The direct loss to fisheries, if any, which would result from the implementation of a FCD project is basically related to the decrease in fish habitat area i.e. to the reduction of the flooded area and/or flood duration and average flood depth which could affect culture fisheries as well. Indeed, fishery productivity (biomass harvested) is a function of the Net Cultivable Area (NCA) in each of the flood zones. To understand and quantify the loss, the productivity (biomass/unit area/unit time) should be used to calculate fish losses. During the phase-I field trips, therefore, the data on the existing (WO) situation of the fisheries resources as well as those on the fisheries production benchmark were collected.

A significant finding of the Rapid Rural Appraisal (RRA) studies (1991) by the Consultant Team (CT) of the FAP 12 (FCD/I Agricultural Study) on 17 projects including the Kurigram South Unit was that large numbers of full time professional fishermen were forced out of business by the negative impact of FCD works on capture fish stocks and catch rates. It was, therefore, considered essential to conduct an inventory of the fishermen community in the project area during the phase-II study period. The RRA studies (OP.cit.) also asserted that the quantify of fish traded per day at the markets both within the impacted areas and outside, had declined since preproject times by as much as 65 percent. Data required on the general economic condition, fishermen's involvement in fishing, their fishing periods, locations, catch statistic etc. were collected from both the impacted and the control areas on selecting 120 respondents from the PA and 40 from outside the PA.

2.4 Linkage and Liaison

During the survey and investigations, appropriate officials of the concerned organizations as well as the relevant team members were contacted personally and consulted. Persons other than those of JICA, when contacted first, were acquainted with the objectives and scope of the project (Kurigram South) and were requested to extend all possible cooperation and assistance.

2.4.1 Previous and On-going Studies Linked

Three previous studies namely the Feasibility Study on the Kurigram FCD/I Project (1969-71), Revised and Updated Feasibility Study (FS) on the Kurigram FCD/I project (1975) and the Revised and Updated F/S on the Kurigram FCD/I project-South Unit (1982) are linked to the present study.

Quite a few FAP studies viz. FAP#2 (North-West Regional Study) inclusive of the Kurigram South area, FAP#9A (Secondary Town Protection Project) which includes Kurigram Town Protection, FAP#12 (FCD/I Agricultural Study) that includes the Kurigram South as one of the 17 study areas for its project impact assessment, FAP#13 (Operation and Maintenance Study) including the Kurigram South area, FAP#15 (Land Acquisition Resettlement) that includes the Kurigram South area as one of its sample areas, FAP#16 (Environmental Study) concerned with environmental impact assessment (EIA) of all FAP projects and FAP#17 (Fisheries Study and pilot project) which is national in scope and so on, and so forth are all linked to the present study.

In addition to the studies mentioned above, an inventory of the other existing schemes was attempted with the assistance of the DFOs of Kurigram and Lalmonirhat. Concerned existing agencies and institutions were visited and linkages were maintained with them. Some of the projects' sites were also visited. Relevant data and publications were collected from all of them, and many other secondary sources mentioned earlier. Arrangements were made for the data/information existing in other agencies or FAP Offices to be made available.

2.5. Analyses of Data

The data collected were edited both in the field and in the office on return. For accomplishing the objective of the study as listed in section 1.3, the data were analysed from the following points of view :

i. annual fish demand (in terms of population) and fish production in the project area;

ii. relative contributions and productivity of the culture and capture fisheries resources in the area;

iii. number, area and present condition of ponds in each Thana;

iv. input costs and Net Production Value (NPV) from the pond fisheries;

v. weight, value and percentage composition of the annual catch of the main fish varieties in different Thanas;

vi. sample size of fishermen, their percentage of total population, average annual fish catch and per capita annual/daily income in FCDI and non-FCDI areas;

vii. involvement of different types of fishermen (full time, part time and subsistence) in fishing activities, their fishing periods and fishing locations;

ix. percentage participation of fisherman family members in different kinds of activities (viz. fishing, fish marketing, fish processing, net weaving, poultry/livestock raising, small trade etc. etc.

x. fishermen's and others' opinions about project impact (Nos. responding)

3. Survey Results and Discussion

3.1 An Overview of Fisheries in the Project Area: Fisheries Potential

Inland fisheries in the project area is limited virtually to the freshwater fisheries, in the sense there is no coastal aquaculture there. The freshwater bodies are usually categorized as those of the open water capture fisheries and those comprising the closed water culture fisheries. The major part of the project area is flooded annually between June and October. This flooding, whilst being disruptive and, at exceptional times, highly damaging, also provides the great benefit of the increased availability of the floodplain aquatic habitat where both fish and shrimps undertake migrations to breed, feed and grow. Inundated floodplains provide most suitable habitats for them to multiply both in numbers and biomass.

