeling and Mapping” by Asian Disaster Preparedness Center (ADPC) and (e) planned local level inundation maps after availability of new DEM data from on-going JICA mapping project.

Assessment: Effectiveness of this aspect is mixed. (a) For the evacuation planning/ flood disaster response system, it is much neglected and no organization is responsible for ensuring flood response. One of the reasons for such weak situation could be linked to the fact that the life loss is not a concern in the haor area. (b) At present there is no effective hazard map for the haor area. The local communities have no clear understanding about an existing flash flood management program. (c) There are few flood shelters in the haor areas. Since the human loss is not a serious issue in the haor area, government and NGOs pay less importance on the flood shelter. It was learned from the community that they do not prefer to evacuate until it is impossible to live in their houses. The common reasons for not going to the flood shelters are, the risk of looting valuable assets and resources from their houses, the shelters are not suitable for women as in many cases separate female toilet facilities are not available, and the shelters lack facilities for cattle head evacuation. (d) Though CDMP II is carrying out a disaster prevention edification and awareness building program, little success can be expected until there are good response planning, hazard mapping and flood shelters. (e) Seed bank is a new idea and needs more campaigns for wider farmers’ participation.

Potential for further interventions: Before any further interventions, impact of on-going activities should be observed.

(6) Livelihood Diversification

Heavy dependence on single crop of boro rice makes the haor people vulnerable to flood damage. The objective of livelihood diversification is flood damage reduction through (a) paddy variety diversification, (b) crop diversification, (c) job diversification, and (d) improved market access.

Present situation: These are the most widely practiced means for flood damage reduction and also these are the most successful interventions till date. Bangladesh Rice Research Institute (BRRI) developed many paddy varieties which are either early plantation type or early harvesting type or short maturation type. In addition, vegetables, potatoes and oil seeds are now possible to grow in the haor area. One special potato variety has an only 40 days maturation time, so that people can cultivate boro rice after potato harvesting.

On-going and planned activities: There are many on-going and planned projects related to livelihood diversification. Among those, examples of activities considered as successful are briefly explained below.

(a) Job diversification by beel nursery is promoted by two IFAD (an UN agency) financed LGED projects. First, Sunamganj Community Based Resource Management Project (SCBRMP) implemented beel nursery in one haor district (Sunamganj) and based on the very positive results it is replicated in Haor Infrastructure and Livelihood Improvement Project (HILIP). Beel is generally defined as the deepest part of the haor area, where water remains even in the dry season. In this scheme, government owned beels are made available to fishery groups, called “Beel User Group (BUG)” through lease agreement. The group then maintain sustainable fishing after getting proper training from the Project. This activity ensured higher production of fish and improved the livelihoods of the local fishermen community. It is estimated that around 20,000 members of the BUGs will benefit from beel nursery of which at least 20% will be women. The HILIP project thus opens up new income source of the people to compensate agricultural flood damage.

(b) Improved market access is promoted by Livelihood Protection Component of HILIP. The agricultural production system is closely linked with storage and marketing facilities. The broad objective of this component is to enhance production, diversification and marketing of crop and livestock produce. This component will develop the capacity of smallholder producers and establish and support market-based institutions. A total of 94,000 persons are expected to directly benefit from this component in the 26 project Upazilas.

Inspired by HILIP success, IFAD is now planning a new project called CALIP to replicate the HILIP model in wider areas. Livelihood will be certainly improved in the flood prone haor area with the success of these activities.

Assessment: Currently, these measures are the most effective in flood damage reduction. (a) As for the paddy variety diversification, many paddy varieties had been developed to cope with the flash flood. Because of such success, rice production in the haor area is actually increased compared to that obtained few decades ago. (b) Previously, the extents of flash flood damage was extreme as the entire haor area was dependent on single boro rice. With the introduction and promotion of vegetables, potatoes and oil seeds, now the cropping intensity is more than 1 for the haor area. (c) As explained above, through well planned IFAD projects, job diversification by beel nursery has been helping marginal poor to reduce their flash flood related damage. (d) Improved market access is an integrated approach under the IFAD projects and its success will be replicated in wider areas under a new IFAD project.

Potential for further interventions: Although a lot had been done and a lot are going on, still there are huge scopes of further intervention.

(7) Flood Proofing of Living Environment

These include raising of houses, tube-wells, latrines, stock yards, and construction of new platforms above the flood level to be used for housing purpose (new villages) and markets.

Though it involves physical construction, flood proofing is widely recognized as a Non Structural Measure. According to UNESCO Guideline, (Guidelines on Non-Structural Measures in Urban Flood Management, International Hydrological Programme -V | Technical Documents in Hydrology | No. 50, UNESCO, Paris, 2001), "Flood proofing is the use of permanent, contingent or emergency techniques to either prevent flood waters from reaching buildings and infrastructure facilities, or to minimize the damage from water that does get in.

Present situation: People are living for many generations in the haor area and thus, they adopted their living style with the normal monsoon flood. In most cases, their houses, tube wells, stock yards, cattle houses, latrines, etc. have been constructed above the normal flooding level. In this way, they can reduce the flood damage. Many people in the haor area raised their living environment either by their own means or with the support of NGOs.

One of the NGOs, POPI extended the traditional idea of raising individual houses, and came up with a new idea to construct a wide platform to be used as a market or a village (see **Photos 9.1.1 and 9.1.2**). POPI constructed 4 platforms between 2011 and 2013. All four platforms are constructed in Chatirchar Union, Nikli Upazilla in Kishoreganj District. One of them is used as a market and the rest are used as a living village. The construction was done using dredge materials extracted from the nearby river. Layers of soil was placed and then compacted by manual means. The height of the platforms was 11 feet.

On-going and planned activities: In the three POPI constructed habitat platforms, the land was given under a lease agreement to the homeless people for 10 years without any ownership right. The priority was given to those who lost their homes due to erosion, female headed family, family with no agricultural land, and very poor. In the 3 living villages, a total of 250 families got rehabilitated. Each family got a land parcel of 25 ft X 15 ft. In the market platform, land was given to existing small shop keepers and the marginal poor.

With the success of POPI, now BWDB is planning to replicate the new platform construction by including this in their Kalni-Kushiara Dredging project. If implemented, this will open up new opportunities.

Assessment: The flood proofing of living environment can be said as an effective measure against flood damage. (a) Almost all households in the haor area and their essential facilities like tube wells, latrines, stock yards are constructed or raised above the normal monsoon flood levels. Because of this approach, people can live in the haor area even when water inundates the mounds. This is the single most important measure against flood damage to save life, cattle, and valuable belongings. (b) The construction of new platform can also be a useful measure. This provides new usable land for living. The demand of habitat land is high because of population growth and land erosion.

Potential for further interventions: Before any further interventions, impact of on-going activities should be observed.

Source POPI

Photo 9.1.1 Construction of New Platform in Nikli Upazilla, Kishoreganj (1/2)

Source: JICAStudyTeam

Photo 9.1.1 Construction of New Platform in Nikli Upazilla, Kishoreganj (2/2)

(8) Participatory Water Resources Management

This is not an independent non structural measure; rather it is an alternate approach to ensure proper O&M of the structural flood measures to ensure flood damage reduction. Under this approach, stakeholders/ beneficiaries are involved in O&M procedure.

Present situation: (a) The Small Scale Water Resources Development (SSWRD) Projects of LGED organizes Water Management Cooperative Association (WMCA) for the participatory operation and management of the facilities. Initially it was funded by ADB and later JICA started funding. (b) Concern, an international NGO, used the participatory approach to carry out village protection works from wave action in 21 mounds (mounds are effectively like islands during the wet season). Concern organized a cooperative society in the target village and the society created a maintenance fund upfront. The beneficiaries also contributed all labor required for the construction. After the completion, the ownership was transferred to the village cooperative society and they took over responsibilities for all kinds of maintenance.

On-going and planned activities: (a) The SSWRD Projects of LGED will continue following the participatory approach and it is expected that more than 1,000 WMCAs will be formed before 2017, and (b) BWDB now is doing a pilot under the WB funded WMIP project to form Water Management Association (WMA) in order to hand over the O&M activities. If successful, this will lead to major improvement in BWDB’s O&M.

Assessment: (a) As mentioned above, LGED’s SSWRD is considered generally as a successful model according to LGED’s internal monitoring. Some problems were identified and future projects are expected to address those. (b) According to Concern, in the past 5 years, there were 2 cases of collapse out of their 21 sub projects; however, the villagers successfully reconstructed those without any assistance from Concern. Thus, the participatory model is considered successful.

Potential for further interventions: Before any further interventions, impact of on-going activities should be observed.

9.2 Non-structural Measures Effective for Haor Area

Based on the above discussion in Section 9.1, it can be inferred that the non-structural measures effective for the haor area are (1) Local disaster management planning, (2) Livelihood diversification, (3) Flood proofing of living environment, and (4) Participatory water resources management. In this Section, conceivable future projects under these 4 measures are examined and potential projects for JICA cooperation are identified.

9.2.1 Conceivable Projects

(1) Local Disaster Management Planning

As mentioned in the previous section, many organizations are now working in various sub-sectors under this measure. An overview of the on-going and planned projects is given below. Details can be found in **Annex 9-1**.

Table 9.2.1 Rationale for Intervention Possibility on Local Disaster Management Planning

Sub sector	On-going and planned projects	Implication and interventions possibility
Response System/ Evacuation Planning	a. Establishment of National Disaster Management Training and Research Centre (CDMP II) b. Establishment of National Disaster Management Volunteer Corps (CDMP II) c. Utilization of Fast Tracked Risk Assessment (FTRA) at the local administration level to produce the Risk Reduction Action Plans (RRAPs) (CDMP II).	In 2012, 242 unions have gone through the FTRA/review of RRAP process. The CDMP II target is to cover 1,780 unions. Evaluation of current approach is required before conceiving new interventions.
Hazard Mapping	a. Local community led hazard mapping on a country wide basis (funded by CDMP II, implemented with NGOs) b. "Multi-Hazard Risk and Vulnerability Assessments, Modeling and Mapping in Bangladesh" (funded by Norway, implemented by Asian Disaster Preparedness Center (ADPC), expected to complete by May 2014)	Evaluation of current approach is required before conceiving new interventions.
Flood Shelter	No concrete planning exists	A flood shelter is not an essential requirement thanks to local flood characteristics. Even the existing facilities are not very popular. A user friendly flood shelter is required. If combined with other use like storage and market, it can enhance economic activities.

Sub sector	On-going and planned projects	Implication and interventions possibility
Edification and awareness building	a. Providing life jackets, solar lanterns and radio sets (CDMP II) b. Disaster management education is provided during the preparation of local Community Risk Assessment (CRA) (CDMP II) c. Introduction of disaster management in school text books (CDMP II) d. Bangladesh and English versions of the Introduction to Disaster Management (IDM) and Comprehensive Disaster Management (CDM) modules are now accessible at http://elearning.cdmp.org.bd. (CDMP II) e. 1 million posters, 50 thousand leaflets and other communication materials are published and distributed to schools countrywide (CDMP II) f. Training Ansar and VDP (two local level Community Police force) as flood management volunteers (CDMP II)	Evaluation of current approach is required before conceiving new interventions.
Seed Bank and Food Bank	Some NGOs are trying the approach as a trial basis.	A systematic and well planned pilot study is required.
Flood Damage/ Crop Insurance	a. "Pilot Project on Weather Index-Based Crop Insurance TA - 46284" will be implemented by Asian Development Bank (ADB) under a grant of $2 million from Japan	Evaluation of the pilot study is required before conceiving new interventions.

Source: JICA Study Team

Thus, the conceivable projects in this measure are as follows,

- Planning and implementation of user friendly flood shelter cum market, and
- Pilot study on seed bank and food bank

(2) Livelihood Diversification

As mentioned in the previous section, this measure can be considered to be the most effective for flood damage reduction in the haor area. Many organizations are now working in various sub-sectors under this measure. An overview of the on-going and planned projects is given below. Details can be found in **Annex 9-1**.

Table 9.2.2 Rationale for Intervention Possibility on Livelihood Diversification

Sub sector	On-going and planned projects	Implication and interventions possibility
Paddy variety diversification	Bangladesh Rice Research Institute (BRRI) developed many hybrid varieties. For example, short maturation type BR-28 (140 days), high yield type BR-29 (7.5 t/ha), early harvesting type BR-45 (early April), etc.	BR-45 suffers from shattering (falling off the grains during harvesting) and BR-29 cannot withstand in very cold temperature. Further research is required.
Crop diversification	Department of Agricultural Extension (DAE) and some NGOs are promoting vegetables, potatoes, oil seeds, grass and bamboo cultivation before Boro rice. DCRMA (Disaster and Climate Risk Management in Agriculture) is a component of CDMP-II, being implemented since 2011 by DAE. DCRMA has project activities on crop diversification, integrated farming, adaptive farming, farmers' capacity building, etc. in 4 Haor districts (Habiganj, Netrokona, Sunamganj and Moulovibazar).	There are scopes of projects similar to DCRMA.
Job diversification	a. To improve the livelihood of haor communities and to reduce the flood damage impact, beel nursery activities were undertaken by LGED with funding from UN agency International Fund for Agricultural Development (IFAD). There are 2 successful projects, namely Sunamganj Community Based Resource Management Project (SCBRMP) and Haor Infrastructure and Livelihood Improvement Project (HILIP). b. The HILIP proposed to provide training and capital support for income generating activities mainly for women on cottage industries based on agro-products. c. Livelihood Protection Component of HILIP will develop the capacity of smallholder producers to participate in selected market-based value chains and establish and support market-based institutions.	The target beneficiaries of "beel nursery" are 90,000 farmers under SCBRMP and 688,000 households under HILIP. Because of the success of these projects, now IFAD is forming a new project called Climate Resiliendce and Livelihood Improvement Project (CALIP) to expand the coverage. A total of 94,000 persons are expected to directly benefit from Livelihood Protection Component in the 26 project Upazilas. Though a lot is going on, still there is room for further extension.

Source: JICA Study Team

Thus, the conceivable projects in this measure are as follows:

- Research on developing paddy variety to sustain flash flood related damage,
- Flash flood resilient agricultural diversification with improved market access, and
- Extension of Beel Nursery.

(3) Flood Proofing of Living Environment

As mentioned in the previous section, this is an effective measure against flood damage. An overview of the on-going and planned projects is given below. Details can be found in **Annex 9-1**.

Table 9.2.3 Rationale for Intervention Possibility on Flood Proofing of Living Environment

Sub sector	On-going and planned projects	Implication and interventions possibility
Raising of habitat area	Most households raise their habitats above the normal flood level for generations. Most people do this by their own or sometimes borrowing money.	This is a traditional activity and suitable for NGOs to support.
Raising of villages and new platform construction	a. Some NGOs are carrying out this activity but not in a coordinated way. b. Kalni-Kushiara Dredging Project (GOB) includes this activity using the dredge materials.	New villages and markets were reclaimed and landless families were settled. Good use of dredge material. New land can be created if combined with wave protection works.

Source: JICA Study Team

Thus, the conceivable projects in this measure are as follows:

- Raising of villages and new platform construction in conjunction with dredging and village wave protection works.

(4) Participatory Water Resources Management

As mentioned in the previous section, this is not an independent non-structural measure; rather it is an alternate approach to ensure proper O&M of the structural flood measures to ensure flood damage reduction. Trials and pilot scale studies have been completed, on-going or planned on 3 models. An overview is given below. Details can be found in **Annex 9-1**.

Table 9.2.4 Rationale for Intervention Possibility on Participatory Water Resources Management

Sub sector	On-going and planned projects	Implication and interventions possibility
WMIP model (participatory O&M, but no asset transfer)	Water Management Improvement Project (WMIP) is an on-going project of BWDB funded by the World Bank and the Netherlands government expected to be completed by 2015. It will define the role of communities in water resources management projects.	Vital for BWDB's future management strategy. Evaluation of the current approach is required before conceiving new interventions.
LGED model (asset transfer, but follow up support)	Small Scale Water Resources Development Projects of LGED (funded by ADB and JICA) organized Water Management Cooperative Association (WMCA) for the operation and management of the small scale facilities. The implementation started from mid 2000 and is currently expected to be continued till 2017.	This LGED model is generally considered to be successful. However, current implementation is trying to address encountered problems. Evaluation of the current approach is required before conceiving new interventions.

Sub sector	On-going and planned projects	Implication and interventions possibility
"Concern" model (asset transfer without follow up support except training)	Concern, an international NGO based in Ireland carried out 21 sub projects in haor area for village protection from wave action with the financial assistance from Irish Aid and European Commission. The project was implemented between October 2006 and December 2011.	According to Concern, in the past 5 years, there were 2 cases of collapse out of the 21 sub projects; however, the villagers successfully reconstructed those without any assistance from Concern. The model is generally considered to be successful.

Source: JICA Study Team

Thus, evaluation of the current approvaches employed in the WMIP and LGED models is required before conceiving future projects.

9.2.2 Potential Projects for JICA cooperation

The conceivable future projects under non-structural flood measures for the haor area are identified in the previous sub-section and listed below.

- Planning and implementation of user friendly flood shelter cum market
- Pilot study on seed bank and food bank
- Research on developing paddy variety to sustain flash flood related damage
- Flash flood resilient agricultural diversification with improved market access
- Extension of Beel Nursery
- Raising of villages and new platform construction in conjunction with dredging and village wave protection works

Although each of the above projects can significantly contribute towards flood related damage reduction, not all projects are suitable for JICA cooperation. In this section, suitability for JICA cooperation is examined for each project listed above. It may be mentioned that even a project is not suitable for JICA cooperation, GOB should implement these from other financial sources. Table 9.2.5 below shows the suitability for JICA undertaking and thus picks up potential projects for JICA cooperation.

Table 9.2.5 Suitability Analysis of Conceivable NSM Projects for potential JICA Cooperation

Conceivable NSM Projects	Suitability Analysis	Suitable for JICA Cooperation
Planning and implementation of user friendly flood shelter cum market	Should be combined with schools, hospitals or markets for better efficiency. In case of market and storage option, it will enhance economic activity.	yes
Pilot study on seed bank and food bank	Technical Assistance / Study	yes
Research on developing paddy variety to sustain flash flood related damage	BRRI has extensive expertise and working closely with International Rice Research Institute, Manila (IRRI). Less scope for JICA.	no

Conceivable NSM Projects	Suitability Analysis	Suitable for JICA Cooperation
Flash flood resilient agricultural diversification with improved market access	Should be combined with transport of harvest, storage, and market linkage for enhancement of economic activity and livelihood improvement	yes
Extension of Beel Nursery	Should be combined with transport of harvest, storage, and market linkage for enhancement of economic activity and livelihood improvement	yes
Raising of villages and new platform construction in conjunction with dredging and village wave protection works	Maximum benefit could be obtained if combined with river dredging project. However, the river dredging component is not included in the cooperation scope.	no

Source: JICA Study Team

Thus, the potential NSM projects for JICA cooperation are enumerated as follows,

- NSM-1: Planning and implementation of user friendly flood shelter cum market
- NSM-2: Pilot study on seed bank and food bank
- NSM-3: Flash flood resilient agricultural diversification with improved market access
- NSM-4: Extension of Beel Nursery

The brief outline of the 4 NSM projects are as provided below.

(1) NSM-1: Planning and implementation of user friendly flood shelter cum market

1) Project location: Five deep Hoar districts.

2) Objectives: To provide opportunities for taking shelters in case of extreme flood events. This can act also as facilities for communal storage of harvest and market.

3) Major Components: Essentially, the shelters are multi storied reinforced concrete frame structures. There must be separate toilet facilities for women. Also, it would be better to have separate women and children’s rooms. There should be areas marked for cattle and poultry; and the staircases must be wide so that cattle can use those. In normal times, the structure can be used as a weekly market (known as ‘hat’). Also, during the harvest period, the place can be used as a temporary storage and processing area. Road connection should be one component to ensure dry season use. Also, few boats should be another component of each shelter to facilitate evacuation.

4) Benefited areas/beneficiaries: All five deep haor districts will be benefitted.

5) Expected execution agency: Implementation is to be done by LGED. Management and maintenance is to be done by local beneficiary groups.

6) Urgency of JICA Cooperation: Medium.

(2) NSM-2: Pilot study on seed bank and food bank

1) Project location : A few upazillas.

2) Objectives: To plan a scheme of seed bank and food bank tailored to local conditions, implement a pilot study, and evaluate possibility of replication.

3) Major Components: In the first step, based on international and national experiences, prepare a plan appropriate for haor conditions. In the second step, a two season pilot study is to be carried out. In the last step, evaluation is to be done and modification is to be proposed for successful full scale implementation.

“Community Food Bank (CFB)” is an idea where buffer stock of food grains is built up at a community level to provide food against seasonal deficits in the lean months (mid-September to mid-November) or during disaster periods. The CFB will keep deposit of food from the beneficiaries and return back it during the crisis period. The depositors may withdraw their food in terms of cash and have the provision in getting interest. Branches can be set up in villages and a central storage is required which may be set up at the upazila level.

After a major flood, usually there is a scarcity of seed. To overcome this problem, there should be some facilities to maintain seed security stock.

4) Benefited areas/beneficiaries: This is a pilot study.

5) Expected execution agency: Department of Agricultural Extension (DAE) in cooperation with local NGOs.

6) Urgency of JICA Cooperation: Medium.

(3) NSM-3: Flash flood resilient agricultural diversification with improved market access

1) Project location: Five deep hoar districts.

2) Objectives: To promote paddy and crop diversification in a way to reduce flash flood related agricultural damages, and to facilitate with storage, transport and forward market linkage.

3) Major Components: It can be modeled based on CDMP II supported "Disaster and Climate Risk Management in Agriculture" (DCRMA) and Livelihood Protection Component of HILIP.

This will have several components. The first component will have activities on crop diversification, integrated farming, adaptive farming, and farmers' capacity building.

Agricultural production system is closely linked with storage and marketing facilities. The inaccessibility of these facilities makes it difficult for farmers to get reasonable prices for their produce. Most of the farmers sell their products in village markets immediately after harvesting when prices are typically low. The producers are then frequently obliged to replace this food grain at higher prices to meet daily consumption requirements during the off-season.

Thus, the second component of the project includes establishment of regulated markets, construction of warehouses, provision for grading of crop quality, standardization of produce, standardization of weight and measures, daily broadcasting of market prices, and improvement of transport facilities. This component will develop the capacity of smallholder producers to participate in selected market-based value chains and establish and support market-based institutions.

4) Benefited areas/beneficiaries: All five deep haor districts will be benefitted.

5) Expected execution agency: Implementation is to be done by LGED in cooperation with DAE. Management and maintenance is to be done by local beneficiary groups.

6) Urgency of JICA Cooperation: Urgent.

(4) NSM-4: Extension of Beel Nursery

1) Project location: Five deep Hoar districts.

2) Objectives: To improve livelihood of haor fishermen communities by increasing haor fish production in beel areas.

3) Major Components: It can be modeled based on Community Resources Management Component of HILIP.

"Beel" is generally defined as the deepest part of a haor, where water remains in the dry season. In this scheme, government owned beels are made available to fishery groups through lease agreement. The groups then maintain sustainable fishing after getting proper training from the Project.

4) Benefited areas/beneficiaries: All five deep haor districts will be benefitted.

5) Expected execution agency: Implementation is to be done by LGED in cooperation with Department of Fisheries. Management and maintenance is to be done by local beneficiary groups.

6) Urgency of JICA Cooperation: Urgent.

CHAPTER 10 FLOOD CONTROL AND RIVER MANAGEMENT PROJECTS UNDER JICA ASSISTANCE

10.1 Proposal of JICA Cooperation Projects

The Study selected the following structural and non-structural measures as the priority projects for flood measures and river management plan in the haor areas:

(1) Structural measures

(1-1) Pre-monsoon Flood Protection and Drainage Improvement Project in Haor Areas (rehabilitation and new development of haor projects, hereinafter referred to as "the Haor Project")

(1-2) Dredging Project in the Surma-Baulai Rivers

(2) Non-structural measures

(2-1) Flash Flood Resilient Agricultural Diversification with Improved Market Access

(2-2) Extension of Beel Nursery

The "JICA Country Analysis Paper (Bangladesh)" has set forth a development issue of "Disaster Management and Climate Change Measures" to be dealt with in a cooperation priority sector of Overcoming social vulnerability and laid down a policy of cooperation aiming at the following:

- Reduction of economic damage and injuries due to natural disaster in Bangladesh which is one of the most vulnerable countries to natural disaster,
- Development of administration/community systems and infrastructure which may well endure the natural disaster in consideration of climate change impacts as well

The above priority projects are in harmony with this policy. However, it is pointed out that periodical maintenance dredging after capital dredging would be essential for securing continuous dredging effects in the case of the Surma-Baulai Rivers and hence it is rather difficult to draw a clear line in the respect of project effects between the capital dredging to be executed in the Project of (1-2) and the maintenance dredging to be repeated after the (1-2).

Therefore, the Study has proposed three priority projects excluding the (1-2) as possible JICA cooperation projects.

The project design of the above non-structural measures is to be entrusted to the ongoing JICA study entitled "Preparatory Survey on Upper Meghna River Basin Watershed Management Improvement Project in the People's Republic of Bangladesh", and this Chapter explains hereinafter the contents of the structural measures (1-1).

10.2 Contents of JICA Assistance Projects

(1) Project Area

The project area is located in the Sunamganj, Kishorganj, Haniganj and Brahmanbaria districts. **Figure 10.2.1** shows the location map of the sub-projects in the project area.

(2) Objectives of the Project

The objectives of the project are as follows;

1) Protect the boro rice during the harvesting period and the fish cultivation from flash floods during the pre-monsoon season in the haor area,
2) Improve the flow capacity of the drainage channel in the haor area,
3) Enhance the productivity of the agriculture including the crop diversification and fishery,
4) Improve the boat transportation of the people in the haor area, and
5) Secure the sustainability of the project in order to maintain a new O&M system related to flood control structures.

(3) Main Activities

The Project consists of i) the rehabilitation of existing haor projects and ii) the construction of new haor projects. Both components include following issues:

- Detailed design and environmental impact assessment related to the projects are carried out,
- Rehabilitation works and new construction of the submergible embankment, regulators, and sluices, and removal of the sedimentation material in the drainage, and
- The capacity development of O&M for flood control structures and the community level organization including the formulation of sustainable O&M organization are carried out.

(4) Beneficiary Area and Beneficiaries

The beneficiary area and the beneficiaries are as follows:

i) Rehabilitation of existing haor projects
Beneficiary area: 84,400 ha
Beneficiaries[1]: 798,000 persons

ii) Construction of new haor projects
Beneficiary area: 63,500 ha
Beneficiaries: 543,000 persons

iii) Total
Beneficiary area: 147,900 ha
Beneficiaries: 1,341,000 persons

[1] Number of beneficiaries is composed of direct and indirect ones.

(5) Executing Agency

Bangladesh Water Development Board (BWDB)

(6) Implementation Schedule

A total of 37 sub-projects (15 for rehabilitation and 22 for new construction) are selected for the Haor Project, as compiled in **Table 10.2.1**. Since the 37 sub-projects are widely scattered over the haor areas (see **Figures 10.2.1 and 10.2.2**), it is proposed to implement these sub-projects stepwise under the Haor Project through phasing.

In additions, it is proposed that the sub-projects be divided into two groups for rehabilitation and new construction, respectively so as to realize higher efficiency of construction works and reduction of construction costs, taking into account (i) the geographical position of each sub-project (in particular, the right or left side of the Surma - Baulai Rivers, which is anticipated to be a constraint of smooth filed activities in hauling and movement of construction materials and equipment) and (ii) a planned construction period (five years on the assumption of implementation as a yen-loan project). The proposed grouping of the sub-projects is also presented in **Table 10.2.1**.

The implementation priority of each group has been examined in the Study from the viewpoint of economical efficiency of project, with the index of "expected average annual reduction of flood damage ("annualized expected benefit: B")/direct construction cost: C. Since most of the areas to be protected from flash floods by the submergible embankment in the Haor Project have been used for boro rice cultivation in the pre-monsoon season, the annualized expected benefit: B is estimated on the assumption that the unit yield (the boro rice yield per hectare) is the same in the haor areas (see **Section 7.2**).

Table 10.2.1 Grouping of Sub-projects in the Haor Project

	Sub-project name	Location	Group	
i) Rehabilitation of existing haor projects			**R-rgt**	**R-lft**
R-1	Dampara Water Management Scheme	Upazila : Purbodhola District : Netrakona	●	
R-2	Kangsa River Scheme	Upazila : Sadar, Purbodhola District : Netrakona	●	
R-3	Singer Beel Scheme	Upazila : Barhatta District : Netrakona	●	
R-4	Baraikhali Khal Scheme	Upzila : Nandail, Hosenpur Kishoreganj Sadar District : Mymensingh, Nandail, Kishoreganj.	●	
R-5	Alalia-Bahadia Scheme	Upzila : Katiadi, Pakundia District : Kishoreganj	●	
R-6	Modkhola Bhairagirchar sub-project Scheme	Upzila : Pakundia,Katiadi District : Kishoreganj	●	
R-7	Ganakkhalli Sub-scheme	Upzila : Kuliarchar District : Kishoreganj	●	
R-8	Kairdhala Ratna Scheme	Upzila : Ajmiriganj, Baniachong District : Habiganj		●
R-9	Bahira River Scheme	Upzila : Ajmiriganj, Baniachong District : Habiganj		●
R-10	Aralia Khal Scheme	Upzila : Baniachong District : Habiganj		●
R-11	Chandal Beel Scheme	Upzila : Bancharampur District : Brammanbaria		●
R-12	Satdona Beel Scheme	Upzila : Bancharampur District : Brammanbaria		●
R-13	Gangajuri FCD Sub-project	Upazila : Bahubol, Baniachong & Sadar District : Habiganj		●
R-14	Kaliajuri Polder #02 Scheme	Upazila : Kaliajuri District : Netrakona		●
R-15	Kaliajuri Polder #04 Scheme	Upazila : Kaliajuri District : Netrakona	●	
ii) Development of new haor projects			**N-rgt**	**N-lft**
N-1	Boro Haor Project (Nikli)	Upazila: Karimganj, Katiadi, Kishoreganj Sadar, Nikli District : Kishorganj	●	
N-2	Naogaon Haor Project	Upazila: Itna, Karimganj, Mithamain, Nikli District : Kishorganj	●	
N-3	Jaliar Haor Project	Upazila: Chhatak District : Sunamganj		●
N-4	Chandpur Haor Project	Upazila: Katiadi, Nikli District : Kishorganj	●	
N-5	Dharmapasha Rui Beel Project	Upazila: Dharmapasha, Kalmakanda, Barhatta, Mohanganj District : Sunamganj/Netrokona	●	
N-6	Suniar Haor Project	Upazila: Tarail District : Kishorganj/Netrokona	●	
N-7	Badla Haor Project	Upazila: Itna, Karimganj, Tarail District : Kishoreganj	●	
N-8	Nunnir Haor Project	Upazila: Bajitpur, Kariadi, Nikli District : Kishorganj	●	
N-9	Dakhshiner Haor Project	Upazila: Ajmirganj, Itna, Mithamain District : Kishorganj		●
N-10	Chatal Haor Project	Upazila: Tarail, Itna, Madan District : Kishorganj	●	
N-11	Ganesh Haor Project	Upazila: Madan, Atpara District : Netrokona	●	
N-12	Dhakua Haor Project	Upazila: Dakshin, Sunamganj, Jamalganj, Sunamganj Sadar District : Sunamganj		●
N-13	Mokhar Haor Project	Upazila: Habiganj Sadar, Baniachanpur, Ajmirganj District : Habiganj		●
N-14	Noapara Haor Project	Upazila: Austagram, Karimganj, Nikli District : Kishorganj	●	
N-15	Dulapur Haor Project	Upazila: Bajitpur District :Kishorganj	●	
N-16	Sarishapur Haor Project	Upazila: Bajitpur District : Kishorganj	●	
N-17	Bara Haor (Kamlakanda)	Upazila: Kamlakanda, Dharmapasha District : Netrokona	●	
N-18	Bansharir Haor Project	Upazila: Kendua, Madan District : Netrokona	●	
N-19	Korati Haor Project	Upazila: Kalimganj, Nikli Distric t :Kishorganj	●	
N-20	Shelnir Haor Project	Upazila: Nasirnagar District : Habiganj/Bramanbaria		●
N-21	Kuniarbandh Haor Project	Upazila: Bajitpur, Kuliar Char District : Kishorganj	●	
N-22	Ayner Gupi Haor*	Upazila: Austagram, Bajitpur District : Kishorganj	●	

Note: * grouped into "N-rgt" exceptionally due to its location
Source: JICA Study Team

As shown in **Table 10.2.2** explaining the results on economic efficiency (B/C) of project by group, the group on the right side has a higher B/C and hence priority for implementation in each case of i) rehabilitation and ii) new construction.

Table 10.2.2 Analysis on Economic Efficiency/Priority for the Haor Projects

Group name	Annualized expected benefit: B	Direct construction cost: C (mil. BDT)	B/C	Priority	Phase
i) Rehabilitation of existing haor projects					
R-rgt	5,356	87	61.56	1	Ph-1
R-lft	4,342	222	19.56	2	Ph-2
Sub Total	9,698	309			
ii) Development of new haor projects					
N-rgt	3,576	3,825	0.93	1	Ph-1
N-lft	983	1,558	0.63	2	Ph-2
Sub Total	4,559	5,383			
Ground Total	**14,257**	**5.692**			

Source: JICA Study Team
Note: rgt/lft=right/left side of the Surma-Baulai River

Besides, an examination with several indices related to urbanization and properties was carried out, as compiled in the follow table, which presents the right side area has a higher value of each index and exceeds in the respects of urban population, agricultural products and economic activity level compared to the left side.

	Indices	Right (R)	Left (L)	R/L
(1) Urbanization	Urban population (people)	697,928	274,424	2.54
	Urbanization rate* (%)	15.85	10.88	1.46
(2) Properties				
- Agricultural products	Net cultivated area (ha)	304,846	180,370	1.69
	Rate of net cultivated area** (%)	64.00	55.43	1.15
	Crop intensity	1.39	1.28	1.09
- Economic activities	Labor wage rate (BDT/person/day)			
	Male	250	216	1.16
	Female	201	158	1.27
	Crop production (Boro rice total: ton)	877,219	459,470	1.91
	Fish production (ton)	115,862	51,270	2.26

Note: * Urban population/Total population, ** Net cultivated area/Total area
Sources：
1. POPULATION AND HOUSING CENSUS 2011, SOCIO-ECONOMIC AND DEMOGRAPHIC REPORT, NATIONAL SERIES, VOLUME – 4, Bangladesh Bureau of Statistics (BBS)
2. POPULATION AND HOUSING CENSUS 2011, Community Report, BBS
3. 2011 Yearbook of Agricultural Statistics, BBS
4. Statistical Yearbook of Bangladesh 2010, BBS
5. Statistical Pocket Book 2010, BBS
6. Census of Agriculture 2008

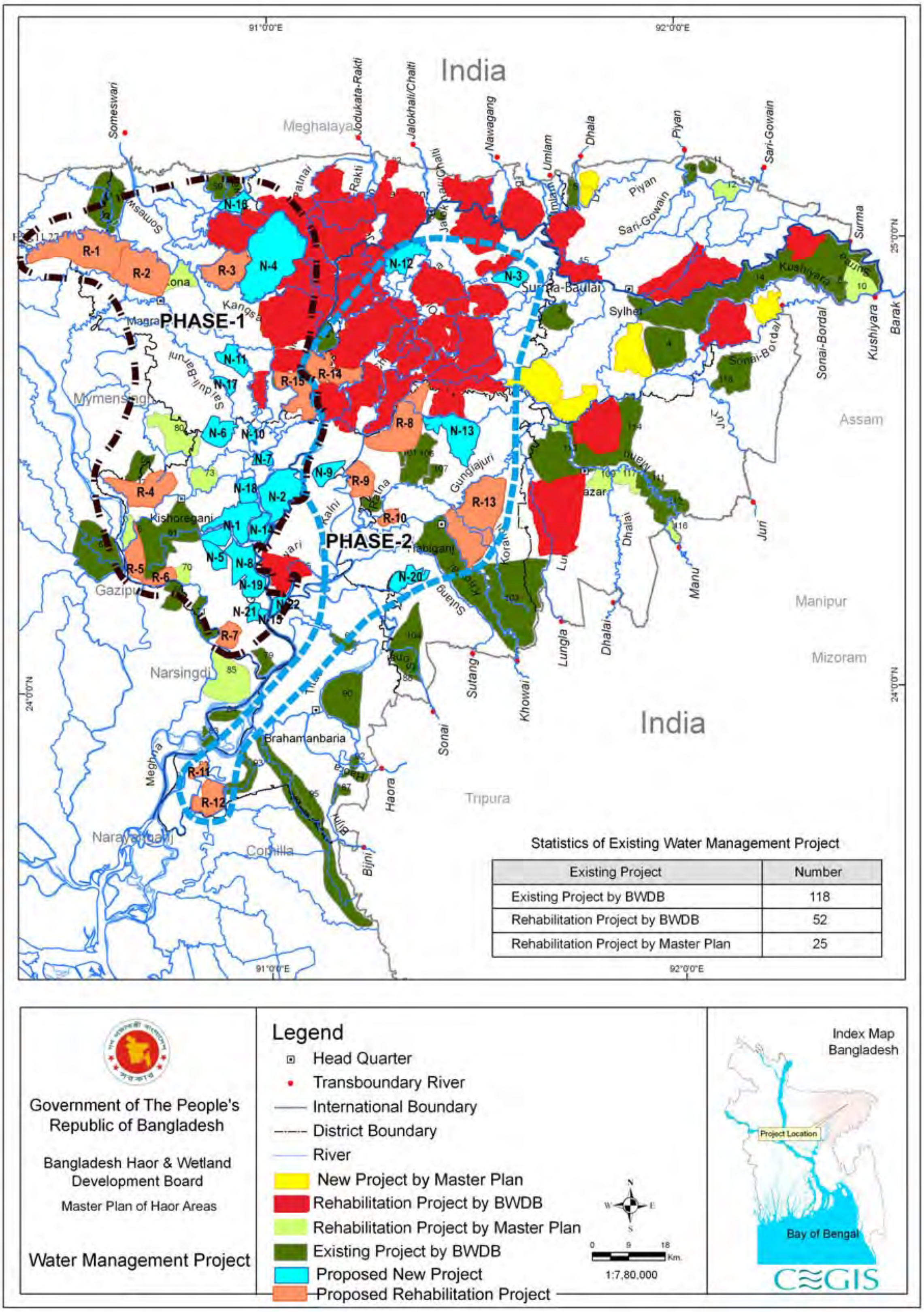
Source: JICA Study Team
Note: Analysis on Upazilla where rehabilitation and new development projects are situated

In due consideration of the above analysis and examination results, it is proposed the Haor Project be implemented in the order of Phase -1 and Phase -2 with a combination of groups presented in **Table 10.2.3 and Figure 10.2.1**.

Table 10.2.3 Phasing of the Haor Project

Phase	i) Rehabilitation	ii) New construction
Phase - 1	R-rgt	N-rgt
Phase - 2	R-lft	N-lft

Source: JICA Study Tam
Note: rgt/lft = right/left side of the Surma-Baulai Rivers



Statistics of Existing Water Management Project

Existing Project	Number
Existing Project by BWDB	118
Rehabilitation Project by BWDB	52
Rehabilitation Project by Master Plan	25

Source：JICA Study Team

Figure 10.2.1 Proposed Phasing of Haor Project

(7) Project Cost

1) Estimation Conditions

(a) Exchange Rate

- USD 1= JPY 99.7
- USD 1= BDT 77.8
- BDT 1 = JPY 1.28

(b) Price Escalation

- Foreign Currency 1.3% per year
- Local Currency 3.4% per year

(c) Physical Contingency

- 5% per year

(d) Price Level July, 2013

(e) Consulting Service

- Base cost is assumed at 10% of the direct construction cost

(f) Administration Cost

- Base cost is assumed at 5% of the total project cost,

(g) Construction interest payment is not considered,

(h) The tax considered is only the value added tax (VAT), and

(i) The construction period is set at 5 years.

2) Assumed Implementation Schedule to Estimate the Project Cost

The assumed implementation schedule in estimating the project cost is considered based on the International Competitive Bid (ICB) as shown in **Table 10.2.4**.

Table 10.2.4 Assumed Implementation Schedule

Issues	Period
Selection of Consultant	10 months
Detailed Design	18 months
Preparation of Prequalification documents and Tender documents	3 months
Prequalification, evaluation and concurrence from JICA for Phase I	3 months
Bidding for Phase I	2 months
Bid evaluation for Phase I	2 months
Concurrence from JICA for Phase I	1.5 months
Concurrence from Purchase Committee for Phase I	1.5 months
Contract negotiation for Phase I	1.5 months
Validation by Ministry of Law, Justice and Parliamentary Affairs for Phase I	1 month
Concurrence from JICA for Phase I	0.5 month
L/C open and L/Com issue for Phase I	1 month
Construction period in Phase I	36 months
Prequalification, evaluation and concurrence from JICA for Phase II	3months
Bidding for Phase II	2 months

Issues	Period
Bid evaluation for Phase II	2 months
Concurrence from JICA for Phase II	1.5 months
Concurrence from Purchase Committee for Phase II	1.5 months
Contract negotiation for Phase II	1.5 months
Validation by Ministry of Law, Justice and Parliamentary Affairs for Phase II	1 month
Concurrence from JICA for Phase II	0.5 month
L/C open and L/Com issue for Phase II	1 month
Construction period in Phase II	24 months

Source: JICA Study Team

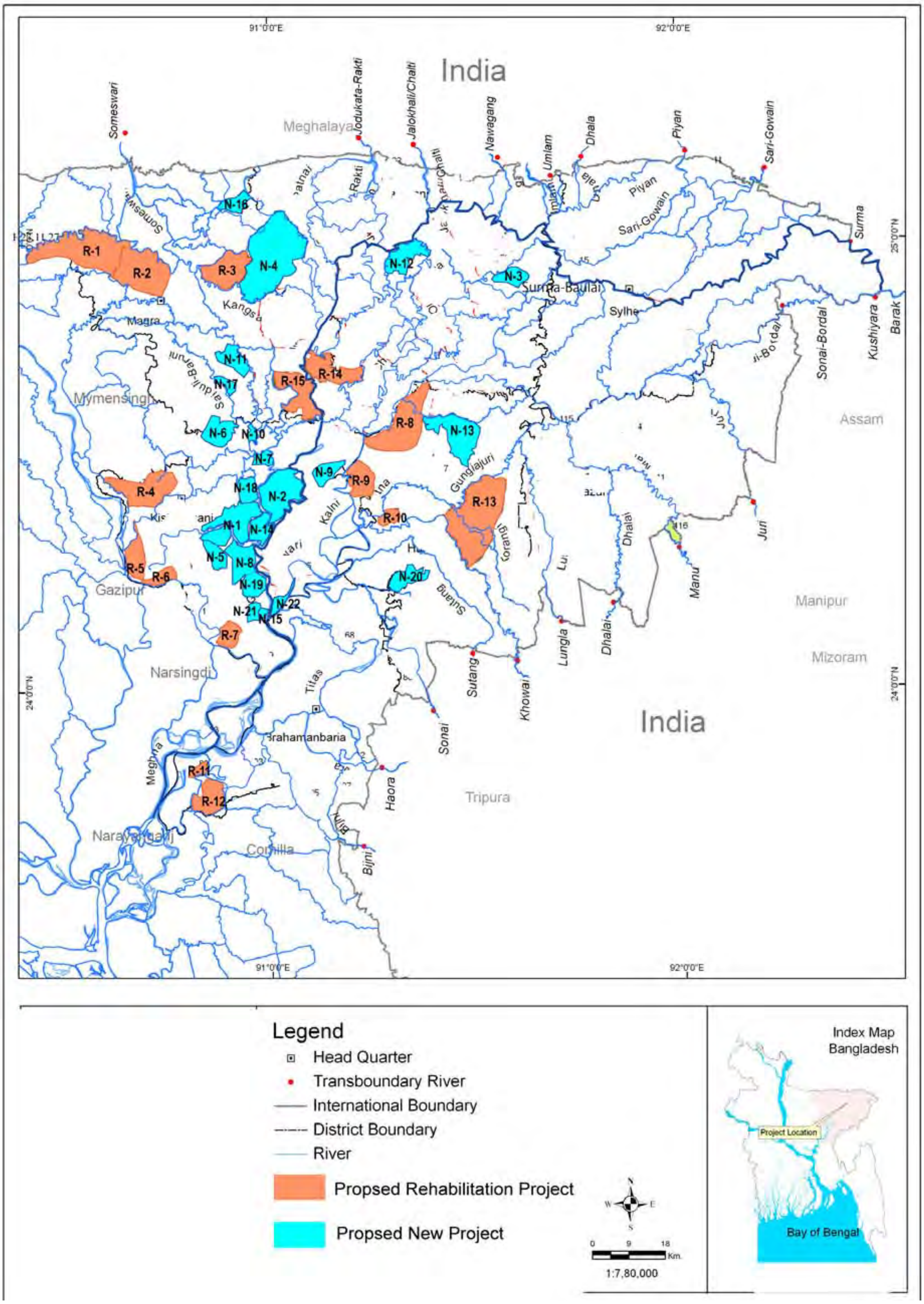
3) Project Cost

The project consists of 15 rehabilitation projects and 22 new haor projects as shown in **Figure 10.2.2**. The project cost is shown in **Table 10.2.5**.

Table 10.2.5 Project Cost

Items	F/C (mil. J. Yen)	L/C (mil. BDT)	Total (mil. J. Yen)
1) Flood control measures	0	5,692	7,286
2) Price escalation	0	1,294	1,656
3) Physical contingency	0	348	445
4) Consulting services	590	217	868
5) Land acquisition cost	0	4,767	6,102
6) Administration cost	0	966	1,236
7) Tax (VAT)	0	2,062	2,639
Grad Total	590	15,346	20,233

Source: JICA Study Team



Source: JICA Study Team

Figure10.2.2 Location Map of Project

CHAPTER 11 CONCLUSIONS AND RECOMMENDATIONS

The haor areas (covering about 8,500 km^2), which extend in the upper Meghna area and are located in the Northeast Region of Bangladesh, have been supporting the regional economy as a food basket during the dry season and a rich fishery during the rainy season. However, the haor areas have suffered from serious flood damage due to (i) flash floods brought about by river waters coming from the hilly areas in the Indian territory during pre-monsoon seasons (which are counted as one of the heaviest rainfall zones in the world), and (ii) long-term flood inundation during the monsoon season. Particularly in a pre-monsoon season, the haor areas sustain serious boro rice damage due to flash floods which occur every two to three years.

The Bangladesh Haor and Wetland Development Board (BHWDB) formulated “Master Plan of Haor Areas (the M/P)” in April 2012 as a comprehensive development plan of the haor areas for the next 20 years. The M/P is to be positioned as an overarching plan and a base of formulation/implementation for future JICA cooperation in the haor areas. The M/P has worked out priority projects through: (i) problem/issue analysis and (ii) reflecting the peoples’ needs clarified through a participatory approach. However, it was pointed out that project impacts on the upstream and/or downstream areas after project implementation are not necessarily verified in the M/P yet.

In such a situation, the Study conducted (i) review of the M/P and (ii) basic study to supplement the M/P. The JICA Study Team has proposed the following structural and non-structural measures as possible JICA cooperation projects for flood measures and river management plan in the haor areas (refer to “**Chapter 10**”):

(1) Structural measures

- Pre-monsoon Flood Protection and Drainage Improvement Project in Haor Areas (rehabilitation and new development of haor projects), hereinafter referred to as “the Haor Project”

(2) Non-structural measures

- Flash Flood Resilient Agricultural Diversification with Improved Market Access
- Extension of Beel Nursery

As to the O/M of the Haor Project and the non-structural measures of the above, project design is to be entrusted to the ongoing JICA study entitled “Preparatory Survey on Upper Meghna River Basin Watershed Management Improvement Project in the People’s Republic of Bangladesh”. The Study has worked out the project design of the structural measures, giving priority to the technical aspect. In these situations, the following are recommended for the succeeding project stage:

(1) The Haor Project, composed of 37 subprojects (15 for rehabilitation and 22 for new development), has been designed based principally on the study and examination of the

technical aspect. Therefore, it is essential in the succeeding stage for project implementation to review and design the project including economic evaluation and environmental/social assessments.

(2) River water level and discharge measurements have been conducted in the haor areas. Ocular observation of water level (usually from 6:00 a.m. to 6:00 p.m.) has been the major work on measurements in accordance with the need for current river management in the country using flood water levels. In the haor areas it is important to incorporate quantitative management of river water into the future water resources management. Therefore, it is recommended to measure water levels by automatic water level gauges including the time from 6:00 p.m. to 6:00 a.m. and provide proper water level-discharge rating curves.

(3) Currently, the design water levels of flood control facilities such as submergible embankment and regulators for the haor projects have been determined basically through frequency analysis of water level data obtained from NERM. However, considering future land use change and river channel movement in the haor area, it is also recommended to incorporate into the design of flood control facilities the different approach wherein a design flood discharge at a facility site is set up first and the design water level is determined based on the design flood discharge.

(4) In the Study, the flood flow analysis in the haor areas, which have a vast area of 8,500 km^2 in total, was carried out, partially modifying the flood runoff model of IWM. During the project implementation stage, it is recommended to confirm the flood flow conditions through detailed hydraulic analysis for specific project areas.

(5) Through the Dutch corn test, soft layers were found to exist at very few sites in the haor areas. The soft layer requires countermeasures such as counterweight embankment for embankment construction of more than 2.0m to 2.5m in height. Therefore, it is recommended to confirm the existence of soft layer (particularly, peat layer) through core boring investigations at around 500 m intervals in the planned alignments of submergible embankment during the project implementation stage so as to correctly reflect the soft layer properties in the detailed structural design.