The fishery production system of the project area supports populations of a large variety of fish and some shrimp species. The check list of these species prepared to show their distribution of habitats during the phass I and supplemented by the phas-II work (Appendix F1) indicates the richness of the area in fish wealth. Most of this wealth (about 70% by weight) are contributed by the capture fisheries. But unfortunately, the stock of these inland fisheries are being adversely affected by several reasons such as silting up of the rivers and the beels, reclamation and utilization of the low-lying/flood land areas, overfishing, inefficient management of the public water bodies, flood control, drainage and irrigation activities and other environmental factors.

3.1.1 Fish Demand and Production

The population of the project area is estimated at 396,989 i.e., about 0.4 million. Based on the world average fish consumption level of 10.5 kg/capita/year, annual fish demand for this population would stand at 4,168 MT-whereas the survey undertaken in January 1992 has recorded a total annual fish production of only 562 MT (Table IX.3.1). This indicates a deficit of 3,606 MT which means the fish production in the project area has to be enhanced by 86.5% over the present level. The present fish production level thus indicates an alarming level of average annual per capita availability of 1.4 kg fish as against the national level of per capita fish consumption ranging from 4.4 kg for the lowest income group to 22.1 kg for the highest income group. As shown by Table IX.3.1, the deficit is directly proportional to the population size showing clearly an increasing trend with increase in population of the different Thanas. Overfishing caused by population pressure this stands out to be one of the important reasons for such fish deficits.

Of the 5 Thanas, one with the lowest population (Chilmari) appears to make almost 20% contribution to the total fish production in the project area while Kurigram and Lalmonirhat with three to six times higher population contributes much less. Nevertheless, the production figure may not be taken as an authentic' one, as it has been based on proportionate production; but we can't help drawing a line somewhere.

3.2 Culture Fisheries: Current Status

Culture fisheries refer to the fisheries in closed or confined waters where fish are produced by stocking with fry and by manipulating the aquatic system. This type of fishery in the project area is restricted solely to the pond fisheries.

The phase I field work and the questionnaire survey indicated that there are as many as 2,633 ponds/tanks covering an area of 262 ha in the 5 constituent Thanas (Table IX.3.2). They cover hardly 0.4% of the total project area, but 64% of the ponds and tanks are under culture and the rest 36% are lying derelict. The ponds under culture are in general, medium in size averaging 0.1 ha (as classified by World Bank, 1991) and, therefore, carp polyculture is practiced in 70% of the total ponds/tanks area.

Out of the total fish production of 562 MT, culture fisheries provide 167 Mt contributing about 30% to the total production in the project area (Table IX.3.3). The Thanawise data obtained on area and productivity of ponds are those proportionate to the areas that fall within the project boundary. Although it is encouraging to note that the contribution of pond fisheries in the project area greatly exceeds the latest Bangladesh average of 21% pond contribution to the total inland fish production as recorded by FRSS (1986), the unit production rates of about 900 kg/ha indicated by the present study, approximate those of the national average for ponds (843 kg/ha/year). These rates are very lower compared to a potential of 3,300 kg/ha/year for well fertilized ponds stocked with carp. In Bangladesh, well fertilized ponds that are stocked with carp in appropriate proportions have the potential to produce as much as 4,000 kg/ha/year.

The reasons for the low productivity may be attributed to:

- Most of the ponds were not designed for fish culture. They were dug to provide fill for homesteads or for other domestic purposes;

- Almost all the ponds are rainfed or they are filled by opening the pond dike to allow water in, thus paving the way for wild stocking with no control over predators or species stocked;

- Current pond culture practices in the study area are almost entirely based on extensive low input/low yield techniques due to its proneness to flooding and consequent loss of fish stock;

- There is minimal preparation or supervision of the ponds, little attempt at fertilization or supplementary feeding or any form of management;

- Non-availability of quality fish seed/fingerlings of the desired species in time;

- Multiple ownership and multiple use of ponds;

- Financial constraints including credit facilities;

- Limited technical knowledge and insufficient extension activities;

- Risk factors such as flooding, drought, fish diseases; and

- Marketing problems (lack of transport and storage facilities, accessibility etc.) and poisoning.

3.2.1 Input Costs and Net Production Value (NPV)

As stated above, no fertilization and feeding are done in the ponds which are even fully diked and are used as household ponds, scattered close to the human settlements. So little investment is usually made in this kind of extensive fish culture. Even then, pond culture proves to be sufficiently profitable. In the present pre-project situation, the net benefit does not seem to be enormous though, when compared to the investment made.

The Net Production Value (NPV) of pond culture practised in the project area is shown in Table IX.3.4. Fish are cultured in ponds covering a total area of 180 ha and the total annual production from this pond culture is estimated at 167 MT that has been valued at a Gross Production Value (GPV) of Tk. 50,10,000.00 i.e. Tk. 5.01 million. The total input cost for this fish culture amounts to Tk. 21,16,000.00 i.e. Tk. 2.12 million. The NPV of pond culture is thus estimated to be around Tk. 16,000/ha consisting of a gross production value of Tk. 27,800/ha and a total input cost of Tk. 11,800/ha.

3.3 Capture Fisheries: Present Status

The open water capture fisheries in the project area comprise the three major rivers-the Dharla, the Teesta and the Brahmaputra plus a network of lesser rivers and tributaries, canals, natural depressions, seasonal floodplains etc. in which fisherhmen use boats and nets to harvest the naturally occurring self-producing and self-sustaining wild fish resources.

The phase-I survey showed the capture fisheries resources totalling overall a water area of about 2,000 ha, the rivers covering 1,740 ha (87%) and the other components (canals, beels and flooded lands combined together) comprising 256 ha (only 13%) of the project area (Table IX.3.5). These data indicate proportions of the Thanawise data provided by the FRSS Survey Officers working in the districts of Kurigram and Lalmonirhat within the project area. Catch statistics relating to the capture fisheries of rivers, beels and floodplains for the period 1983 to 1989 have been published for each one of the former administrative districts. As part of the FRSS, SPARRSO was commissioned to collect data on water bodies using satellite imagery, aerial photographs and ground truth surveys and to estimate the total area of water bodies usable for fish production.

According to the fish catch statistic as recorded during the Phase-I survey, fish catch from the proportionate open water capture fisheries of the project area is roughly estimated at only 397 Mt which represents over 70% contribution of the capture fisheries to the total inland fish catch from the project area (Table IX.3.5). The capture fisheries cover an estimated total area of 1996 ha surface water out of a total surface water area of 2,176 ha including only the 180 ha culture fisheries within the project boundary, and thus the open water capture fisheries occupies about 92% of the total fisheries area leaving only 8% for the pond fisheries. Of the total annual catch of 397 Mt from the capture fisheries, the rivers contribute 375 Mt i.e. 94% while the three other components combined only 6%. The average unit catch from the capture fisheries of the present project area appears to be 199 kg/ha while the same from the rivers comes to 216 kg/ha, from the other components combined together 84 kg/ha (Table IX.3.5). Fish catch statistics of Bangladesh, as recorded by FRSS (1986) indicate 75% contribution of capture fisheries and 25% contribution of culture fisheries to the total inland fish production in 1985/86. The data obtained in the project area are thus more or less in agreement with those of the nation. The average unit catch data from the rivers (216 kg/ha) approximate those of the country in that the country's unit area yield of rivers has been recorded as 209/kg/ha by FRSS (1986).

The fish species of the capture fisheries can be divided into two groups-river fish and beel fish from the view point of reproductive behaviour. River fish such as the major carp (Katla, Rui, Mrigal etc.) spawn upstream in the major rivers at the beginning of the rainy season. The eggs, larvae, fingerlings and some adults of these species flow with the water current, finally entering the floodplains of the project area at the end of June. The inundated floodplains provide the aforesaid fish species all the nutrients needed for growth. The carps migrate passively back to the main rivers as soon as the water recedes from the floodplains.

Beel fish such as snakeheads (Taki, shol etc.), catfish (Shingh, Magur etc.), Climbing perch (Koi) etc. can survive the harsh environmental conditions of the floodplain during the dry season. This group reproduces in the pre-monsoon as soon as the water level in the beel rises. First nursing occurs in the inundated areas adjacent to the beel; later on they disperse all over the floodplain, once the river flood water enters. With the receding waters, this group migrates back or gets trapped in the low lying beels and pagards. The field survey undertaken in January 1992 indicated that the beel fish were major contributors to the daily fish consumption during the dry season.