(6) As mentioned above, the haor areas have been subjected to serious boro rice damage due to frequent flash floods during pre-monsoon season. The Haor Project can mitigate the flood damage and contribute towards raising the level of economic and social activities and realizing poverty reduction and livelihood improvement in the haor areas. In due consideration of the disastrous situation in the haor areas, having been repeatedly devastated by flash floods, earlier realization of the Haor Project is strongly needed. It is recommended that the Government of Bangladesh take necessary actions timely for further steps such as securing finance, technical assistance, etc. to realize the Haor Project.

Annexes

Annex-3.1

Operational Guideline for Working Group

JICA
Data Collection Survey on Water Resources Management
in
Haor Area of Bangladesh

OPERATIONAL GUIDELINE FOR WORKING GROUP

1. General

JICA decided to conduct the "Data Collection Survey on Water Resources Management in Haor Area of Bangladesh (the Study)" in Bangladesh by dispatching the JICA Study Team (the Study Team) headed by Mr. Koji KAWAMURA from 27 November 2012. The objectives of the Study are:

(1) To review "Master Plan of Haor Areas (the M/P), 2012, BHWDB" as well as other plans on water resources management in the haor areas,
(2) To conduct basic study on matters having hardly been addressed so far in these plans, and
(3) To identify possible JICA cooperation projects for flood and river management in the haor areas.

JICA understands that the M/P has identified priority projects reflecting the local peoples' needs and is considered to be an overarching plan for future JICA cooperation in the haor areas. However, JICA has some concern that the detailed selection process including background information and the evaluation of possible impact of these prioritized projects have not fully been explained in the M/P. It is crucial to verify these points through the Study to consider future JICA cooperation.

Under such situations, the Working Group (WG) has been formed for the Study.

This operational guideline for the WG shall address the following:

i) the purpose,
ii) the final outputs,
iii) the members,
iv) the activities,
v) the time schedule, and
vi) the operation.

2. Purpose

The purpose of the WG is to review the detailed formulation process and backgrounds of the M/P and to clarify the matters having hardly been addressed yet in the M/P, which are subject to "basic study" in the Study so as to consider future JICA cooperation in the haor areas.

3. Final Output

The final outputs of the WG are the scope of the "basic study" to be carried out in the Study.

4. Members

The WG is composed of the members presented in Table 1.

Table 1 Members of Working Group

Positions	Organizations/Personnel Assigned		
	BWDB	CEGIS	JICA Study Team
Group Leader*	Director, Planning-1	-	-
Deputy Group Leader	Executive Engneer, Office Chief Planning	-	Team Leader
Water Resources Management	-	Director, Climate Change Study Division	Team Leader
Flood Measures	-	Flood Measures Expert	Deputy Team Leader
Facility Plan/Design	-	Facility Plan/Design Expert	Facility Plan/Design Expert

Note: the group leader shall be a chairperson of the WG meeting.

5. Activities

The activities of the WG are:

1) To identify and compile the items to be reviewed,
2) To collect and scrutinize the data used and analysis results regarding each review item,
3) To confirm and assess project selection criteria and results, and
4) To provide items and their contents of the "basic study".

It is noted that the items and their contents of the "basic study" need to be finalized with an approval of JICA.

The items to be reviewed by the WG are itemized below at this initial stage of the Study, which are subject to change in the curse of the review work of the M/P:

(1) Item 1: Process for project prioritization and selection, and technical/environmental/social data and information used in water resources sector,

(2) Item 2: Clarification of applied method and data used to hydrological and hydraulic analysis,

(3) Item 3: Verification of the consistency and reliability of exiting hydrologic, hydraulic, and sediment data,

(4) Item 4: Selection process of WR-01 to WR-09 in Table 2,

(5) Item 5: (i) Selection process of subprojects in WR-01 to WR-09, including confirmation of peoples' needs and selection criteria, and (ii) planning process of such structures as submergible embankments, sluices, platforms, etc. from a technical viewpoints, particularly hydrologic, hydraulic, geomorphic, and geotechnical ones,

(6) Item 6: Basis of cost estimation, and

(7) Item 7: Possible project impacts.

Table 2 Projects Identified in the M/P for Water Resources Sector

(Duration in year and Cost in lakh taka)

DA Code	Project Title	Duration Year	Short Term	Medium Term	Long Term	Total cost
	Water Resources		(lakh taka)			
WR-01	Pre-Monsoon Flood Protection and Drainage Improvement in Haor Areas	5	12,550	-	-	12,550
WR-02	Flood Management of Haor Areas	7	28,575	53,068	-	81,643
WR-03	River Dredging and Development of Settlement	5	44,073	4,897	-	48,970
WR-04	Development of Early Warning System for Flash Flood Prone Areas in Haor and Dissemination to Community Level	20	353	215	200	768
WR-05	Village Protection against Wave Action of Haor Area	3	31,046			31,046
WR-06	Monitoring of the Rivers in Haor Area	4	450	450	-	900
WR-07	Impact Study of the Interventions of Transboundary River System	5	1,350	150	-	1,500
WR-08	Study of the Climate Change Impact of Haor Area	4	400	400	-	800
WR-09	Strengthening and Capacity Development of BHWDB	2	197	-	-	197
	Total		118,994	59,180	200	178,374

Source : "Master Plan of Haor Area (2012)"

Notes: DA: Development Area
Short Term (FY 2012-13 ～ FY 2016-17)
Medium Term (FY 2017-18 ～ FY 2021-22)
Long Term (FY 2022-23 ～ FY 2031-32)

6. Time Schedule

	Time Schedule*
Item 1	December 2012
Item 2	
Item 3	
Item 4	
Item 5	
Item 6	January 2013
Item 7	December 2012

Note: * If the items to be reviewed are changed, the time schedule shall be reset.

7. Operation of the WG

(1) The WG will hold their regular progress meeting every two weeks as a rule on a pre-set date determined by the Chairperson. (Note: more discussions shall be required between the Study Team and CEGIS).

(2) The WG will hold any extraordinary meeting when necessary based on a proposal by any of the WG members and the decision of the Chairperson.

(3) The Chairperson shall chair all the meetings. The Study Team shall record the minutes of meetings and any other issues that may arise in the meetings.

(4) All the records will be kept and maintained by the Study Team.

Annex 3-2
Minutes of Discussion

Annex-3.2.1

Minutes of Discussion on the Inception Report

Annex

Minutes of Discussion on the Inception Report Presentation Meeting on "JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh" held on 10th December, 2012 at 3:00 pm in Conference of Director General, BWDB and agreed upon between Bangladesh Water Development Board of People's Republic of Bangladesh and Japan International Cooperation Agency (JICA) Study Team .

Introduction

The Government of Japan (hereinafter referred to as "the GOJ") through Japan International Cooperation Agency (JICA) conducted the "Preparatory Planning Study for Meghan River Basin Management" between September 2010 and March 2011 (the JICA 2010 Study). After that the JICA conducted "Preparatory Survey on Cooperation Program for the Disaster Management in Bangladesh" between September 2011 and June 2012 (the JICA 2011 Study) to formulate JICA cooperation program for flood related disaster management in the Upper Meghna River basin and to work out preliminary plans of promising projects incorporated into the said cooperation program. The JICA 2011 Study was essentially based on the "Haor Master Plan" prepared by the Bangladesh Haor and Wetland Development Board (hereinafter referred to as "BHWDB").

JICA understands that the Master Plan of Haor Areas (the M/P, BHWDB, 2012) has identified priority projects reflecting the local peoples' needs, and is considered to be an overarching plan for future JICA cooperation in the haor areas. However, JICA has some concern that (i) the detailed selection process including background information and (ii) the evaluation of possible impact of these prioritized projects have not fully been explained in the M/P. Since it is crucial to verify these points in order to consider future JICA cooperation, JICA has decided to conduct "Data Collection Survey on Water Resources Management in Haor Area of Bangladesh" (the Study).

To conduct the Study, JICA thus dispatched the Study Team (hereinafter referred to as "the JICA Study Team"), headed by Mr. Koji Kawamura of Nippon Koei Co., Ltd., to Bangladesh from 27 November 2012.

The JICA Study Team held this meeting on 10th December 2012 at Bangladesh Water Development Board (hereinafter referred to as "BWDB"), WAPDA Bhaban to explain the contents of the Inception Report covering the Study area, background, outlines, approach to implementation of the Study, Study schedule, plan of operation, staffing schedule and reporting to the officials of BWDB, BHWDB and other Bangladeshi stakeholders concerned (hereinafter referred to as "the Bangladeshi side") to share information and exchange opinions with the Bangladeshi side about the study approach and operation strategy in order to obtain maximum effectiveness.

The Bangladeshi side and the JICA Study Team had a discussion after the presentation by the JICA Study Team. The list of participants is attached hereto in Annex-1.

Results of Discussions:

The Bangladeshi side basically accepted the contents of the Summary Inception Report presented in the meeting, and mentioned some comments and requests in the discussion as follows:

1. **Comments from DG, BWDB**

- The submerged embankments constructed in the haor areas need to be repaired almost on a yearly basis after the rainy season even after 90 % compaction. Director General, BWDB requested the Study Team to come up with some ideas so that such yearly repairs are not or less required. One of the possibilities is to fix the height of embankment at selected locations lower than the designed embankment crest with causeways/runoff bridges (like an un-gated spillway). In this way, it might be possible to use less O&M money.

2. **Request from the JICA Study Team**

- The JICA Study Team requested the BWDB and other concerned agencies to provide support to assist in data/information collection and to assist the Study Team in arrangements for the field survey. The DG assured that the Study Team will get every assistance and support from BWDB in any respect and in anywhere.

3. **Closing Remarks by the DG, BWDB**

- The DG thanked the JICA Study Team for their hard work. He also thanked the participants for their presence.

(K A M SHAHIDUZZAMAN)
Director General
Bangladesh Water Development Board
Dhaka.

List of Participants

List of participants attended the meeting on Inception Report of "JICA Data Collection survey on Water Resources Management in Haor Area of Bangladesh" held on 10th December, 2012 at 3:00 P.M. at the DG's Conference room of BWDB, WAPDA Building (2rd Fl.), Motijheel , Dhaka.

Sl.No.	Name and Designation	Organization	Contact no./email	Signature
1.	Md. Abdul Mannan ADG (ER)	BWDB	01753303133	
2.	Md. Afzal Hossain ADG (P)	BWDB	9562293	
3.	Mallah Ruhul Alam Water Resource Expert	CEGIS	01715406565	
4.	Md. Humayun Kabir Senior Specialist	IWM	01713041830	
5	GILBERTO CAVALLI	NHC JICA STUDY TEAM	gcavalli@nhc web.com	
6	Yasuhiro AZUMA	JICA STUDY TEAM	01982272808	
7.	KOJI KAWAMURA	"	017-62001580	
8	NURUL ISLAM	"	017-13121445	
9	Michio OTA	JICA Expert	01713-043172	
10.	Md. Sarfaraz Wahed.	CEGIS.	01712209364	
11.	S.M. ATAUR RAHMAN	BWDB EE / Hydrology	01729788425	
12	Dr. Dilruba Ahmed	CEGIS	—	
13.	Md Ansar Ali Mral CE / Hydrology	BWDB	01726-664204	10/12/12
14.	Md. Ferdous CE, NE-2 Comilla	BWDB	01715292824	10/12/12
15	Md. Abul Kalam Azad / SE	BWDB	01711384988	10.12.12
16.	Md. Abdul Hye / EE Sunamganj	BWDB	01716094096	10.12.12.
17.	Md. Mustafizur Rahman. Xen, BWDB, Moulvibazar	BWDB	01714-003067	10.12.12

List of Participants

List of participants attended the meeting on Inception Report of "JICA Data Collection survey on Water Resources Management in Haor Area of Bangladesh" held on 10th December, 2012 at 3:00 P.M. at the DG's Conference room of BWDB, WAPDA Building (2rd Fl.), Motijheel , Dhaka.

Sl.No.	Name and Designation	Organization	Contact no./email	Signature
18.	Musa Nurur Rahman	XEN, BWDB	01715 740505	[signature] 10.12.12
19	Dr. Shamal Chandra Das XEN, Office of the C.P.	BWDB	01759693375 shamal1967@yahoo.com	[signature] 10.12.12
20	FAZLUR RASHID Executive Engineer	BWDB	01711151652 fazlur64@gmail.com	[signature] 10.12.12
21	TANJIR SAIF AHMED Asst. Engr.	BWDB	01716483997	Tanjir Saif Ahmed 10.12.12
22	Tania Mostafa	BWDB	01553562001	Tania 10.12.12
23	Md. Mustafizur Rahman	BWDB	01736740168	[signature] 10.12.12
24.	Md. Akbar Hossain	Planning-I, BWDB	01818-614543	Akbar
25	Naoki Matsumura	JICA Bangladesh office	01714138111	[signature]

Annex-3.2.2

Minutes of Discussion for the First Working Group Meeting

BANGLADESH WATER DEVELOPMENT BOARD
Directorate of Planning-I
WAPDA Building (6th Floor), Motijheel C/A
Dhaka-1000

Ph. No: 9551088
Fax :+880-2-9564702
email:dplanning1@gmail.com

Memo No. WDB/P-I/ 1290

Dated : 31.12.2012

Subject: Minutes of Discussion for the First Working Group Meeting on "JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh".

Distribution: (Not as per seniority)

1. Director, Planning-1, BWDB and Group Leader of the Working Group.
2. Dr. Shamal Chandra Das, Executive Engineer, Office of Chief Planning, BWDB and Deputy Group Leader of Working Group.
3. Mr. Koji KAWAMURA, Team Leader, JICA Study Team and the Deputy Group Leader of Working Group.
4. Mr. Yasuhiro AZUMA, JICA Study Team and the member of Working Group.
5. Ms. Nazneen Aktar, Sr. Professional, CEGIS, House No. 6, Road No. 23C, Gulshan-1, Dhaka.
6. Mr. Md. Sahadat Hossain Choudhury, Professional, CEGIS, House No. 6, Road No. 23C, Gulshan-1, Dhaka.

C.C.

1. Additional Director General, Planning, BWDB, Dhaka.
2. The Chief Planning, BWDB, Dhaka.
3. CSO to Director General, BWDB, Dhaka.

31.12.12
(Musa Nurur Rahman)
Executive Engineer
Planning-I, BWDB,

Minutes of Discussion for the First Working Group Meeting on the JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh held on 10 December 2012 at 12:00 noon in the Office-room of Director, Planning-1.

The first meeting of the Working Group(WG) set up under the "JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh" was held at the office of the Director, Planning -1 of Bangladesh Water Development Board (BWDB) on 10th December 2012 at 12:00 noon under the chairmanship of Mr. Fazlur Rashid, Executive Engineer, Planning -1. Mr. Fazlur Rashid presided over the meeting as Director, Planning-1 and Team Leader of Working Group was not present in the meeting. The list of participants is shown in the **Annex-A**.

It was clarified at the beginning that participants from the CEGIS are representing the WG members nominated from CEGIS in their absence. The chairperson requested them to brief the original members regarding this meeting outcome.

At the outset of the meeting the Chairperson welcomed the participants and requested Mr. Koji Kawamura, the Team Leader of the JICA Study Team to explain the operational guideline of the WG. Mr. Kawamura explained the background of the Study and the purpose of setting the WG. He also explained activities of the WG and the final expected output.. The operational guideline for WG was presented by Mr. Kawamura is shown in the **Annex-B**.

The Chair thanked the presenter for his nice presentation. The Chair then opened the floor and requested the participants to give their comments on the presentations.

Mr. Kawamura proposed that on 12th December 2012 the JICA Study Team would visit CEGIS and hold detail technical discussion with concerned CEGIS staffs for the Haor Master Plan review. The CEGIS representatives agreed to convey this request. The probable discussion points are:

(1) Item 1:Process for project prioritization and selection, and used technical data and information,

(2) Item 2:Selection process of WR-01 to WR-09 in Haor MP,

(3) Item 3:(i) Selection process of subprojects in WR-01 to WR-09, including confirmation of peoples' needs and selection criteria, and (ii) planning process of such structures as submergible embankments,

sluices, platforms, etc. from a technical viewpoints, particularly hydraulic and geotechnical ones

Mr. Kawamura mentioned that CEGIS Executive Director was eager to provide a room for the Study Team to conduct their review work. The CEGIS representatives were requested to convey it to the concerned authorities.

The chairperson requested CEGIS to provide 2 sets of Haor MP (hard and soft copies), one to BWDB and one to JICA Study Team.

The WG wanted to know the project selection process used in the Haor MP. The representatives of CEGIS explained the process. It was concluded that more discussion would be held on 12th December at CEGIS.

Mr. Kawamura requested CEGIS to provide all background information regarding Haor Master Plan in documented form on 12th December, 2012.

The Chairperson thanked all the members of the WG for their excellent presentation & valuable observation and comments on the study. He hoped that in due consideration of the comments and opinions expressed the WG will achieve its objective.

The next meeting of the WG was set at 10-30 AM on 23rd December, 2012.

As there was no other agenda to discuss, the meeting ended with a vote of thanks from the Chair.

31.12.12
(Fazlur Rashid)
Executive Engineer, Planning -1
BWDB, Dhaka.

List of Participants

List of participants attended in the meeting of Working Group for the review of "Master Plan of Haor Areas, 2012, BHWDB" under "JICA Data Collection survey on Water Resources Management in Haor Area of Bangladesh" held on 10th December, 2012 at 12:00 Noon at the office of the Planning-I, BWDB, WAPDA Building (6th Fl.), Motijheel Dhaka.

Sl.No.	Name and Designation	Organization	Contact no./email	Signature
1	Dr. Shamal Chandra Das Executive Engr.	BWDB	01759693375 shamal1967@yahoo.com	[signature]
2	Koji Kitamura Team Leader	JICA Study Team	017-6200-1580 a2737@n-koei.co.jp	[signature]
3	Fazlur Rasid	BWDB	9551088 fazlur64@gmail.com	[signature]
4	Nurul Islam	JICA Study Team	017-13121425 a4980@n-koei.co.jp	[signature]
5	Yasuhiro AZUMA	JICA Study Team	019-82272808 a3769@n-koei.co.jp	[signature]
6	Gilberto Camali	JICA STUDY Team	[illegible]	[signature]
7	Michio Ota	JICA Expert	monarbo7810@gmail.com	[signature]
8.	Musa Nurur Rahman	XEN, Planning-I BWDB	mnrplanning1@gmail.com	[signature] 10.12.12
9.	Nazneen Aktar	Sr. Professional PESD, CEGIS	naktan@cegis bd.com	Nazneen 10.12.12
10.	Md. Shahadat Hossain Chowdhury	Professional CEGIS.	[illegible]@gmail.com	MSH 11.12.12
11.	TANJIR SAIF AHMED	AE, BWDB	01716483997	[signature] 10.12.1[illegible]

JICA
Data Collection Survey on Water Resources Management
in
Haor Area of Bangladesh

OPERATIONAL GUIDELINE FOR WORKING GROUP

1. General

JICA decided to conduct the "Data Collection Survey on Water Resources Management in Haor Area of Bangladesh (the Study)" in Bangladesh by dispatching the JICA Study Team (the Study Team) headed by Mr. Koji KAWAMURA from 27 November 2012. The objectives of the Study are:

(1) To review "Master Plan of Haor Areas (the M/P), 2012, BHWDB" as well as other plans on water resources management in the haor areas,
(2) To conduct basic study on matters having hardly been addressed so far in these plans, and
(3) To identify possible JICA cooperation projects for flood and river management in the haor areas.

JICA understands that the M/P has identified priority projects reflecting the local peoples' needs and is considered to be an overarching plan for future JICA cooperation in the haor areas. However, JICA has some concern that the detailed selection process including background information and the evaluation of possible impact of these prioritized projects have not fully been explained in the M/P. It is crucial to verify these points through the Study to consider future JICA cooperation.

Under such situations, the Working Group (WG) has been formed for the Study.

This operational guideline for the WG shall address the following:

i) the purpose,
ii) the final outputs,
iii) the members,
iv) the activities,
v) the time schedule, and
vi) the operation.

2. Purpose

The purpose of the WG is to review the detailed formulation process and backgrounds of the M/P and to clarify the matters having hardly been addressed yet in the M/P, which are subject to "basic study" in the Study so as to consider future JICA cooperation in the haor areas.

3. ·Final Output

The final outputs of the WG are the scope of the "basic study" to be carried out in the Study.

4. Members

The WG is composed of the members presented in Table 1.

Table 1 Members of Working Group

Positions	Organizations/Personnel Assigned		
	BWDB	CEGIS	JICA Study Team
Group Leader*	Director, Planning-I	-	-
Deputy Group Leader	Executive Engneer, Office Chief Planning	-	Team Leader
Water Resources Management	-	Director, Climate Change Study Division	Team Leader
Flood Measures	-	Flood Measures Expert	Deputy Team Leader
Facility Plan/Design	-	Facility Plan/Design Expert	Facility Plan/Design Expert

Note: the group leader shall be a chairperson of the WG meeting.

5. Activities

The activities of the WG are:

1) To identify and compile the items to be reviewed,
2) To collect and scrutinize the data used and analysis results regarding each review item,
3) To confirm and assess project selection criteria and results, and
4) To provide items and their contents of the "basic study".

It is noted that the items and their contents of the "basic study" need to be finalized with an approval of JICA.

The items to be reviewed by the WG are itemized below at this initial stage of the Study, which are subject to change in the curse of the review work of the M/P:

(1) Item 1: Process for project prioritization and selection, and technical/environmental/social data and information used in water resources sector,

(2) Item 2: Clarification of applied method and data used to hydrological and hydraulic analysis,

(3) Item 3: Verification of the consistency and reliability of exiting hydrologic, hydraulic, and sediment data,

(4) Item 4: Selection process of WR-01 to WR-09 in Table 2,

(5) Item 5: (i) Selection process of subprojects in WR-01 to WR-09, including confirmation of peoples' needs and selection criteria, and (ii) planning process of such structures as submergible embankments, sluices, platforms, etc. from a technical viewpoints, particularly hydrologic, hydraulic, geomorphic, and geotechnical ones,

(6) Item 6: Basis of cost estimation, and

(7) Item 7: Possible project impacts.

Table 2 Projects Identified in the M/P for Water Resources Sector

(Duration in year and Cost in lakh taka)

DA Code	Project Title	Duration Year	Short Term	Medium Term	Long Term	Total cost
	Water Resources		(lakh taka)			
WR-01	Pre-Monsoon Flood Protection and Drainage Improvement in Haor Areas	5	12,550	-	-	12,550
WR-02	Flood Management of Haor Areas	7	28,575	53,068	-	81,643
WR-03	River Dredging and Development of Settlement	5	44,073	4,897	-	48,970
WR-04	Development of Early Warning System for Flash Flood Prone Areas in Haor and Dissemination to Community Level	20	353	215	200	768
WR-05	Village Protection against Wave Action of Haor Area	3	31,046			31,046
WR-06	Monitoring of the Rivers in Haor Area	4	450	450	-	900
WR-07	Impact Study of the Interventions of Transboundary River System	5	1,350	150	-	1,500
WR-08	Study of the Climate Change Impact of Haor Area	4	400	400	-	800
WR-09	Strengthening and Capacity Development of BHWDB	2	197	-	-	197
	Total		118,994	59,180	200	178,374

Source : "Master Plan of Haor Area (2012)"

Notes: DA: Development Area
Short Term (FY 2012-13 ~ FY 2016-17)
Medium Term (FY 2017-18 ~ FY 2021-22)
Long Term (FY 2022-23 ~ FY 2031-32)

6. Time Schedule

	Time Schedule*
Item 1	December 2012
Item 2	
Item 3	
Item 4	
Item 5	
Item 6	January 2013
Item 7	December 2012

Note: * If the items to be reviewed are changed, the time schedule shall be reset.

7. Operation of the WG

(1) The WG will hold their regular progress meeting every two weeks as a rule on a pre-set date determined by the Chairperson. (Note: more discussions shall be required between the Study Team and CEGIS).

(2) The WG will hold any extraordinary meeting when necessary based on a proposal by any of the WG members and the decision of the Chairperson.

(3) The Chairperson shall chair all the meetings. The Study Team shall record the minutes of meetings and any other issues that may arise in the meetings.

(4) All the records will be kept and maintained by the Study Team.

Annex-3.2.3

Minutes of Discussion for the Second Working Group Meeting

Minutes of Discussion for the Second Working Group Meeting on the "JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh" held on 23 December 2012 at 11:00 am in the Office chamber of Director, Planning-1.

The second meeting of the Working Group (the WG) set up under the "JICA Data Collection Survey on Water Resources Management in Haor Area of Bangladesh (the Study)" was held at the office of the Director ,Planning -1, Bangladesh Water Development Board (BWDB) on 23rd December 2012 under the chairmanship of Mr. Md. Abdur Rahman Akhanda, Director, Planning -1. The list of participants is shown in the Annex-A.

At the outset of the meeting, the Chairperson welcomed the participants and requested Mr. Koji Kawamura, the Team Leader of the JICA Study Team (the Study Team) to explain briefly the operational guideline of the WG for the first-time participants. Mr. Kawamura explained the background of the Study and the purpose of setting the WG. He also explained the final expected output, members and activities of the WG, referring to the operational guideline. This guideline was attached to the minutes of discussion of the first WG meeting.

The Chairperson thanked Mr. Kawamura for his nice presentation, and then opened the floor and requested the participants to continue the proceedings.

It was pointed out that official nomination for the WG from the CEGIS was not yet confirmed. The Chairperson requested the CEGIS representatives to issue a letter with their nominations.

Mr. Kawamura reported the WG that after the first WG meeting on 10th December 2012, the Study Team had technical discussion with CEGIS on the "Master Plan of Haor Area (the M/P)" thrice, namely, on Dec. 12, Dec. 17 and Dec. 20, 2012 but unfortunately the progress was rather less than expectation. In reply, the CEGIS representative said that since one of the key members of the M/P Team was not available, there were some delays in data provision. However, he assured that from now on CEGIS will provide all their support to the Study Team in the review work of the M/P. The Study Team and CEGIS thus agreed to have another technical discussion on 24th Dec. at the CEGIS office.

It was reported by the Study Team that in line with the decision concluded in the first WG meeting, CEGIS provided the soft and hard copies of the main report and one annex of the M/P to the Study Team. The Chairperson requested CEGIS to provide the remaining annexes of the M/P to the Study Team.

One of the WG members raised a question of study area extent. It was confirmed by the Study Team that the area including the Brahmanbaria area should be considered as the study area.

Regarding the information on river cross section survey by BWDB and the design guideline for the crest elevation of submergible embankment, the Chairperson arranged appointments with the

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Superintending Engineer , Morphology Circle , BWDB, Dhaka and the Superintending Engineer , Design Circle -1 , BWDB , Dhaka respectively.

It was decided that the Chairperson will issue a letter to IWM requesting sharing with the Study Team all BWDB owned data kept with IWM.

The Chairperson thanked all the members of the WG for their excellent presentation and valuable observation and comments on the Study. He hoped that in due consideration of the comments expressed the WG will achieve its objective.

The next meeting of the WG is set at 11-00 AM on 14th January, 2013.

The meeting ended with a vote of thanks from the Chair.

Sd/-

(Md. Abdur Rahman Akhanda)
Director,
Planning -1
BWDB, Dhaka.

Memo No. BWDB/P-1/ 78 (5)

Date: 23/.01.2013

Distribution : (Not as per seniority)

1. Executive Director, CEGIS, House-6, Road-23/C, Gulshan-1, Dhaka.
2. Dr. Shamal Chandra Das, Executive Engineer, Office of the Chief Planning, BWDB, Dhaka and Deputy Group Leader of the Working Group.
3. Mr. Michio Ota, JICA Expert, WAPDA Buliding, Motijheel, Dhaka.
4. Mr. Koji KAWAMURA, Team Leader, JICA Study Team and Deputy Group Leader of the Study Group.
5. Mr. Fida A. Khan, Director, CCSD, CEGIS, House-6, Road-23/C, Gulshan-1, Dhaka.

C.C.

1. Additional Director General (Planning), BWDB, Dhaka.
2. Chief Planning, BWDB, Dhaka.
3. C.S.O. to Director General, BWDB, Dhaka.

23.1.13

(Musa Nurur Rahman)
Executive Engineer
Planning -1
BWDB, Dhaka.

- 2 -

List of Participants

List of participants attended in the 2nd meeting of Working Group for the review of "Master Plan of Haor Areas, 2012, BHWDB" under "JICA Data Collection survey on Water Resources Management in Haor Area of Bangladesh" held on 23rd December, 2012 at 11:00 A.M. at the office of the Planning-I, BWDB, WAPDA Building (6th Fl.), Motijheel Dhaka. The meeting is presided over by the Director, Planning-I, BWDB.

Sl.No.	Name and Designation	Organization	Contact no./email	Signature
1.	Koji KAWAMURA (NIPPON KOEI)	JICA Study	a2717@n-koei.co.jp	[signature]
2.	(NIPPON KOEI) NURUL ISLAM	JICA Study	a4890@n-koei.co.jp	[signature]
3.	Michio Ota	(JICA Expert) BWDB	monarbo7810@gmail.com	太田
4	Mohd. Fida A. Khan Director ECSD, CEGIS	CEGIS	mkhan@cegisbd.com	[signature]
5.	Md. Shakhawat Hossain Chowdhury	CEGIS	shchowdhury@cegisbd.com	MSH
6.	Dr. Shamal1967@yahoo.com XEN, Office of the Chief Planning	BWDB	shamal1967@yahoo.com	[signature]
7.	Musa Nurur Rahman, XEN	BWDB	01715740505	[signature] 23.12.12
8.	Mohammad Akbar Hossain, Research Officer.	Planning-I, BWDB	01818-614543 akborgazi@yahoo.com	[signature]

Annex-3.2.4

Minutes of Discussion for the Third Working Group Meeting

Minutes of Discussion for the Third Working Group Meeting on the "JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh" held on 14 January 2013 at 11:00 am in the Office-room of Director, Planning-1 , BWDB, Dhaka.

The third meeting of the Working Group(the WG) set up under the "JICA Data Collection Survey on Water Resources Management in Haor Area of Bangladesh (the Study)" was held at the office of the Director , Planning -1 , Bangladesh Water Development Board (BWDB) on 14th January 2013 under the chairmanship of Mr. Md. Abdur Rahman Akhanda, Director, Planning-1. The list of participants is shown in the **Annex-A.**

At the outset of the meeting, the Chairperson welcomed the participants and requested Mr. Koji Kawamura, the Team Leader of the JICA Study Team (the Study Team) to explain briefly the progress since the last working group meeting held on 23rd December, 2012. Mr. Kawamura explained that discussions between the JICA Study Team and CEGIS were held on December 31, January 7, 9 and 13 (4 times in total), and the progress was satisfactory although many more things remained to be clarified. Mr. Azuma, the Deputy Team Leader of the JICA Study Team, then presented the summary of project and sub project selection process used in the preparation of the Haor Master Plan. He also pointed out that the selection process for the river dredging needed to be clarified. The representative of CEGIS invited the JICA Study Team to visit CEGIS to have further discussion on this on the same day (14th January). The Chairperson thanked the representative of CEGIS for prompt response.

The Chairperson thanked Mr. Azuma for his nice presentation, and then opened the floor and requested the participants to continue the proceedings.

In response to the query on the progress of Kalni-Kushiara River Management Project (KKRMP), CEGIS informed that an Inception Report was already submitted by them and the Progress Report will be presented in March 2013. The chairperson requested CEGIS to provide a copy of Inception Report to the Study Team.

In response to another query on the progress of the on-going 52 haors rehabilitation project by BWDB, CEGIS mentioned that the study for 37 haors has been completed by IWM and that for the rest 15 is now in progress by CEGIS. The Chairperson requested CEGIS to provide all reports for the 15 haors to the Study Team.

It was decided that the Chairperson will issue a letter to Chief Engineer, Central Zone, BWDB, Dhaka and Chief Engineer, North-Eastern Zone, BWDB, Comilla requesting their cooperation during the Study Team's field visit.
Regarding the requirement of some meteorological data, the Chairperson suggested that relevant data can be

- 1 -

found in WARPO and he advised to send a letter to BWDB in this regard.

Regarding the requirement of some topographic data, CEGIS proposed that the Study Team check the DEM available with CEGIS and if applicable, the Study Team get the DEM.

Regarding the MOD for ICR meeting, BWDB explained that the official process for issuance of the MOD is still in progress.

The Chairperson thanked all the members of the WG for their excellent presentation and valuable observation and comments on the Study. He hoped that in due consideration of the comments expressed the WG will achieve its objective.

The next meeting of the WG was not fixed. The Chairperson requested the Team Leader of the JICA Study Team to inform him whenever the next WG meeting needs to be conveyed.

The meeting ended with a vote of thanks from the Chair.

Sd/-
(Md. Abdur Rahman Akhanda)
Director,
Planning -1
BWDB, Dhaka.

Memo No. BWDB/P-1/79 (5). Date: 23/.01.2013

Distribution : (Not as per seniority)

1. Executive Director, CEGIS. House-6, Road-23/C, Gulshan-1, Dhaka.
2. Dr. Shamal Chandra Das, Executive Engineer, Office of the Chief Planning, BWDB, Dhaka and Deputy Group Leader of the Working Group.
3. Mr. Michio Ota, JICA Expert, WAPDA Buliding, Motijheel, Dhaka.
4. Mr. Koji KAWAMURA, Team Leader, JICA Study Team and Deputy Group Leader of the Study Group.
5. Mr. Yasuhiro AZUMA, Deputy Team Leader, JICA Study Team.
6. Mr. Fida A. Khan, Director, CCSD, CEGIS, House-6, Road-23/C, Gulshan-1, Dhaka.

C.C.

1. Additional Director General (Planning), BWDB, Dhaka.
2. Chief Planning, BWDB, Dhaka.
3. C.S.O. to Director General, BWDB, Dhaka.

23.1.13
(Musa Nurur Rahman)
Executive Engineer
Planning -1
BWDB, Dhaka.

- 2 -

List of Participants

List of participants attended in the 3rd meeting of Working Group for the review of "Master Plan of Haor Areas, 2012, BHWDB" under "JICA Data Collection survey on Water Resources Management in Haor Area of Bangladesh" held on 14th January, 2013 at 11:00 A.M. at the office room of Director, Planning-I, BWDB, WAPDA Building (6th Fl.), Motijheel Dhaka. The meeting is presided over by the Director, Planning-I, BWDB.

Sl.No.	Name and Designation	Organization	Contact no./email	Signature
1.	Koji KANAMORI	JICA Study Team	+880 17-[illegible] 157	[illegible]
2.	Tetsuhiro AZUMA	JICA Study Team	a3769@n-koei.co.jp	[illegible]
3.	Michio Ota	JICA Expert	monarbo7810@gmail.com	[illegible]
4.	NORUL ISLAM	JICA Study Team	a4980@n-koei.co.jp	[illegible]
5	Gilberto Canali	JICA STUDY TEAM	gecanali@comcast.net	[illegible]
6.	Musa Nurun Rahman, XEN	BWDB	01715740505	[illegible] 14.1.13
7	Malik Fida A. Khan	CEGIS	01819261279	[illegible]
8.	Mohammad Akbar Hossain (Research Officer)	BWDB	01818-614543	[illegible]

Annex-3.2.5

Minutes of Discussion on the Draft Final Report

Minutes of the Meeting on Draft Final Report in connection with the Review meeting for **"JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh"** held on 13th November, 2013 in the conference room of JICA Bangladesh office between Bangladesh Water Development Board and JICA Study Team.

A review meeting to discuss the Draft Final Report (the DFR) on "JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh" was held on 13th November, 2013 in the conference room of JICA Bangladesh office at Gulshan, Dhaka. The meeting was presided over by Mr. Zahirul Islam, Chief Planning, BWDB, Dhaka. List of the participants who attended the meeting is attached herewith **(Annexure-1)**.

The Chairman welcomed the participants and requested Mr. Koji Kawamura, Team Leader of the JICA Study Team to present the DFR. The JICA Study Team then made a power point presentation on major essence of the DFR. After the presentation, the Chair thanked the Study Team and opened the floor for discussion. BWDB officials made comments and observations and then the Study Team responded to them.

The Bangladeshi side basically accepted the contents and outcomes of the DFR in the meeting and made some comments as discussed below to improve the Report further.

It was observed by Mr. Zahirul Islam, Chief Planning, BWDB, Dhaka that the submersible embankments used to remain under water for 5 to 6 months in the monsoon season, even after recommended by JICA for 95% compaction. The JICA Study Team replied that many earthen dams and parts of many embankments usually remain under water for a long time, but due to proper compaction there is no problem. The Chair further queried how to obtain the required compaction. The Study Team replied that it would be obtained through the use of roller compactors and bulldozers. The Chief Planning responded that it would be impossible to carry the heavy equipment to sites of poor and in most cases, little communication facilities. The Study Team replied that a competent contractor could arrange that as in the case of some gas pipe construction works currently going on in the haor areas. To the Chair, it was felt unrealistic on the ground of attenuated accessibility to the haors located in remote corners and he doubted whether the Consultant had visited all the interior locations. No satisfactory answer was found from the Consultant's side. He termed 95% compaction as an absurd imagination and opined that it would not be achieved if included in the work schedule leaving it as wastage of budget. He then observed that the wet-dry cycle test used to find out an optimum compaction level might not represent actual field conditions. The JICA Study Team proposed to include trial embankment during the succeeding detail design stage to confirm compaction level. The BWDB side agreed to this proposal, suggested to boost up pilot implementation works and select the haor in middle area of the haor region.

Related to Study Team's recommendation to carry out soil investigation to confirm existence of a super soft layer, the Chief Planning suggested that tests should also be done for a peat layer @ 500 m interval and an investigation cost should be included in the project cost. The Study Team agreed with his proposition.

Mr. Fazlur Rashid, Executive Engineer, Directorate of Planning-1, BWDB, Dhaka mentioned that the last paragraph of Page 9 in the summary of the DFR, it is mentioned that BWDB river cross-sections were not applied to hydraulic analysis due to low reliability of pillar information. He objected this statement and wanted some clarification about this. The JICA Study Team explained that after plotting the pillar information of the cross-sections, some deviations were found mismatching. As a result, the JICA Study Team used their own first hand river cross-sections data along with some IWM data. The JICA Study Team agreed to share the soft copy of the river cross-sections with BWDB.

He then pointed out that the number of surveyed river cross-sections mentioned in Page 10 of the summary was different from that in Table 4.1.4. The JICA Study Team mentioned that this would be checked and revised in the Final Report.

He further mentioned that the total length of embankment mentioned in Page 13 seemed less than the figure actually would be. The JICA Study Team authenticated the figure and mentioned that this figure surveyed by the Study Team. However, inclusion of this explanation in the Final Report was agreed by the study team.

Mr. Rashid then pointed out that there was difference in flood depth mentioned in Page 4 and that mentioned under "flood mark" in Page 13. The JICA Study Team explained that the value shown in Page 4 is the definition of land classification for the whole area, while the value mentioned in "flood mark" was related to only haor project surveyed in this study. This explanation would be included in the Final Report.

After threadbare discussion, the following decisions were taken:

- All the comments, observations and suggestions would be replicated in the Final Report.
- Necessary explanation of quarries made in the discussions would be incorporated in the Final Report.

As there was no other agenda to discuss, the meeting ended with a vote of thanks from the Chair.

(Zahirul Islam)
Chief Planning
BWDB, Dhaka.

Memo No. BWDB/DP-1/ 1309 Date: 01.12.2013.

Distribution (not as per seniority):

1. Additional Director General (Planning), BWDB, Dhaka.
2. Chief Planning, BWDB, Dhaka.
3. C.S.O. to Director General, BWDB, Dhaka.
4. Koji Kawamura, Team Leader, JICA Survey Team.

(Md. Abdur Rahman Akhanda)
Director
Planning-1
BWDB, Dhaka.

Annexure-1

Title : Meeting on Draft Final Report, JICA Data Collection Survey on Water Resources Management in Haor Areas of Bangladesh

Venue : JICA Bangladesh Office

Date : November 13, 2013

No.		Designation
1	Zahirul Islam	Chief Planning, BWDB
2	A.M. Aminul Haque	SE, JMREMP, BWDB
3	Fazlur Rashid	Executive Engineer, Pl-1, BWDB
4	Tanjir Saif Ahmed	Assistant Engineer, Pl-1, BWDB
5	Michio Ota	JICA Expert, BWDB
6	Naoki Matsumura	JICA Bangladesh Office
7	Anisuzzaman Chowdhury	SPO, JICA Bangladesh Office
8	Norio Takayanagi	JICA Survey Team / Team Leader
9	Koji Kawamura	JICA Survey Team/ Team Leader
10	Junichi Fukuwatari	JICA Survey Team/ Co Team Leader
11	Tatsuhiko Hiraiwa	JICA Survey Team/ Rural Infrastructure
12	Kazuhiro Yamakawa	JICA Survey Team/ Facility Planning & Design
13	Shinsuke Hino	JICA Survey Team/ Implementation &OM
14	Takashi Shiraki	JICA Survey Team/ Agr. Promotion
15	Hikaru Sugimoto	JICA Survey Team/ O&M Planning
16	Nurul Islam	JICA Survey Team/ Social Consideration
17	Yasuhiro Azuma	JICA Survey Team/ Deputy Team Leader

Annex-4.1

River Cross Section Data from BWDB

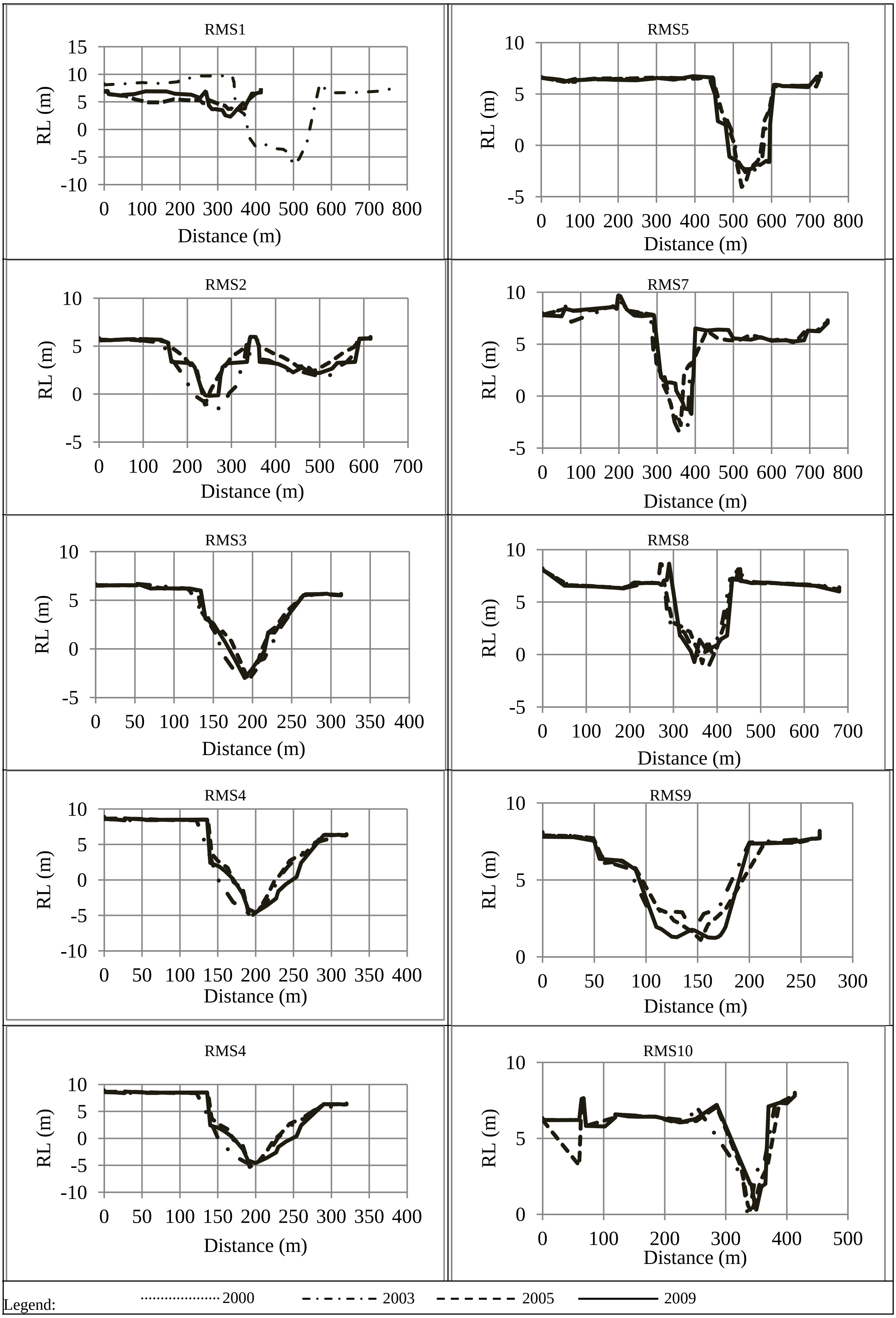


Figure A-1 Histrical River Cross Section of Surma River (1/5)

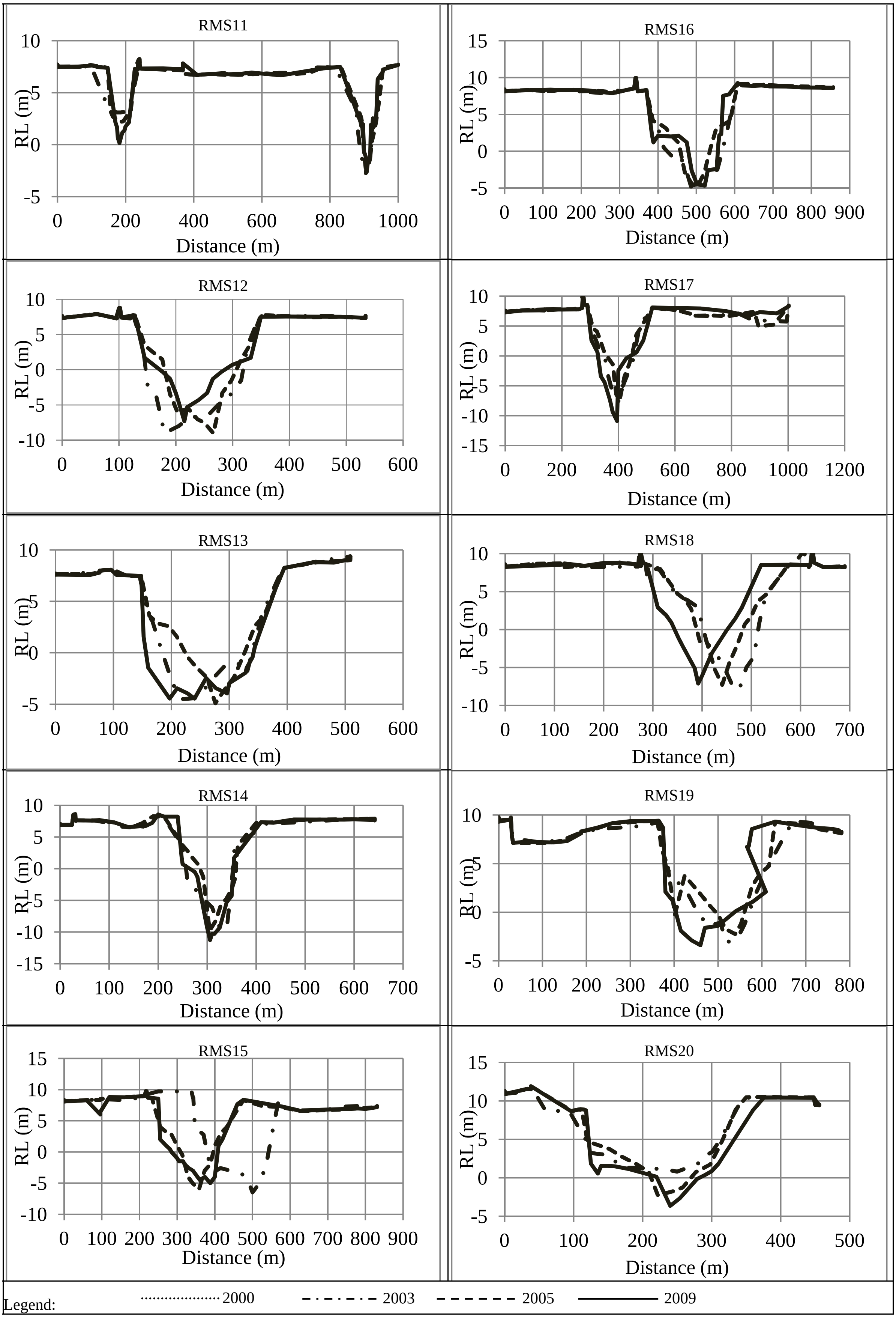


Figure A-1 Histrical River Cross Section of Surma River (2/5)

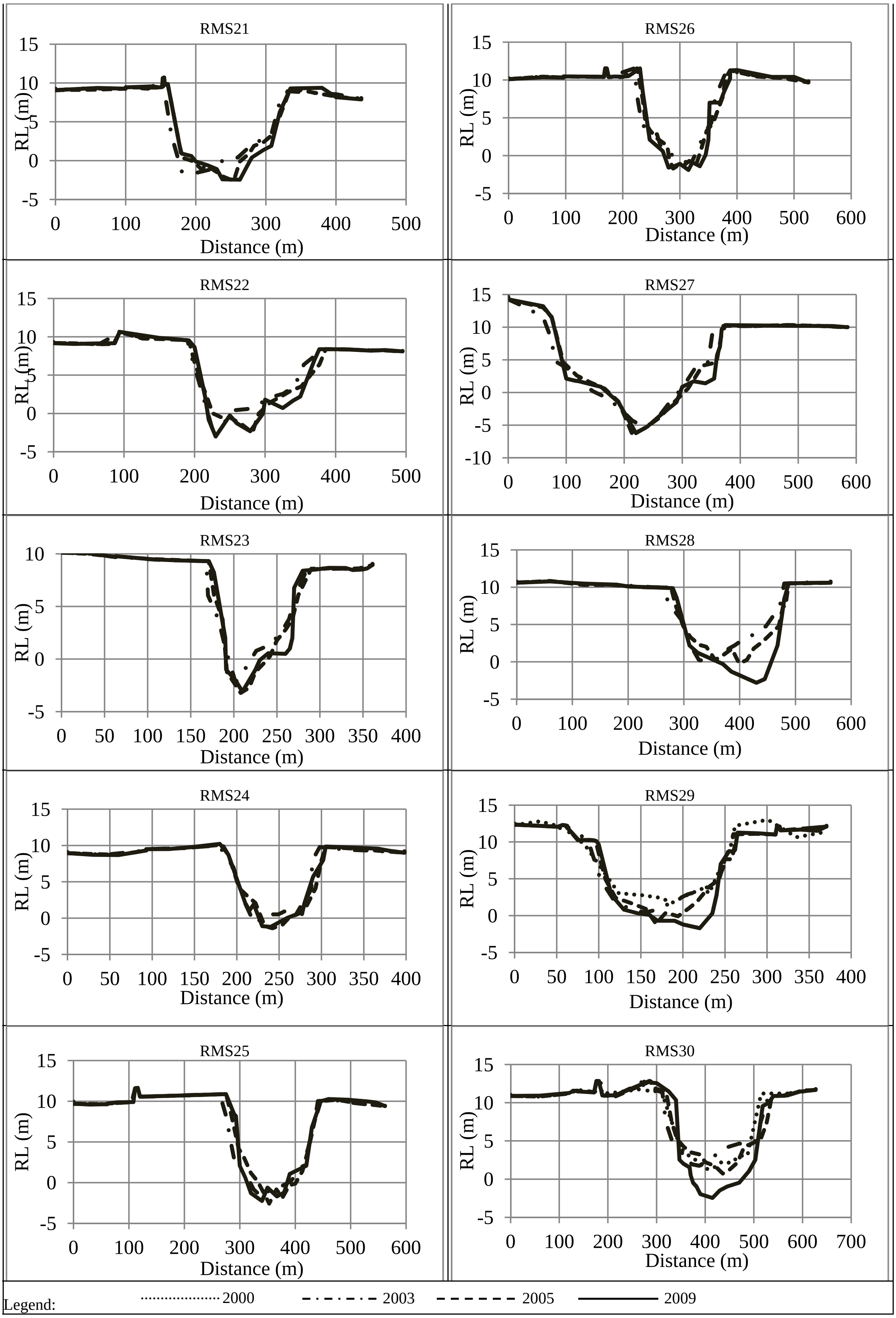


Figure A-1 Histrical River Cross Section of Surma River (3/5)

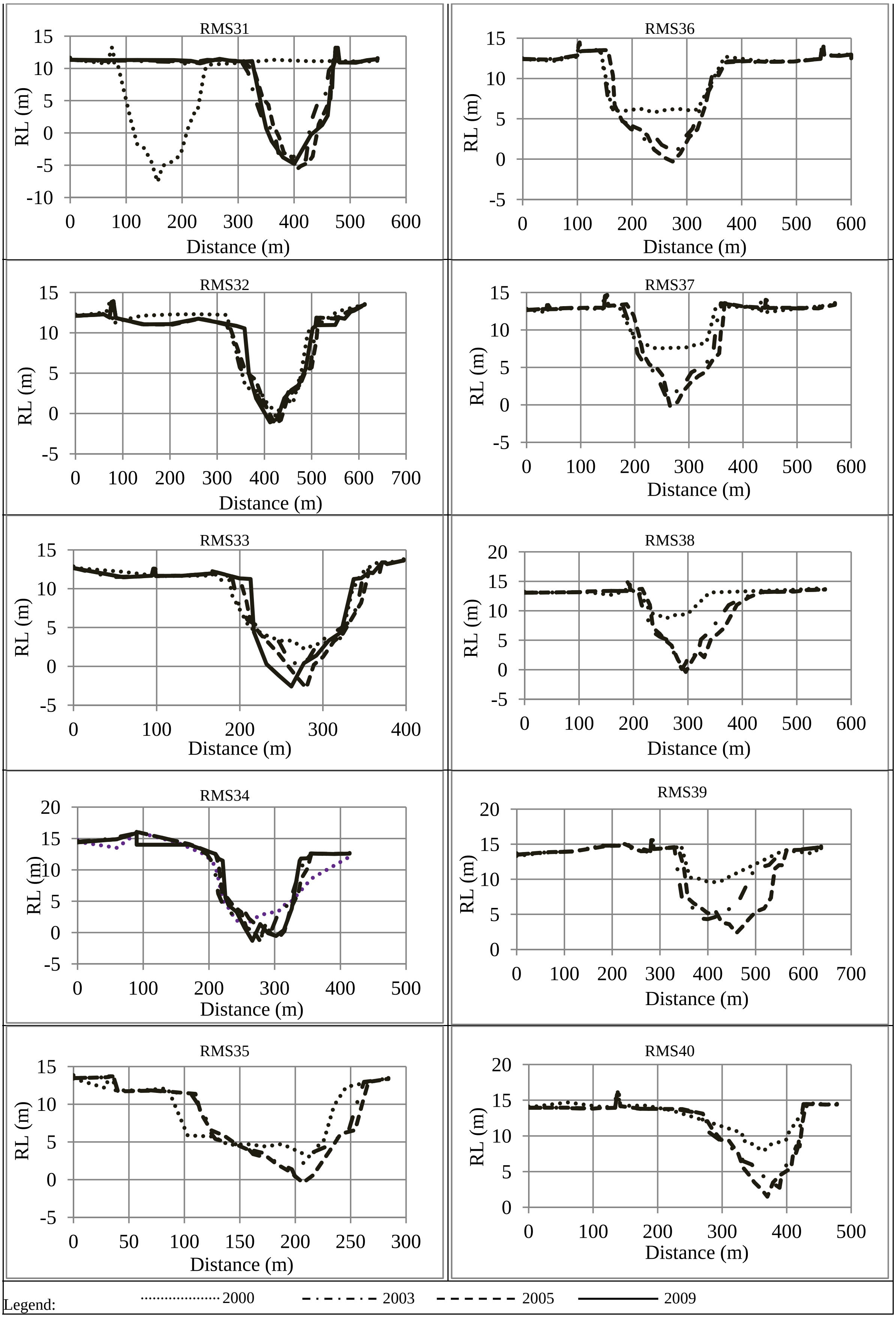


Figure A-1 Histrical River Cross Section of Surma River (4/5)

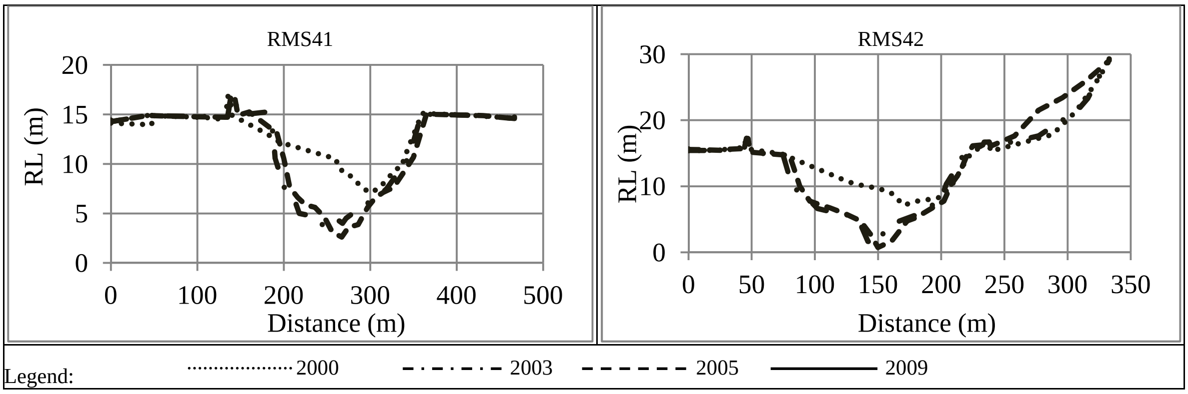


Figure A-1 Histrical River Cross Section of Surma River (5/5)

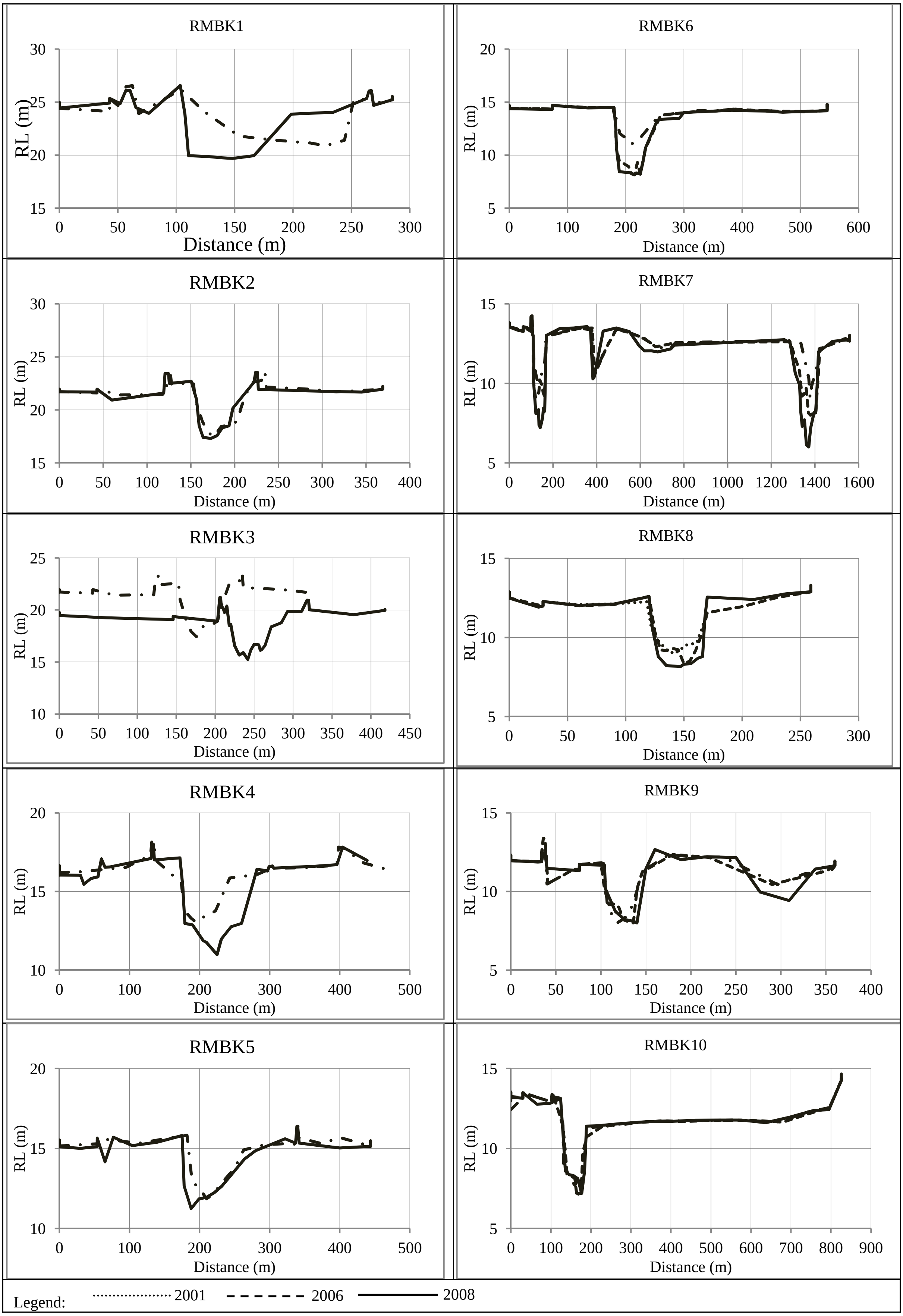


Figure A-3 Histrical River Cross Section of Bogai-Kangsha River (1/3)

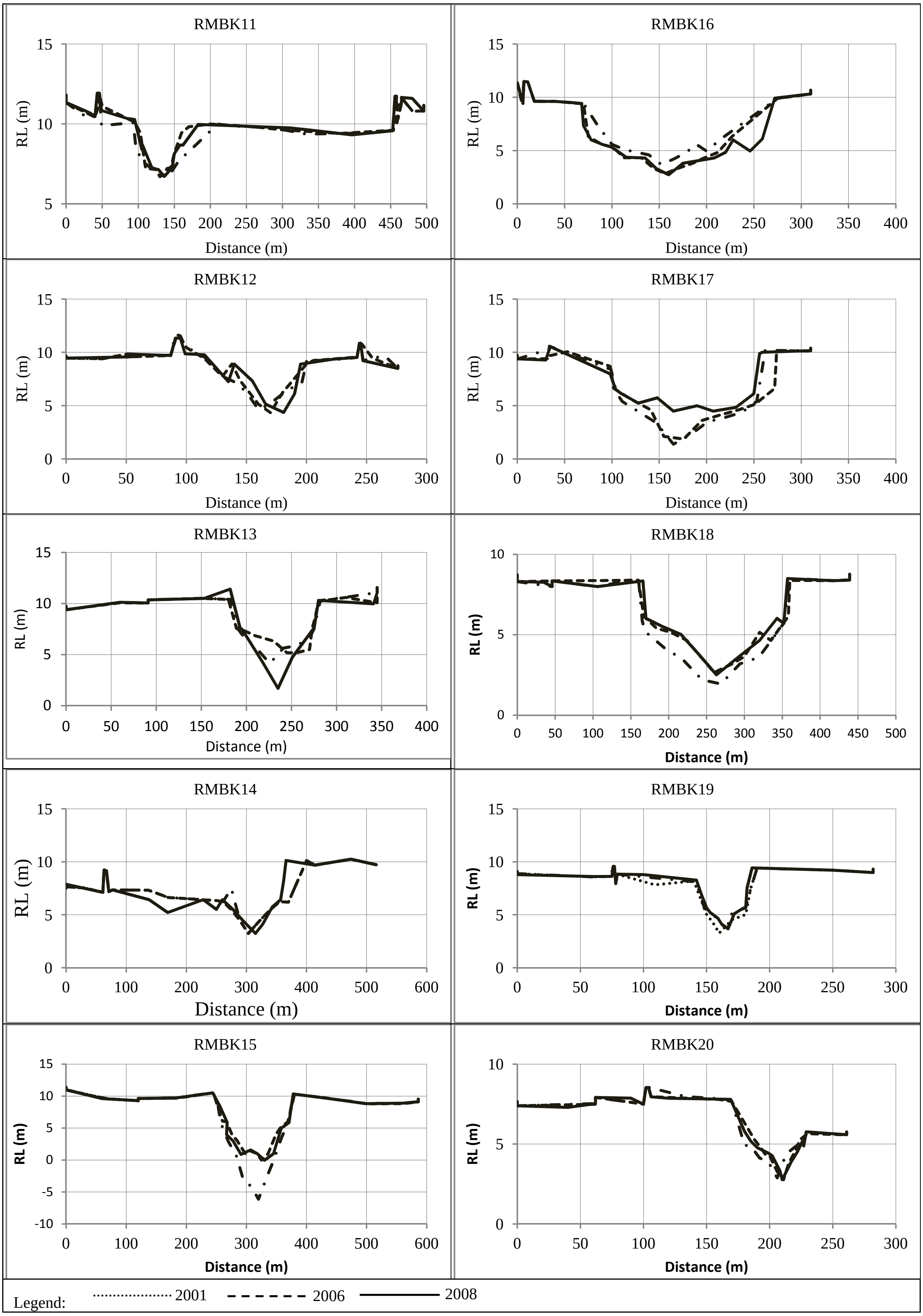


Figure A-3 Histrical River Cross Section of Bogai-Kangsha River (2/3)

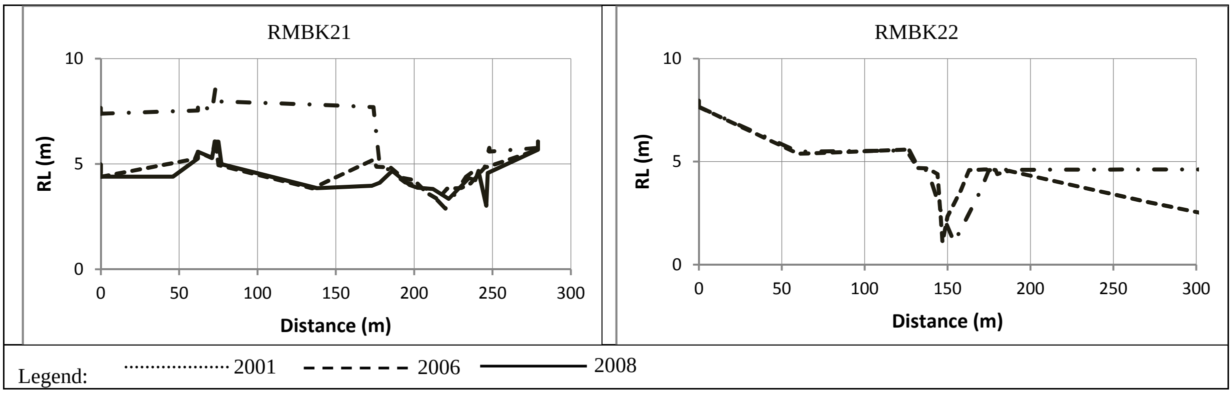


Figure A-3 Histrical River Cross Section of Bogai-Kangsha River (3/3)

Annex-4.2

Analysis of Geotechnical Investigation and Laboratory Test Result

1. Soil Classification according to Drilling Survey and Dutch Cone Test

1.1 Soil Classification by N-Value

Table 1.1 shows simplified Soil Classification by N-Value.

N-values of cohesive soil are classified to 3 categories, N≦4, N=5 to 8 and N>8 from Table 1.2. Cohesive soil of N≦4 is considered to occur problem of settlement and sliding, and of N>8 is almost problem-free layer due to stiff. Cohesive soil of N=5 to 8 is necessary for examination in case of high embankment, but has less problem if embankment height 4m. If N≧20, it is assumed as bearing layer for pile foundation.

N-values of sand are classified to 4 categories, N≦10, N=11~29, N=30~49 and N≧50, as follows from Table 1.3.

N≦10; loose sand layer
N=11~29; necessary for examination in case of high embankment
(less problem if embankment height is less than 4m in Haor)
N=30~49; assumed as bearing layer for pile foundation
N≧50; assumed as bearing layer for pile foundation

Haor area is undelain by problemless sandy ground of N-value 11~29.

Generally soft silt layer exists within GL.-3m, increasing its consistency by depth, and changes to sand layer around GL.-10m. This typical pattern is shown at n-6, n-9, n-13, n-17, n-18, r-7, r-9.

However, n-2 has loose sand and soft clay layer exists within GL.-3m, and layer below GL.-3 show the same pattern mentioned above. The borehole r-1 has medium cohesive layer in GL.-1 to -3m, and soft layer reaches to GL.-6.5m. The borehole r-8 has loose sand layer up to GL.-4m, and increases its consistency and density by depth below. No cohesive layer exists in this borehole.

It is difficult to assume the pattern of soil layers by region, because, for example there is much difference even between adjacent boreholes such as n-6 and n-13, n-9 and r-8.

Table 1.2 Consistency and Cone Resistance for Clay

Consistency	N value	Unconfined strength q_u (Mpa)	Cone resistance q_c (Mpa)
Very soft	0 ~ 2	0 ~ 25	0 ~ 0.4
Soft	2 ~ 4	25 ~ 50	0.4 ~ 0.8
Medium	4 ~ 8	50 ~ 100	0.8 ~ 1.5
Stiff	8 ~ 15	100 ~ 200	1.5 ~ 3.0
Very stiff	15 ~ 30	200 ~ 400	3.0 ~ 6.0
Hard	>30	>400	>6.0

Source: Terzaghie & Peck, Soil mechanics in engineering practice(1996)

Table 1.3 Density Index and Cone Resistance for Sand

Density index	N value	Cone resistance q_c (Mpa)	Internal friction angle φ (deg)
Very loose	0 ~ 4	0.0 ~ 2.5	29 ~ 32
Loose	4 ~ 10	2.5 ~ 5.0	32 ~ 35
Medium dense	10 ~ 30	5.0 ~ 10.0	35 ~ 37
Dense	30 ~ 50	10.0 ~ 20.0	37 ~ 40
Very dense	>50	>20	40 ~ 42

Source: Terzaghie & Peck, Soil mechanics in engineering practice(1996)
EN 1997-2 (2007) (English): Eurocode 7: Geotechnical design - Part 2: Ground investigation and testing, Annex D (informative) Cone and piezocone penetration tests, Table D.I - An example for deriving values of the effective angle of shearing resistance (qf) and drained Young's modulus of elasticity (E') for quartz and feldspar sands from cone penetration resistance (qc)

Table 1.1 Soil Classification by N-value

Depth (m)	n-2 N value	n-6 N value	n-9 N value	n-13 N value	n-17 N value	n-18 N value	r-1 N value	r-7 N value	r-8 N value	r-9 N value
0.0										
0.5										
1.0	9	4	3	4	4	6	6	5	6	3
1.5										
2.0	1	4	4	8	4	4	5	4	6	4
2.5										
3.0	12	7	5	6	5	9	4	5	7	6
3.5										
4.0	8	6	6	7	8	11	3	15	11	7
4.5										
5.0	12	6	7	5	6	25	3	18	13	10
5.5										
6.0	14	7	8	30	8	19	4	5	18	20
6.5										
7.0	31	8	10	16	9	24	14	6	21	22
7.5										
8.0	18	10	11	17	10	12	16	8	22	23
8.5										
9.0	20	13	15	19	11	29	19	18	24	33
9.5										
10.0	48	12	20	18	12	35	16	21	26	38
10.5										
11.0	43	14	21	22	15	35	18	23	29	44
11.5										
12.0	41	18	24	25	18	52	25	26	30	48
12.5										
13.0	80	19	26	28	28	61	8	28	33	51
13.5										
14.0	66	22	29	31	30	43	30	34	34	55
14.5										
15.0	43	44	31	33	32	75	32	38	35	57
15.5										
16.0	40	45	33	37	33	60	30	57	38	62
16.5										
17.0	40	46	35	39	36	71	30	59	37	65
17.5										
18.0	40	46	37	43	22	85	32	61	37	69
18.5										
19.0	66	47	40	47	27	83	35	64	39	87
19.5										
20.0	46	49	41	49	31	83	37	68	40	89
20.5										
21.0	26	42	44	55	41	82	42	69	41	88
21.5										
22.0	28	44	45	57	44	90	46	67	43	83
22.5										
23.0	27	45	47	55	49	77	46	69	45	85
23.5										
24.0	30	47	50	47	52	79	49	72	49	86
24.5										
25.0	18	47	51	53	56	33	46	76	52	89
25.5										
26.0	21	49	55	59	63	18	48	81	55	90
26.5										
27.0	9	50	58	64	87	12	47	86	57	91
27.5										
28.0	12	52	62	66	89	11	49	88	60	92
28.5										
29.0	9	55	64	69	93	9	51	89	66	92
29.5										
30.0	11	60	70	64	95	18	56	91	36	93

Remark

Clay		N=<4
		N>8
Silt		N=<4
		N=5~8
		N>8
Sand		N<=10
		N=11~29
		N=30~49
		N>=50

Soft Grand bottom (red line)
Bearing stratum top (blue line)

Source: JICA Study Team

1.2 Soil Classification by DCT (Cone Penetration Resistance)

Table 1.4 shows soil formation in each area.

Figure 1.1 shows the vertical distribution of N-value and qc (cone resistance by DCT) in the same project area. The definition of soft ground and bearing stratum in is shown in the following table.

Table 1.5 Soft ground and bearing stratum

	Soft ground	Bearing stratum
Clay layer	N=<4 q_c=<0.8Mpa	N>=20 q_c>=4Mpa
Sand layer	N=<10 q_c=<5Mpa	N>=30 q_c>=10Mpa

Source: JICA Study Team

* Division depends on those in Table 1.2/1.3

* N-value of bearing stratum is common required value for pile foundation

Table 1.4 Distribution of Soil Type by N-value and Cone Resistance

Depth (m)	n-2 N value	n-2 DCT-1	n-2 DCT-2	n-2 DCT-3	Depth (m)	n-6 N value	n-6 DCT-1	n-6 DCT-2	n-6 DCT-3
0.0		0.6	0.8	0.8	0.0		0.1	1.6	1.6
0.5		0.6	0.8	0.8	0.5		0.2	2	1.3
1.0	9	0.6	1	1.5	1.0	4	0.3	3.5	2.3
1.5		0.6	1	1.5	1.5		0.2	5	2.3
2.0	1	0.6	1	1.5	2.0	4	0.4	1.5	2.1
2.5		0.6	2.5	1.5	2.5		0.4	6	3
3.0	12	0.6	1	1.5	3.0	7	1.5	8	3
3.5		1.5	1	1.5	3.5		1.1	8	4
4.0	8	1.5	2.5	4	4.0	6	1.4	8	4
4.5		1	1	4	4.5		1.4	8	4
5.0	12	0.5	0.5	4	5.0	6	1.8	8	8
5.5		0.8	0.5	4	5.5		1.6	12	8
6.0	14	0.8	0.5	4	6.0	7	1	12	8
6.5		1	0.5	6	6.5		1.8	12	8
7.0	31	1	0.8	6	7.0	8	1.6		8
7.5		1	0.8	7	7.5		2.7		8
8.0	18	1	0.8	6	8.0	10	2		6
8.5		1	2	4	8.5		6.5		4
9.0	20	1	2	0.5	9.0	13	6.5		6
9.5		1	4	1	9.5		6.5		9
10.0	48	1	8	0.8	10.0	12	6.5		
10.5		1	6	1.5	10.5		6.5		
11.0	43	6	4	1.5	11.0	14	6.5		
11.5		10	7	1.5	11.5		6.5		
12.0	41	12	8	4	12.0	18			
12.5		12	4	2	12.5				
13.0	80	14	4	2	13.0	19			
13.5		14	5	3	13.5				
14.0	66	14	5	3	14.0	22			
14.5		14	4	5	14.5				
15.0	43	14	4	4	15.0	44			
15.5		14	4	3	15.5				
16.0	40	14	4	5	16.0	45			
16.5		14	4	12	16.5				
17.0	40	14	4	20	17.0	46			
17.5		14	4	21	17.5				
18.0	40	10	4	19	18.0	46			
18.5		10	5	18	18.5				
19.0	66	10	6	16	19.0	47			
19.5		10	4	18	19.5				
20.0	46	10	4	15	20.0	49			
20.5		10	4	18	20.5				
21.0	26	16	5	18	21.0	42			
21.5		16	6	14	21.5				
22.0	28	16	6	18	22.0	44			
22.5		16	16	14	22.5				
23.0	27	16	16	11	23.0	45			
23.5		16	16	14	23.5				
24.0	30	16	16	18	24.0	47			
24.5		20	16	18	24.5				
25.0	18	20	16	16	25.0	47			
25.5		20			25.5				
26.0	21	20			26.0	49			
26.5					26.5				
27.0	9				27.0	50			
27.5					27.5				
28.0	12				28.0	52			
28.5					28.5				
29.0	9				29.0	55			
29.5					29.5				
30.0	11				30.0	60			

Depth (m)	n-9 N value	n-9 DCT-1	n-9 DCT-2	n-9 DCT-3	Depth (m)	n-13 N value	n-13 DCT-1	n-13 DCT-2	n-13 DCT-3
0.0		2.5	2.5	2.5	0.0		0.8	0.0	0.4
0.5		2.5	2.5	2.5	0.5		1.5	0.1	1
1.0	3	2.5	1.5	2	1.0	4	1.1	0.3	1
1.5		2.5	1.5	1.5	1.5		1.1	0.4	1
2.0	4	3	3	0.8	2.0	8	1	0.6	1
2.5		2.5	2	2.5	2.5		1	0.7	1
3.0	5	4	3.5	3.5	3.0	6	1	0.9	0.5
3.5		4.5	2	4.5	3.5		0.6	1.0	0.5
4.0	6	3	3	3.5	4.0	7	0.6	1.1	0.8
4.5		4.5	4	3.5	4.5		5	1.3	1
5.0	7	4	4	4	5.0	5	6	1.4	0.7
5.5		6	4.5	2.5	5.5		5	1.6	0.8
6.0	8	7	5	5	6.0	30	4.5	1.7	1
6.5		6.5	6	2.5	6.5		5	6	1
7.0	10	6	5	3	7.0	16	5	8	1
7.5		6.5	10	4.5	7.5		5	8	1
8.0	11	6	8	4	8.0	17	7	8	1.7
8.5		5	6.5	5	8.5		5	8	1.1
9.0	15	3.5	5	4	9.0	19	5		1.5
9.5		4	7	5.5	9.5		4		3
10.0	20	4.5	5	9	10.0	18	4.5		5
10.5		5	5	6.5	10.5		2		7
11.0	21	4	6.5	6.5	11.0	22	4		7
11.5		6	6.5	6	11.5		2		10
12.0	24	10	6	8	12.0	25			
12.5		7.5	6	6.5	12.5				
13.0	26	7.5	6	7	13.0	28			
13.5		9	6.5	6.5	13.5				
14.0	29	9.5	8	6.5	14.0	31			
14.5		9	16	7	14.5				
15.0	31	10	16	6	15.0	33			
15.5		6.5	10	6.5	15.5				
16.0	33	8	7	7	16.0	37			
16.5		14	7	10	16.5				
17.0	35	8	8.5	14	17.0	39			
17.5		12	11	8	17.5				
18.0	37	9	8	8	18.0	43			
18.5		8	5	6.5	18.5				
19.0	40	20	6.5	6.5	19.0	47			
19.5		20	7	7	19.5				
20.0	41	14	8.5	7	20.0	49			
20.5		12	8	8	20.5				
21.0	44	6.5	15	8	21.0	55			
21.5		13			21.5				
22.0	45				22.0	57			
22.5					22.5				
23.0	47				23.0	55			
23.5					23.5				
24.0	50				24.0	47			
24.5					24.5				
25.0	51				25.0	53			
25.5					25.5				
26.0	55				26.0	59			
26.5					26.5				
27.0	58				27.0	64			
27.5					27.5				
28.0	62				28.0	66			
28.5					28.5				
29.0	64				29.0	69			
29.5					29.5				
30.0	70				30.0	64			

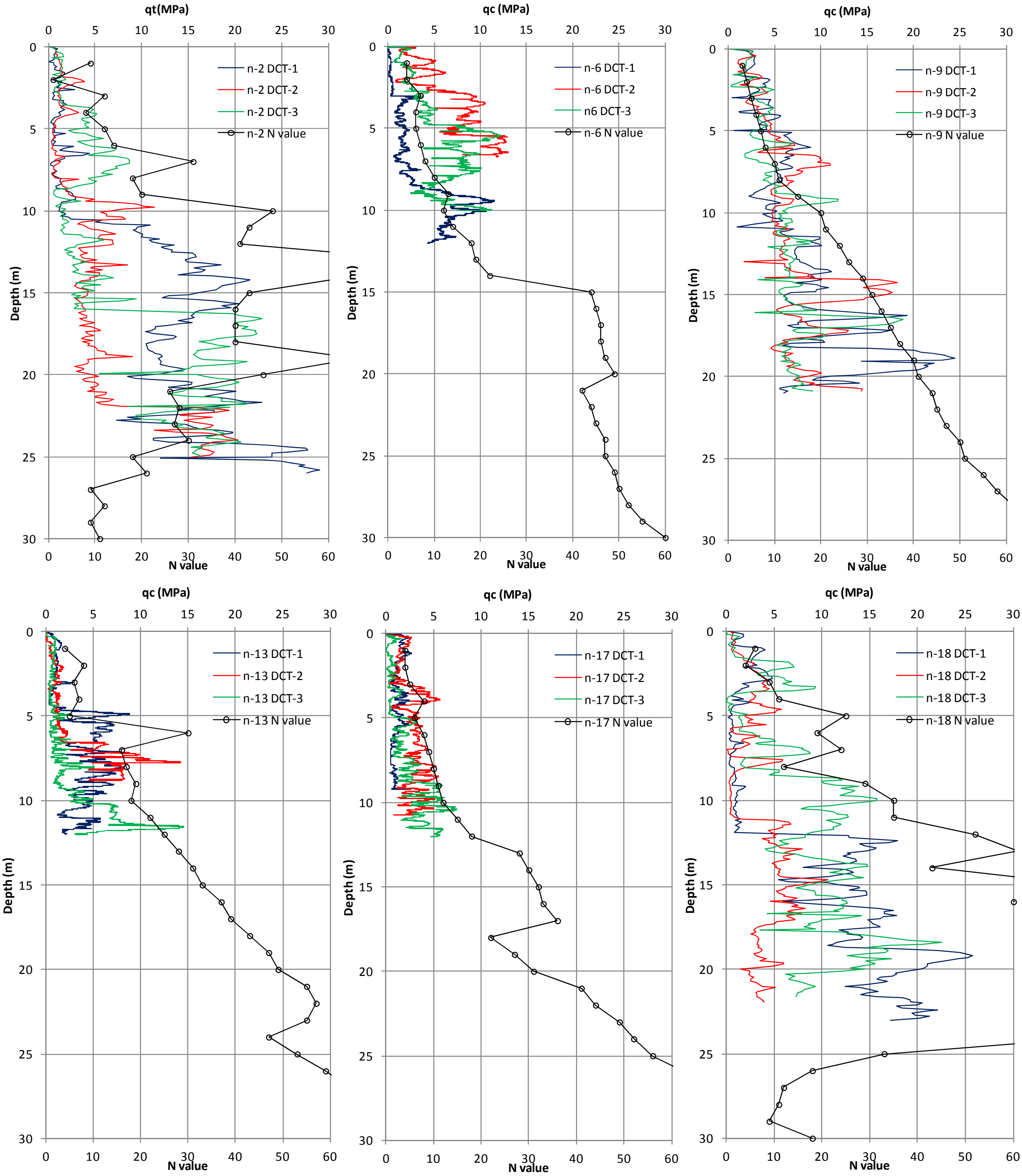
Depth (m)	n-17 N value	n-17 DCT-1	n-17 DCT-2	n-17 DCT-3	Depth (m)	n-18 N value	n-18 DCT-1	n-18 DCT-2	n-18 DCT-3
0.0		1.8	2.3	0.7	0.0		0.7	0.8	
0.5		1.8	1.7	0.2	0.5		0.7	0.8	
1.0	4	1.8	1.2	0.4	1.0	6	0.8	0.8	
1.5		1.4	1.2	0.5	1.5		3	1	
2.0	4	1.4	1.2	0.5	2.0	4	2.5	2.5	
2.5		1.4	0.9	0.5	2.5		3.5	3	
3.0	5	1.4	3.5	0.8	3.0	9	4.5	4	0.8
3.5		1.7	4.4	0.8	3.5		1.3	4	0.8
4.0	8	1.7	2.3	0.4	4.0	11	0.5	2.5	0.8
4.5		1.1	2.8	0.4	4.5		1	3	6
5.0	6	1.6	3	2.3	5.0	25	0.5	5	6
5.5		1.2	3	1.7	5.5		0.5	2.5	5.5
6.0	8	0.58	3	1.2	6.0	19	0.5	0.5	6.5
6.5		0.55	3.4	1.2	6.5		0.5	1	0.8
7.0	9	0.5	3	1.2	7.0	24	1	1	0.5
7.5		0.5	4	2.5	7.5		0.5	0.5	0.5
8.0	10	0.9	4	2.5	8.0	12	0.5	5	0.9
8.5		0.9	4	2.5	8.5		1	1	0.9
9.0	11	2.5	2.6	5	9.0	29	0.8	0.5	3
9.5			2.6	5	9.5		1.5	0.5	3.5
10.0	12		2.6	5	10.0	35	1	0.5	8
10.5			2.6	3.3	10.5		1	0.5	2
11.0	15			3.3	11.0	35	1	0.5	4
11.5				5.4	11.5		1	6	10.5
12.0	18				12.0	52	1	5	12
12.5					12.5		14	5	13
13.0	28				13.0	61	15	6	12
13.5					13.5		13	6.5	12
14.0	30				14.0	43	10	5	12
14.5					14.5		12	6	10
15.0	32				15.0	75	8	9	7
15.5					15.5		14	6	5
16.0	33				16.0	60	9	7	8
16.5					16.5		12	7	12
17.0	36				17.0	71	16	7	13
17.5					17.5		16	5	12
18.0	22				18.0	85	13	3.5	8
18.5					18.5		12	4	11
19.0	27				19.0	83	16	4	12
19.5					19.5		22	4	13
20.0	31				20.0	83	20	4	9
20.5					20.5		18	3	10
21.0	41				21.0	82	16	3	18
21.5					21.5		15	4	17
22.0	44				22.0	90	19	4	15
22.5					22.5		20		15
23.0	49				23.0	77	20		7.5
23.5					23.5				8
24.0	52				24.0	79			8
24.5					24.5				6
25.0	56				25.0	33			
25.5					25.5				
26.0	63				26.0	18			
26.5					26.5				
27.0	87				27.0	12			
27.5					27.5				
28.0	89				28.0	11			
28.5					28.5				
29.0	93				29.0	9			
29.5					29.5				
30.0	95				30.0	18			

Remark

Soil	N	qc	Soil	N	qc
Silt	N=<4	qc<=0.8Mpa	Sand	N<=10	qc<5Mpa
	N=5~8	qc=0.8~3Mpa		N=11~29	qc=5~10Mpa
	N>8	qc>3Mpa		N=30~49	qc=10~20Mpa
Clay	N=<4	qc<=0.8Mpa		N>=50	qc>20Mpa
	N>8	qc>3Mpa			

Red line: Soft grand bottom
Blue line: Bearing stratum top

Source: JICA Study Team



Source: JICA Study Team

Figure 1.1 Depth distribution of N-value and cone penetration resitance

2. Soil Properties

2.1 Distribution in depth direction

Figure 2.1 shows vertical distribution of drilling investigation results (N-value, cone penetration resistance and coefficient of permeability) and laboratory test results.

N-value in soft ground, intermediate layer and bearing layer, shows two patterns as step-like increasing/decreasing or linear increasing. Soft layer of less than 0.8Mpa in qc (cone resistance) is found within 10m deep, mostly less than 3m deep.

Data for wet density, dry density and void ratio are limited within depth of 5m. Wet density varies widely from 1.6 to 2.0g/cm3, dry density varies widely from 1.1 to 1.7g/cm3 as well.

Void ratio is divided into two categories such as around 0.8 and 1.2~1.4, which can be one of a parameter for an assessment of soil texture. Moisture content also varies widely as 22 to 42%.

Grain size within 5m depth consists mostly of fine fraction (<0.075mm), and that in deeper than 10m consists of much sand fraction. Cohesive soil including around 30% of sand content exists in depth from 5 to 10m, as an intermediate silt layer.

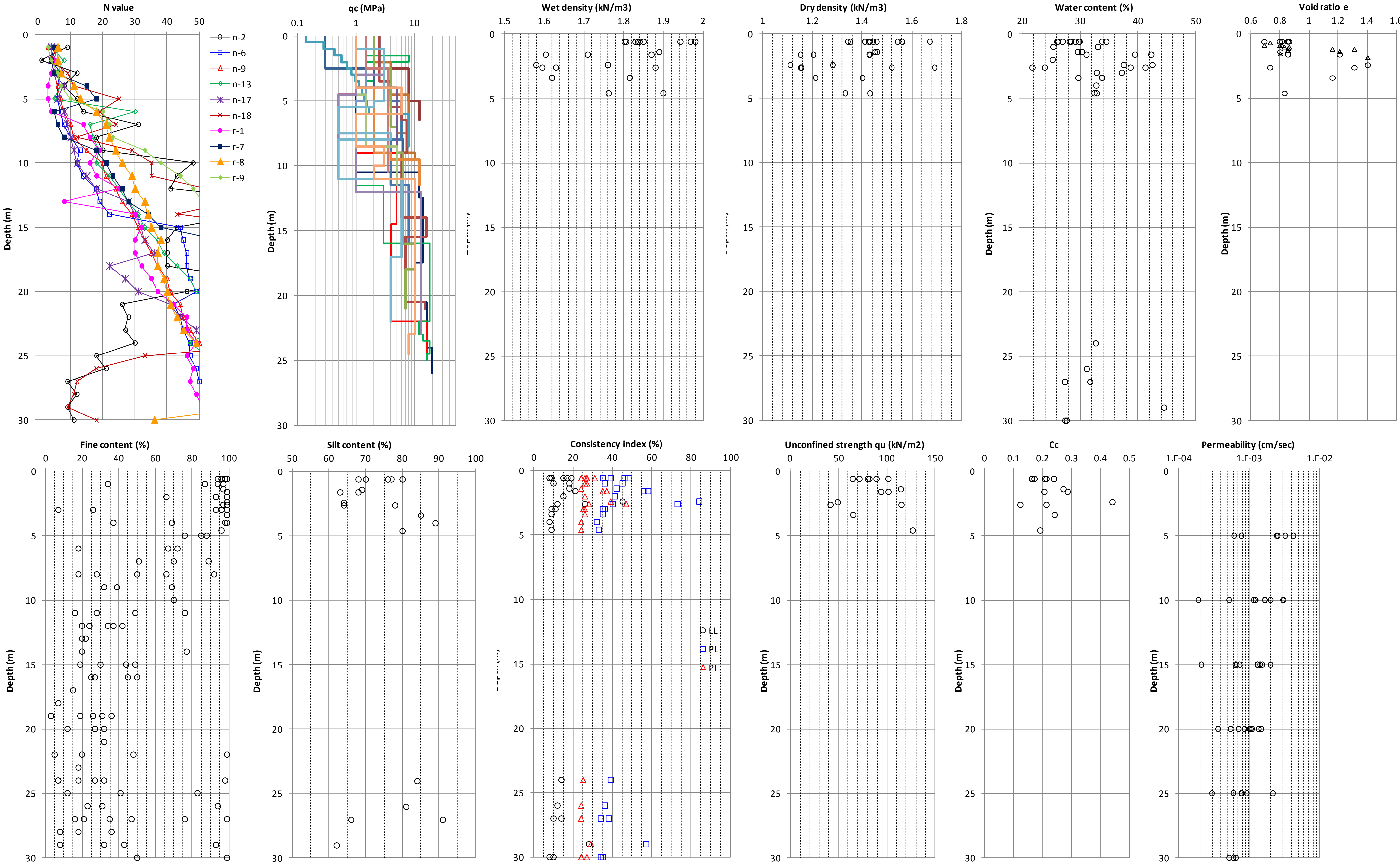
Representative physical values of silt layer within 5m depth are said as dry density 1.4g/cm3, water content of 30%, wet density of 1.8g/cm3 and void ratio of 0.85 for central value. This silt layer contains 65 to 90 % of silt fraction (0.075 to 0.002mm), and less clay fraction (under 2μ).

Liquid limit (w_L) and plastic limit (w_P) have a tendency to decrease by depth, and plastic index (PI) as those deference shows around 25% constantly. Soil class of large liquid limit is cohesive soil containing organic matter. Cohesive soil deeper than 24m shows same value as depth of 4 to 5m.

Unconfined compressive strength qu varies widely as 40~130kN/m2 and no tendency by depth is identified.

Compression index Cc varies widely as 0.12~0.3, central value (0.2) can be defined as a representative. This value is considered to be smaller than usual cohesive soil, and consolidation settlement is also considered to be smaller. Only one large value of Cc is seen for cohesive soil including organic matter.

Coefficient of permeability shows order from 10^{-4} to 10^{-3}cm/sec, and a slight tendency to decrease by depth is identified. Smaller coefficient of permeability is seen in silt fraction, and larger is seen in sand fraction.



Source: JICA Study Team

Figure 2.1 Soil Propeties in Depth Distribution

2.2 Physical Characteristics

(1) Grain size distribution

Figure 2.3 shows the gradation curve.

Grain size distribution is classified into two categories such as cohesive soil and sand.

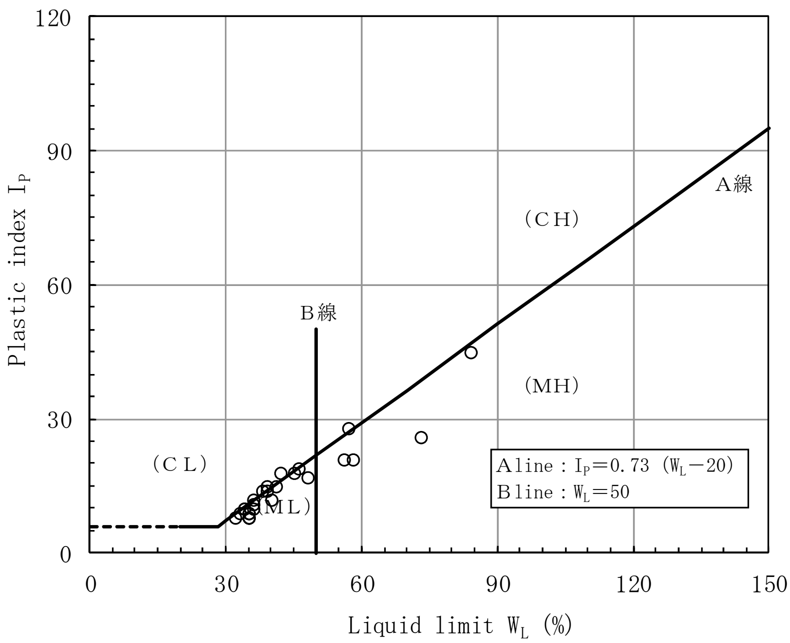
Though grain size of cohesive soil consists of fine fraction of more than 90%, the fine fraction predominantly consists of silt fraction of 0.075~0.002mm, and less clay fraction (under 2μ) of 10~40%.

Maximum grain size of sand is 2mm, however, size under 0.4mm is predominant.

Note) Above grain size classification is based on British Standard.

(2) Plasticity chart

Figure 2.4 shows plasticity chart. Soil contains mainly ML (silt with low liquid limit), partly MH (silt with high liquid limit).



Source: JICA Study Team（Plastic Chart is based on British Standard）

Figure 2.2 Plasticity chart

(3) Correlation in soil parameter

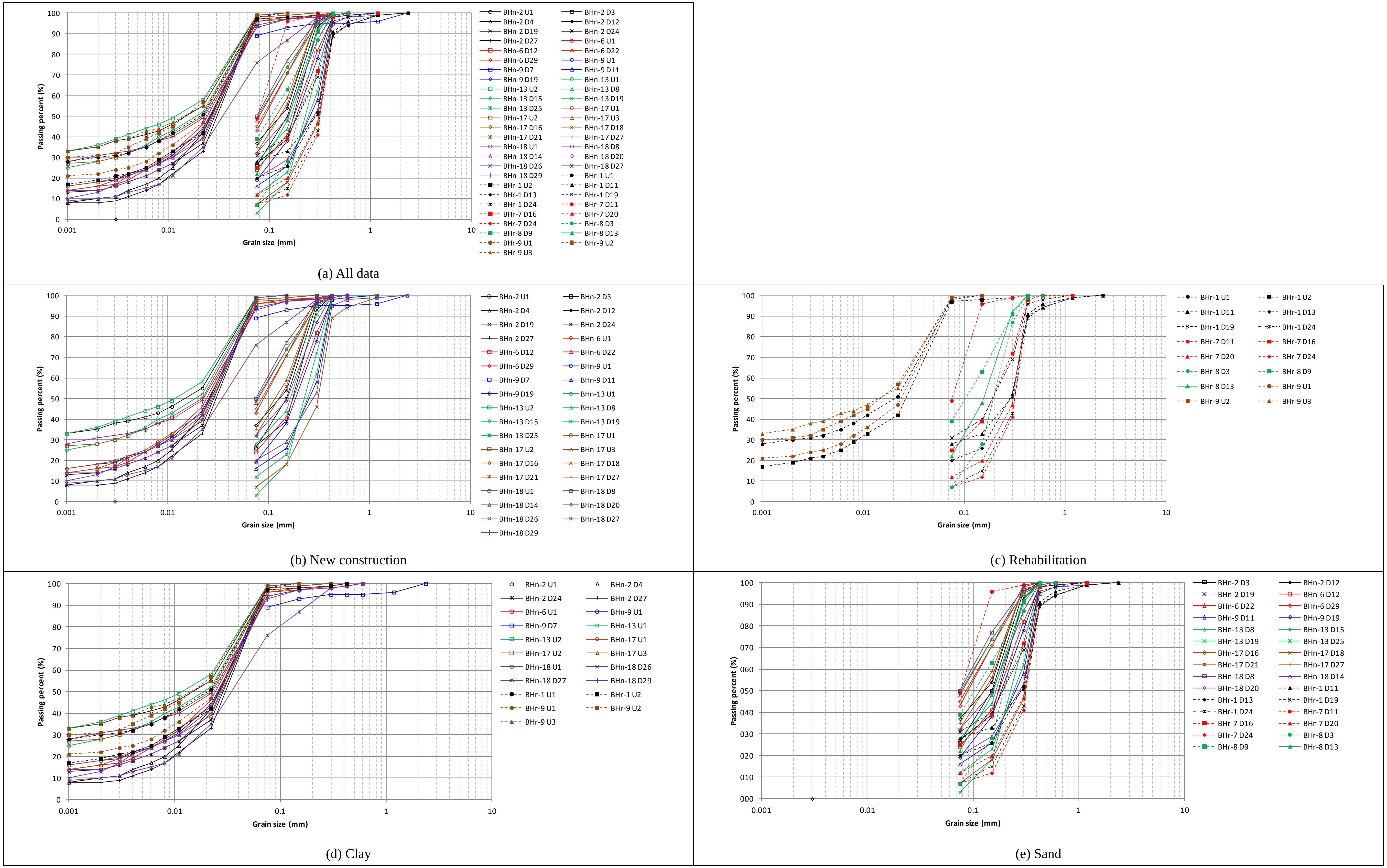
Figure 2.4 shows correlation chart in soil parameter.

Wet density has best correlation with void ratio, and next with water content. Unconfined compressive strength is identified correlation with void ratio.

Skempton showed that compression index has correlation with liquid limit by the following formula.

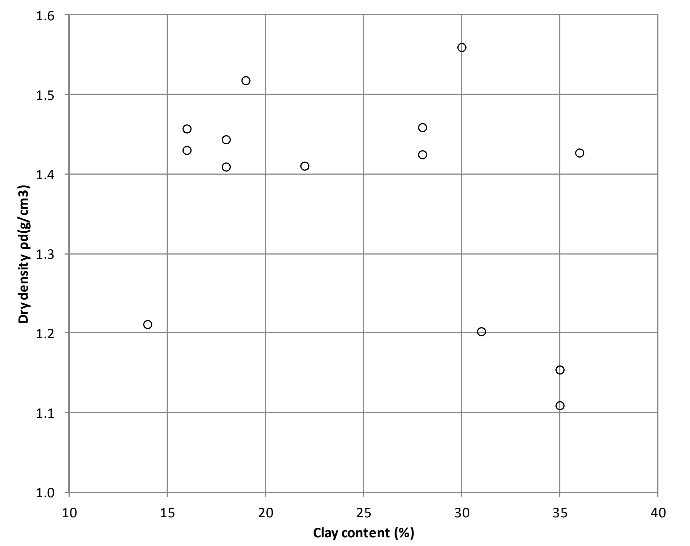
$$Cc=0.009(w_L-10) \quad \text{(Eq.1)}$$

However, compression index has little correlation with liquid limit but void ratio well.

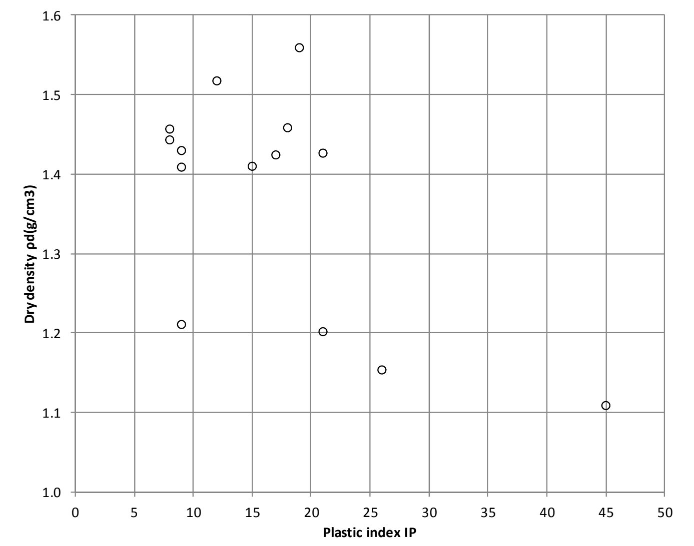


Source: JICA Study Team

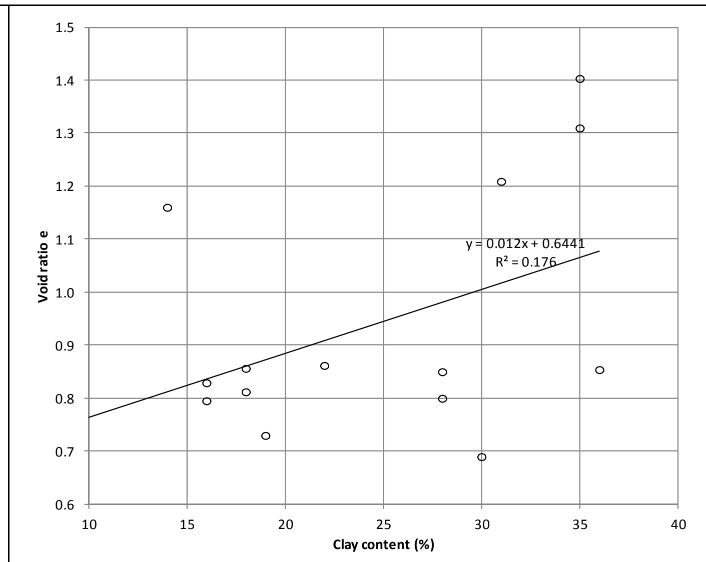
Figure 2.3 Grain size distribution



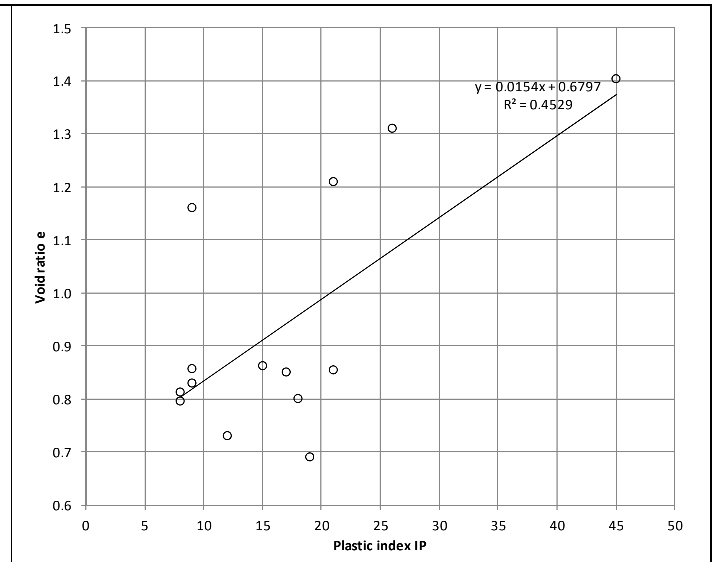
(1) Clay content and Dry density



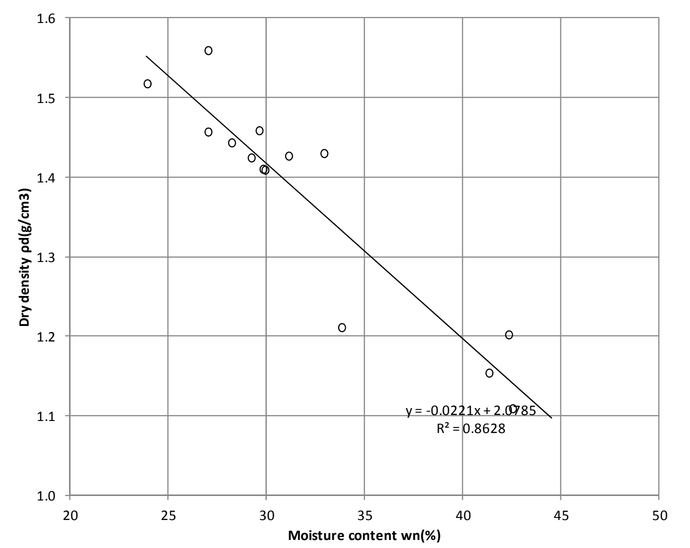
(2) Plastic index and Dry density



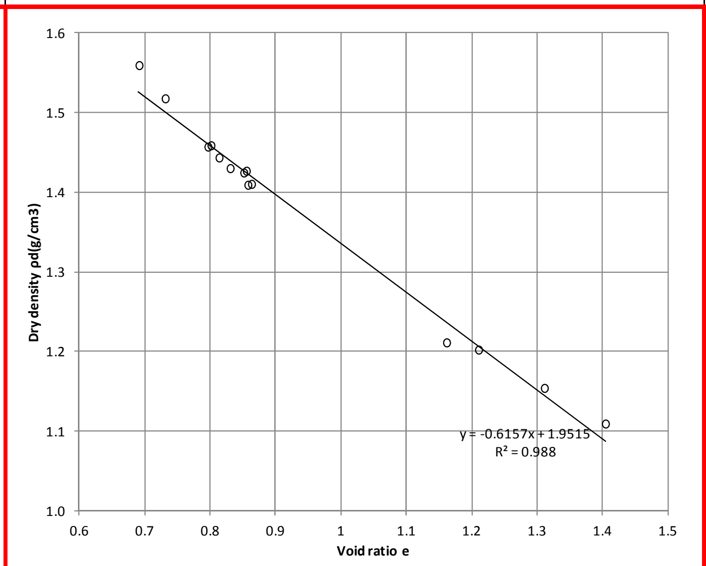
(3) Clay content and Void ratio



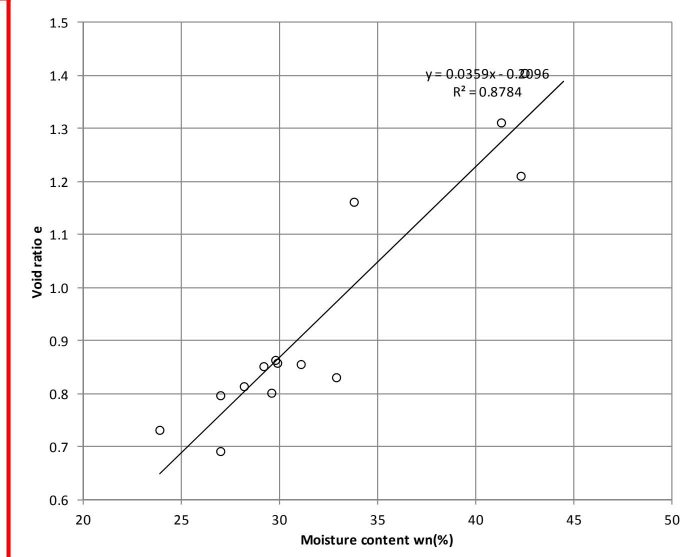
(4) Plastic index and Void ratio



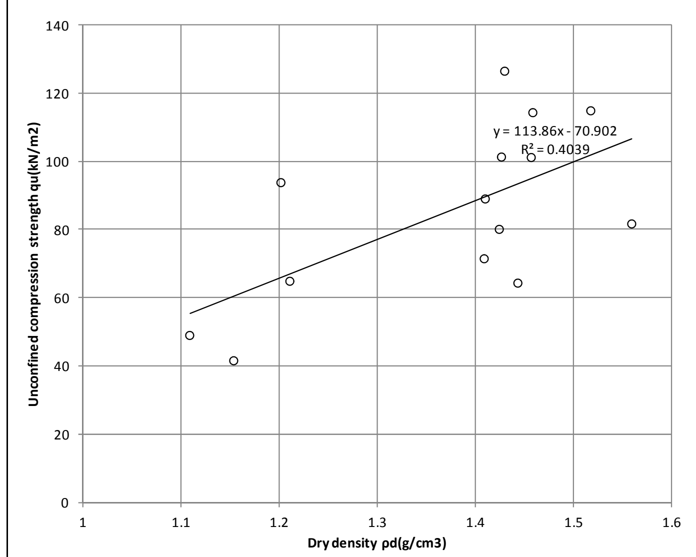
(5) Moisture content and Dry density



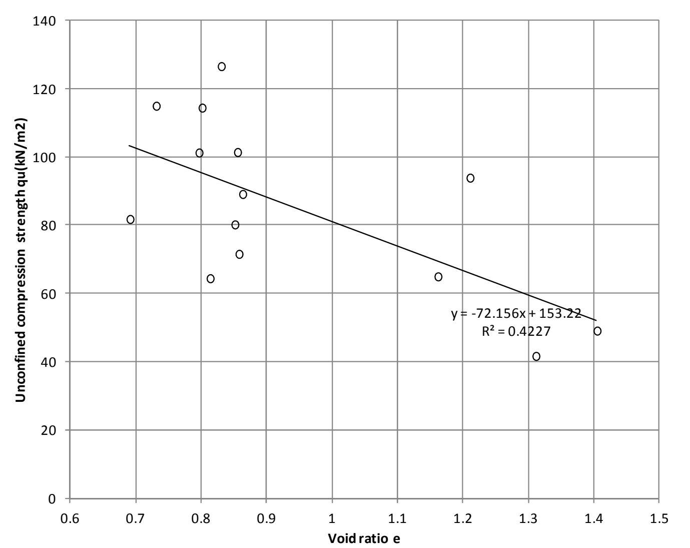
(6) Void ratio and Dry density



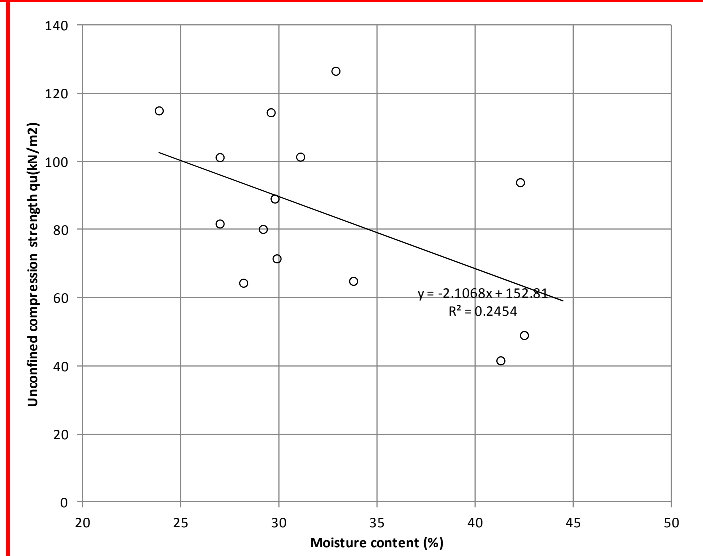
(7) Moisture content and Void ratio



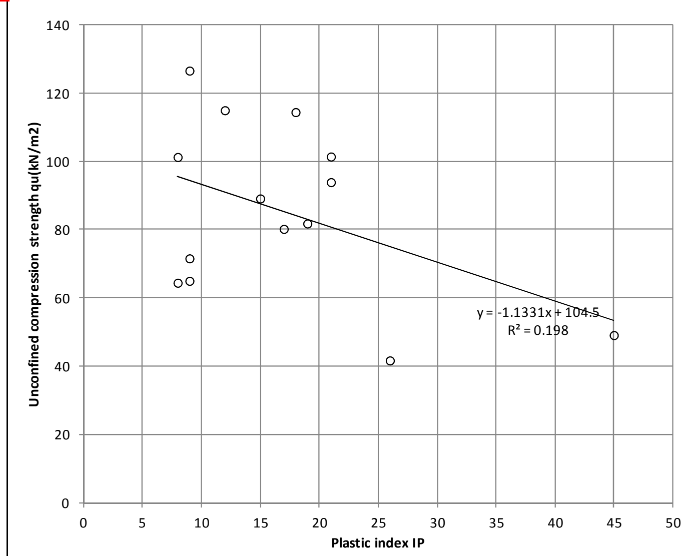
(8) Dry density and Unconfined compression strength



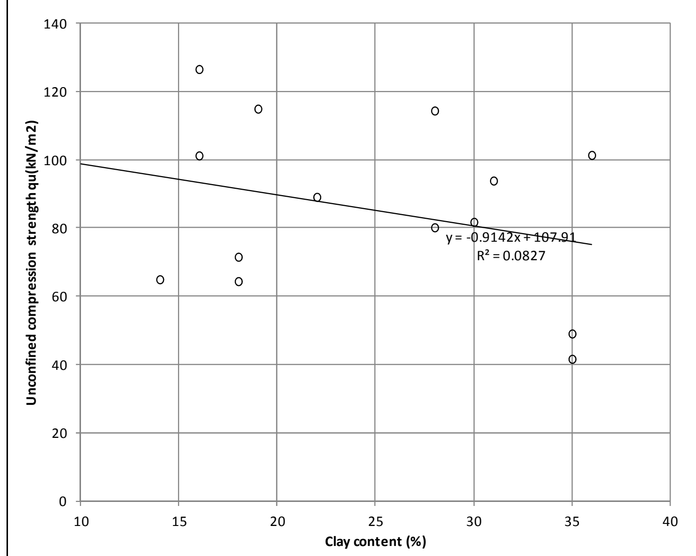
(9) Void ratio and Unconfined compression strength



(10) Moisture content and Unconfined compression strength



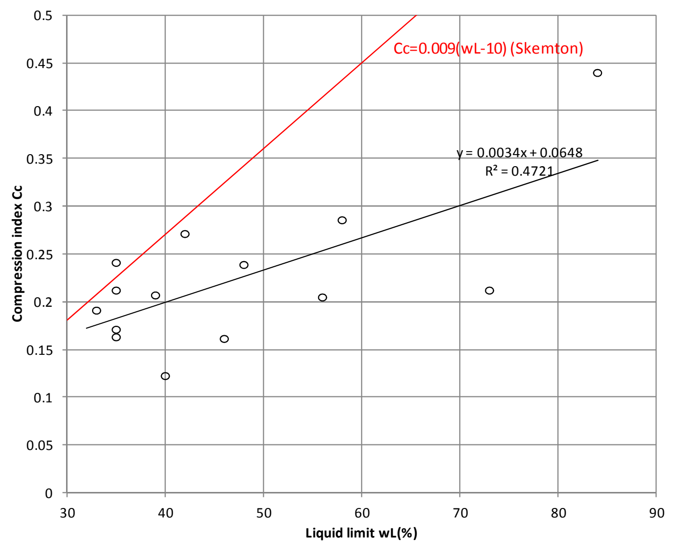
(11) Plastic index and Unconfined compression strength



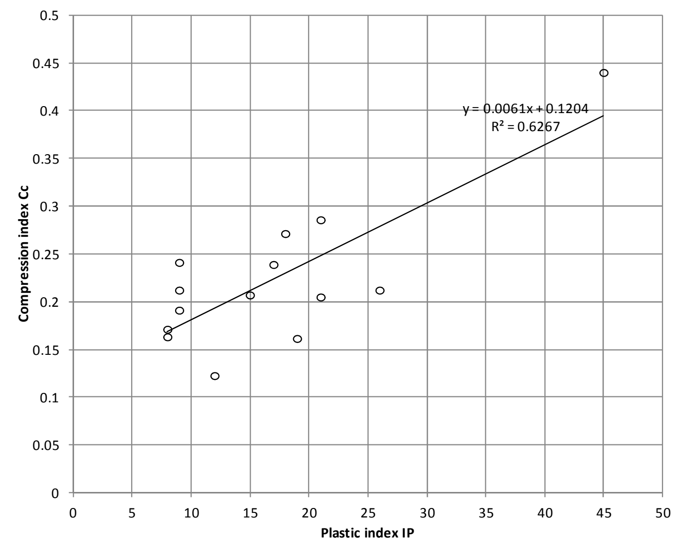
(12) Clay content and Unconfined compression strength

Source: JICA Study Team

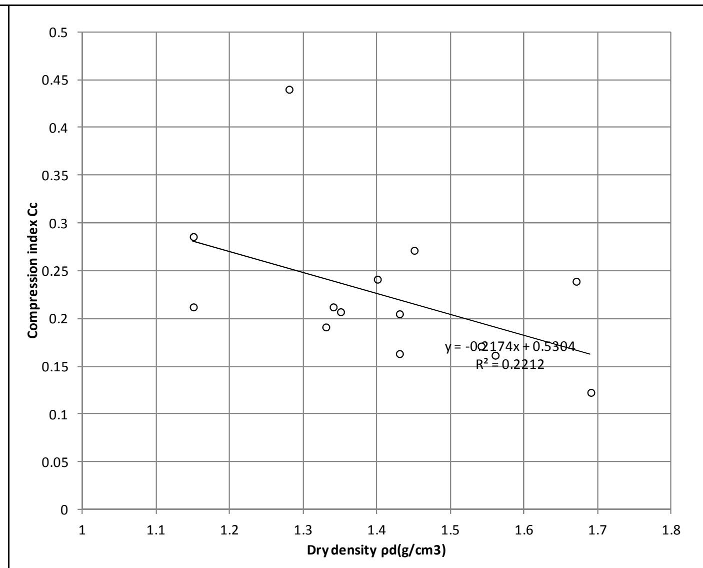
Figure 2.4(1) Correlation in Soil Parameter



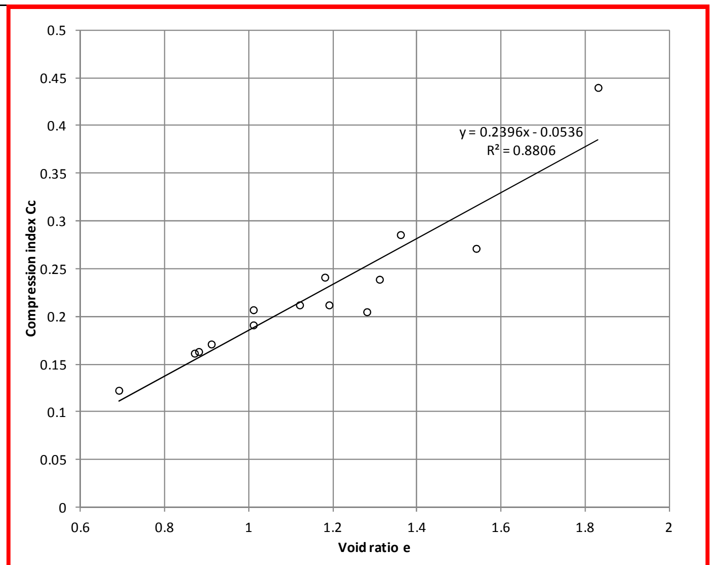
(13) Liquid limit and Compression index



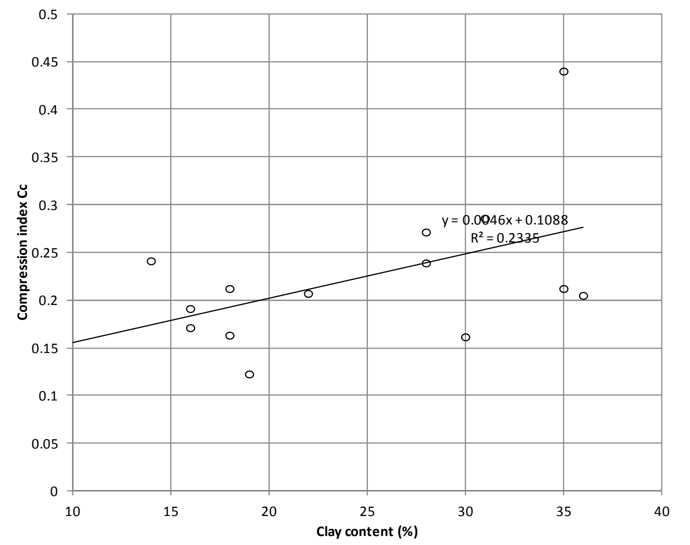
(14) Plastic index and Compression index



(15) Dry density and Compression index



(16) Void ratio and Compression index



(17) Clay content and Compression index

Source: JICA Study Team

Figure 2.4(2) Correlation inSoil Parameter

SUMMARY OF SOIL TEST RESULTS(1)

Bore Hole No.	Sample No. Tested	Depth of Sample (m)	Wet Unit Weight (kN/m^3)	NMC (%)	Dry density (g/cm3)	Void Ratio e	LL (%)	PL (%)	PI (%)	Sand (%)	Silt/ Clay (%)	Clay (%)	Specific Gravity	Classification of Soil USCS Group Symbol	Unconfined Compression Test q_u (kPa)	Unconfined Compression Test SF (%)	Consolidation Test Cc	Consolidation Test Specific Gravity	Consolidation Test Dry Density (g/cm3)	Consolidation Test Moisture Content (%)	Consolidation Test Initial Void Ratio	Organic Content by Loss-on Ignition %	Coefficient of Permeability (cm/sec)
1	2	3	4	5			6	7	8	9	10		11	12	13	14	15				16	18	19
BHn-2	D1	1.00					#N/A	#N/A	#N/A	66	34			SM									
	U1	2.40	15.8	42.50	1.11	1.404	84	39	45	1	99	35	2.72	MH	49.0	7.0	0.440	2.655	1.28	37.53	1.83		
24.89375	D3	3.00					#N/A	#N/A	#N/A	74	26			SM									
90.99114	D4	4.00		32.83			32	24	8	1	99	10	2.66	ML									
	D7	7.00					#N/A	#N/A	#N/A	30	70			ML									
	D8	8.00					#N/A	#N/A	#N/A	34	66			ML									
		10.00																					1.65E-03
	D12	12.00					#N/A	#N/A	#N/A	63	37			SM									
	D15	15.00					#N/A	#N/A	#N/A	70	30			SM									6.26E-04
	D19	19.00					#N/A	#N/A	#N/A	74	26			SM									
		20.00																					5.39E-04
	D22	22.00					#N/A	#N/A	#N/A	1	99		2.67	ML									
	D24	24.00		32.74			39	25	14	2	98	14	2.68	ML									
	D27	27.00		31.76			34	24	10	1	99	8	2.67	ML									
BHn-6	U1	0.60	18.5	27.00	1.46	0.796	35	27	8	4	96	16	2.67	ML	101.2	10.0	0.171	2.638	1.54	26.07	0.91		
	D3	3.00					#N/A	#N/A	#N/A	7	93			ML									
		5.00																					7.65E-04
24.334	D6	6.00					#N/A	#N/A	#N/A	33	67		2.66	ML									
90.993	D9	9.00					#N/A	#N/A	#N/A	31	69			ML									
	D10	10.00					#N/A	#N/A	#N/A	30	70			ML									5.12E-04
	D12	12.00					#N/A	#N/A	#N/A	76	24			SM									
	D15	15.00					#N/A	#N/A	#N/A	56	44		2.65	SM									1.30E-03
		20.00																					7.00E-04
	D22	22.00					#N/A	#N/A	#N/A	52	48		2.65	SM									
	D25	25.00					#N/A	#N/A	#N/A	59	41			SM									5.89E-04
	D27	27.00					#N/A	#N/A	#N/A	53	47			SM									
	D29	29.00					#N/A	#N/A	#N/A	57	43		2.65	SM									
		30.00																					6.41E-04
BHn-9	U1	0.60	18.3	29.90	1.41	0.857	35	26	9	6	94	18	2.67	ML	71.50	7.5	0.212	2.666	1.34	34.53	1.12		
24.19583	D1	1.00		33.10			36	26	10	6	94			ML									
90.88503	D2	2.00					#N/A	#N/A	#N/A	1	99			ML									
	D4	4.00					#N/A	#N/A	#N/A	2	98		2.66	ML									
		5.00																					6.04E-04
	D7	7.00					#N/A	#N/A	#N/A	11	89			ML									
		10.00																					1.88E-04
	D11	11.00					#N/A	#N/A	#N/A	84	16		2.65	SM									
	D15	15.00					#N/A	#N/A	#N/A	81	19			SM									2.07E-04
	D19	19.00					#N/A	#N/A	#N/A	81	19		2.65	SM									
		20.00																					3.57E-04
	D23	23.00					#N/A	#N/A	#N/A	82	18			SM									
		25.00																					2.94E-04
	D27	27.00					#N/A	#N/A	#N/A	84	16		2.64	SM									
BHn-13	UD1	0.60	18.4	29.20	1.42	0.851	48	31	17	2	98	28	2.69	ML	80.1	5.0	0.239	2.638	1.67	28.44	1.31		
	UD2	1.60	18.7	31.10	1.43	0.855	56	35	21	1	99	36	2.70	ML	101.3	8.0	0.205	2.643	1.43	1.28	1.28		
24.35675	D3	3.00		32.90			36	25	11	1	99			ML									
90.95917	D5	5.00					#N/A	#N/A	#N/A	15	85			ML									2.42E-03
	D8	8.00					#N/A	#N/A	#N/A	72	28		2.65	SM									
		10.00																					1.21E-03
	D12	12.00					#N/A	#N/A	#N/A	80	20			SM									
	D15	15.00					#N/A	#N/A	#N/A	51	49			SM									1.41E-03
	D19	19.00					#N/A	#N/A	#N/A	97	3		2.64	SP									
		20.00																					1.09E-03
	D22	22.00					#N/A	#N/A	#N/A	95	5			SP									
	D25	25.00					#N/A	#N/A	#N/A	88	12			SP-SM									9.17E-04
	D29	29.00					#N/A	#N/A	#N/A	92	8		2.65	SP-SM									
		30.00																					5.90E-04
BHn-17	UD1	0.60	18.5	28.20	1.44	0.813	35	27	8	2	98	18	2.67	ML	64.4	8.5	0.164	2.652	1.43	28.39	0.88		
24.509	UD2	1.40	18.9	29.60	1.46	0.801	42	24	18	3	97	28	2.68	ML	114.4	8.0	0.272	2.640	1.45	30.32	1.54		
91.13333	UD3	4.60	19.0	32.90	1.43	0.830	33	24	9	4	96	16	2.67	ML	126.5	7.0	0.191	2.644	1.33	32.50	1.01		
	D8	8.00					#N/A	#N/A	#N/A	8	92			ML									
		10.00																					3.05E-03
	D11	11.00					#N/A	#N/A	#N/A	24	76			ML									
	D14	14.00					#N/A	#N/A	#N/A	23	77			ML									
		15.00																					1.29E-03
	D16	16.00					#N/A	#N/A	#N/A	55	45		2.65	SM									
	D18	18.00					#N/A	#N/A	#N/A	93	7			SP-SM									
	D19	19.00					#N/A	#N/A	#N/A	64	36			SM									
		20.00																					1.05E-03
	D21	21.00					#N/A	#N/A	#N/A	68	32			SM									
	D24	24.00					#N/A	#N/A	#N/A	73	27			SM									
		25.00																					7.60E-04
	D26	26.00					#N/A	#N/A	#N/A	69	31			SM									
	D27	27.00					#N/A	#N/A	#N/A	65	35		2.64	SM									
	D28	28.00					#N/A	#N/A	#N/A	64	36			SM									
	D29	29.00					#N/A	#N/A	#N/A	68	32			SM									
BHn-18	D1	1.00					#N/A	#N/A	#N/A	13	87			ML									
24.72558	D3	3.00		37.20			35	26	9	4	96			ML									
90.91225	U1	3.40	16.2	33.80	1.21	1.161	35	26	9	1	99	14	2.67	ML	64.9	7.5	0.241	2.645	1.40	29.69	1.18		
	D5	5.00					#N/A	#N/A	#N/A	24	76			ML									3.22E-03
	D8	8.00					#N/A	#N/A	#N/A	50	50		2.66	ML									
		10.00																					1.99E-03
	D12	12.00					#N/A	#N/A	#N/A	58	42			SM									
	D14	14.00					#N/A	#N/A	#N/A	80	20			SM									
		15.00																					1.52E-03
	D20	20.00					#N/A	#N/A	#N/A	68	32			SM									1.35E-03
	D25	25.00					#N/A	#N/A	#N/A	17	83			ML									
	D26	26.00		31.17			36	24	12	6	94	13	2.67	CL									
	D27	27.00		27.39			38	24	14	24	76	10	2.68	CL									
	D29	29.00		44.50			57	29	28	7	93	31	2.70	CH									
	D30	30.00		27.45			34	24	10	50	50			SC									

SUMMARY OF SOIL TEST RESULTS(2)

Bore Hole No.	Sample No. Tested	Depth of Sample (m)	Wet Unit Weight (kN/m^3)	NMC (%)	Dry density (g/cm3)	Void Ratio e	LL (%)	PL (%)	PI (%)	Sand (%)	Silt/ Clay (%)	Clay (%)	Specific Gravity	Classification of Soil USCS Group Symbol	Unconfined Compression Test		Consolidation Test					Organic Content by Loss-on Ignition %	Coefficient of Permeability (cm/sec)
															q_u (kPa)	SF (%)	Cc	Specific Gravity	Dry Density (g/cm3)	Moisture Content (%)	Initial Void Ratio		
1	2	3	4	5			6	7	8	9	10		11	12	13	14	15				16	18	19
BHr-1	U1	0.60	19.8	27.00	1.56	0.691	46	27	19	2	98	30	2.69	ML	81.7	7.0	0.162	2.628	1.56	26.19	0.87		
24.36758	D1	1.00		25.40			45	27	18	3	97			ML									
91.64572	D2	2.00		25.29			41	26	15	7	93			ML									
	U2	2.60	18.8	23.90	1.52	0.731	40	28	12	3	97	19	2.68	ML	114.9	7.5	0.123	2.625	1.69	21.76	0.69		
	D8	8.00					#N/A	#N/A	#N/A	82	18			SM									
		10.00																					1.65E-03
	D11	11.00					#N/A	#N/A	#N/A	72	28		2.64	SM									
	D13	13.00					#N/A	#N/A	#N/A	80	20			SM									
		15.00																					6.26E-04
	D16	16.00					#N/A	#N/A	#N/A	73	27			SM									
	D19	19.00					#N/A	#N/A	#N/A	69	31		2.65	SM									
		20.00																					5.39E-04
	D22	22.00					#N/A	#N/A	#N/A	80	20			SM									
	D24	24.00					#N/A	#N/A	#N/A	93	7			SP-SM									
		25.00																					7.65E-04
	D26	26.00					#N/A	#N/A	#N/A	77	23		2.67	SM									
		30.00																					5.12E-04
BHr-7	D2	2.00					#N/A	#N/A	#N/A	34	66		2.66	ML									
	D4	4.00					#N/A	#N/A	#N/A	31	69			ML									
25.01478	D6	6.00					#N/A	#N/A	#N/A	28	72			ML									
		10.00																					1.22E-03
90.62486	D11	11.00					#N/A	#N/A	#N/A	51	49		2.66	SM									
		15.00																					6.55E-04
	D16	16.00					#N/A	#N/A	#N/A	75	25		2.65	SM									
	D20	20.00					#N/A	#N/A	#N/A	88	12			SP-SM									8.48E-04
	D24	24.00					#N/A	#N/A	#N/A	93	7		2.64	SP-SM									
		25.00																					7.76E-04
	D28	28.00					#N/A	#N/A	#N/A	92	8		2.64	SP-SM									
BHr-8	D3	3.00					#N/A	#N/A	#N/A	93	7		2.64	SP-SM									
		5.00																					4.21E-03
	D6	6.00					#N/A	#N/A	#N/A	82	18			SM									
24.13386	D9	9.00					#N/A	#N/A	#N/A	61	39		2.66	SM									
		10.00																					2.97E-03
90.92586	D13	13.00					#N/A	#N/A	#N/A	78	22			SM									
		15.00																					1.98E-03
	D17	17.00					#N/A	#N/A	#N/A	85	15		2.64	SM									
		20.00																					1.46E-03
	D24	24.00					#N/A	#N/A	#N/A	82	18		2.65	SM									
		25.00																					2.14E-03
	D27	27.00					#N/A	#N/A	#N/A	79	21			SM									
	D30	30.00		27.70			35	27	8	1	99		2.68	ML									
BHr-9	U1	0.60	18.3	29.80	1.41	0.863	39	24	15	1	99	22	2.68	CL	89.1	5.0	0.207	2.650	1.35	33.82	1.01		
	U2	1.60	17.1	42.30	1.20	1.210	58	37	21	1	99	31	2.71	MH	93.8	9.0	0.286	2.645	1.15	39.50	1.36		
	U3	2.60	16.3	41.30	1.15	1.311	73	47	26	1	99	35	2.72	MH	41.6	6.5	0.212	2.645	1.15	38.74	1.19		
	D4	4.00					#N/A	#N/A	#N/A	63	37			SM									
	D5	5.00					#N/A	#N/A	#N/A	12	88			ML									2.50E-03
	D7	7.00					#N/A	#N/A	#N/A	49	51			ML									
	D9	9.00					#N/A	#N/A	#N/A	68	32			SM									
		10.00																					1.15E-03
	D12	12.00					#N/A	#N/A	#N/A	66	34			SM									
		15.00																					7.21E-04
	D16	16.00					#N/A	#N/A	#N/A	50	50			SM									
	D20	20.00					#N/A	#N/A	#N/A	73	27		2.65	SM									1.01E-03
	D24	24.00					#N/A	#N/A	#N/A	68	32			SM									
	D28	28.00					#N/A	#N/A	#N/A	82	18		2.64	SM									

Source: JICA Study Team

2.3 Soil Parameter

Cohesion of soft silt layer is set from the results of laboratory test and DCT.

The relation between unconfined compressive strength (qu) and cone resistance (qc) is presented by the following formula Eq.1 according to "Road Earthwork Guideline for Countermeasures of Soft Ground, Japan Road Association".

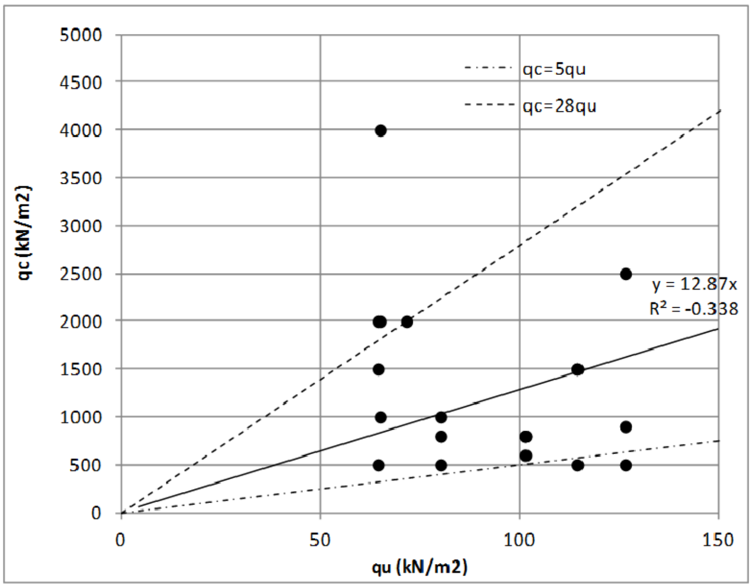
$$qu = (1/10 \text{ to } 1/15)qc \qquad \text{(Eq.1)}$$

The correlation between unconfined compressive strength and cone resistance is in the range of Eq.1, although unevenness is recognized because the drilling survey and DCT were conducted at different places.

Then, unconfined compressive strength shall be estimated from cone resistance by Eq. 2. And cohesion can be estimated by Eq.3, as cu=qu/2.

$$qu=1/15qc \qquad \text{(Eq.2)}$$

$$cu=qu/2=1/30qc \qquad \text{(Eq.3)}$$



Source: JICA Study Team

Fig. 2.5 Correlation between cone resistance (qc) and unconfined strength (qu)

The strength of intermediate and bearing layer is presumed by cone resistance for cohesive soil and empirical equation of $\varphi = (15N)^{0.5}+15$ for internal friction angle of sand. Density is supposed as typical value.

In addition, the relation between friction angle φ and cone resistance can be estimated by following Eq.4 (BS EN 1997-2:2007).

$$\varphi = 13.5 \times \log qc + 23 \qquad \text{(Eq.4)}$$

Table 2.1 Setting soil parameter

	Soft Layer	Intermediate Layer		Bearing Layer	
	Silt Layer	Silt Layer	Sand Layer	Silt Layer	Sand Layer
Specific gravity Gs	2.65	2.65	2.65	2.65	2.65
Wet density ρ_t(kN/m^2)	18	19	21	19	21
Dry density ρ_d(kN/m^2)	13	14.5	17.5	15	18
Water content w_n(%)	38	30	20	25	20
Void ratio e	1.0	0.8	0.5	0.7	0.5
Cone penetration resistance q_c(kN/m^2)	800	1,500	—	4,500	—
N-value	—	—	20	—	30
Unconfined compressive strength qu(kN/m^2)	53	100	0	300	0
Cohesion c_u(kN/m^2)	27	50	0	150	0
Internal friction angle φ(deg)	0	0	32	0	36
Compression index Cc	0.2	0.1	—	—	—
Coefficient of compressibility cv(m2/day)	1×10^{-2}	1×10^{-2}	—	—	—

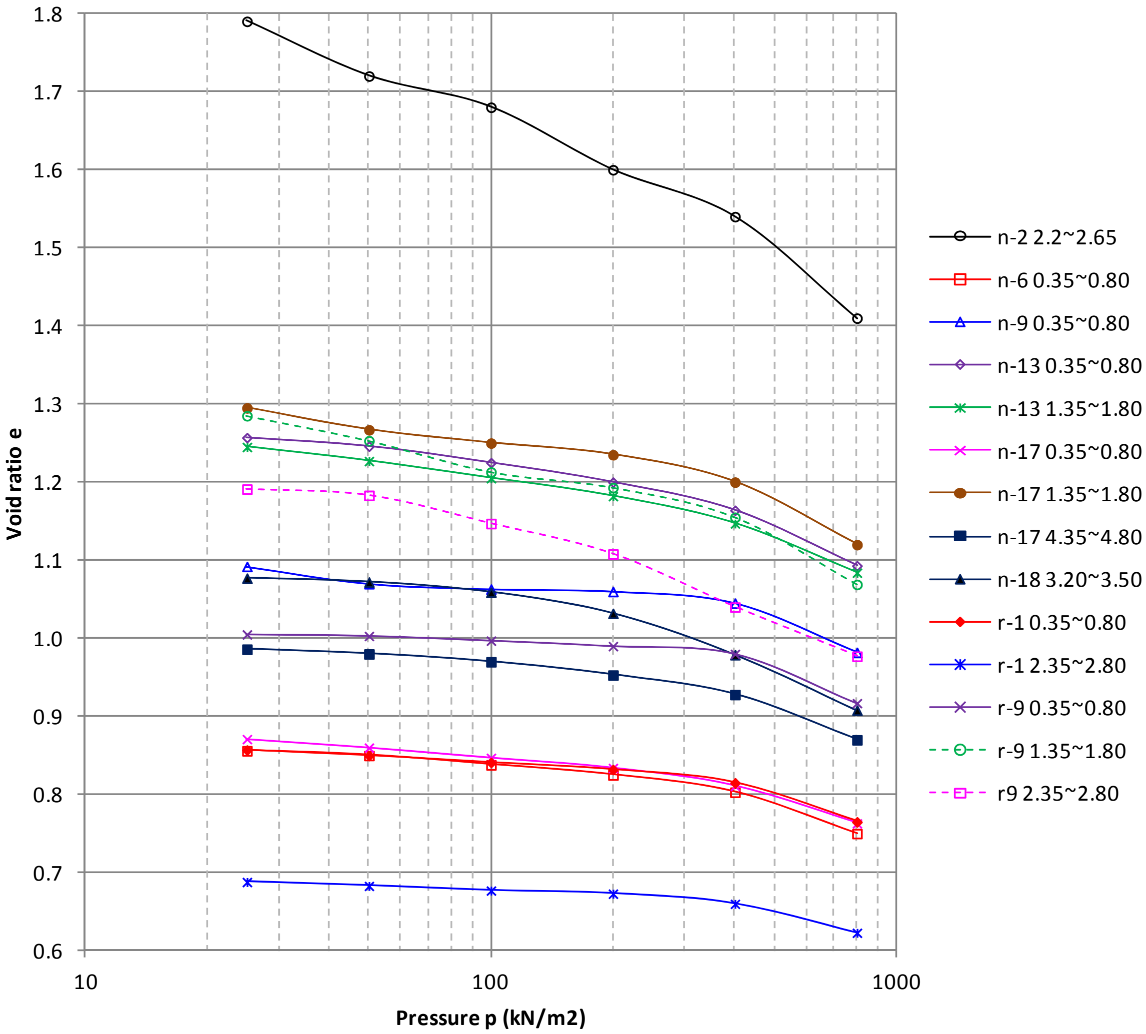
Source: JICA Study Team

3. Settlement

3.1 Consolidation Test Result

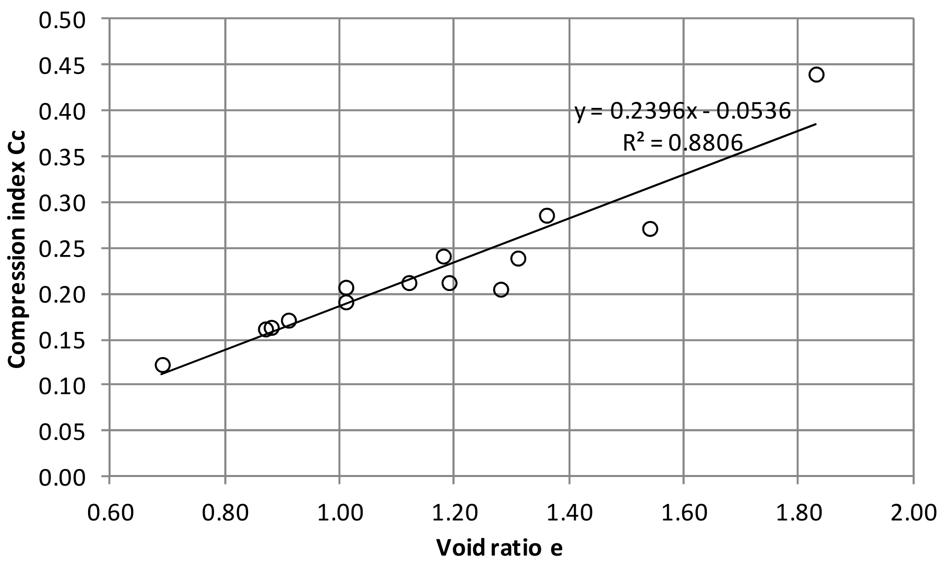
Figure 3.1 shows e ~ log(p) curves. The pre-compression load will be more than 200kN/m2 because void ratio comes down after 200kN/m2. This matter shows overburden was generally more than 20tf/m2, but it is impossible to consider the overburden like this in the project area. This is considered to be effect of drying shrinkage in dry season.

Figure 3.2 shows correlation between void ratio e and compression index Cc, indicating a extremely good correlation. The average void ratio of undisturbed samples is e=0.94, of which correspondent compression index will be Cc=0.17. This value is small due to cohesive soil of dominant silt contents.



Source: JICA Study Team

Figure 3.1 e ~ log(p) curves



Source: JICA Study Team

Figure 3.2 Correlation between Void ratio e and Compression index Cc

3.2 Setting Compression Index

As laboratory test result shows Cc=0.15~0.3, average 0.20, consolidation settlement is considerably low.

Estimate equations for Cc are as follows:

Cc = 0.009(WL - 10) Skempton
Cc = 0.017 (WL - 18) Nobi Plain

From above equations, Skempton derives Cc=0.18- 0.36 using liquid limit of 30- 50%, and Nobi Plain derives Cc=0.12- 0.29 using natural water content of 25- 35%. These results are almost same range as laboratory result.

As a result, representative compression index in the investigation area is assumed to be Cc=0.20.

3.3 Preliminary Settlement Estimation

(1) Basic condition for study of consolidation

Objective consolidation layer will be soft ground of N<4 or qc<0.8Mpa.

Thickness of soft ground is less than 6m from observed N-value, and less than 12m from observed qc. Embankment height is less than 4m, slope gradient of 1:3.0 and crest width of 4.3m. Embankment rising rate is 3cm/day as general value for soft ground.

(2) Soil parameter of soft ground

Initial void ratio is uneven but can be set as e0=0.85. Wet (saturated) density is 19.0kN/m^3. Compression index is Cc=0.2. Coefficient of consolidation can be cv=1.0x$10^{-2}$$m^2$/day as cohesive soil of dominant silt, considering common alluvial clay is 10^{-3} to $10^{-2}$$m^2$/day.

(3) Soil parameter of embankment

Maximum dry density can be set as central value of 17.0kN/m^3 from 16.7 to 17.2kN/m^3. Given compaction degree of 95%, dry density is 16.2kN/m3. If optimum moisture content is 18% as central value, wet density is 19.1kN/m^3 and saturated density is 20.2kN/m^3.

Table 3.1 Soil Properties

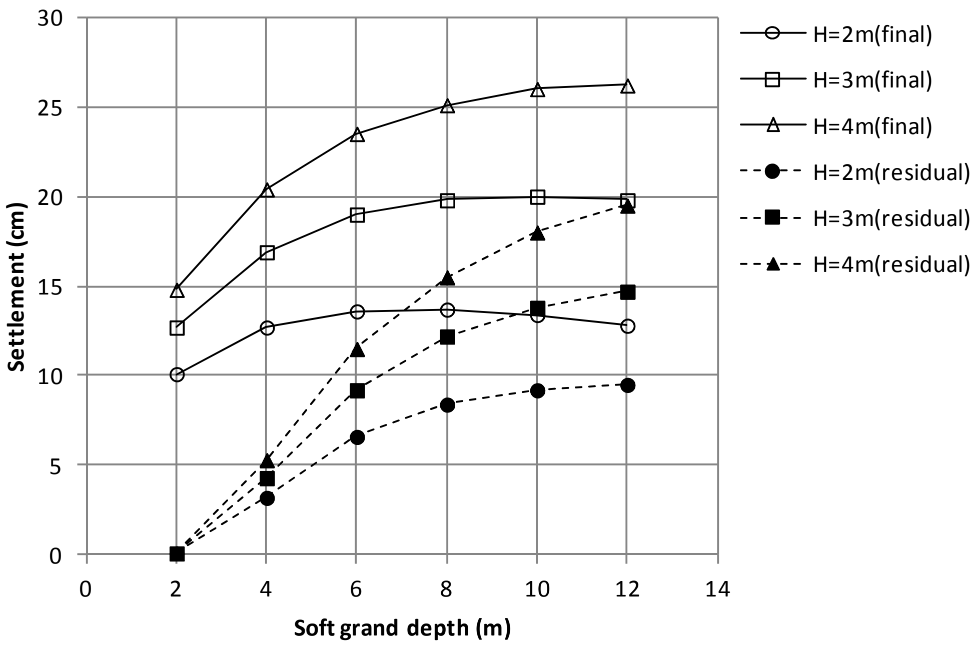
	Specific gravity Gs	Natural water content w_n (%)	Water content at satration w_{sat} (%)	Dry density ρ_d (kN/m^3)	Saturated density ρ_{sat} (kN/m^3)	Wet density ρ_t (kN/m^3)	Void ratio e	Compression index Cc	Coefficientof consolidation Cv m^2/day
Soft layer	2.66	32.0	32.0	14.4	19.0	19.0	0.85	0.2	1x10^{-2}
Embankment	2.68	18.0	24.4	16.2	20.2	19.1	0.65		

Source: JICA Study Team

(4) Settlement by Consolidation

Figure 3.3 shows estimated settlement due to consolidation.

Total settlement can be estimated as 26cm under the condition of soft ground thickness 12m and embankment height 4m. As residual settlement can be 20cm after construction of embankment, problem due to settlement will not occur. If the thickness of soft ground is smaller than 5m, residual settlement can be estimated less than 10cm.



Source: JICA Study Team

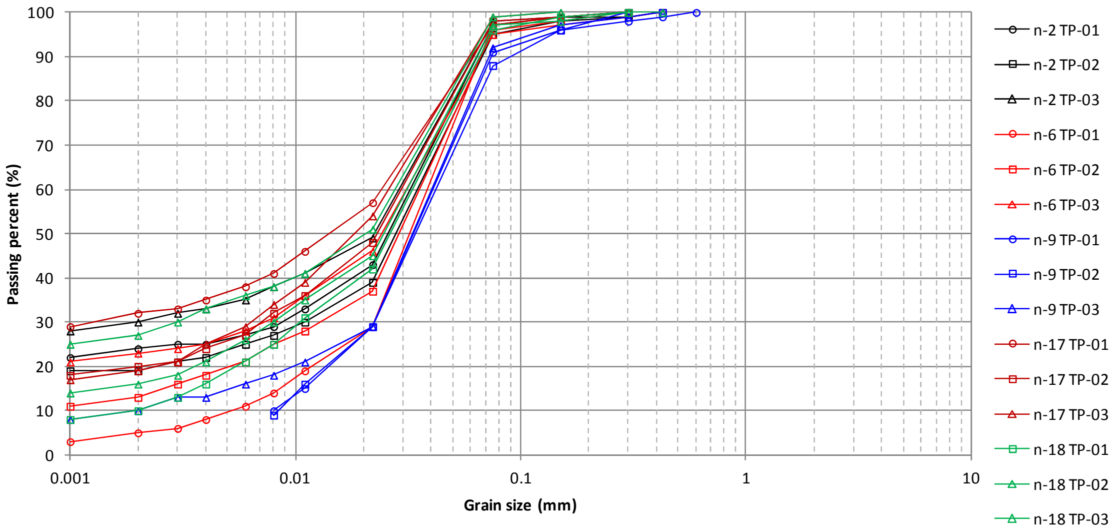
Figure 3.3 Estimated Settlement due to Consolidation

4. Embankment Material

4.1 Result of Laboratory Test for Embankment Material

(1) Physical Characteristics

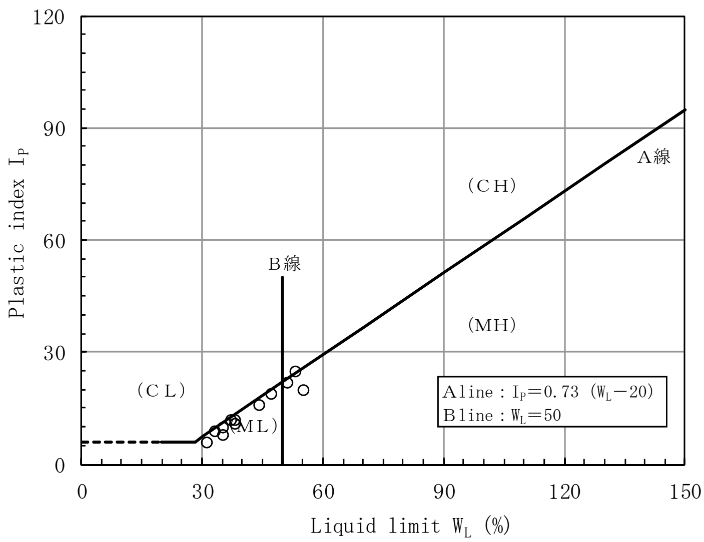
Figure 4.1 shows the gradation curve, and materials are cohesive soil mainly composed by silt with sand fraction of less than 12%. The silt fraction shows around 70 to 90% (Average 80%).



Source: JICA Study Team

Figure 4.1 Grain Size Curve

Figure 4.2 shows plasticity chart, and soil classification of materials are comprised in ML (silt with low liquid limit), partly MH (silt with high liquid limit) and CH (clay with high liquid limit).



Source: JICA Study Team (Plastic Chart is based on British Standard)

Figure 4.2 Plasticity chart

(2) Compaction Characteristics

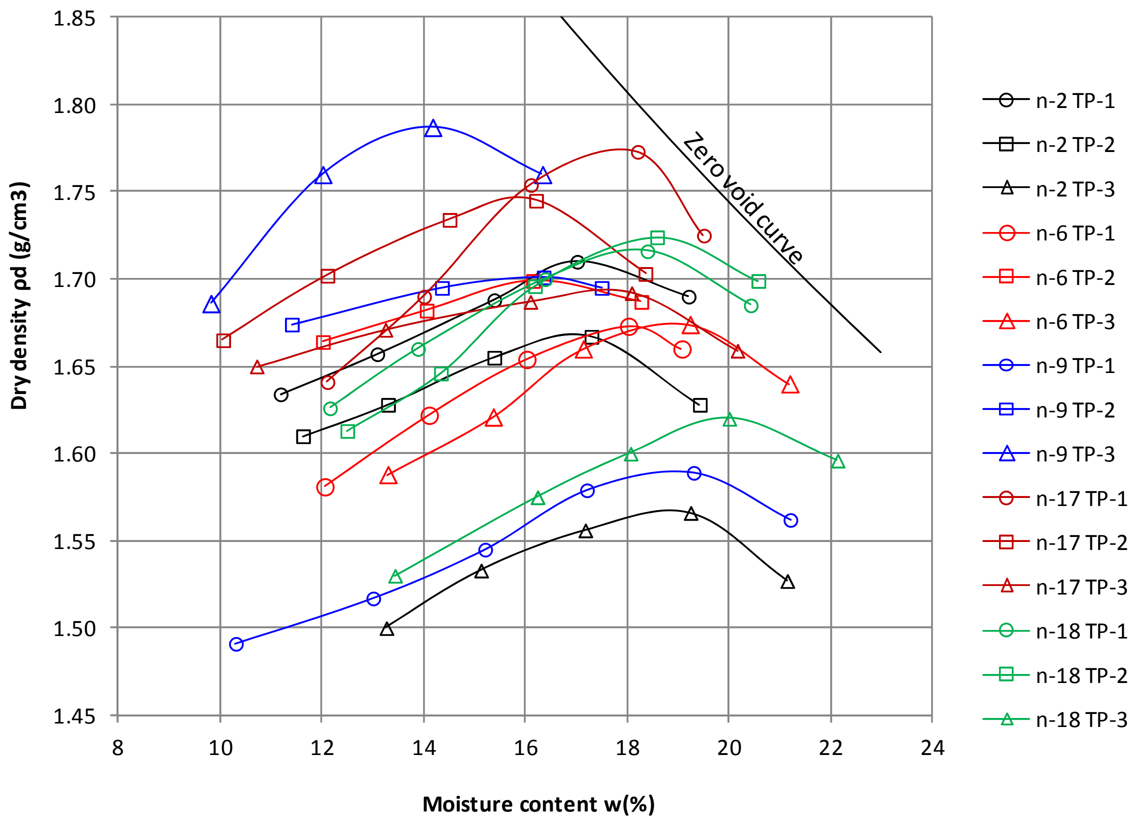
Figure 4.3 shows compaction curve.

Table 4.1 shows the relationship between optimum moisture content and dry density. This data show that optimum moisture content of 18% and dry density of around 1.7g/cm3 with unevenness.

Table 4.1 Compaction Test Result

	Maximum dry density ρ_{dmax} (g/cm^3)	Optimum moisture content W_{opt} (%)	Wet density ρ_t (g/cm^3)
Range	1.57~1.79	14.2~20.0	1.86~2.09
Average	1.69	17.6	1.99

Source: JICA Study Team



Source: JICA Study Team

Figure 4.3 Compaction Curve

(3) Soil Strength Characteristics

1) Unconfined compression strength test

Unconfined compression strength test was performed under condition of compaction degree of 90% and 95%.

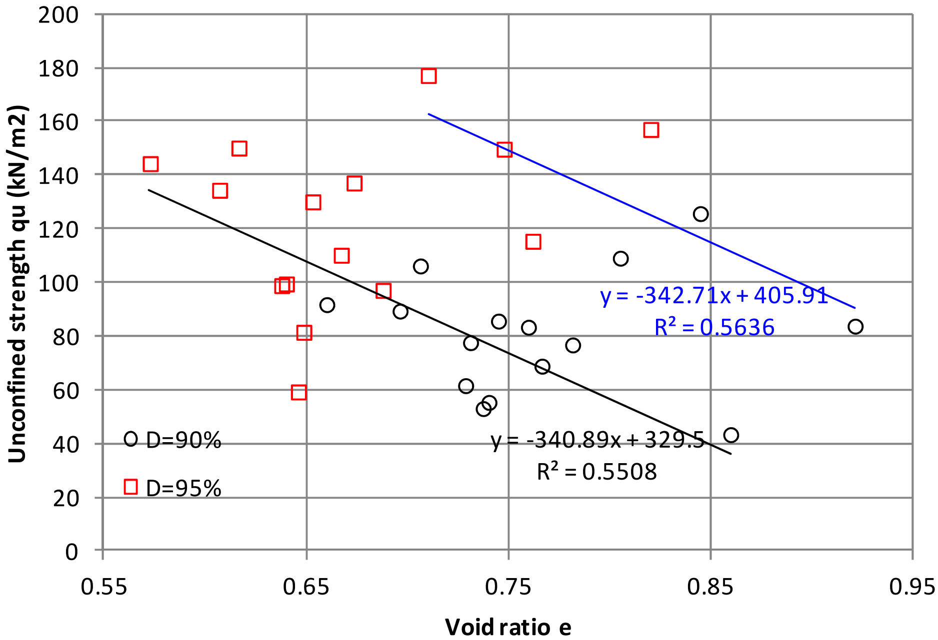
Figure 4.4 shows the correlation between void ratio (e) and unconfined compression strength (qu), with tendency of less qu in proportion as more e.

The strength of materials are classified to two categories, namely bigger strength is included in MH (silt with high liquid limit).

For D=90%, qu is expected more than 60kN/m^2, and for D=95%, qu is expected more than 100kN/m^2.

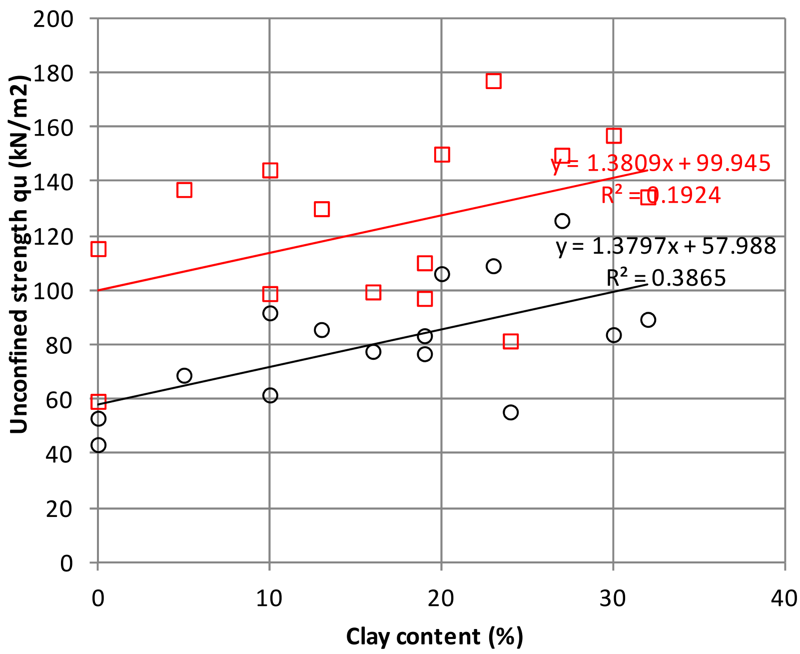
Figure 4.5 shows the correlation between clay contents and qu, with tendency of much qu in proportion as more clay content.

Figure 4.6 shows the correlation between qu of 90% and qu of 95%, with result that the latter shows 1.5 times of the former.



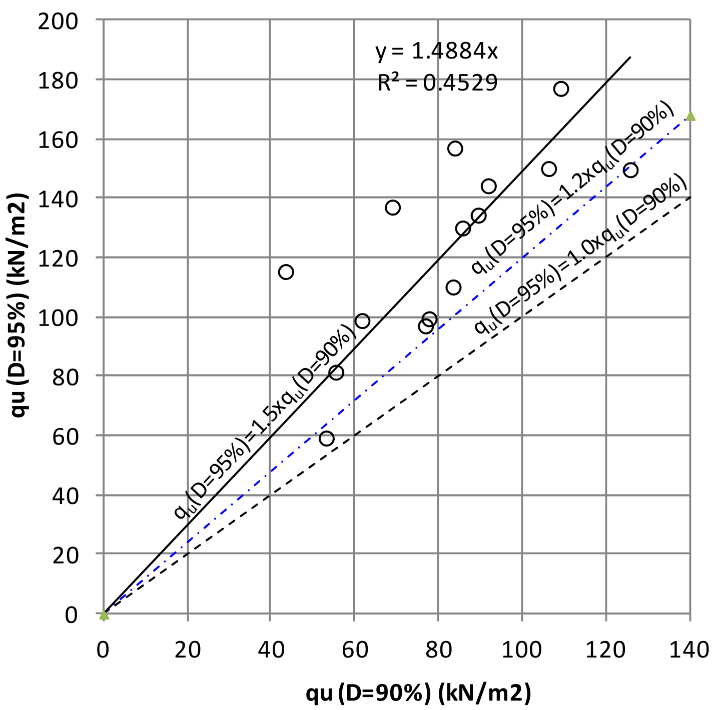
Source: JICA Study Team

Figure 4.4 Unconfined Compression Strength and Void Ratio



Source: JICA Study Team

Figure 4.5 Unconfined compression strength and clay content



Source: JICA Study Team

Figure 4.6 Relation of unconfined compression strength with D=90% and D=95%

2) Triaxial compressive strength test

The following table shows the strength of compacted material presumed from the triaxial compressive strength test results. In addition, unconfined compression test results are also evaluated comprehensively as triaxial compressive strength test as of confining pressure zero, for estimating strength parameter.

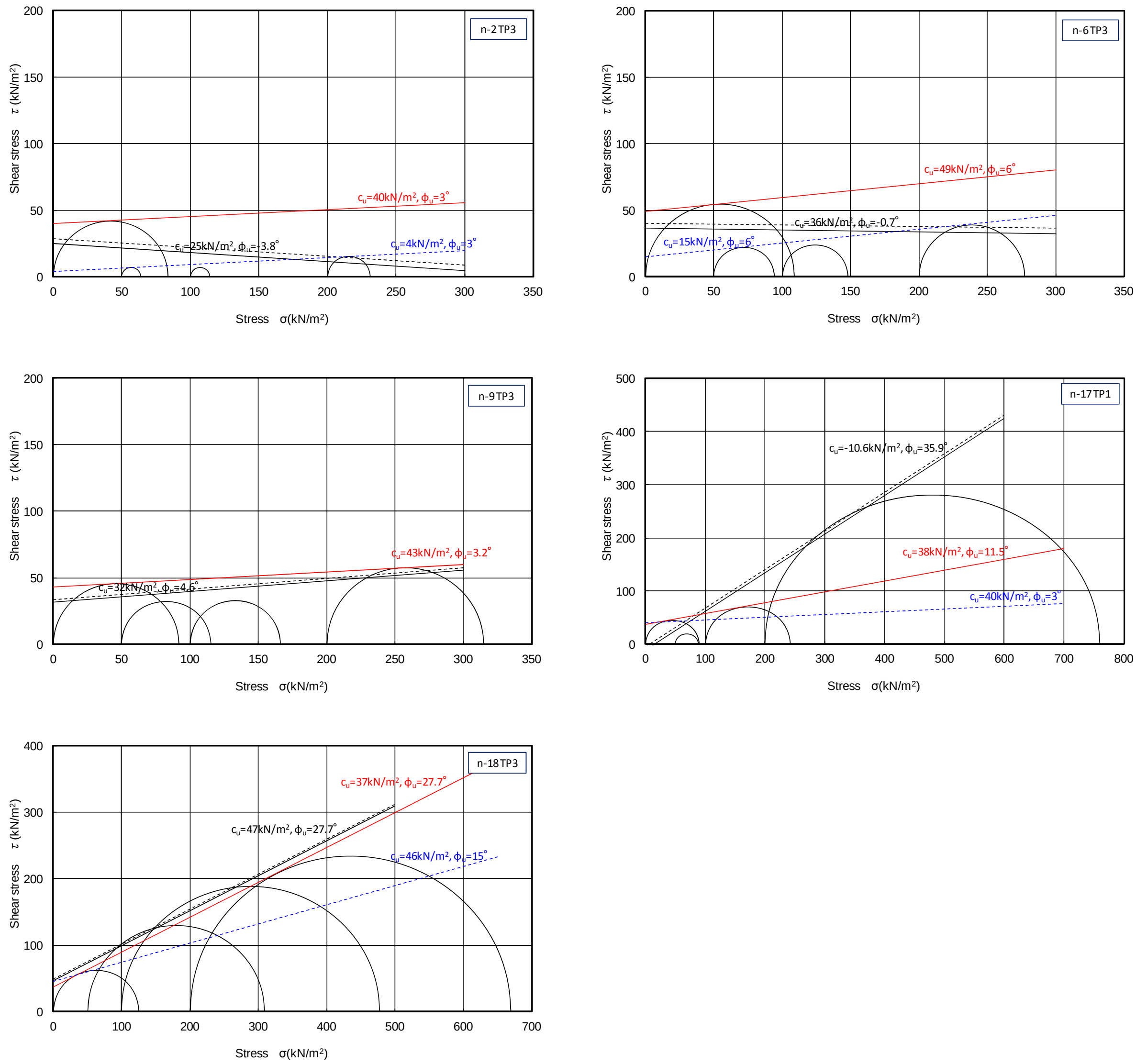
Table 4.1 Estimation for Strength Parameter from Triaxial Compression Test Result

Location	Condition*1	Dry density ρ_d (g/cm^3)	Water content w (%)	Degree of compaction D (%)	Cohesion c_u (kN/m^2)	Internal friction angle ϕ_u (deg)
n-2	Sat.	1.40~1.43 (1.418)*2	17.2~19.0 (18.2)*2	89.3~91.3 (90.5)*2	40	3
n-6	Sat.	1.51~1.53 (1.518)*2	10.8~19.0 (13.2)*2	90.2~91.4 (90.7)*2	49	9
n-9	Uns.	1.61~1.64 (1.633)*2	13.0~14.2 (13.5)*2	89.9~91.6 (91.2)*2	43	3
n-17	Uns.	1.60~1.70 (1.643)*2	14.6~18.0 (16.2)*2	90.1~95.8 (92.5)*2	38	11
n-18	Uns.	1.46~1.50 (1.480)*2	18.5~20.0 (19.6)*2	90.1~92.6 (91.4)*2	46	15

Source: JICA Study Team

*1 : Sat. is saturated and Uns. is unsaturated before triaxial compression test is done,

*2 : The values given in parentheses are mean.



Source: JICA Study Team

Figure 4.7 Results of Unconfined Compression Test and Triaxial Compression Test

(4) Advisability for Embankment Material

The embankment material should fill the following conditions according to the Manual of River Earthwork in Japan. In terms of soil classification, silt is possible to be used for embankment if moisture content is proper.

1) Grain size distribution should provide high density, and stable embankment with high shear strength.
2) Impermeable as much as possible, without seepage extending to toe of slope of protected area side.
3) Materials of no deformation and no expansivity so as not to effect to embankment body.
4) Good workability, especially easy to compact.
5) Stable and safe for sliding and clack against environmental variation such as inundation and dryness.
6) No content of deleterious organic matter and dissolving ingredient.

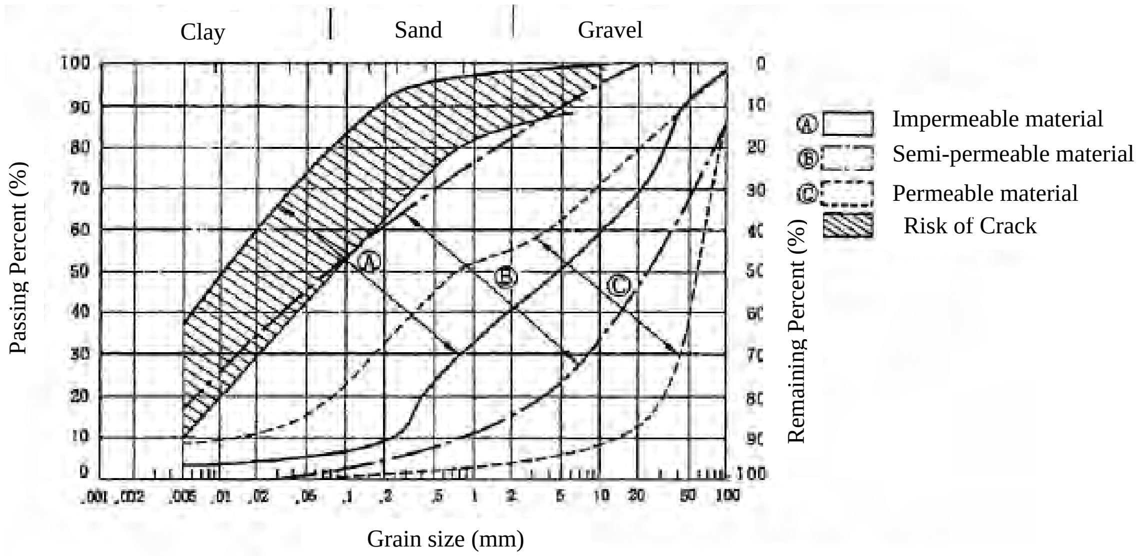
Source: The Manual of River Earthwork, Japan

The descriptions regarding expected embankment materials are as follows:

1) Soil of not much silt content: slope failure is apt to occur in the embankment of degraded shearing resistance by erosion and seepage water. Those weakened soil is considered to be affected by silt content.
2) Soil of not much content of fine grained fraction (<0.075mm): As soil of fine grained fraction of more than 50% is apt to be cracked in dry condition, it is preferable to use the soil of less than 50%.

Source: The Manual of River Earthwork, Japan

In terms of the grain size distribution, the materials with much silt content have high risk of cracks, according to the proper range for embankment materials by US Reclamation Bureau.



Source: The Manual of River Earthwork, Japan

Figure 4.8 Range Sample for Embankment Material (USRB 1974)

Therefore, if the silty materials will be used for embankment, it is important to consider the following matters;

- Take measures so as not to be cracked in embankment body.
- Take measures so as not to be eroded.
- Take consideration for slope stability in infiltration of seepage water.

Vegetation is generally effective for countermeasures against cracks and erosion. Especially *Dubra Grass* of endemic species as slope protection is widely used in this region, so this method is considered to be also effective for the slope protection of submergible embankment.

Dubra Grass will die down by submergence, however its roots survives and may prevent cracks and erosion partly. If ineffective by only vegetation, covering by high quality soil (above-mentioned blended grained soil) or geo-textile is considered to be good measures.

Table 4.2 Soil Evaluation as Embankment Material

<table>
<tr><th colspan="3">Soil Classification</th><th colspan="2">Evaluation for Embankment Material</th><th rowspan="2">Countermeasures</th></tr>
<tr><th colspan="2">Name</th><th>Symbol (JUSCS*)</th><th>Evalu-ation</th><th>Issues to be concerned</th></tr>
<tr><td rowspan="4">Coarse Grained Soil</td><td>Gravel</td><td>(GW),(GP)</td><td>○</td><td>Permeability is very high.</td><td>Measures for permeability and vegetation will be required.</td></tr>
<tr><td>Gravelly Soil</td><td>(G-M),(G-C),(G-O),(G-V),(GM),(GC),(GO),(GV),</td><td>○</td><td></td><td></td></tr>
<tr><td>Sand</td><td>(SW),(SP)</td><td>○</td><td>As permeability is high, slope collapse will be apt to occur.</td><td>Measures for permeability will be required.</td></tr>
<tr><td>Sandy Soil</td><td>(S-M),(S-C),(S-O),(S-V),(SM),(SC),(SO),(SV),</td><td>○</td><td></td><td></td></tr>
<tr><td rowspan="4">Fine Grained Soil</td><td>Silt</td><td>(ML),(MH)</td><td>○</td><td rowspan="3">If soil is wet, it is hard to construct by machine, as compaction might not be enough. (Countermeasure will be required as the case.)</td><td rowspan="3">Cut down of moisture content by drying, or stabilize by soil stabilization additive.</td></tr>
<tr><td>Cohesive Soil</td><td>(CL),(CH)</td><td>○</td></tr>
<tr><td>Volcanic Cohesive Soil</td><td>(OV),(VH1),(VH2)</td><td>○</td></tr>
<tr><td>Organic Soil</td><td>(OL), (OH)</td><td>△</td><td>As frequent high moisture content, compaction and forming by machine are difficult without modification.</td><td>Cut down of moisture content by drying, or stabilize by soil stabilization additive, or grain size control using good soil.</td></tr>
<tr><td colspan="2">Highly Organic Soil</td><td>(Pt),(Mk)</td><td>×</td><td>As high moisture content, compaction is very difficult. Compressive deformation is large and stability is low for environmental variation such as flooding and drying.</td><td></td></tr>
<tr><td colspan="6">○ Possible to use as embankment material
△ Possible to use as embankment material if some countermeasures are done
× Inappropreate for embankment material</td></tr>
</table>

*: Japan Unified Soil classification system

Source: River Earthwork Manual

SUMMARY OF CLASSIFICATION AND COMPACTION CHARACTERISTICS

FOR EMBANKMENT MATERIAL

Scheme No.	Test Pit No.	Coordinate	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Grain Size Analysis			Specific Gravity	Classification of Soil USCS Group Symbol	Proctor Compaction Test			Unconfined Com-pression Test						Trixial Shear Test (UU)	
							Sand (%)	Silt (%)	Clay (%)			MDD (gm/cm^3)	Void ratio e	OMC (%)	D=90%			D=95%				
															q_u (kPa)	e	SF (%)	q_u (kPa)	e	SF (%)	q_u (kPa)	SF (%)
n-2	TP-1	N-24^0 58' 06.2" E-91^0 04' 57.6"	13.4	44	28	16	3	73	24	2.68	ML	1.71	0.57	17.0	55.4	0.74	3.5	81.5	0.649	2.0		
n-2	TP-2	N- 25º 02′ 35.1″ E- 91º 03′ 44.7″	30.9	35	25	10	5	76	19	2.67	ML	1.67	0.60	16.9	76.8	0.782	3.5	97.1	0.688	2.5		
n-2	TP-3	N- 25º 02′ 59.6″ E- 91º 00′ 00.5″	18.8	55	35	20	2	68	30	2.71	MH	1.57	0.73	19.0	83.8	0.922	2.0	157.0	0.8	1.5		
n-6	TP-1	N-24^0 22' 49.8" E-91^0 01' 55.1"	34.1	#N/A	#N/A	#N/A	3	92	5	2.66	ML	1.67	0.59	18.0	68.9	0.767	3.5	137.1	0.674	2.5		
n-6	TP-2	N-24^0 17' 31.4" E-91^0 04' 37.8"	25.9	31	25	6	4	83	13	2.67	ML	1.70	0.57	16.1	85.7	0.7	2.5	130.1	0.7	3.5		
n-6	TP-3	N-24^0 19' 57.7" E-91^0 07' 06.4"	19.8	51	29	22	5	72	23	2.72	MH	1.67	0.62	19.0	109.1	0.805	2.0	177.1	0.71	2.5		
n-9	TP-1	N-24^0 12' 00.7" E-90^0 54' 02.4"	21.6	#N/A	#N/A	#N/A	9	91	0	2.66	ML	1.59	0.67	19.2	43.4	0.86	5.0	115.4	0.762	2.5		
n-9	TP-2	N-24^0 13' 46.2" E-90^0 52' 34.4"	16.6	#N/A	#N/A	#N/A	12	88	0	2.66	ML	1.70	0.56	16.5	53.1	0.738	5.5	59.3	0.646	4.5		
n-9	TP-3	N-24^0 12' 41.9" E-90^0 51' 20.8"	17.8	33	24	9	8	82	10	2.67	ML	1.79	0.49	14.2	91.8	0.66	2.0	144.3	0.573	3.0		
n-17	TP-1	N-24^0 30' 29.8" E-91^0 09' 26.0"	18.7	53	28	25	3	65	32	2.71	CH	1.78	0.53	18.0	89.4	0.696	7.0	134.4	0.607	7.5		
n-17	TP-2	N-24^0 30' 11.0" E-91^0 06' 58.0"	29.7	37	25	12	2	78	20	2.68	ML	1.75	0.54	16.0	106.2	0.706	2.5	150.1	0.617	3.0		
n-17	TP-3	N-24^0 27' 33.1" E-91^0 06' 53.0"	23.9	38	27	11	1	80	19	2.68	ML	1.69	0.58	17.8	83.4	0.76	2.5	110.2	0.667	2.0		
n-18	TP-1	N-24^0 46' 36.0" E-90^0 53' 46.8"	24.4	35	27	8	4	86	10	2.67	ML	1.72	0.56	18.4	61.7	0.7	2.5	98.9	0.6	3.0		
n-18	TP-2	N-24^0 25' 40.8" E-90^0 55' 16.5"	25.9	38	26	12	3	81	16	2.68	ML	1.72	0.56	18.6	77.7	0.7	2.5	99.5	0.64	3.5		
n-18	TP-3	N-24^0 44' 24.8" E-90^0 56' 36.0"	24.8	47	28	19	1	72	27	2.69	ML	1.62	0.66	20.0	125.7	0.845	2.5	149.7	0.748	2.5		

Source: JICA Study Team

4.2 Required Strength of Embankment Material

(1) Basic Condition

Embankment section is considering the most dangerous condition as follows:

- Height of embankment; 4.0m
- Slope gradient; 1: 2.0
- Seepage water; rapid rising and falling condition of flood water level
- Density of embankment; D= 95%

(2) Result of Calculation

As a result of slope stability analysis, cohesion is 14kN/m^2 to satisfy the required safety factor of 1.2 as shown in Figure 4.9.

As cohesion is expected as 38 49 kN/m^2 according to the unconfined compression tests and tri-axial tests, then the initial strength of embankment is enough. The strength must not decrease up to cu=14kn/m^2 even under the repeating submergence and dry.

Assuming that initial strength is 38kN/m^2, 14kN/m^2 is corresponding 37% (63% strength reduction). According to the dry-wet test up to 8 cycles test at present, the strength reduction is 45% from initial strength under the condition of compaction degree of 90%, and 36% under compaction degree of 98%. For compaction degree of 80%, dry-wet cyclic test is not able over 4 cycles, since any specimens cannot keep their form. The strength reduction under compaction degree of 90% is within the allowable range according to the result of dry-wet test up to 8 cycles.

Table 4.2 Slope Stability Analysis Result

Cohesion Cu (kN/m^2)	Min. safety factor	
	Rising	Drop down
10	1.003	0.919
12	1.204	1.102
13	-	1.194
14	-	1.286
20	2.006	1.837
30	3.009	2.756

Source: JICA Study Team

4.3 Shape of Embankment

(1) Study for Embankment Stability

Cohesive soil of N<4 and qc<0.8Mpa might be problem for embankment stability.

Assuming qc=0.8Mpa up to GL.-10m, stability has been examined.

1) Basic Condition

Set cohesion of cohesive soil as follows:

$$cu=1/2qu=1/30qc=1/30*0.8Mpa=26.7kN/m^2$$

Table 4.3 Analytical Parameter

Analytical parameter	Embankment	Soft ground
Saturated density ρ_{sat} (kN/m^3)	20.2	18.0
Wet density ρ_t (kN/m^3)	19.1	18.0
Cohesion c_u(kN/m^2)	10.0	26.7
Friction angle φ_u(deg)	0.0	0.0

Source: JICA Study Team

2) Water level condition

Set residual water level condition at depression head.

3) Embankment shape

Set three kinds of height as H=2.0m, 3.0m, 4.0m.

Set two kinds of slope gradient as 1: 2.0 and 1: 3.0.

Set crest width as 4.3m.

4) Result of calculation

Table 4.4 shows the result of calculation, cu=26.7kN/m^2 satisfies the required safety factor.

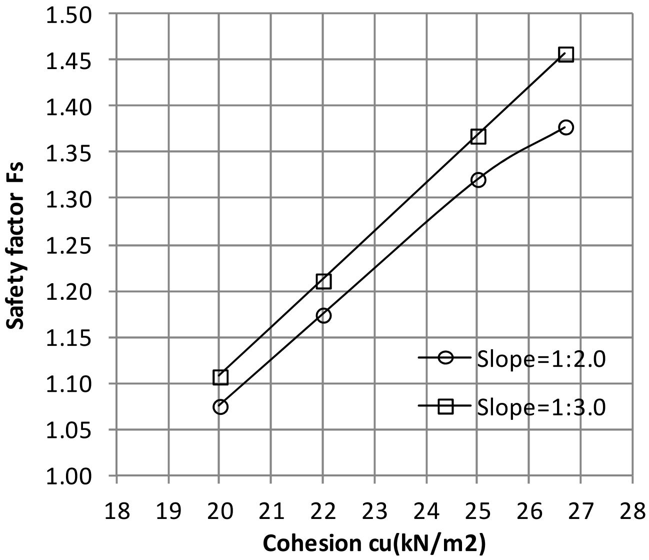
Cohesion of more than 23kN/m^2 satisfies the safety factor of 1.2 as shown in Figure 4.9.

Therefore, cone resistance of more than 0.8Mpa will be evaluated as no problem in stability.

Table 4.4 Stability Analysis Result

Embankment Height (m)	Cohesion of Grand cu (kN/m2)	Min. safety factor	
		Slope=1:2.0	Slope=1:3.0
4	26.7	1.378	1.457
4	25.0	1.321	1.368
4	22.0	1.174	1.211
4	20.0	1.075	1.107

Source: JICA Study Team



Source: JICA Study Team

Figure 4.9 Cohesion and safety factor

(2) Soft Ground

The cone resistance of less than 0.8Mpa is corresponding as soft ground.

The most soft ground is qc=0.3Mpa of GL.-3.0m at DCT-1 point in n-6 area. Embankment shape will be examined at this point.

1) Analytical parameter

The strength of soft ground at this point will be found as using foresaid formula Eq.2 and Eq.3.

Table 4.5 Analytical Parameter(2)

Parameter	Embankment	Soft grand
Saturated density ρ_{sat} (kN/m^3)	20.2	18.0
Wet density ρ_t (kN/m^3)	19.1	18.0
cohesion c_u(kN/m^2)	10.0	15.0
Internal friction angle φ_u(deg)	0.0	0.0

Source: JICA Study Team

2) Water level condition

Set residual water level condition at depression head.

3) Embankment shape

Set three kinds of height as H=2.0m, 3.0m, 4.0m.

Set two kinds of slope gradient as 1: 2.0 and 1: 3.0.

Set crest width as 4.3m.

4) Result of calculation

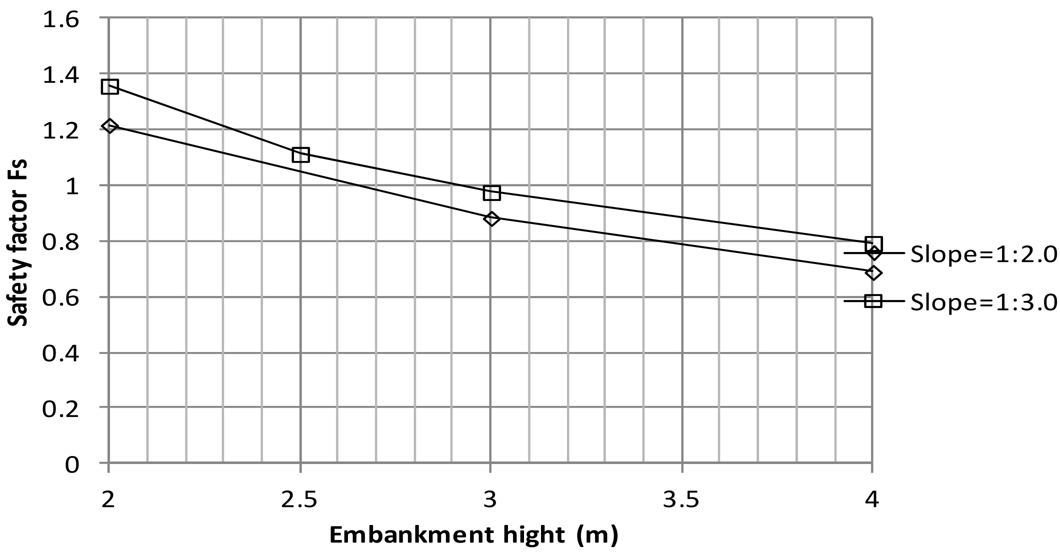
The required safety ratio of 1.2 cannot be satisfied in case of height of more than 2.0m as shown in the Table below.

Table 4.6 Minimum safety factor with embankment height on soft ground

Embankment Height (m)	Min. safety factor	
	Slope=1:2.0	Slope=1:3.0
4	0.688	0.792
3	0.882	0.975
2.5	-	1.112
2	1.216	1.357

Source: JICA Study Team

The maximum height will be 2.0m at the gradient of 1:2.0, and 2.3m at the gradient of 1:3.0 as shown in Figure 4.10. Therefore, it is required that embankment alignment shall be changed to avoid the soft ground in case of further embankment height.



Source: JICA Study Team

Figure 4.9 Embankment height and safety factor

5. Method of Dry-Wet Cycle Test for Evaluating of Decrease of Local Durability on Submergible Embankment due to Repeated Submergence

5.1 Objectives of Test

Submergible embankment will be supposed to deteriorate gradually due to decrease of surface local durability under the condition of repeated submergence and drying process. This decrease of local durability is more strongly influenced by surface density reduction due to swelling and cracks through saturation and drying process if the compaction work of embankment was not carried out sufficiently.

The purpose of this test was to examine the relation between density and durability reduction through dry-wet cycle by evaluating unconfined compression strength as an indicator, using specimens compacted with various degree.

5.2 Condition of Test

Optimum moisture content (W_{opt}) and maximum dry density (ρ_{dmax}) of the embankment material was obtained by corresponding compaction test. Local durability of embankment was evaluated by using unconfined compression strength as an indicator, therefore unconfined compression tests (UCTs) were carried out for 2 specimens per 1 cycle. Number of tests is presented in following table.

Table 5.1 Numer of Case and Tes

Case No.	Moisture Content	Degree of Compaction	Wet and Dry Condition	Number of Specimens for UCT	
D80-0a	Wopt	80%	None (already finished by compaction test)	2	14
D80-0b			Wet	2	
D80-01			Wet → (Dry → Wet) x 1 cycle	2	
D80-02			Wet → (Dry → Wet) x 2 cycle	2	
D80-04			Wet → (Dry → Wet) x 4 cycle	2	
D80-08			Wet → (Dry → Wet) x 8 cycle	2	
D80-16			Wet → (Dry → Wet) x 16 cycle	2	
D90-0a	Wopt	90%	None (already finished by compaction test)	2	14
D90-0b			Wet	2	
D90-01			Wet → (Dry → Wet) x 1 cycle	2	
D90-02			Wet → (Dry → Wet) x 2 cycle	2	
D90-04			Wet → (Dry → Wet) x 4 cycle	2	
D90-08			Wet → (Dry → Wet) x 8 cycle	2	
D90-16			Wet → (Dry → Wet) x 16 cycle	2	
D95-0a	Wopt	95%	None (already finished by compaction test)	2	14
D95-0b			Wet	2	
D95-01			Wet → (Dry → Wet) x 1 cycle	2	
D95-02			Wet → (Dry → Wet) x 2 cycle	2	
D95-04			Wet → (Dry → Wet) x 4 cycle	2	
D95-08			Wet → (Dry → Wet) x 8 cycle	2	
D95-16			Wet → (Dry → Wet) x 16 cycle	2	
D100-0a	Wopt	100%	None (already finished by compaction test)	2	14
D100-0b			Wet	2	
D100-01			Wet → (Dry → Wet) x 1 cycle	2	
D100-02			Wet → (Dry → Wet) x 2 cycle	2	
D100-04			Wet → (Dry → Wet) x 4 cycle	2	
D100-08			Wet → (Dry → Wet) x 8 cycle	2	
D100-16			Wet → (Dry → Wet) x 16 cycle	2	
Total				56	

Source: JICA Study Team

5.3 Preparation of Specimens

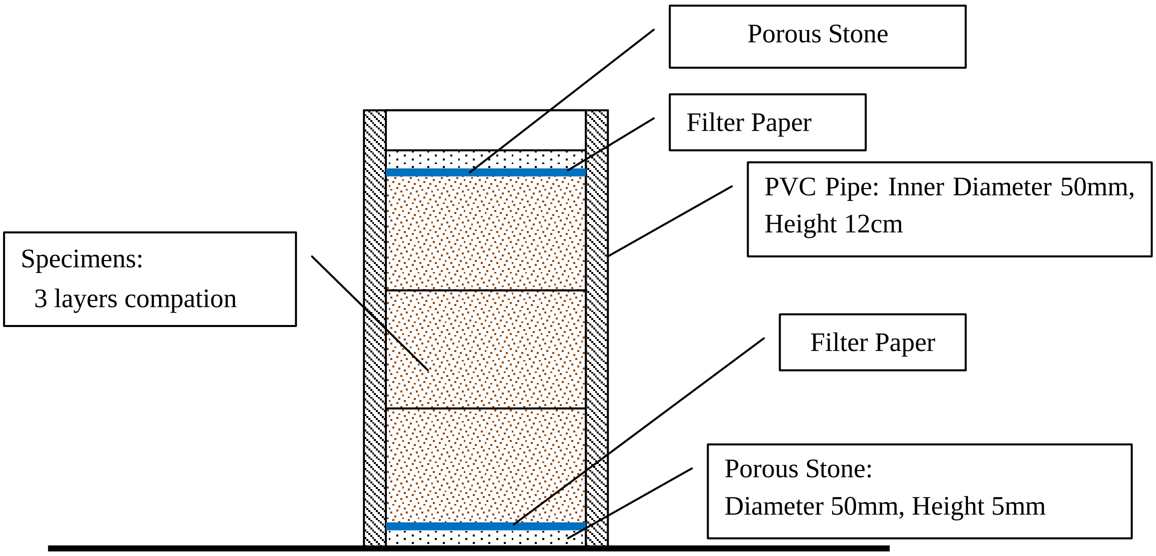
(1) PVC pipe of 50 mm diameter was cut to around 12 cm length as the mold for a specimen.

(2) Put a porous stone into the bottom of the PVC mold with a filter paper on it.

(3) Prepare embankment material which is corresponding to required density in the mold of 5 cm diameter and 12 cm height.

(4) Split the embankment material into 3 pieces and compact them inside the mold separately (4 cm thickness each x 3 layers) by a stick.

(5) Cover a filter paper with a porous stone on the specimens.



Source: JICA Study Team

Figure 5.1 Preparation of Specimens

5.4 Dry-Wet Cycle and Unconfined Compression Test

(1) The weight of the PVC pipe, porous stone and filter paper were measured before preparing specimens. Then, weight of the specimen was measured with the PVC pipe, porous stone and filter paper.

(2) The specimens were kept in water tank to be submerged for 3 days, then kept under the circumstance which is of high temperature, well ventilated and without direct sunshine to dry for 7days. A box with holes like next photograph was used for this drying.

(3) (2) and (3) were repeated as required.

(4) The specimens were thrust out from the PVC pipes and cut their upper and bottom portion by 1 cm to be formed. Then weight, height and diameter of the specimens were measured.

(5) Unconfined compression tests were carried out conforming to the standard of ASTM, and moisture contents were measured. Two specimens were tested for 1 case and 1 cycle, therefore, the unconfined compression strength was defined as the average of two specimens.

5.5 Results of Dry-Wet Cycle Test

Following table presents the relationship between unconfined compression strength and number of dry-wet cycles by degree of compaction.

Table 5.2 List of Test Results

Liquid Limit	Plasticity Index	Proctor Compaction Test		Degree of Compaction	Specimen Number	Wet and Dry Condition	Average Moisture Content	Unconfined Compression Test	
(%)	(%)	MDD (gm/cm^3)	OMC (%)	(%)			%	q_u (kPa)	Average q_u (kPa)
48	24	1.68	18.3	98%	D98-ob	Wet	25.7	97.6+97.1	**97.4**
					D98-01	1 cycle	26.0	93.9+93.7	**93.8**
					D98-02	2 cycle	26.1	91.2+87.6	**89.4**
					D98-04	4 cycle	26.6	73.7+74.6	**74.2**
					D98-08	8 cycle	26.8	64.3+59.6	**62.0**
					D98-16	16 cycle	27.9	57.4+55.8	**56.6**
				90%	D90-0b	Wet	27.5	90.8+82.1	**86.5**
					D90-01	1 cycle	28.2	63.0+65.7	**64.4**
					D90-02	2 cycle	28.7	56.5+56.0	**56.3**
					D90-04	4 cycle	29.0	51.1+52.7	**51.9**
					D90-08	8 cycle	29.5	49.2+45.2	**47.2**
					D90-16	16 cycle	30.3	36.8+36.8	**36.8**
				80%	D80-0b	Wet	33.5	70.5+70.1	**70.3**
					D80-01	1 cycle	36.0	16.2+16.3	**16.3**
					D80-02	2 cycle	36.7	14.3+14.3	**14.3**
					D80-04	4 cycle	--	Not Possible	**--**
					D80-08	8 cycle	--	Not Possible	**--**
					D80-16	16 cycle	--	Not Possible	**--**

Source: JICA Study Team

Annex 4-3

Facility Survey

1. Project Features

Structural Features

1. Cheghaia Khal Scheme

(1) Location:Upazila:Baniachong, Habiganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	2.5	4.27*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg.-1	Cheghaia	2.8*	4.37*	N/A	1	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Cheghaia Khal	20	40

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

No 1tructure

(7) Maximum Water Depth during Flood

4m (average) in 1988

2. Gangajuri FCD Sub-scheme

(1) Location:Upazila: Bahubol, Baniachong and Sadar, Habiganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	46	4.27*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Shikarpur	14.21*	22.87*	N/A	7	1.52	1.82	N/A	Not function
Reg-2	Moktarpur	4.27*	4.27*	N/A	2	1.52	1.82	N/A	Not function
Reg-3	Goharua	14.03*	4.27*	N/A	7	1.52	1.82	N/A	Not function
Reg-4	Jitka	13.57*	4.42*	N/A	5	1.52	1.82	N/A	Not function
Reg-5	Vobanipur	2.32*	4.27*	N/A	1	1.52	1.82	N/A	Not function
Reg-6	Sialdona	9.76*	4.27*	N/A	5	1.52	1.82	N/A	Not function
Reg-7	Zaira	2.32*	4.37*	N/A	1	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Cheghaia Khal	4.5	40

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)
Pipe Slice	3	1	0.64
Pipe Sluice	2	1	1.02

(6) Culvert

No 2Structure

(7) Maximum Water Depth during Flood

3m (average) in 1988

3. Sukti River Embankment

(1) Location:Upazila: Ajimirigang and Baniachong, Habiganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	20*	N/A	N/A	N/A	N/A

Note: * measured

(3) Regulator

No regulator

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Shukti	11.5	40

(5) Inlet/Outlet/Pipe Sluice

No Structure

(6) Culvert

No Structure

(7) Maximum Water Depth during Flood

4m (average) in 1988

4. Madhabpur Scheme

(1) Location:Upazila: Madhabpur, Habiganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	38	4.27*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No regulator

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Madhabpur Khal	38	40

(5) Inlet/Outlet/Pipe Sluice

No Structure

(6) Culvert

No 4Structure

(7) Maximum Water Depth during Flood

3m (average) in 1988

5. Aralia Khal Scheme

(1) Location:Upazila: Baniachong, Habiganj district

(2) Embankment

No Embankment

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Shinger	4.6*	3.6*	N/A	2	1.52	1.82	N/A	Not function
Reg-2	Shotomukha	3.1*	6.0*	N/A	2	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Aralia	2.39	30

(5) Inlet/Outlet/Pipe Sluice

No Structure

(6) Culvert

No 5Structure

(7) Maximum Water Depth during Flood

1.5m (average) in 1988

6. Kairdhala Ratna Scheme

(1) Location:Upazila: Ajimirigang and Baniachong, Habiganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	26	3.96*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Korcha	4.4*	4.4*	N/A	2	1.52	1.82	N/A	Not function
Reg-2	Paharpur	4.4*	4.4*	N/A	2	1.52	1.82	N/A	Not function
Reg-3	Badalpur	10.67*	12.2*	N/A	5	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Kairdhala Khal	40	25

(5) Inlet/Outlet/Pipe Sluice

No 6Structure

(6) Culvert

No 6Structure

(7) Maximum Water Depth during Flood

1.5m (average) in 1988

7. Bashira River Re-excavation

(1) Location:Upazila: Ajimirigang and Baniachong, Habiganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	15	3.5*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Matikata	6.25*	5.00*	N/A	2	1.52	1.82	N/A	Not function
Reg-2	Islampur	6.25*	4.75*	N/A	2	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Bashira	20	40

(5) Inlet/Outlet/Pipe Sluice

No 7Structure

(6) Culvert

No 7Structure

(7) Maximum Water Depth during Flood

3.5m (average) in 1988

8. Datta Khola & Adjoing Beel

(1) Location:Upazila: Chor Islampur & Mojlishpur, Brammanbaria district

(2) Embankment

No Embankment

(3) Regulator

No Regulator

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Titas	15	25
2	Loiska (Paranga)	11	20
3	Dewdina	11	30
4	Boalia	3.5	20
5	Modhyaganga	15	35
6	Baliajuri	18	40

(5) Inlet/Outlet/Pipe Sluice

No Structure

(6) Culvert

No 8Structure

(7) Maximum Water Depth during Flood

3.8m (average) in 1998

9. Chandal Beel Scheme

(1) Location:Upazila: Bancharampur, Brammabvaria district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	2.74	3.66*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Mullukbari	4.27*	4.40*	N/A	2	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Mullukbari Khal	1.5	25

(5) Inlet/Outlet/Pipe Sluice

No 9Structure

(6) Culvert

No 9Structure

(7) Maximum Water Depth during Flood

2.75m (average) in 1988

10. Akashi & Shapla Beel Scheme

(1) Location:Upazila: Nashirnagar and Sarail, Brammabvaria district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	5.5	4.5*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No regulator

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Akashi Khal	6.5	30

(5) Inlet/Outlet/Pipe Sluice

No 10Structure

(6) Culvert

No 10Structure

(7) Maximum Water Depth during Flood

3.5m (average) in 1998

11. Satodana Beel Scheme

(1) Location:Upazila: Bancharampur, Brammabvaria district

(2) Embankment

No embankment

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Bhurburia	4.27*	4.40*	N/A	2	1.52	1.82	N/A	Not function
Reg-2	Mirpur	4.40*	4.40*	N/A	2	1.52	1.82	N/A	Not function

Note: * measured

(4) Channel/River

No channel/river

(5) Inlet/Outlet/Pipe Sluice

No 11Structure

(6) Culvert

No 11Structure

(7) Maximum Water Depth during Flood

3.5m (average) in 1988

12. Singer Beel Scheme

(1) Location:Upazila: Sadar, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	3.5	3.0*	N/A	1:2.0	1:2.0
Full	13.15	3.6*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Dashdhara	5	4.5	N/A	1	1.52	1.82	N/A	Function
Reg-2	Tumnir	6.5	6	N/A	3	1.52	1.82	N/A	Function
Reg-3	Kamalpur	6.5	6	N/A	3	1.52	1.82	N/A	Function
Reg-4	Putukia	5	4.5	N/A	1	1.52	1.82	N/A	Function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Tumnir Khal	2.5	20
2	Kamalpur Khal	3.0	18

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Width (m)	Height(m)
Inlet	2	1.5	1.8

(6) Culvert

Type	Number of Location	Number of Pipe	Diameter(m)
Pipe Culvert	2	1	0.3

(7) Maximum Water Depth during Flood

2.8m (average) in 1988

13. Takurakona Sub-project

(1) Location:Upazila: Sadar, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	13.15	4.27*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Thakurakona	6.5	6.0	N/A	3	1.52	1.82	N/A	Function
Reg-2	Betati	6.0	5.5	N/A	2	1.52	1.82	N/A	Not function
Reg-3	Krisnapur	6.5	6.0	N/A	3	1.52	1.82	N/A	Function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Betati Khal	4.0	18.5
2	Krisnapur Khal	2.5	17

(5) Inlet/Outlet/Pipe Sluice

No Structure

(6) Culvert

No Structure

(7) Maximum Water Depth during Flood

2.9m (average) in 1988

14. Kangsha River Scheme

(1) Location:Upazila: Purbodhola and Sadar, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	20	4.27	12.20 to 10.90	1:3.0	1:2.0

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Saldigha	11.0	8.0	N/A	4	1.52	1.82	N/A	Not function
Reg-2	Jhamdia	6.5	6.0	N/A	3	1.52	1.82	N/A	Not function
Reg-3	Kurikonia	6.5	6.0	N/A	3	1.52	1.82	N/A	Not function
Reg-4	Borari	6.5	6.0	N/A	3	1.52	1.82	N/A	Not function
Reg-5	Digjan	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function
Reg-6	Raju bazar	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function
Reg-7	Putukia	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

Type	Number of Location	Number of Pipe	Diameter (m)
Pipe Culvert	3	1	0.3

(7) Maximum Water Depth during Flood

3m (average) in 1988

15. Dampara Water Management

(1) Location:Upazila: Purbodhola, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	27	2.44	10.14 to 11.80	1:2.0	1:3.0
Full	20	4.27	12.20 to 13.14	1:3.0	1:2.0

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Chorervita	25.0	16.0	N/A	10	1.52	1.82	N/A	Function
Reg-2	Khatuary	13.0	7.5	N/A	5	1.52	1.82	N/A	Not function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Motiara Khal	5.0*	16*
2	Kalihor Khal	12.0*	15*

Note: * measured

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Inlet	1	2	0.30	
Inlet	24	1	0.30	4nos. Not Function
Inlet	1	1	0.60	
Type	Number of Location	Width (m)	Height (m)	
Inlet	1	1.5	1.8	

(6) Culvert

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Pipe Culvert	20	1	0.30	2nos. Not function

(7) Maximum Water Depth during Flood

3.15m (average) in 1988

16. Someswari River Sub-scheme

(1) Location:Upazila: Durgapur, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	6	4.27*	N/A	1:3.0	1:2.0

Note:* measured

(3) Regulator

No regulator

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

(6) Culvert

Type	Number of Location	Width (m)	Height (m)	Remark
Box Culvert	1	0.90	0.45	
Box Culvert	1	0.45	0.90	

(7) Maximum Water Depth during Flood

3.20m (average) in 1988

17 Khaliajuri FCD Polder #2

(1) Location:Upazila: Khaliajuri, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	52.1	2.96*	N/A	1:2.0	1:3.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Sanrinagar	5.0	4.5	N/A	1	1.52	1.82	N/A	Function
Reg-2	Nayari	6.5	6.0	N/A	3	1.52	1.82	N/A	Not function
Reg-3	Koller	5.0	4.5	N/A	4	1.52	1.82	N/A	Not function
Reg.-4	Ranichapur	11.0	8.0	N/A	4	1.52	1.82	N/A	Under Const.
Reg.-5	Bagain	11.0	8.0	N/A	4	1.52	1.82	N/A	Under Const.
Reg.-6	Bolli	5.0	4.5	N/A	1	1.52	1.82	N/A	Function
Reg.-7	Uporchaitar	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function
Reg.-8	Namachaitar	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function
Reg.-9	Mujibangar	6.0	5.5	N/A	2	1.52	1.82	N/A	Function
Reg.-10	Batani	6.0	5.5	N/A	2	1.52	1.82	N/A	Function

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Inlet	4	1	0.75	4nos. Not Function

(6) Culvert

Type	Number of Location	Width (m)	Height (m)	Remark
Box Culvert	2	0.60	0.60	

(7) Maximum Water Depth during Flood

3. 5m (average) in 1988

18 Khaliajuri FCD Polder #4

(1) Location:Upazila: Khaliajuri, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	47.0	2.96*	N/A	1:2.0	1:3.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Jalukhali	6.5	6.0	N/A	3	1.52	1.82	N/A	Under Const.
Reg-2	Putia	11.0	8.0	N/A	4	1.52	1.82	N/A	Under Const.
Reg-3	Kumaria	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function
Reg.-4	Cadaria 1	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function
Reg.-5	Cadaria 2	5.0	4.5	N/A	1	1.52	1.82	N/A	Not function

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Inlet	5	1	0.45	5nos. Not Function

(6) Culvert

Type	Number of Location	Width (m)	Height (m)	Remark
Box Culvert	4	0.60	0.60	1 no. Not Function
Box Culvert	1	0.45	0.90	Function
Type	Number of Location	Number of Pipe	Diameter (m)	
Pipe Culvert	1	1	0.3	1 no. Not Function

(7) Causeway 2 location

(8) Maximum Water Depth during Flood

3. 7m (average) in 1988

19 Mohadao Nadi Embakment

(1) Location:Upazila: Kamlakanda, Netrakona district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Submergible	3.0	2.44*	N/A	1:2.0	1:2.0
Full	7.5	3.00*	N/A	1:3.0	1:2.0

Note: * measured

(3) Regulator

No regulator

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

No Structuer

(6) Culvert

Type	Number of Location	Width (m)	Height (m)	Remark
Box Culvert	3	1.20	0.60	2 nos. Not Function

(7) Maximum Water Depth during Flood

2.75 m (average) in 1988

20 Sunamganj Town Protection Project

(1) Location:Upazila: Sadar, Sunamganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	1.6	2.00*	N/A	1:3.0	1:2.0

Note: * measured

(3) Regulator

No regulator

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

No Structure

(6) Culvert

No Structure

(7) Maximum Water Depth during Flood

2.40 m (average) in 1988

21 Sukhaijuri Bathai Sub-project

(1) Location: Upazila: Nandail, Mymenshingh district

Upazila: Tarail, Kishoreganj district

Upazila: Kendua,Netrakona disrict

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	20.85	3.00*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Kaliganj Bazar	N/A	N/A	N/A	1	1.52	1.82	N/A	Not Function
Reg-2	Chikni	N/A	N/A	N/A	6	1.52	1.82	N/A	Not Function

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Pipe Sluice	3	1	0.9	

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 75m (average) in 1988

22. Gazaria Beel Sub-project

(1) Location:Upazila: Karimganj and Tarail, Kishoreganj district

(2) Embankment

No Embankment

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Gabba	8.0	3.0	N/A	1	1.52	1.82	N/A	Not function
Reg-2	Gazaria	N/A	N/A	N/A	2	1.52	1.82	N/A	Function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Gazaria Khal	6.215	13.0
2	Kalihor Khal	2.66	9.5

Note: * measured

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Pipe Sluice	3	1	0.90	

(6) Culvert

No Structure

(7) Maximum Water Depth during Flood

2.75m (average) in 1988

23 Boraikhali Khal Sub-project

(1) Location:Upazila: Nandail, Mymenshingh district

Upazila: Hosenpur and Sadar, Kishoreganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	5.3	3.00*	N/A	1:2.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Brahman kachuri	N/A	N/A	N/A	6	1.52	1.82	N/A	Not Function
Reg-2	Chikni	N/A	N/A	N/A	6	1.52	1.82	N/A	Not Function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Boraikhali Channel	24.5	20

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Pipe Sluice	2	1	0.9	

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 50m (average) in 1988

24. Char Ferradee-Jangalia Sub-Project

(1) Location:Upazila: Hosenpur and Pakundia, Kishoreganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	11.6	4.27*	N/A	1:2.0	1:3.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Char Kushsha	N/A	N/A	N/A	5	1.52	1.82	10.0	Function

(4) Channel/River

No Channel

(5) Inlet/Outlet/Pipe Sluice

Type	Number of Location	Number of Pipe	Diameter (m)	Remark
Pipe Sluice	1	1	0.9	

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 75m (average) in 1988

25. Singua River Re-excavation Sub-Project

(1) Location:Upazila: Pakundia, Sadar and Nikli, Kishoreganj district

(2) Embankment

No Embankment

(3) Regulator

No Regulator

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Singua River	55	40

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 50m (average) in 1988

26. Adampur Sub-Project

(1) Location:Upazila: Katiadi, Kishoreganj district

(2) Embankment

No Embankment

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Adampur	N/A	N/A	N/A	2	1.52	1.82	10.5	Function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Adampur Canal	9.4	12

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 50m (average) in 1988

27. Alalia Bahadia Sub-Project

(1) Location:Upazila: Katiadi and Pakundia, Kishoreganj district

(2) Embankment

No Embankment

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Bahadiar	N/A	N/A	N/A	2	1.52	1.82	N/A	Function

(4) Channel/River

No.	Name	Length (km)	Top Width (m)
1	Alalia Canal	5	13
2	Bahadia Canal	3	12

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 25m (average) in 1988

28. Motokhola-Bairagir Char Sub-Project

(1) Location:Upazila: Palimdia and Katiadi, Kishoreganj district

(2) Embankment

Type	Length (km)	Crest width (m)	Crest Elevation (EL.m)	Slope	
				River side	Land side
Full	10.8	3.00*	10.50	1:3.0	1:2.0

Note: * measured

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Betal	N/A	N/A	3.65	3	1.52	1.82	9.90	Function

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 50m (average) in 1988

29. Bhairab Bazar Erosion Protection Sub-Project

(1) Location:Upazila: Bhairab, Kishoreganj district

(2) Embankment

No Embankment

(3) Regulator

No.	Name	Length (m)	Width (m)	Sill Elevation (EL. m)	Gate			Operation Deck (EL.m)	Remark
					No.	Width(m)	Height(m)		
Reg-1	Ganakkhali	N/A	N/A	N/A	2	1.52	1.82	N/A	Not function
Reg-2	Katakhali	N/A	N/A	N/A	1	1.52	1.82	N/A	Not function

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

No structure

(6) Culvert

No structure

(7) Maximum Water Depth during Flood

2. 50m (average) in 1988

30. Ganakkali Sub-Project

(1) Location:Upazila: Kuliarchar, Kishoreganj district

(2) Embankment

No Embankment

(3) Regulator

No Regulator

(4) Channel/River

No Channel/River

(5) Inlet/Outlet/Pipe Sluice

No structure

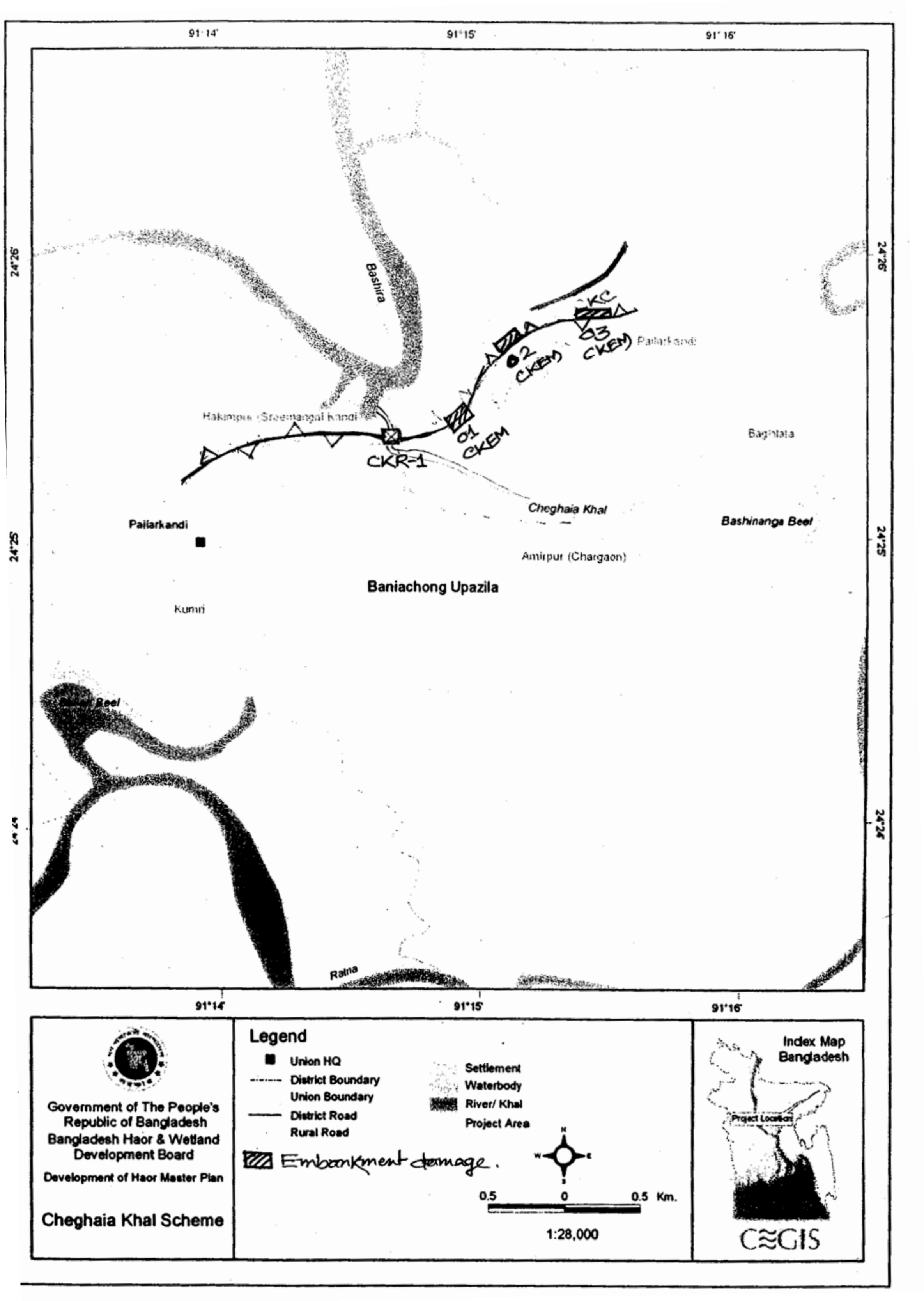
(6) Culvert

No structure

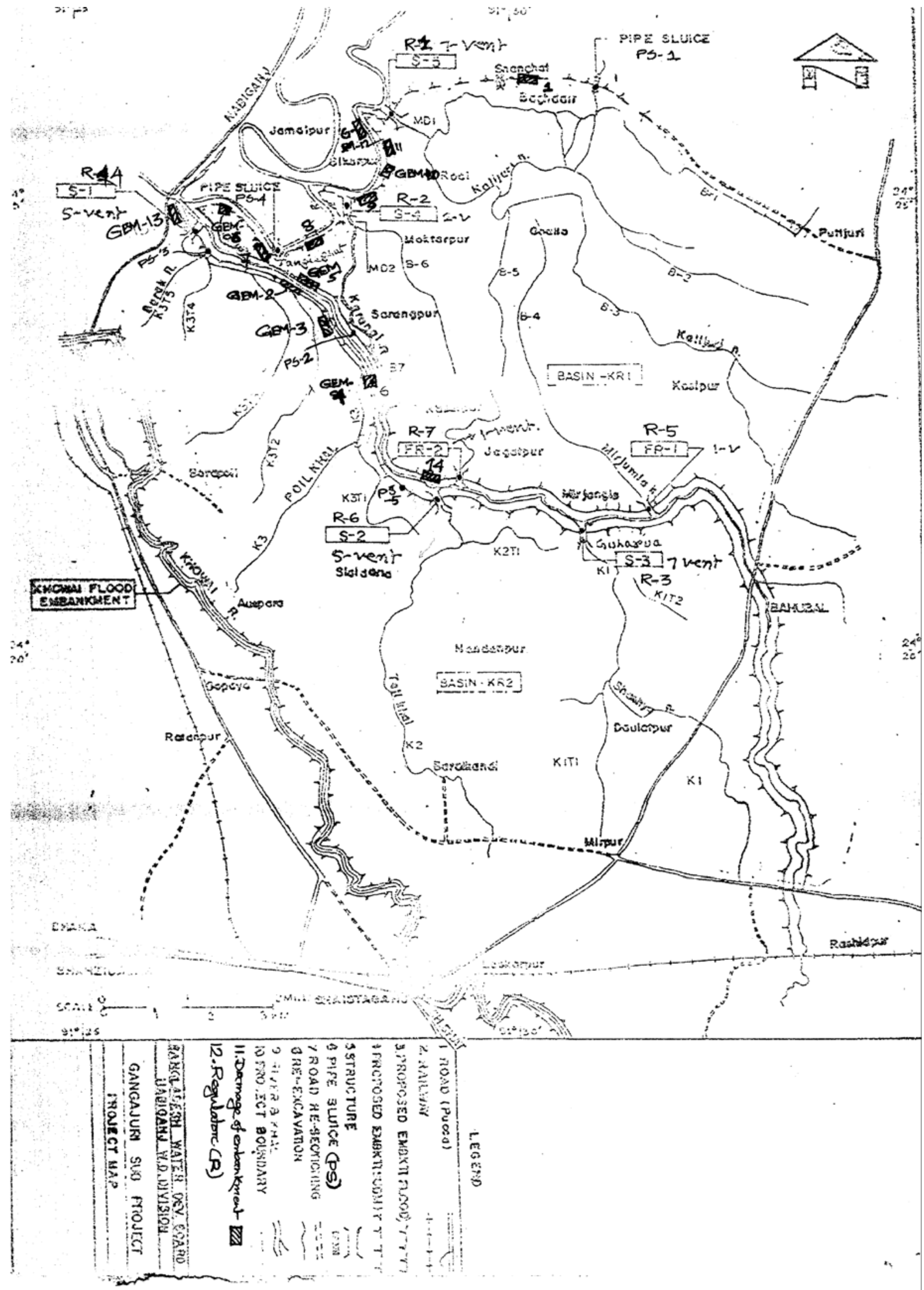
(7) Maximum Water Depth during Flood

2. 75m (average) in 1988

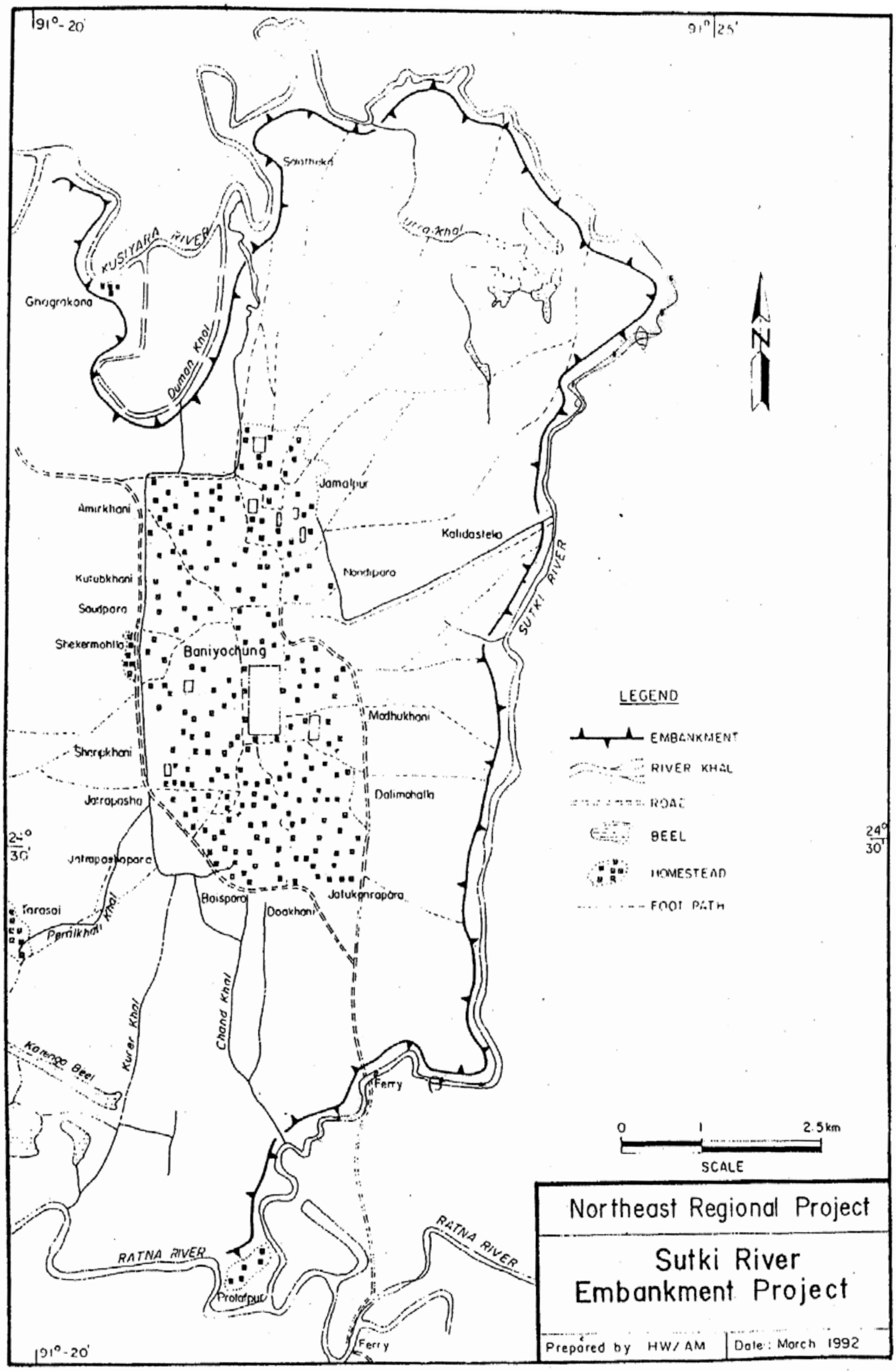
2. Index Map



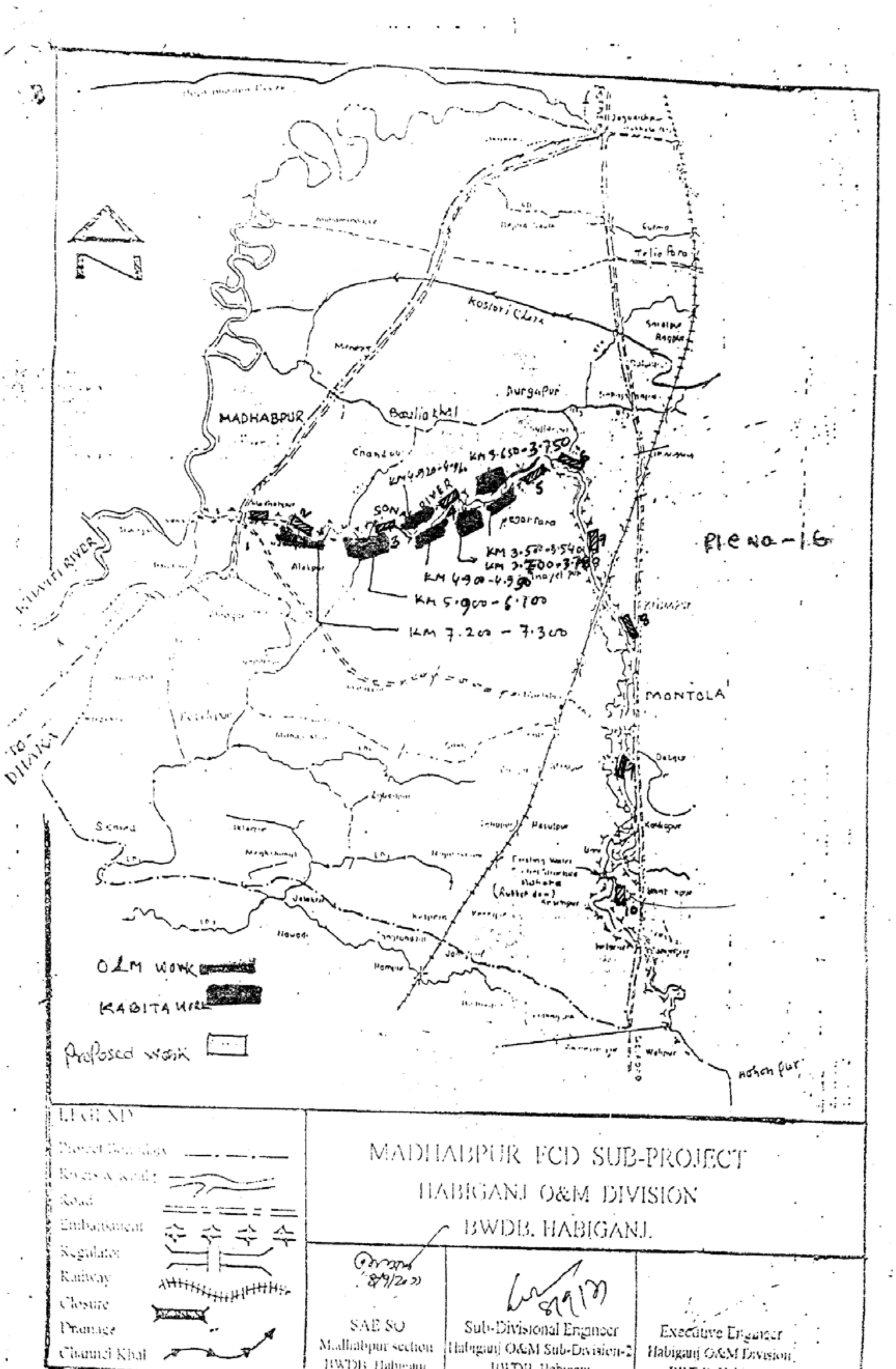
Cheghaia Khal Scheme



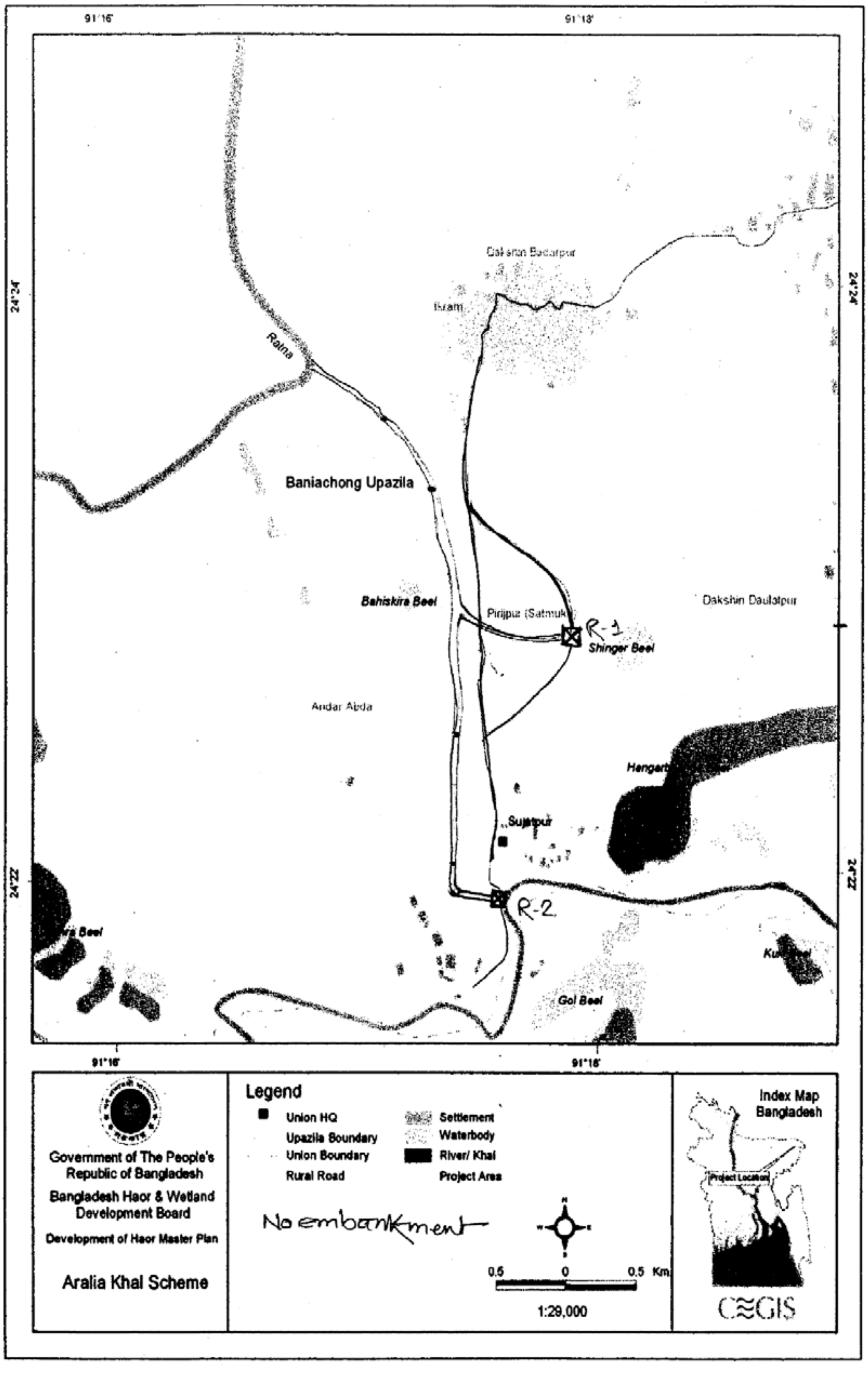
Gangajuri FCD Sub-scheme



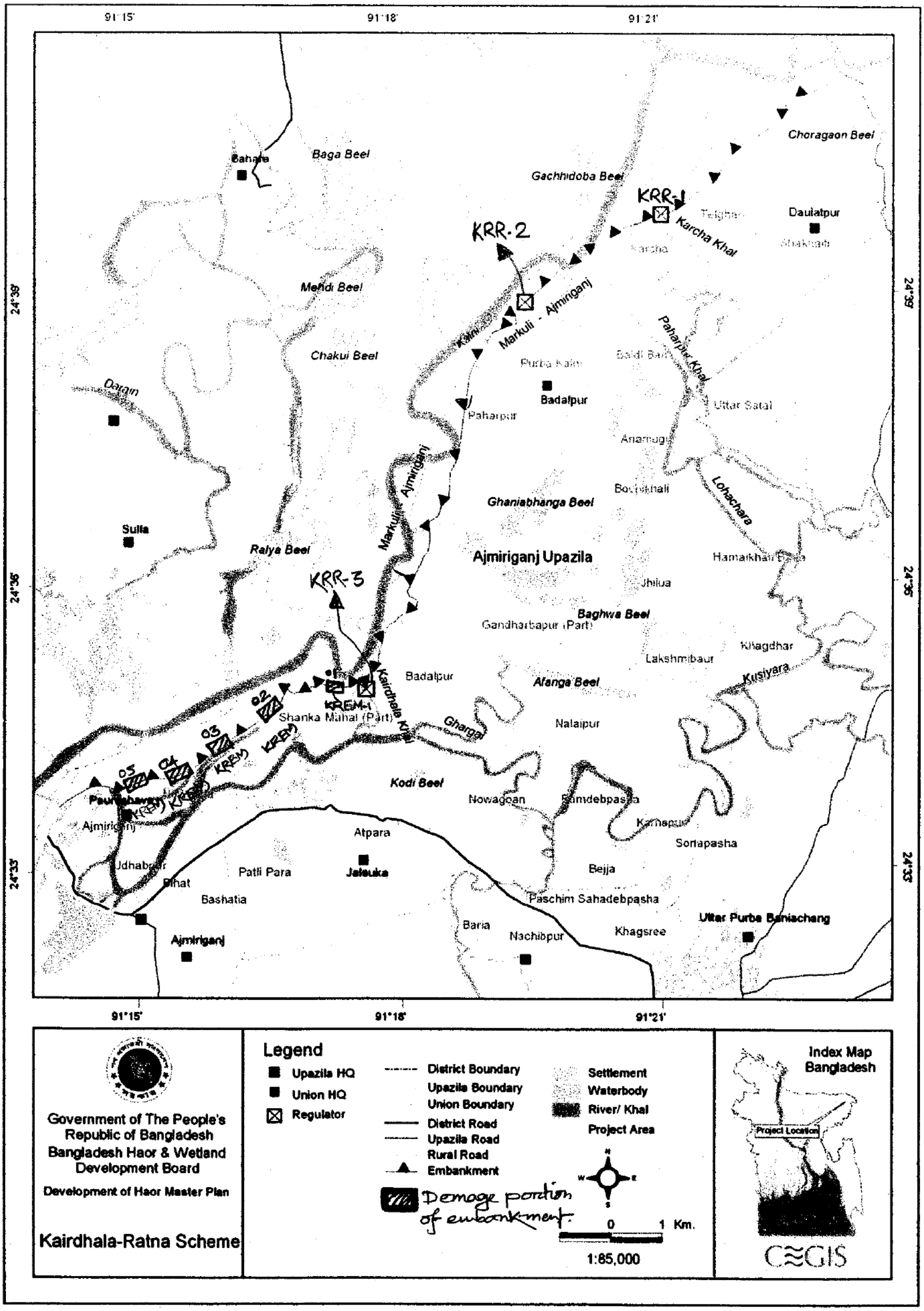
Sukti River Embankment Project



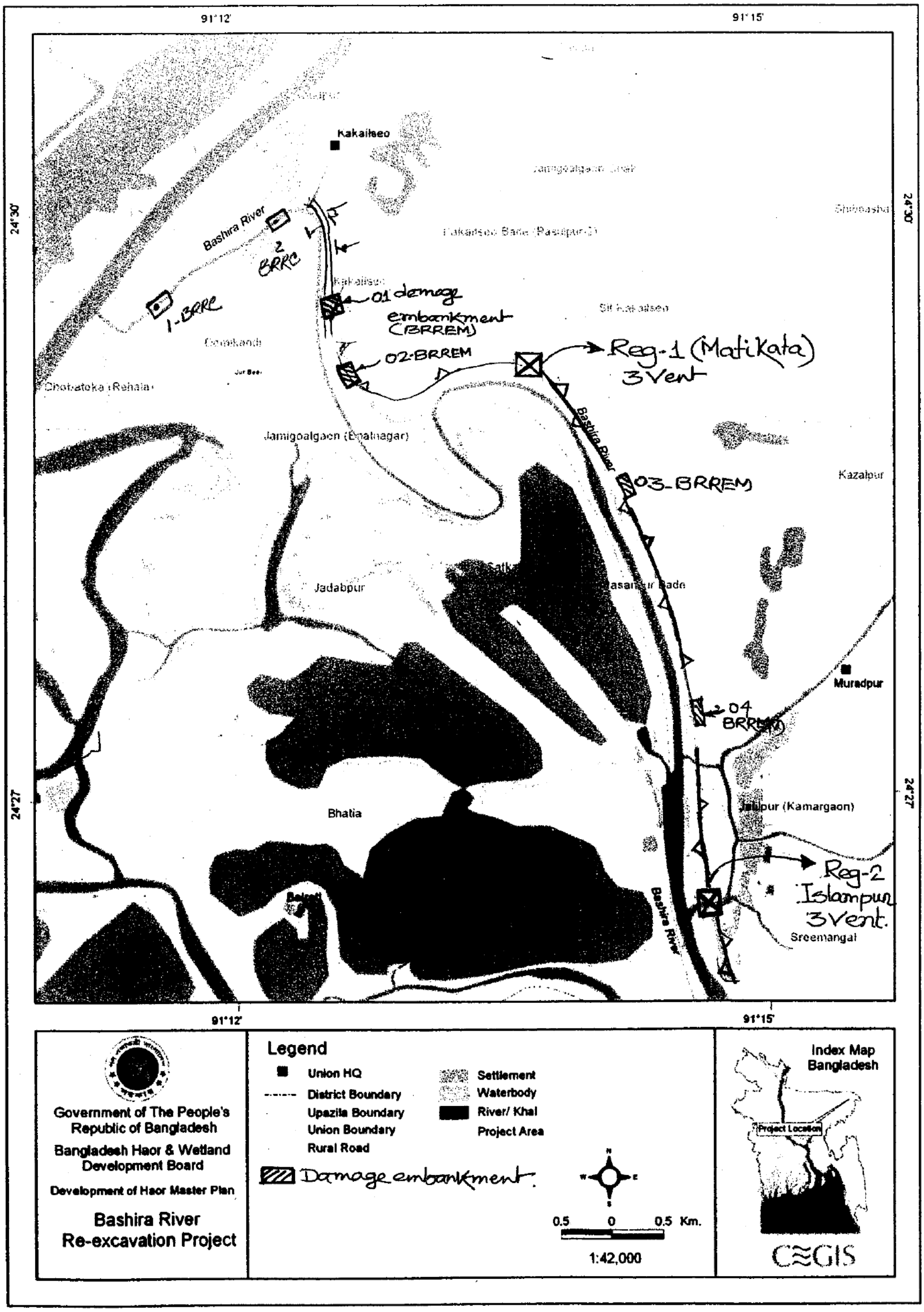
Madhbpur Scheme



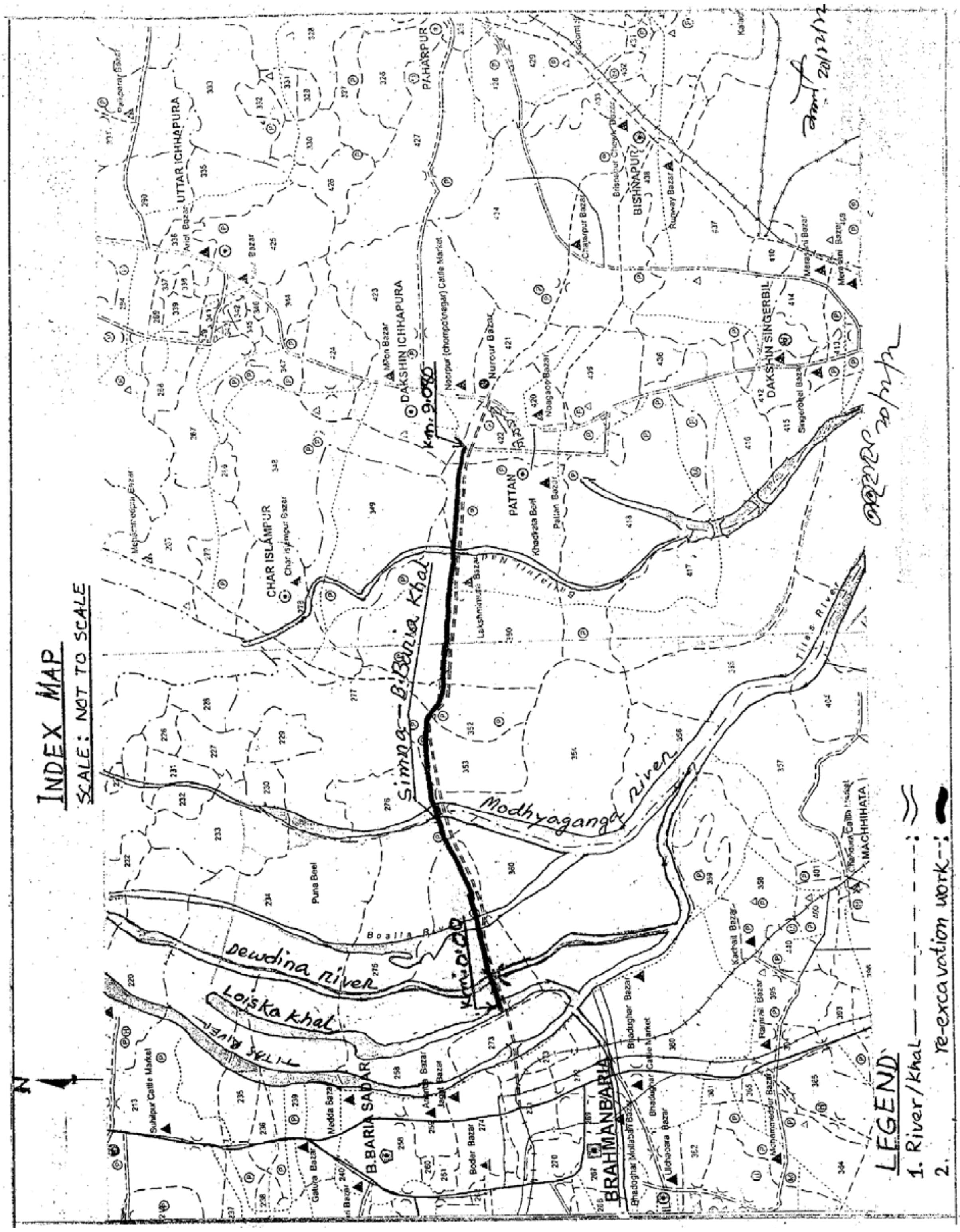
Aralia Khal Scheme



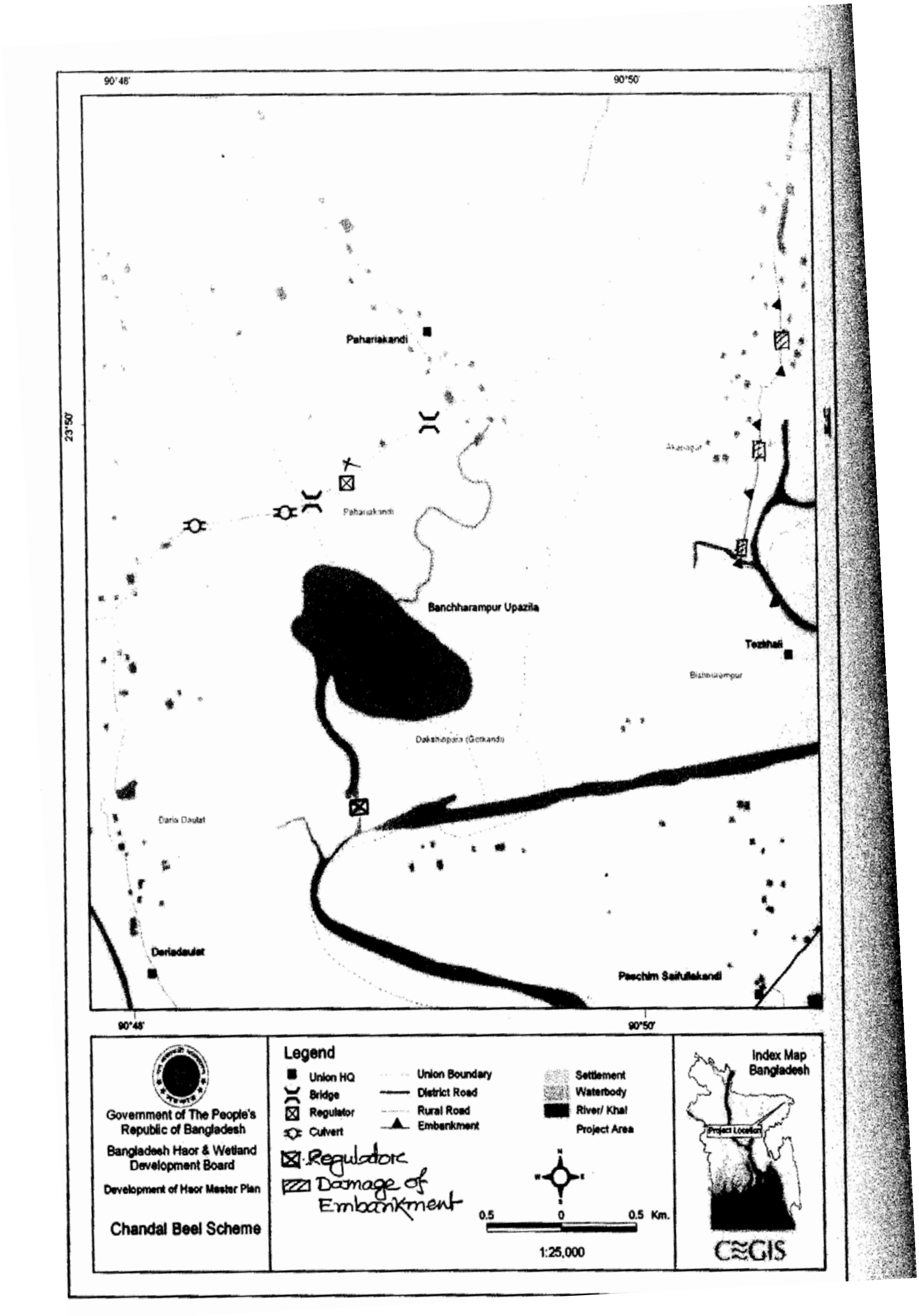
Kairdhala-Ranta Scheme



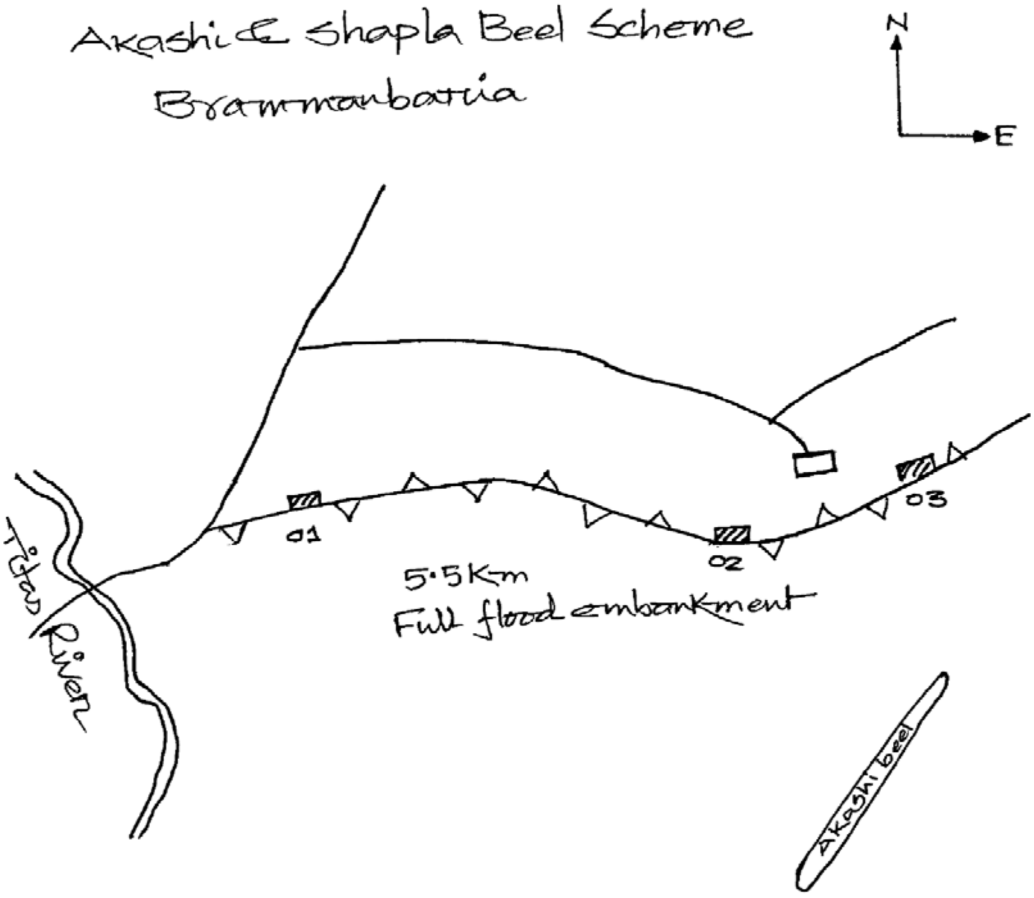
Bashira River Re-excavation Scheme



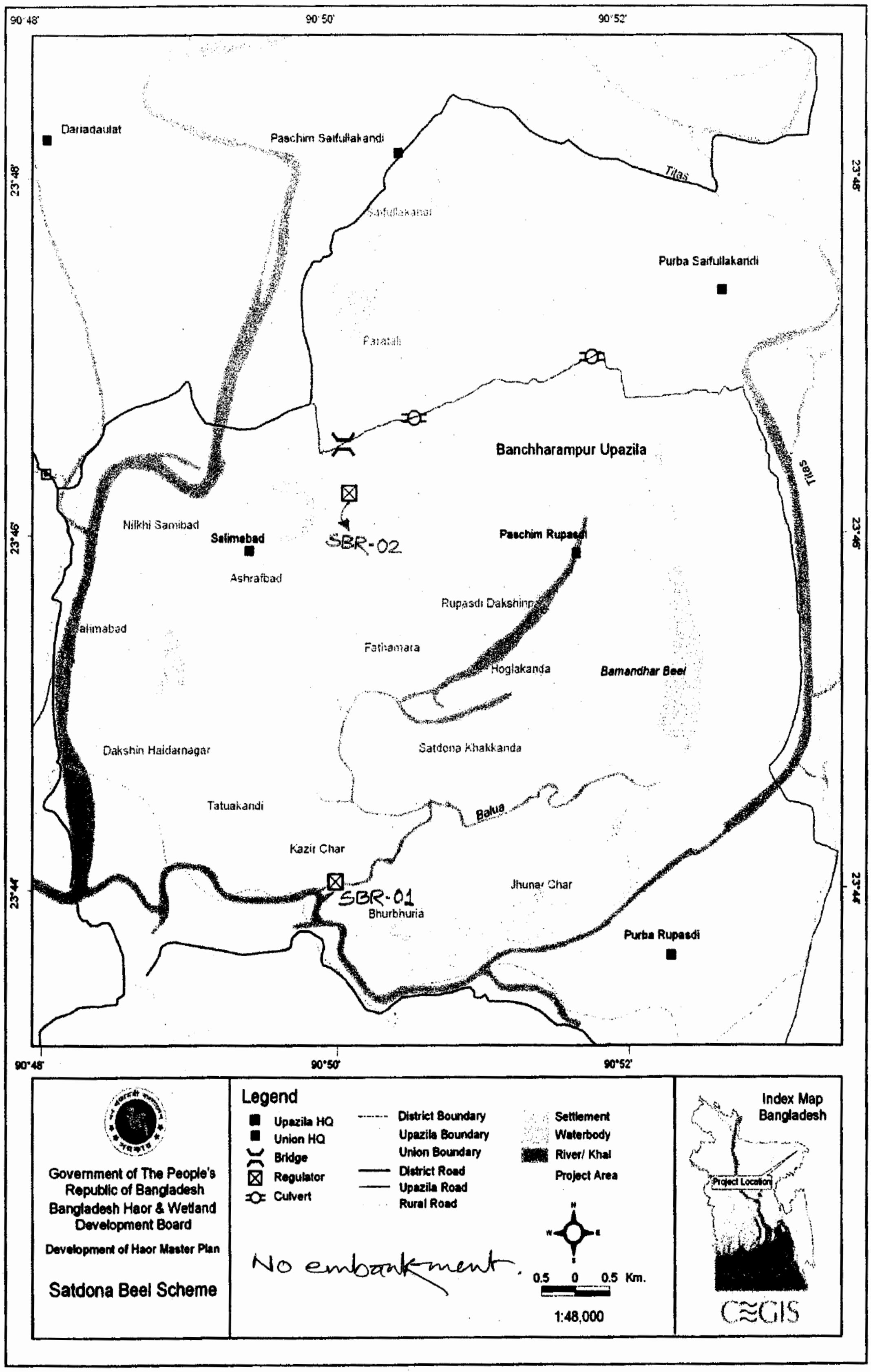
Datta Khola and Adjoining Beel Scheme



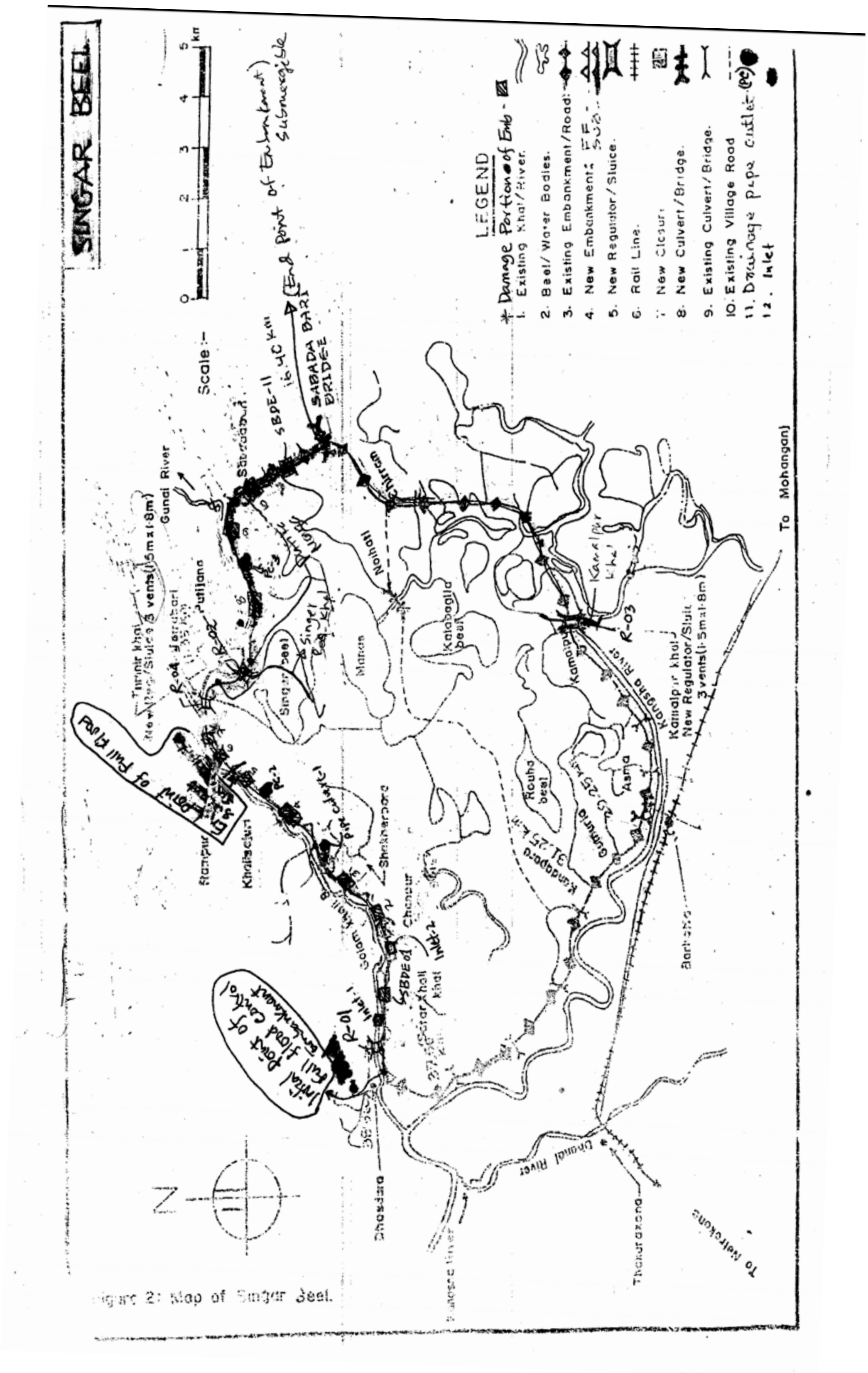
Chandal Beel Scheme



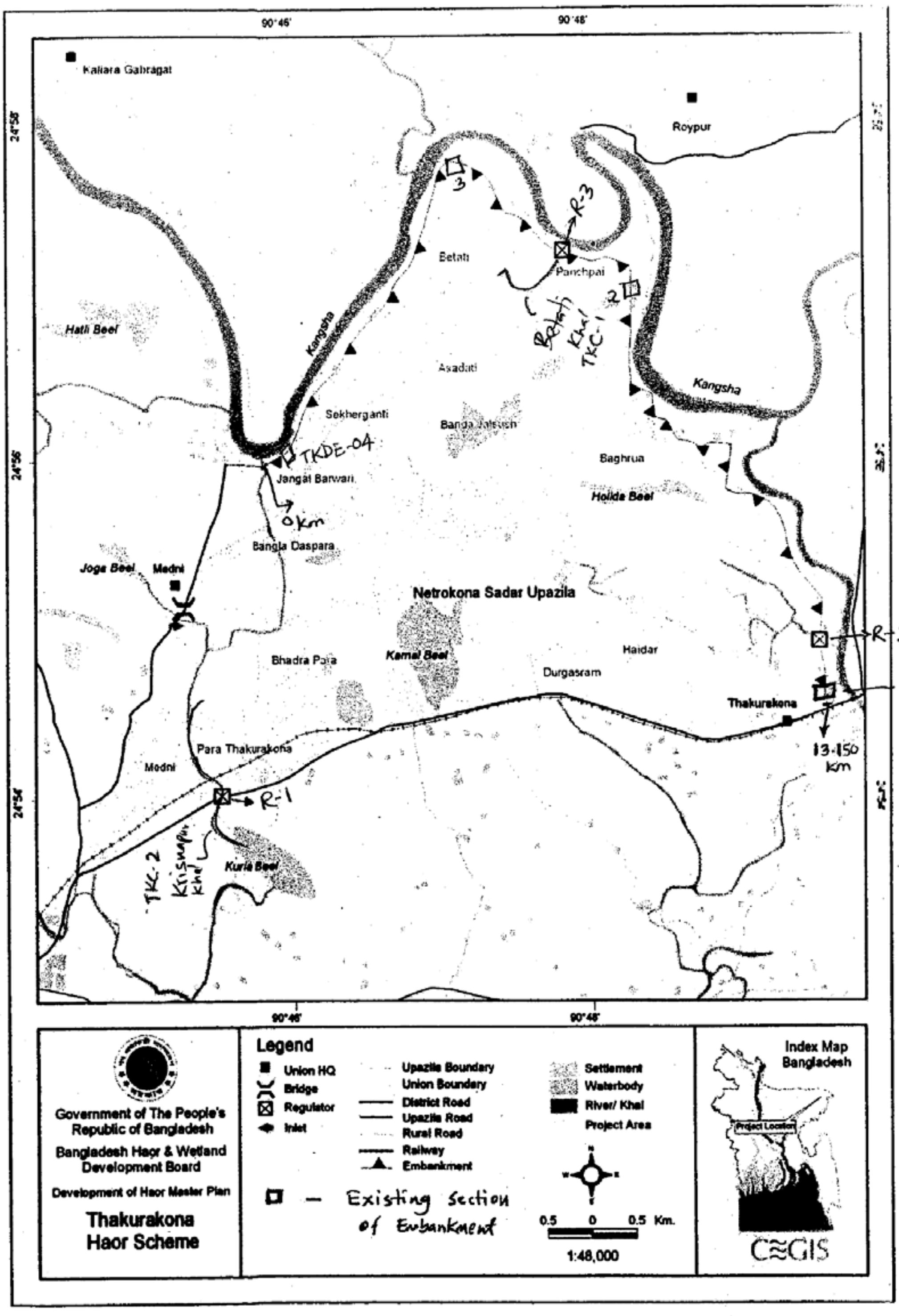
Akashi and Shapla Beel Scheme



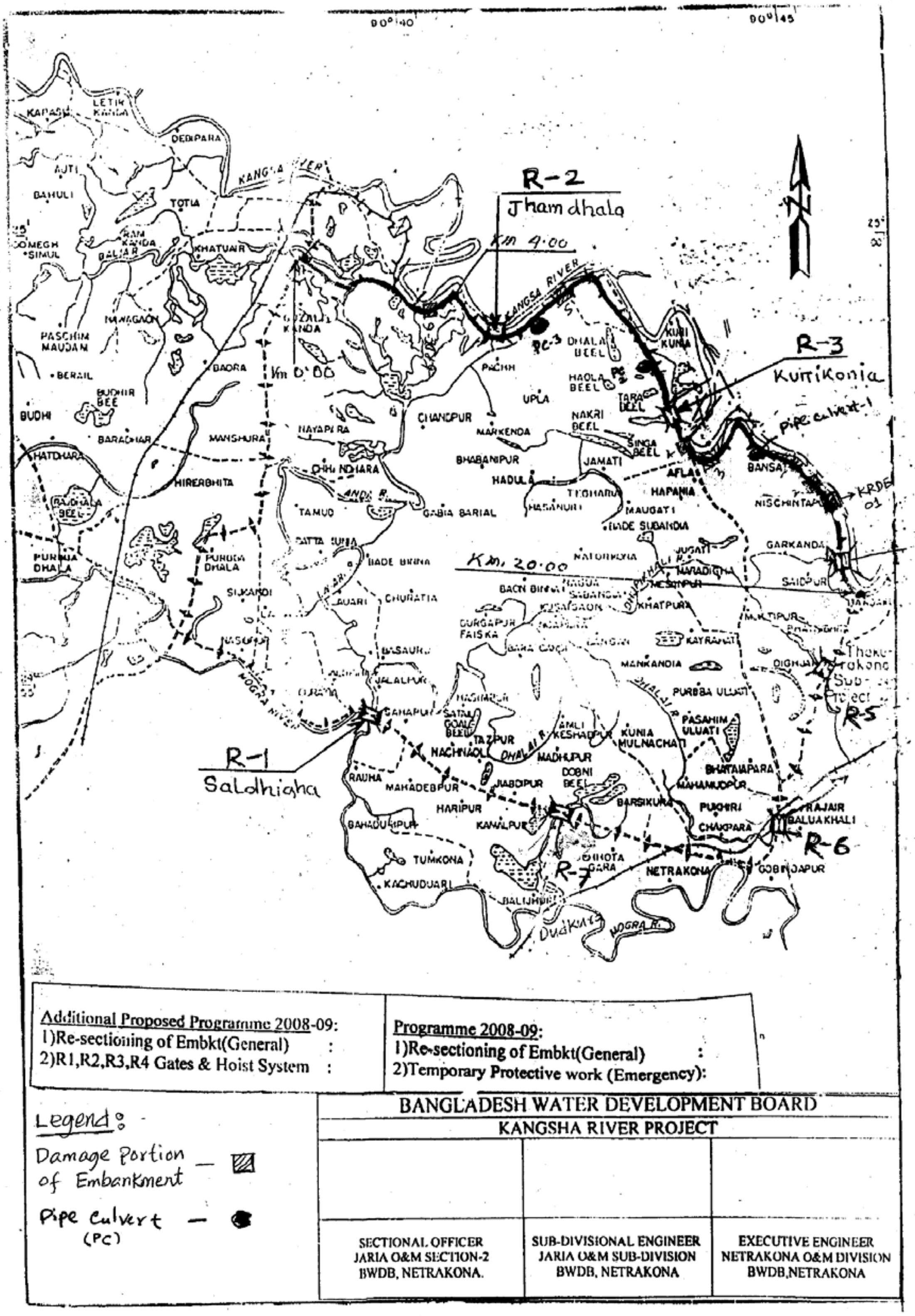
Satdona Beel Scheme



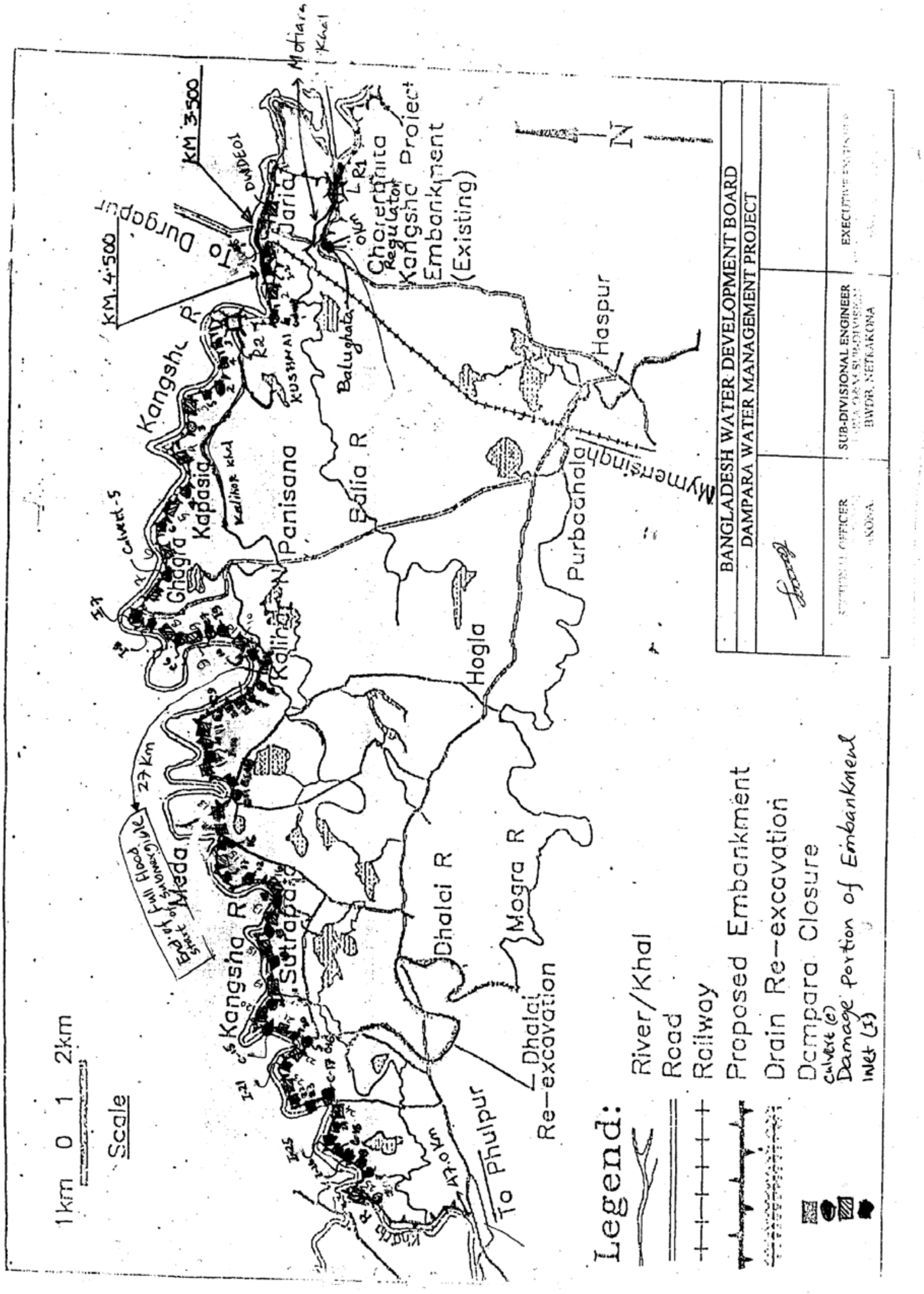
Singer Beel Scheme



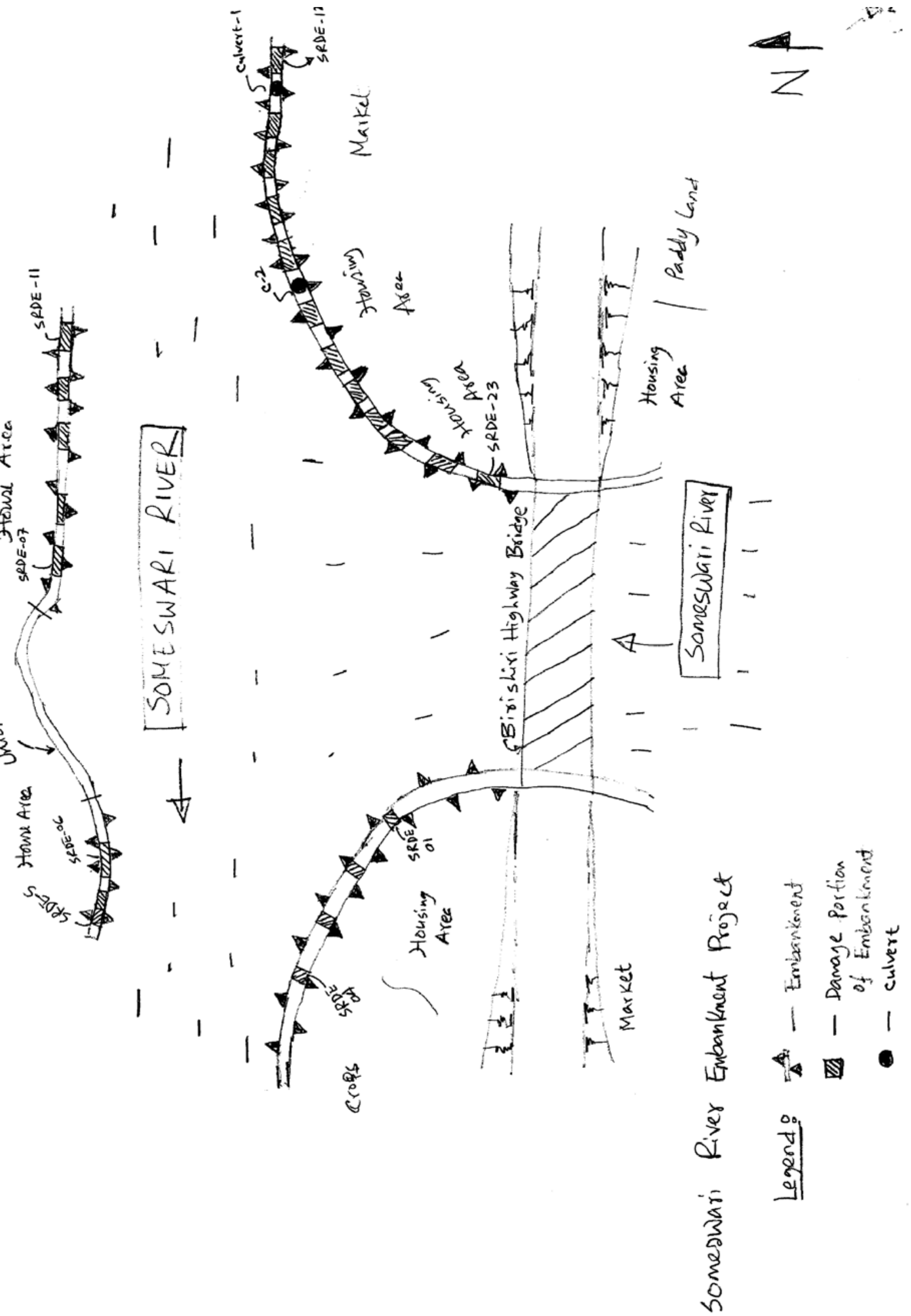
Thakurakona Haor Scheme



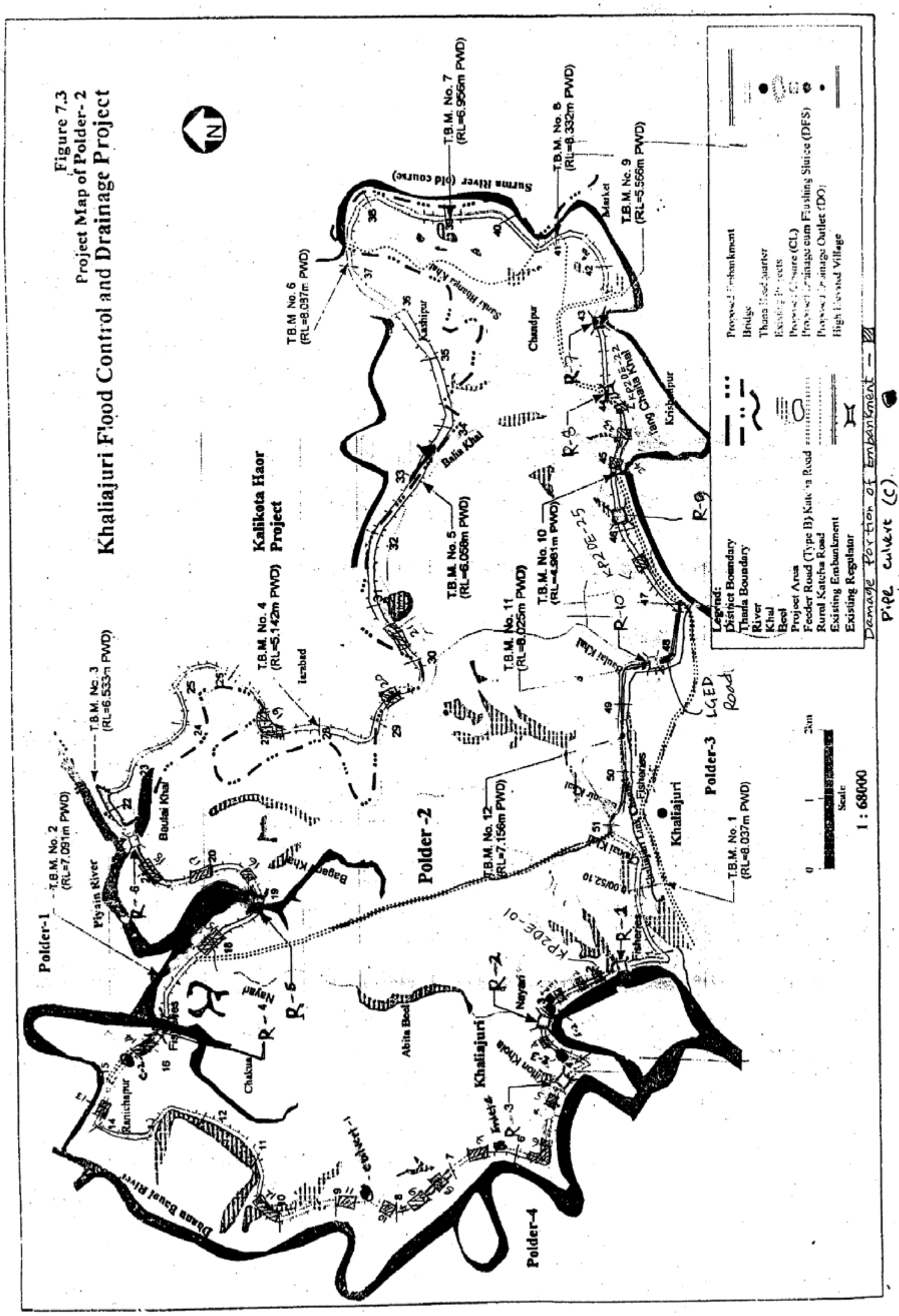
Kangsha River Project



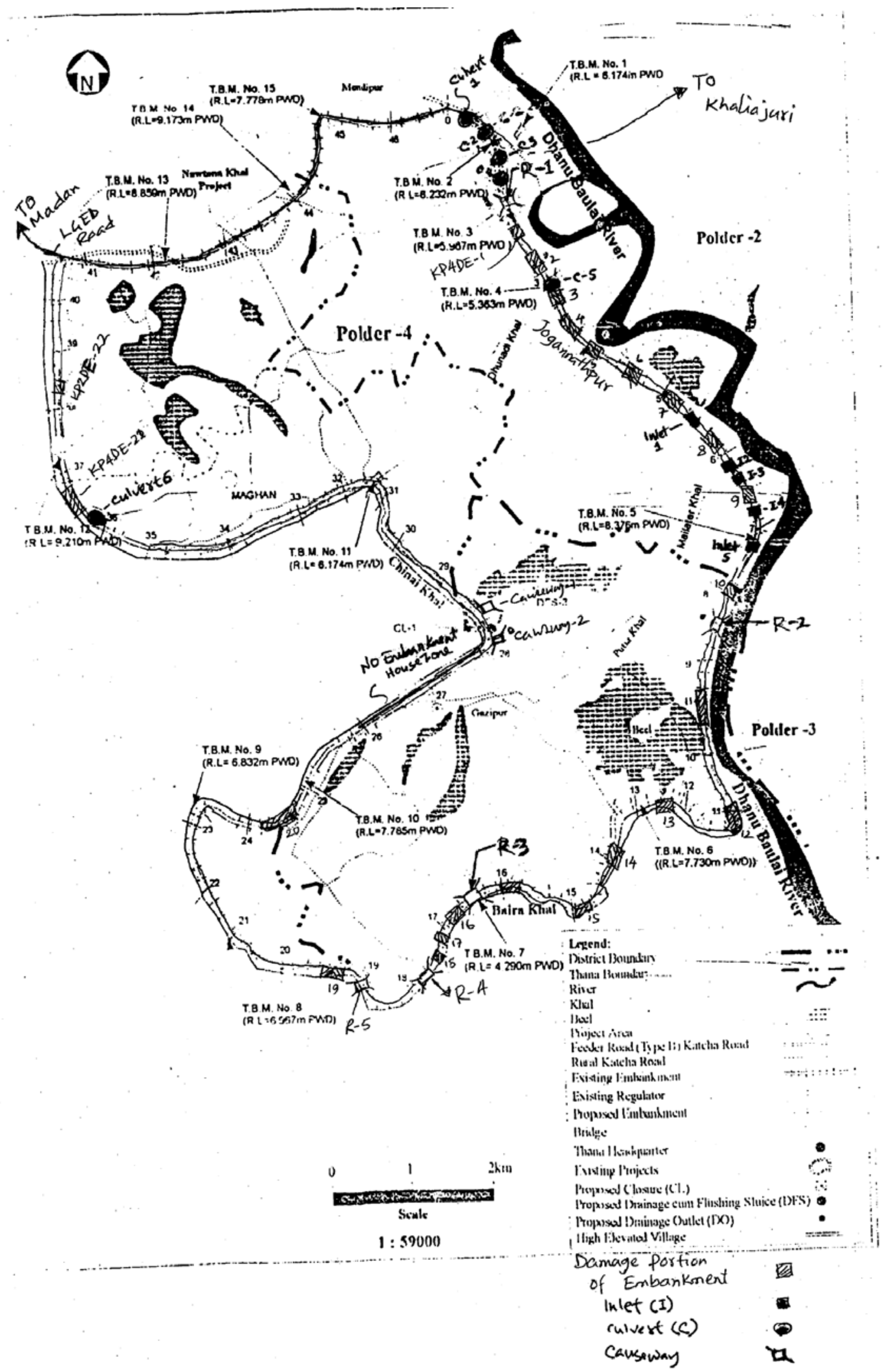
Dampara Water Management Project



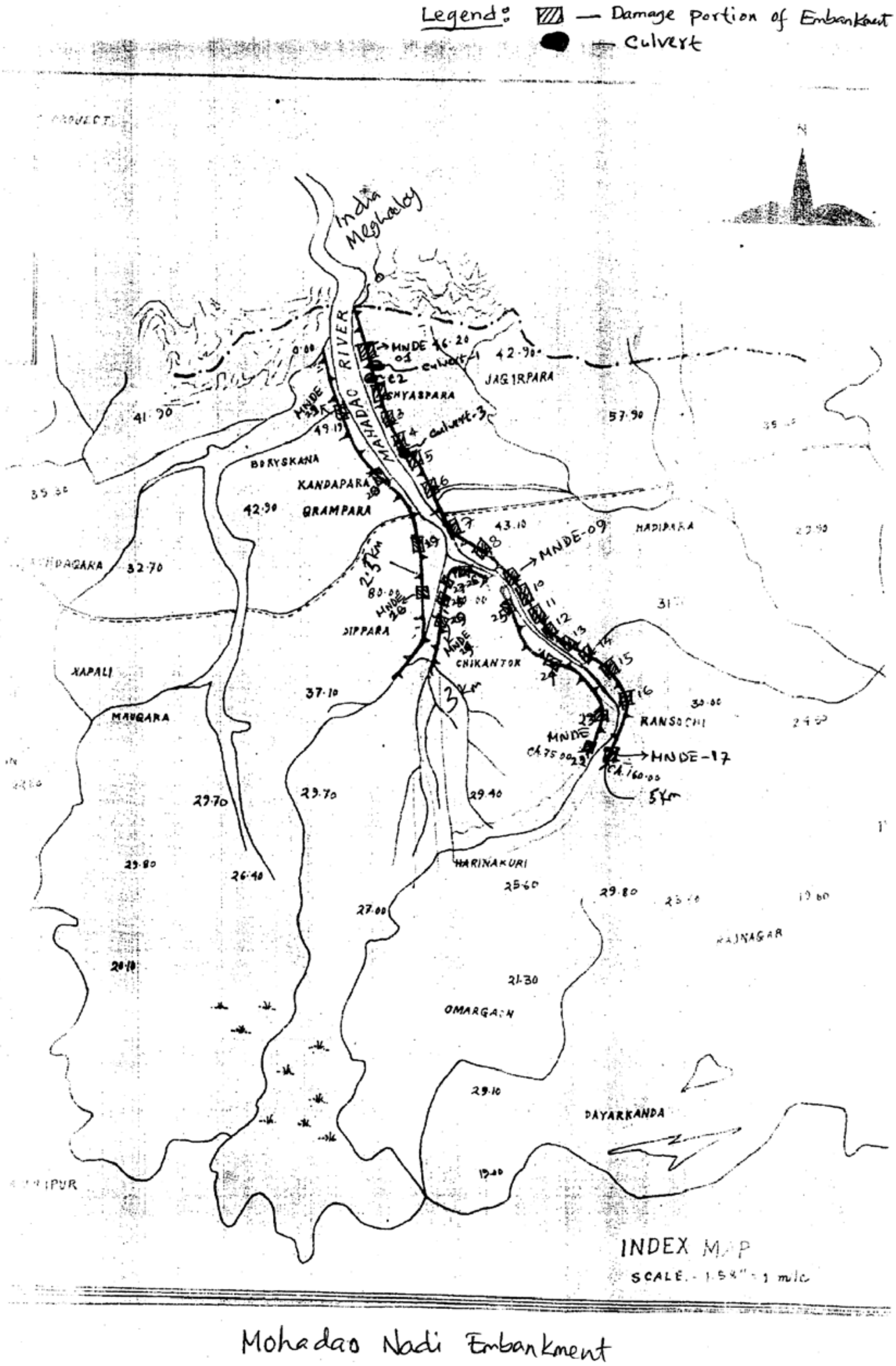
Someswari River Sub-Scheme



Khaliajuri FCD Polder #2

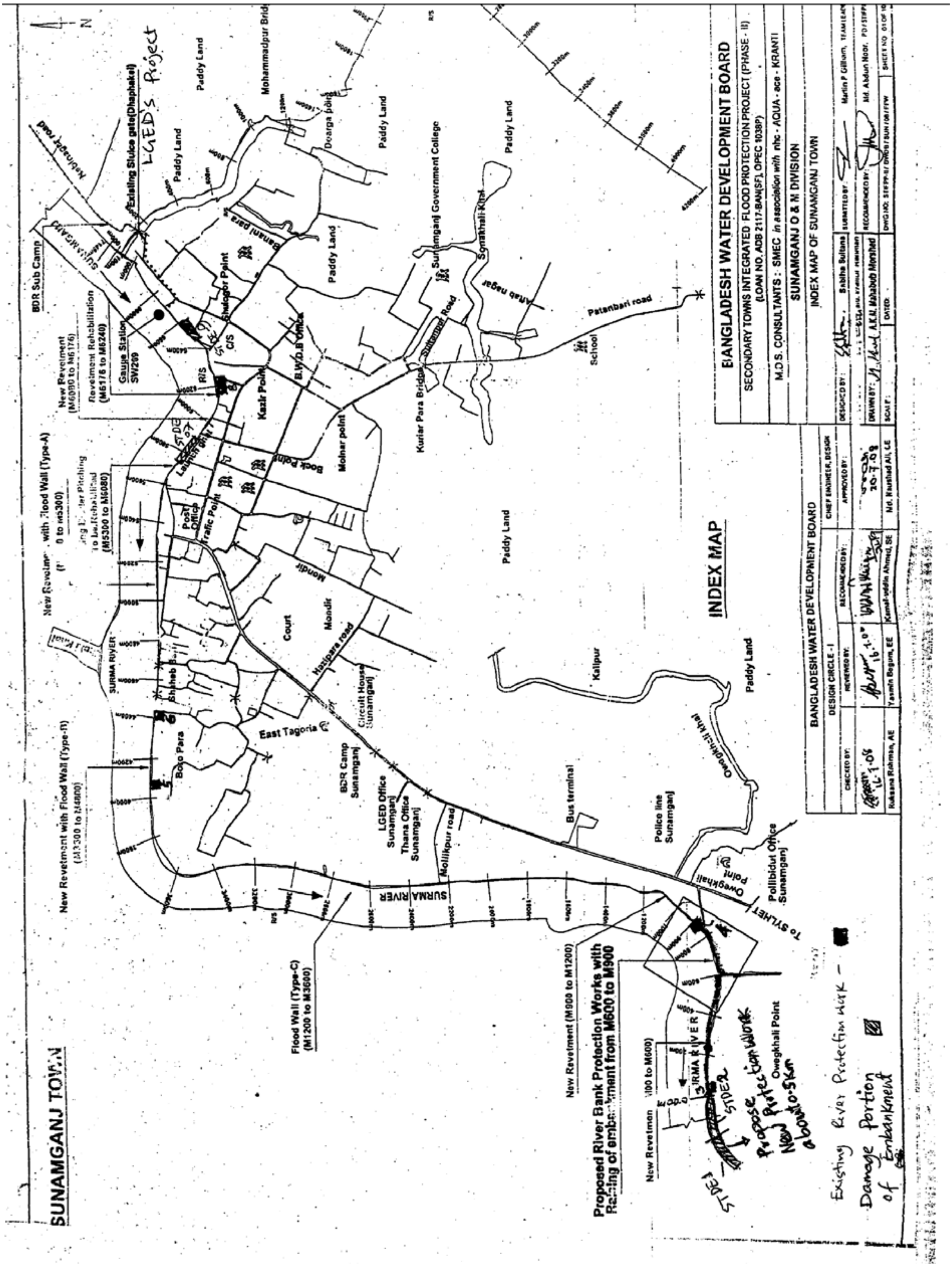


Khalirjuri FCD Polider #4

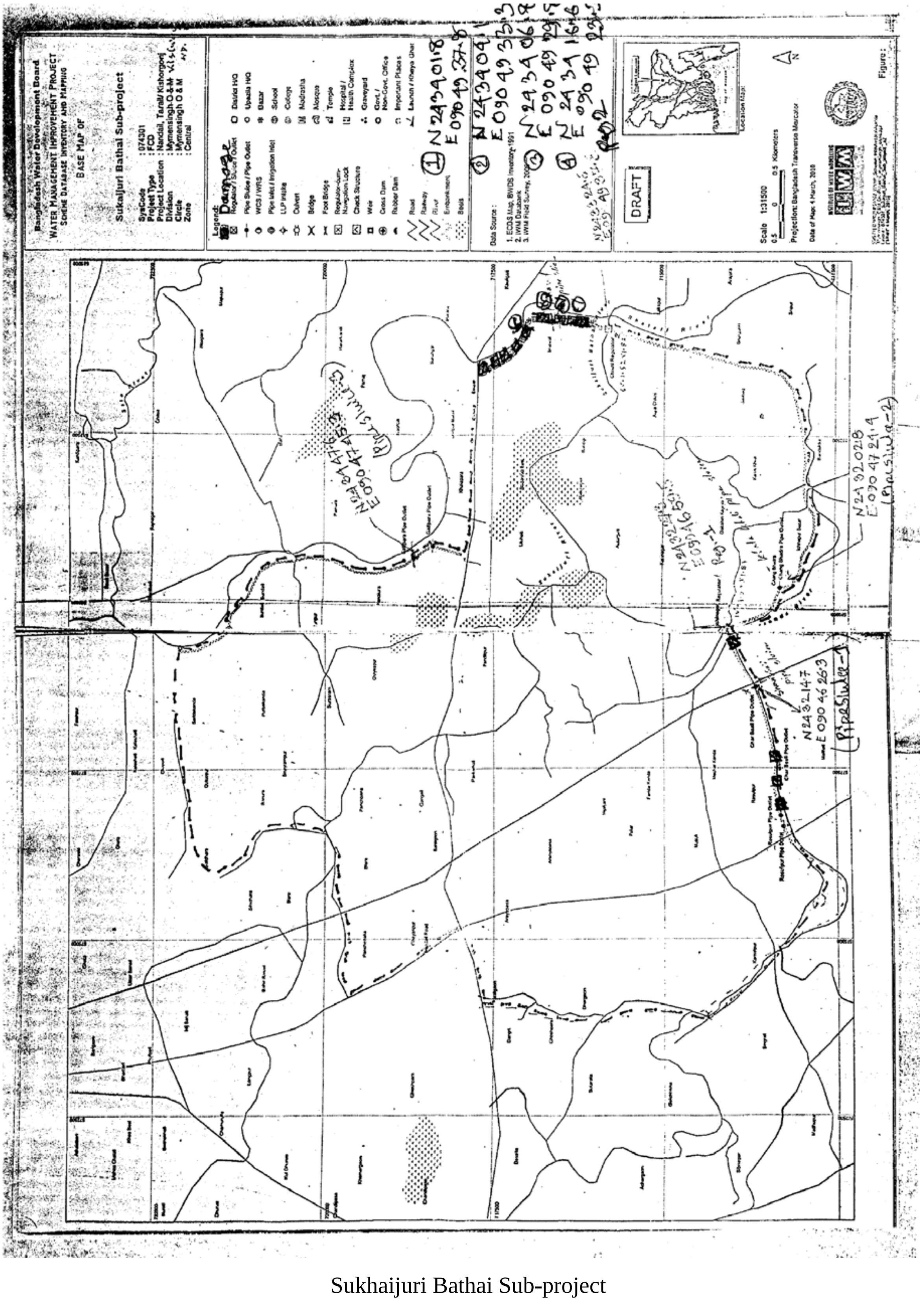


Mohadao Nadi Embankment

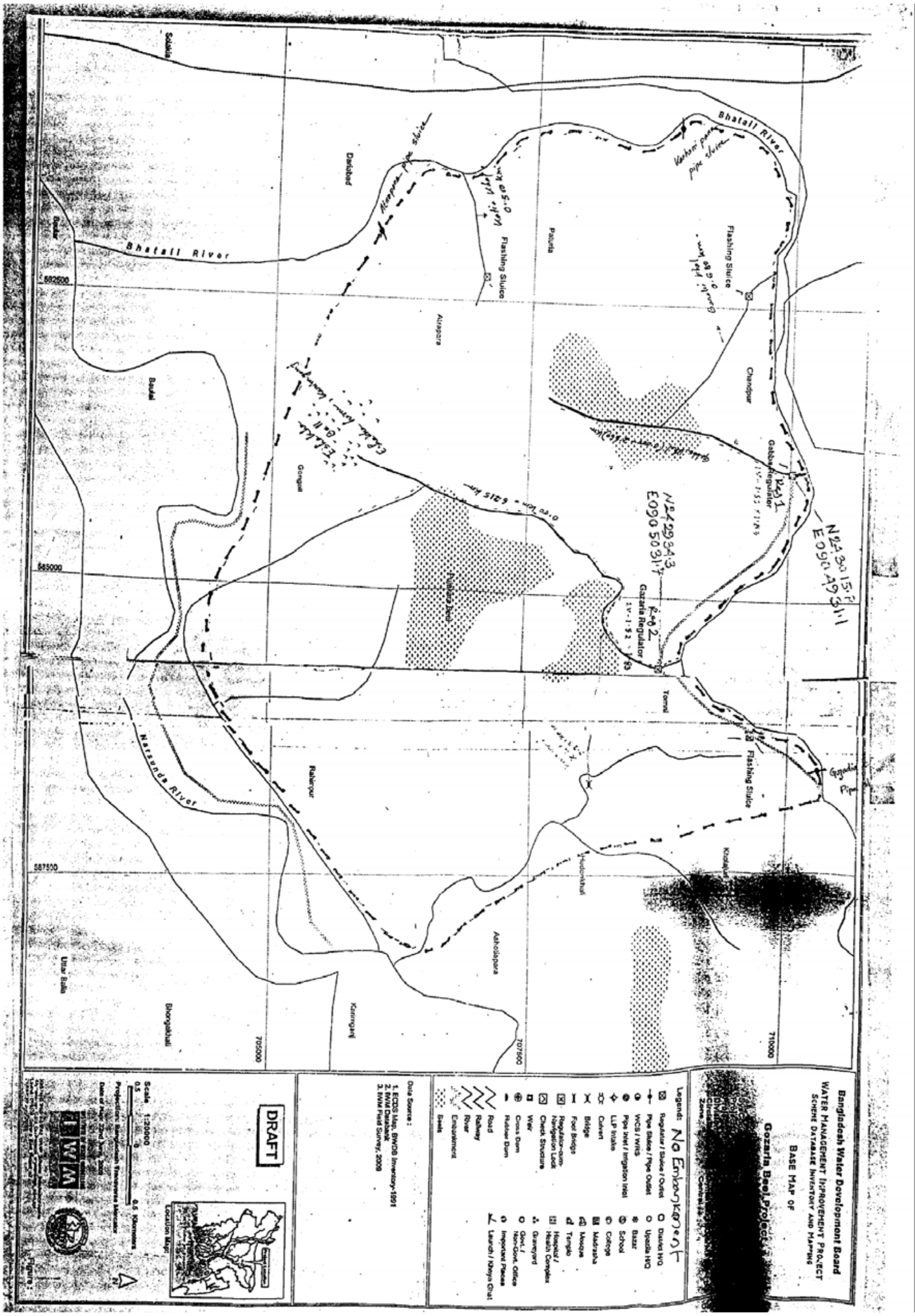
Mohadao Nadi Embankment



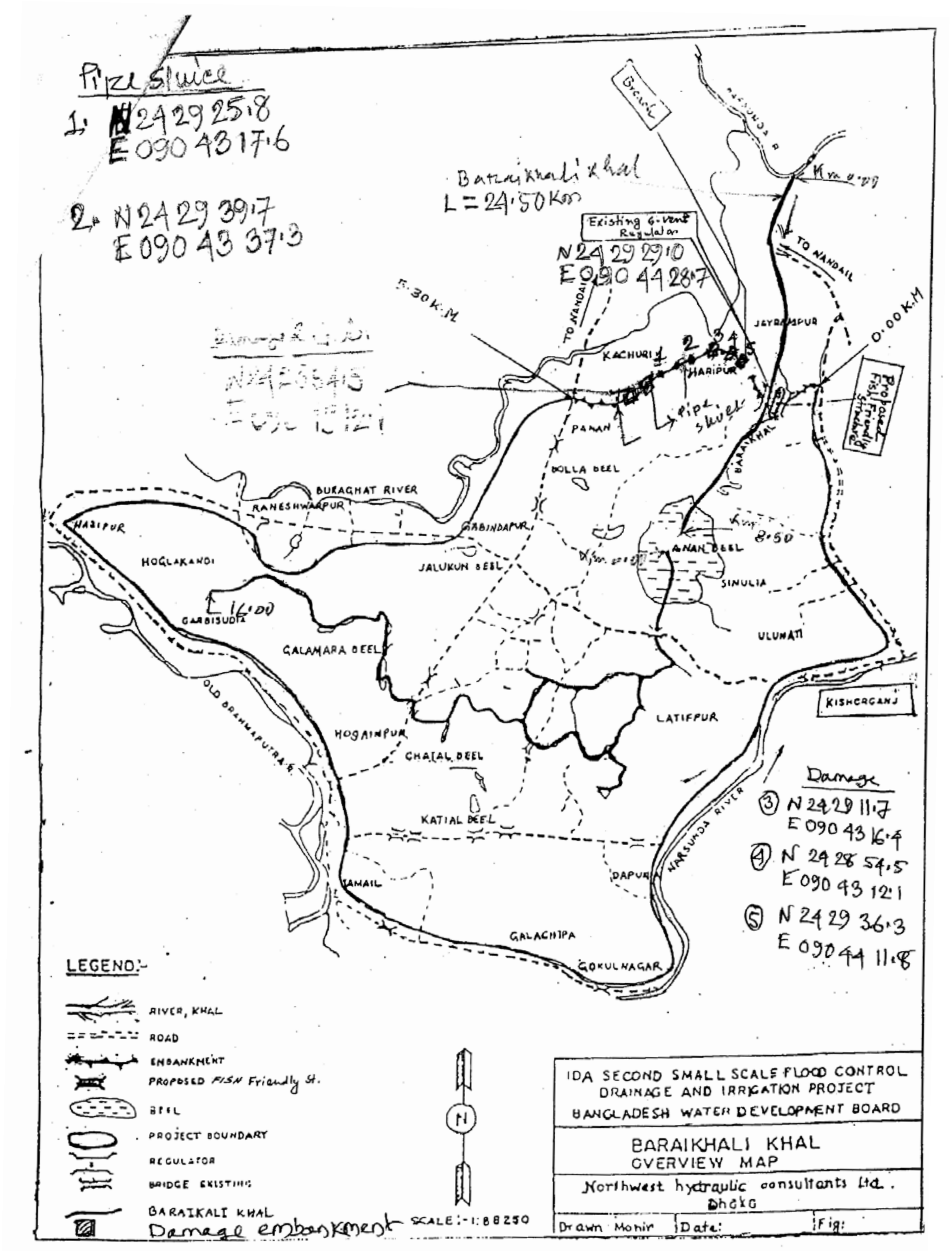
Sunamganj Town Protection



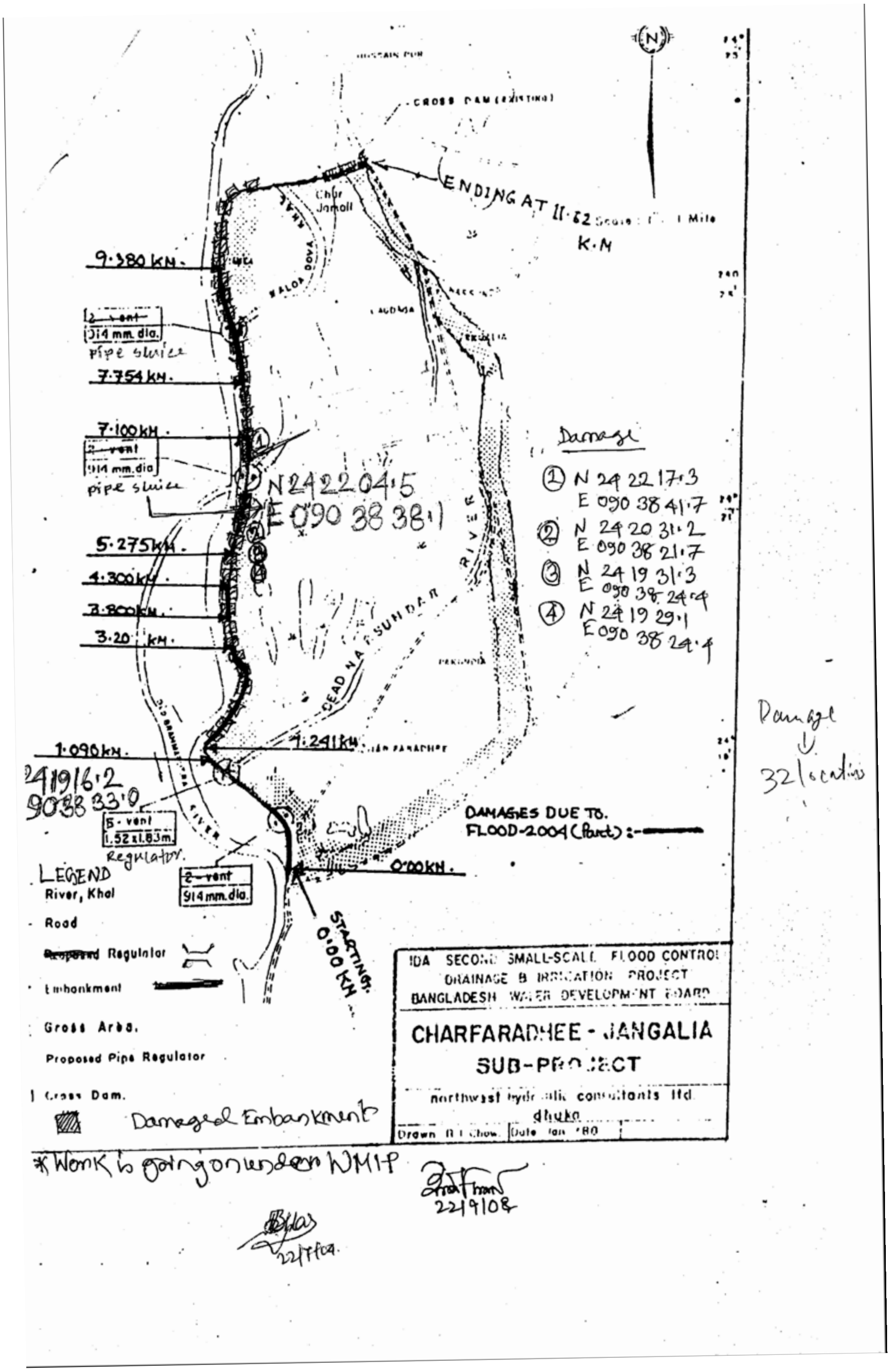
Sukhaijuri Bathai Sub-project



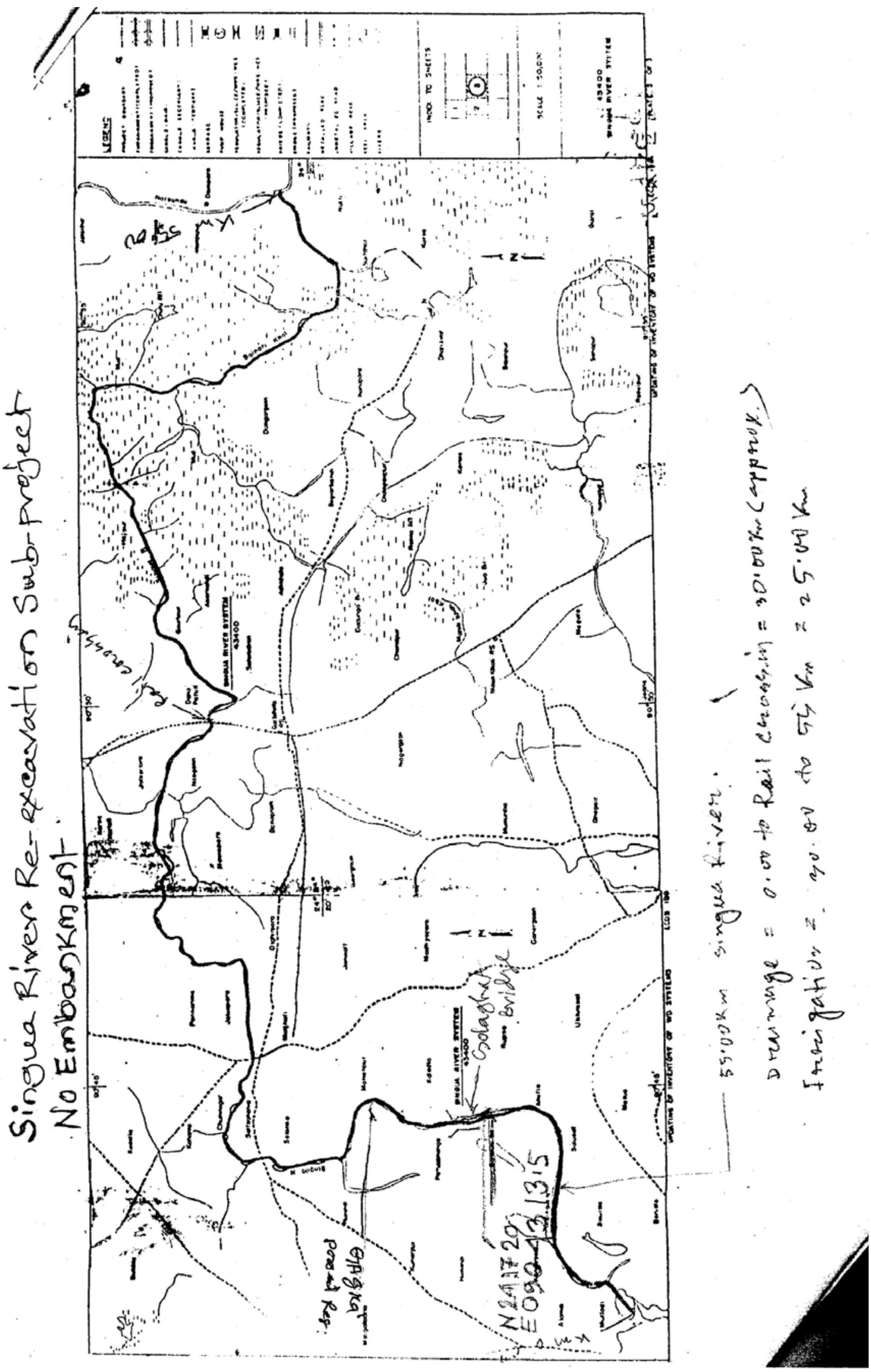
Gazaria Beel Sub-project



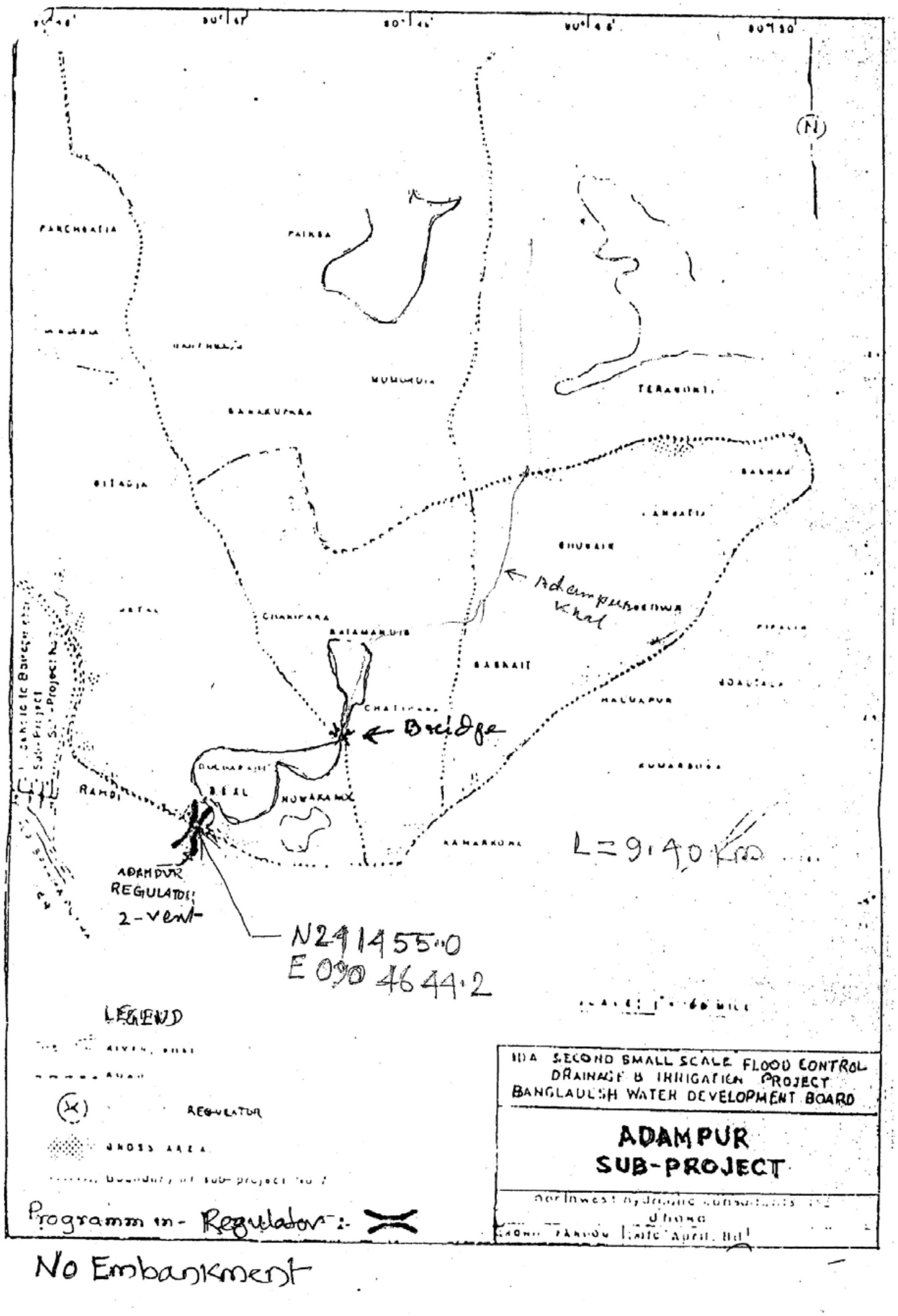
Braikali Khal sub-project



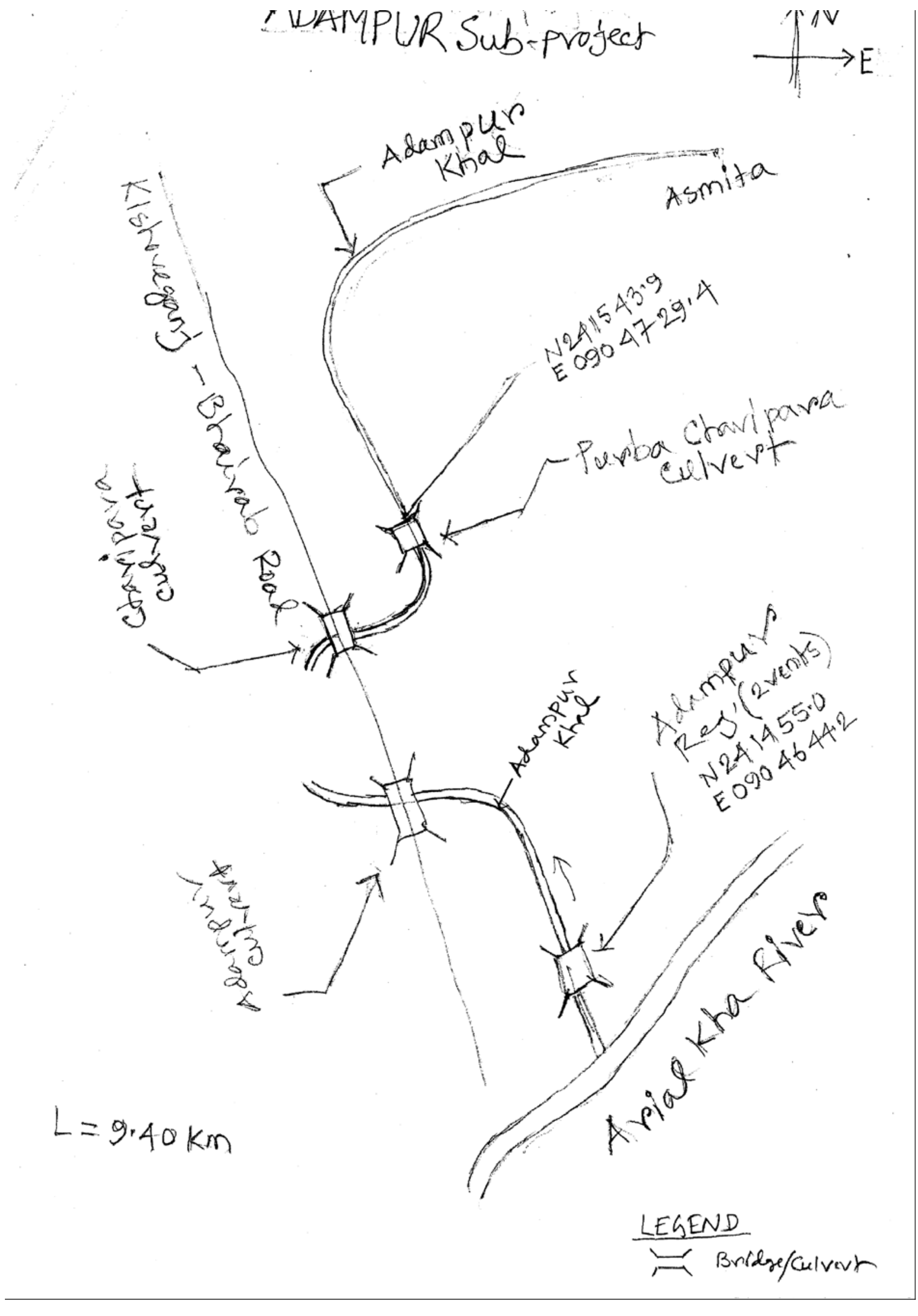
Charfaradhee-Jangalia Sub-project



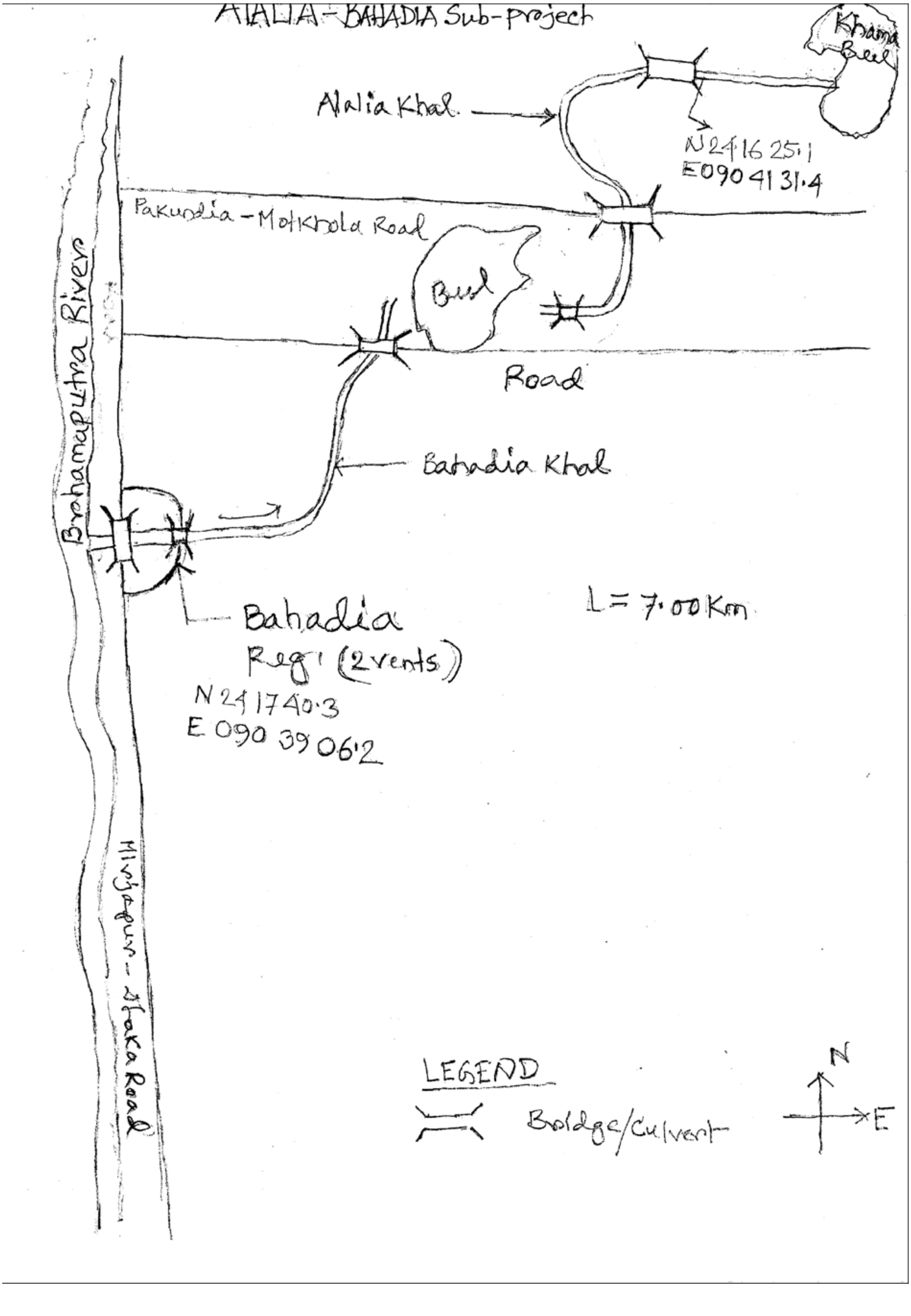
Singua River Re-excavation Sub-project



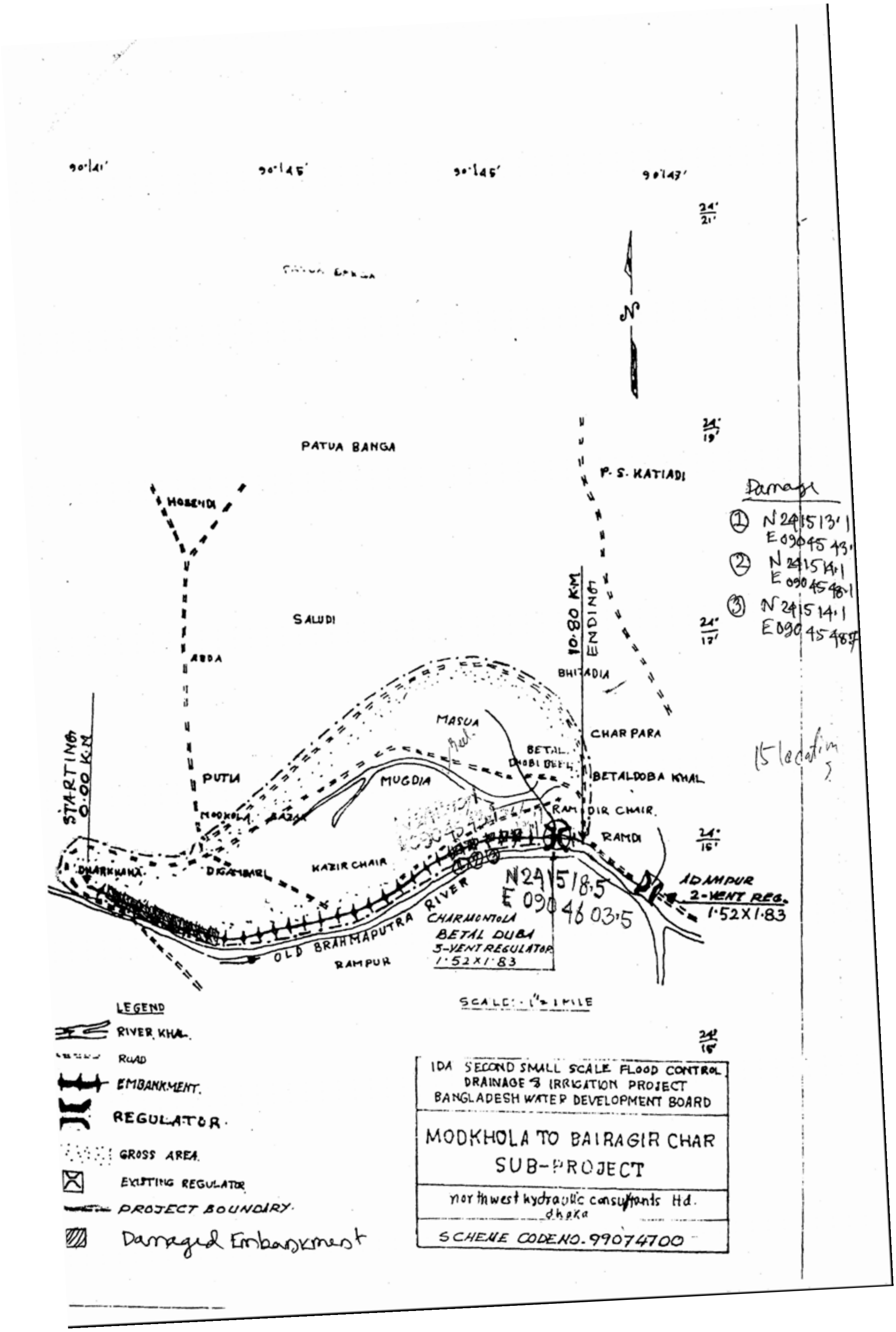
Adampur Sub-project (1/2)



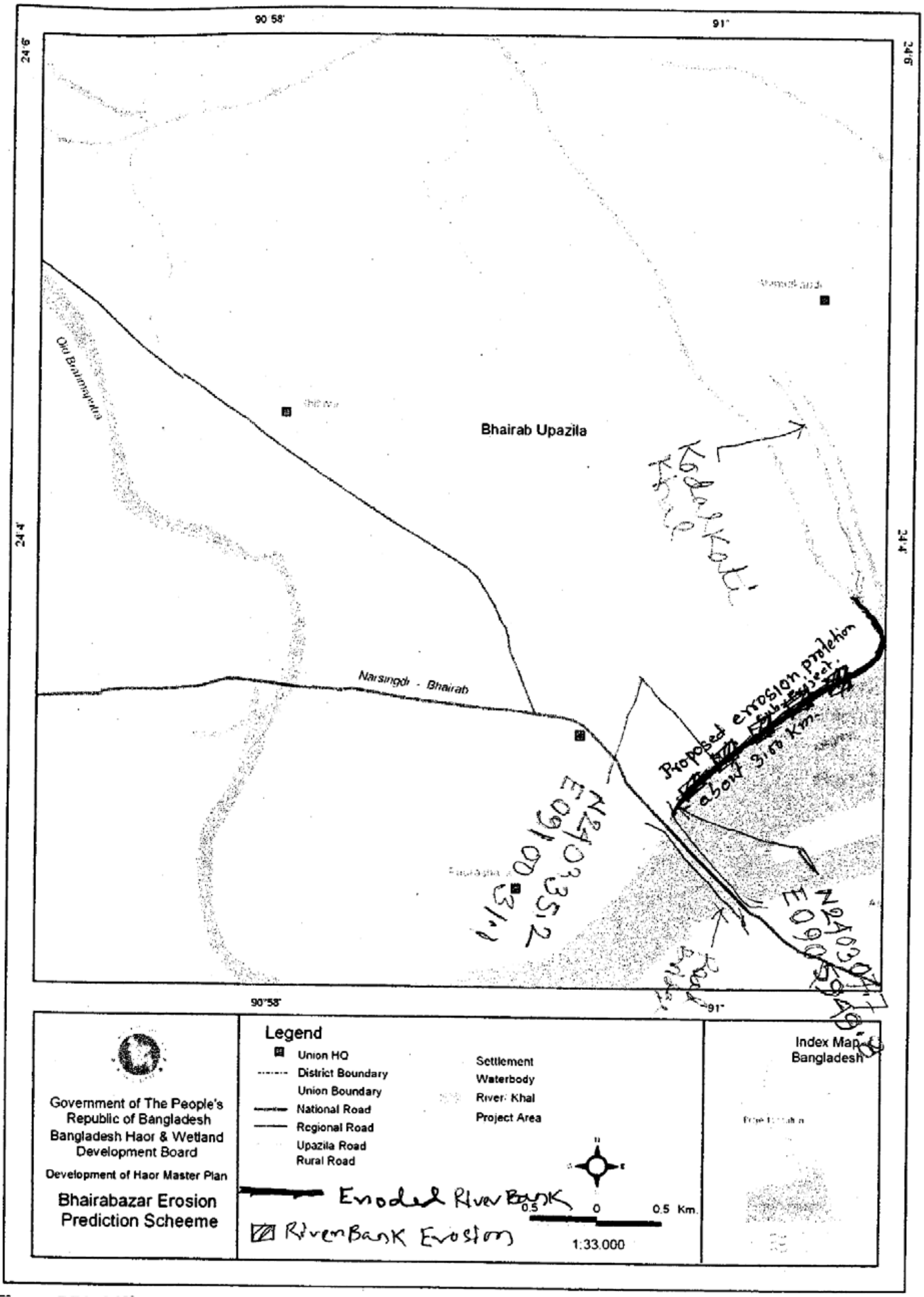
Adampur Sub-project (2/2)



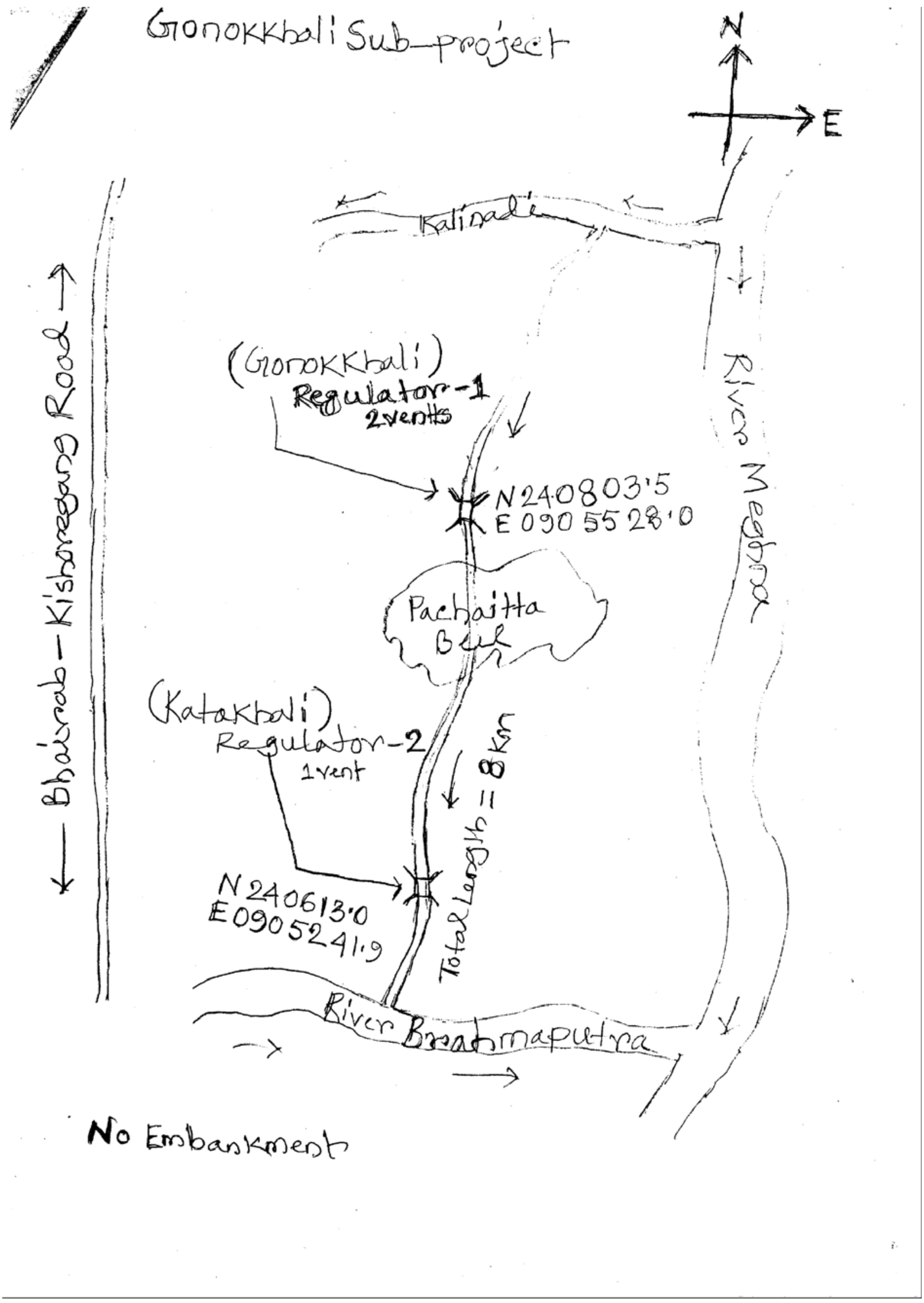
Alalia Bahadia Sub-Project



Modkola-Bairagir Char Sub-Project



Bhairab bazaar Erosion Protection Project



Ganakkali Sub-project

3. List of Contact Person

No.	Project Name	Contact Person
1	Cheghaia Khal Scheme	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Md. Sumon Miah, Sectional Officer, BWDB Habiganj Md. Jamal, Work Assistant, BWDB Habiganj Khoez Ali, Upzila Chairman
2	Gangajuri FCD Sub-scheme	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Md. Raihan, Sectional Officer, BWDB Habiganj Md. Habibullahl, Work Assistant, BWDB Habiganj Md. Yeaqub Miah, Upzila Chairman Md. Alamgir Chowdhuri, Operator
3	Sukti River Embankment	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Md. Sumon Miah, Sectional Officer, BWDB Habiganj Md. Jamal, Work Assistant, BWDB Habiganj Abul Kashem, Upzila Chairman
4	Madhabpur Scheme	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Abdul Mannan, Sectional Officer, BWDB Habiganj Md. Jamal, Work Assistant, BWDB Habiganj Md. Dhanu Miah, Upzila Member
5	Aralia Khal Scheme	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Md. Sumon Miah, Sectional Officer, BWDB Habiganj Md. Jamal, Work Assistant, BWDB Habiganj Enam Khan, Upzila Chairman
6	Kairdhala Ranta Scheme	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Abdul Mannan, Sectional Officer, BWDB Habiganj Md. Jamal, Work Assistant, BWDB Habiganj Orun Dey, Upazila Member Md. Iqbal, Upazila Member
7	Bashira River Re-excavation	Md. Abdul Hekim, Executive Engineer, BWDB Habiganj Md. Mostafa, Sub-division Engineer, BWDB Habiganj Abdul Mannan, Sectional Officer, BWDB Habiganj Md. Jamal, Work Assistant, BWDB Habiganj Md. Iqbal, Upazila Member
8	Datta Khola & adjoining Beel	Md. Zakir Hossain, Executive Engineer, BWDB Brammanbaria Md. Abul Hossain, Sub-division Engineer, BWDB Brammanbaria Shah Md.Aminul Islam, Sub Assist. Engineer, BWDB Brammanbaria Md.Abdul Helal, Work Assistant, BWDB Brammanbaria Aiyub Miah, Upazila Chairman (Islampur) Tajul Islam, Upazila Chairman (Pattan) Anu Miah, Upazila Member (Pattan)
9	Chandal Beel Scheme	Md. Zakir Hossain, Executive Engineer, BWDB Brammanbaria Md. Abul Hossain, Sub-division Engineer, BWDB Brammanbaria Shah Md.Aminul Islam, Sub Assist. Engineer, BWDB Brammanbaria Md.Abdul Helal, Work Assistant, BWDB Brammanbaria Goni Talukdar, Upazila Chairman (Paharikandi)
10	Akashi & Shapla Beel Scheme	Md. Zakir Hossain, Executive Engineer, BWDB Brammanbaria Md. Abul Hossain, Sub-division Engineer, BWDB Brammanbaria Shah Md.Aminul Islam, Sub Assist. Engineer, BWDB Brammanbaria Abdul Awal, Work Assistant, BWDB Brammanbaria Abu Ali, Upazila Member
11	Satodana Beel Scheme	Md. Zakir Hossain, Executive Engineer, BWDB Brammanbaria Md. Abul Hossain, Sub-division Engineer, BWDB Brammanbaria Shah Md.Aminul Islam, Sub Assist. Engineer, BWDB Brammanbaria

		Md.Abdul Helal, Work Assistant, BWDB Brammanbaria Rostom Ali, Upazila Chairman (Solimabad)
12	Singer Beel Scheme	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Khandakar Shahidur Rahman, Sectional Officer, BWDB Netrakona Md. Aminul Islam, Work Assistant, BEDB Netrakona Abdur Rashid, Upazila Chairman (Baushi Barhatta) Abdul Kuddus Noyun, Upazila Chairman (Chiram Barhatta) Md. Shahajahan, Operator (Tumnir Regulator)
13	Thkurakona Scheme	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Khandakar Shahidur Rahman, Sectional Officer, BWDB Netrakona Md. Badrul Alam, Sectional Officer, BWDB Netrakona Md. Aminul Islam, Work Assistant, BEDB Netrakona Alhaz Mizanur Rahman, Upazila Chairman (Medni Sadar) Abul Kashem, Operator (Thakurakona Regulator) Md. Nasir, Operator (Betati Regulator)
14	Kangsha River Scheme	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Md. Badrul Alam, Sectional Officer, BWDB Netrakona Md. Amiruddin Ahmed, Work Assistant, BWDB Netrakona Alhaz Mizanur Rahman, Upazila Chairman (Medni Sadar) Raseduzzaman, Upazila Chairman (Purbodhola) Jubaed Hossain, Operator (Saldigha Regulator), Dulal, Operator (Borari Regulator) Azharul Islam, Operator (Digjan Regulator)
15	Dampara Water Management	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Md. Badrul Alam, Sectional Officer, BWDB Netrakona Md. Amiruddin Ahmed, Work Assistant, BWDB Netrakona Polash, Operator (Chorervita Regulator)
16	Someswari River Sub-Scheme	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Md. Badrul Alam, Sectional Officer, BWDB Netrakona Md. Amiruddin Ahmed, Work Assistant, BWDB Netrakona Md. Abdur Razzak Sarkar, Upazila Chairman (Gaukandia Durgapur) Md. Imruz, Commissioner, Durgapur
17	Khaliajuri FCD Polder #2	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Md. Shahabuddin Ahmed, Sectional Officer, BWDB Netrakona Md. Raisuddin, Work Assistant, BWDB Netrakona Golam Abu Ishak, Upazila Chairman (Khaliajuri) Md. Dewan Rahmat Ali, Upazila Chairman (Chakua) Md. Raju Mia, Operator (Shantinagar Regulator)
18	Khaliajuri FCD Polder #4	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Md. Alauddin, Sectional Officer, BWDB Netrakona Md. Raisuddin Work Assistant, BWDB Netrakona Md. Lukman, Upazila Chairman (Mendipur) Md. Masud, Upazila Chairman (Gazipur) Md. Raju Mia, Operator (Shantinagar Regulator)
19	Mohadao Nadi Embankment	Md. Faruk Bhuiyan, Executive Engineer, BWDB Netrakona Md. Mofazzel Hossain, Sub-division Engineer, BWDB Netrakona Md. Badrul Alam, Sectional Officer, BWDB Netrakona Md. Amiruddin Ahmed, Work Assistant, BWDB Netrakona Md. Babul Upazila Chairman (Rangchati Kamlakanda)
20	Sunamganj Town Protection Project	Gouropodo Sutradhar, Sub-division Engineer, BWDB Sunamganj Md. Barkotullah Bhuiyan, Sectional Officer, BWDB Sunamganj Md. Abdul Wahab, Work Assistant, BWDB Sunamganj

		Md. Jahangir Islam, Stakeholder
21	Sukhaijuri Bathai Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Md. Rakibul Islam Rajib, Sectional Officer, BWDB Kishoreganj A,K,M. Siddique, Work Assistant, BWDB Kishoreganj Daster Ali Bhuiyan, Chairman of Sluice-1 committee Chan Mia, Chairman of Sluice-2 committee
22	Gazaria Beel Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Md. Rakibul Islam Rajib, Sectional Officer, BWDB Kishoreganj A,K,M. Siddique, Work Assistant, BWDB Kishoreganj Habibur Rahaman, Secretary of Sluice-1 Committee Kenu Mia, Chairman of Sluice-2 Committee
23	Boraikhali Khal Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Azizur Rahaman, Sectional Officer, BWDB Kishoreganj Md. Rafiqul Islam Nazim, Work Assistant, BWDB Kishoreganj Habibur Rahaman, Chairman of Boraikhali Sluice Committee
24	Char Ferrade-Jangalia Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Azizur Rahaman, Sectional Officer, BWDB Kishoreganj Md. Rafiqul Islam Nazim, Work Assistant, BWDB Kishoreganj Hadiul Islam, Chairman of Char Kushsha Sluice Committee
25	Singua River Re-excavation Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Azizur Rahaman, Sectional Officer, BWDB Kishoreganj Md. Rafiqul Islam Nazim, Work Assistant, BWDB Kishoreganj Advocate Md. Sohrab Hossen, Upazila Chairman (Pakundia)
26	Adampur Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Azizur Rahaman, Sectional Officer, BWDB Kishoreganj Md. Rafiqul Islam Nazim, Work Assistant, BWDB Kishoreganj Fazlul Haque Rana, Chairman of Adampur Sluice Committee
27	Alalia Bahadia Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Azizur Rahaman, Sectional Officer, BWDB Kishoreganj Md. Rafiqul Islam Nazim, Work Assistant, BWDB Kishoreganj Md. Lal Mia, Chairman of Bhadia Sluice Committee
28	Motkhola-Bairaguir Char Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Md. Moajjem Hossen, Sub-division Engineer, BWDB Kishoreganj Azizur Rahaman, Sectional Officer, BWDB Kishoreganj Md. Rafiqul Islam Nazim, Work Assistant, BWDB Kishoreganj Jalal Uddin, Chairman of Betal Sluice Committee
29	Bhairab Bazar Erosion Protection Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Saidur Islam Khan, Sub-division Engineer, BWDB Kishoreganj Munshi Jahirul Islam, Sectional Officer, BWDB Kishoreganj Md. Nuruzzaman, Work Assistant, BWDB Kishoreganj
30	Ganakkali Sub-project	Syed Hasan Imam, Executive Engineer, BWDB Kishoreganj Saidur Islam Khan, Sub-division Engineer, BWDB Kishoreganj Munshi Jahirul Islam, Sectional Officer, BWDB Kishoreganj Md. Nuruzzaman, Work Assistant, BWDB Kishoreganj

4. Present Situation of Each Haor Project

1. Cheghaia Khal Scheme

(1) Embankment



Artificial cutting due to boat transportation and fishing

(2) Regulator


Regulator-01

(3) Chnnel/Khal



Siltation problem

2. Gangajuri FCD Sub-Scheme

(1) Embankment		
		
Erosion due to wave action and heavy rainfall		
(2) Regulator		
		
Regulator-1	Regulator-2	Regulator-3
		
Regulator-4	Regulator-5	Regulator-6

		
Regulator-7		
Many equipments were stolen and poor maintenance.		
(3) Canal		
		
Sedimentation Problem		
(4) Pipe Sluice		
		
Sedimentation problem and no repair work		

3. Sukti River Embankment

(1) Canal

Sedimentation Problem

4. Madhabpur Scheme

(1) Embankment









Erosion due to wave action and heavy rainfall

(2) Canal/Khal


Local people requested to construct regulator at downstream of canal for water store purpose.

5. Aralia Khal Scheme

(1) Regulator		
		
Regulator-1	Regulator-2	
(2) Canal/Khal		
		
Sedimentation Problem		

6. Kairdhala Ranta Scheme

(1) Embankment		
		
		
Erosion due to overtop, wave action and heavy rainfall		
(2) Regulator		
		
Regulator-1	Regulator-2	Regulator-3

7. Bashira River Re-excavation

(1) Embankment		
		
Erosion due to overtop, wave action and vehicle passsing		
(2) Canal		
		
		
Sedimentation problem		

8. Datta Khola and adjoining Beel

(1) Canal		
		
		
Sedimentation Problem		

9. Chandal Beel Scheme

(1) Embankment		
		
Erosion due to wave action		
(2) Regulator (No.1)		
		
(3) Canal/Khal		
		
Local people requested additional storage water for irrigation purpose.		

10. Akashi and Shapla Beel Scheme

<table>
<tr><td>(1) Embankment</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Artifical cutting and erosion due to wave action</td></tr>
<tr><td colspan="3">(2) Canal/Khal</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Sedimentation Problem</td></tr>
</table>

11. Satodana Beel Scheme

(1) Regulator		
		
Regulator-1	Regulator-2	

12. Singer Beel Scheme

(1) Embankment		
		
		
		
		
Artificial cutting, Erosion due to wave action, heavy rainfall, viechle passing and overtop.		
(2) Regulator		
		
Regulator-1	Regulator-2	Regulator-3

		
Regulator-4		
(3) Canal/Khal		
		
Sedimentation Problem		
(4) Pipe Culvert and Inlet		
		
		

13. Thakurakona Scheme

(1) Embankment		
		
On going by WMIP		
(2) Regulator		
		
Regulator-1	Regulator-2	Regulator-3
(3) Canal/Khal		
		
Sedimentation problem		

14. Kangsha River Scheme

(1) Embankment		
		
		
Artificial cutting and erosion due to heavy rainfall and overtop		

15. Dampara Water Management

(1) Embankment		
		
		
		
		
		










Artificial cutting and erosion due to heavy rainfall and overtop

(2) Regulator

Regultor-1

Regulator-2

(3) Canal/Khal

		
(4) Inlet		
		
		
		

16. Someswari River Scheme

(1) Embankment		
		
		
		
		
		







Erosion due to heavy rainfall, overtop, wave action

(2) Culvert


17. Khaliajuri FCD Polder #2

(1) Embankment		
		
		
		
		
		

		
		
		
		
Artificial cutting and erosion due to heavy rainfall, overtop, wave action		
(2) Regulator		
		
Regulator-1	Regulator-2	Regulator-3

		
Regulator-4	Regulator-5	Regulator-6
		
Regulator-7	Regulator-8	Regulator-9
		
Regulator-10		
3) Inlet		
		

18. Kaliajuri FCD Polder #4

(1) Embankment		
		
		
		
		
		







Artificial cutting and erosion due to heavy rainfall, overtop

(2) Regulator

Regulator-1

Regulator-2

Regulator-3

Regulator-4

Regulator-5

3) Inlet		
		
		
4) Culvert		
		
		
5) Causeway		
		

19. Mohadao Nadi Embankment

(1) Embankment		
		
		
		
		
		

Artificial cutting and erosion due to heavy rainfall, overtop

2) Culvert

20. Sunamganj Town Protection

(1) Embankment		
		
		
		

21. Sukhaijuri Bathai Sub-project

(1) Embankment













Erosion due to heavy rainfall

2) Regulator		
		
Regulator-1	Regulator-2	
3) Sluice		
		

22. Gazaria Beel Sub-project

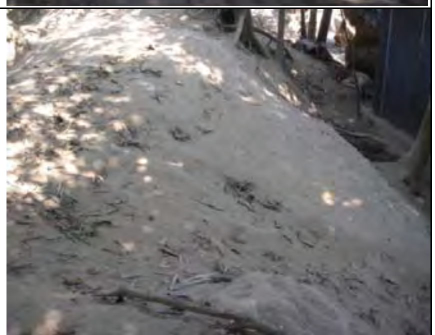
(1) Regulator		
		
Regulator-1	Regulator-2	
(2) Canal/Khal		
		
Sedimentation Problem		
(3) Sluice		
		

23. Boraikhali Khal Sub-project

(1) Embankment		
		
		
Erosion due to heavy rainfall		
(2) Regulator		
		
Regulator-1		
(3) Canal/Khal		
		
Sedimentation Problem		

(4) Sluice		
		

24. Char Ferradee-Jangalia Sub-project

(1) Embankment		
		
		
		
		
		

		
Erosion due to heavy rainfall		
(2) Regulator	(3) Sluice	
		
Regulator-1		

25. Singua River Re-excavation Sub-project

(1) Canal/Khal		
		
Sedimentation Problem		

26. Admpur Sub-project

(1) Regulator	(2) Cannal/Khal	
		
Regulator-1	Sedimentation Problem	

27. Alalia Bahadia Sub-project

(1) Regulator	(2) Cannal/Khal	
		
Regulator-1	Sedimentation Problem	

28. Motkhola-Bairagir Char Sub-project

(1) Embankment		
		
		
		
		
Erosion due to heavy rainfall		
(2) Regulator		
		

29. Bhairab Bazar Erosion Protection Project

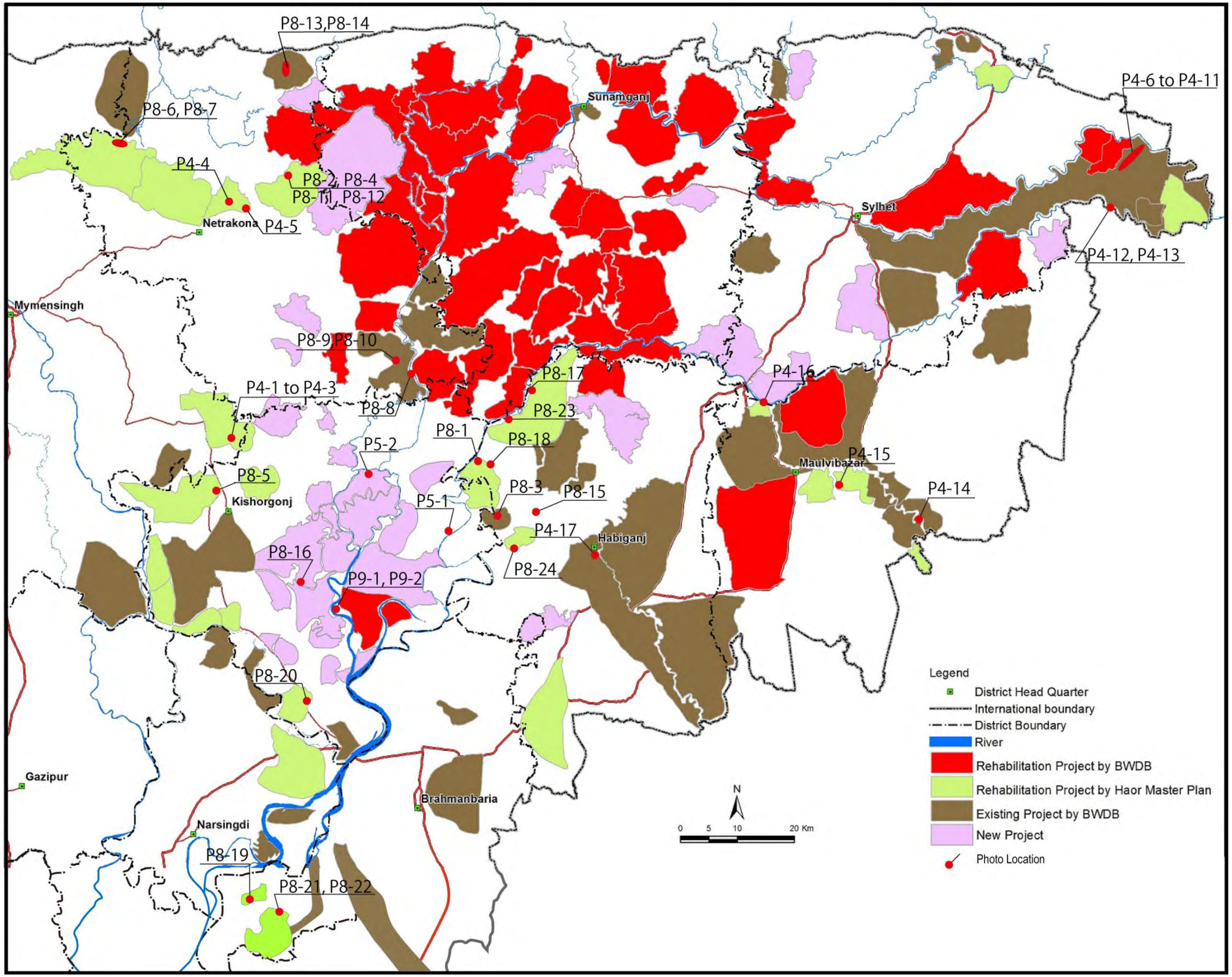
(1) Revetment	(2) High water channel	
		
		

30. Ganakkali Sub-project

(1) Regulator		
		
Regulator-1	Regulator-2	

Annex-4.4

Location Map of Photographs


P8-13,P8-14
P8-6, P8-7
P4-4
P8-2, P8-4
P8-11, P8-12
P4-5
Netrakona
Sunamganj
Sylhet
P4-6 to P4-11
P4-12, P4-13
Mymensingh
P8-9 P8-10
P4-1 to P4-3
P8-8
P8-17
P8-23
P4-16
P8-1
P8-18
P5-2
P8-5
Kishorgonj
P8-3
P8-15
P5-1
Maulvibazar
P4-15
P4-14
P4-17
Habiganj
P8-16
P9-1, P9-2
P8-24
P8-20
Gazipur
Brahmanbaria
Narsingdi
P8-19
P8-21, P8-22
N
0 5 10 20 Km
Legend
District Head Quarter
International boundary
District Boundary
River
Rehabilitation Project by BWDB
Rehabilitation Project by Haor Master Plan
Existing Project by BWDB
New Project
Photo Location