During the Phase-II field survey undertaken in August 1992, decline in capture fisheries production of both groups, during the last decade became apparent. For carps, the reasons seem to be blockage of migration routes, reduction of habitat by FCD, increased fishing intensity and probably massive capture of fry for aquaculture purpose. For beel fish, one of the important causes is the disease known as Epizootic Ulcerative Syndrome (EUS) which spread over Bangladesh in 1988 and severely infected the beel fishes.

3.3.1 Problems Affecting Capture Fisheries.

The general constraints that hinder the maintenance and development of capture fisheries are loss of habitats interference with migrations for feeding, breeding etc., disappearance of or reduction in the open access subsistence fisheries etc. etc. caused by FCD/I activities. The details of the fishery impacts of FCD/I projects will be dealt with in a subsequent section.

The other constraints to the development of capture fisheries as identified during the Phase-II field work are the following :-

- Heavy fishing pressure/overfishing;
- Silting up of rivers and beels;

- Reduction in the area of seasonal and perennial fishing grounds;
- Increased use of agro-chemicals (chemicals, fertilizer and pesticides and consequent pollution);
- Lack of effective fisheries management (lack of enforcement of fisheries regulations, resulting in harmful and illegal fishing methods, non-establishment of the New Fisheries, Management Policy for public water bodies/Jalmahals, (leases given to non-fishermen);
- Lack of information essential for fisheries planning purposes including the formulation of development and management policies;
- Absence of minimal inter agency coordination for integrated water use and planning;
- Absence of any environmental monitoring programmes;
- Lack of a broader understanding of fish resources in terms of fish biology, behaviour and population dynamics particularly of the commercially important fish/shrimp species including of course, the miscellaneous floodplain species.
- Reduced dry season river flows which harm fish stocks not only by reduction in the area of available riverine habitats but also by increasing their susceptibility to capture;
- Lack of capital and credit facilities for the fishermen;
- Lack of ice and storage facilities;
- Middlemen problems

3.4 Impacts of FCD/FCDI on Inland Fisheries

The two main areas of fisheries impact relate to pond culture which is often facilitated by the FCD/I project, and capture fisheries which are often devastated. The former impact tends to benefit a small group of privileged individuals while the latter impact affects large number of poor and landless fishermen. The main impacts of a total of 17 completed flood control, drainage and irrigation (FCD/I) projects in Bangladesh have been evaluated by the Flood Action Plan (FAP) 12 study (1991). Five of these 17 evaluations have been made on application of Project Impact Evaluation (PIE) methods using formal questionnaire approach and probability sampling. The Rapid Rural Appraisal (RRA) techniques used for the remainder was also used for preliminary reconnaissance of the 5 PIE projects. The project Kurigram South was one of these 5 projects that was selected as an example of FCD Embankment system along three main rivers-the Dharla, the Brahmaputra and the Teesta. The 5 PIEs took place during the peak and second half of the monsoon from June to October which is also the peak time for subsistence floodplain fishing. It was, therefore, useful to see conditions during the flood season despite the added difficulty in travelling to contact the fishermen and the pond owners. In the present study also, the Phase-II field work was undertaken during the second half of the monsoon in August 1992, and the same PIE method was followed for fisheries impact assessment.

3.4.1 Impacts on the Capture Fisheries and the Fishing Community

The Kurigram Flood Control and Irrigation Project (Kurigram South) set out as an ambitious project including a barrage and pumping plant, drainage and irrigation components which were not completed as planned. As stated earlier, the irrigation component was not implemented.

The PIE coverage of FAP#12 study included interviews with 21 fishermen out of an estimated total of 1,500 in the impacted area and with 15 of an estimated total of 1,000 fishermen in the control area of the Kurigram South project. The average number of fishing days per fisherman per year both in the peak and the lean periods was more or less the same during the study period and before. But the number of these fishing days was, to some extent, lower during the study period than before (113 against 120 during the peak period and 130 against 144 during the lean period) in the impacted area. The average catch data per fisherman in the impacted project area as obtained by the PIE enumerates was found to be lesser during the study period than before (2.3 kg against 4.7). The overall conclusion was a negative impact on capture fish stocks and consequently on catch rates in the capture fisheries with the result that large numbers of full time professional fishermen were forced out of business. The RRA finding in this regard was that the capture fishery landings had fallen by upto 75% in all the FULL FCD project area.

The Phase-II field work included interviews with a total respondents of 160 fishermen-120 sampled out of an estimated total of 2,548 fishermen from 12 villages in the FCD/I impacted area and 40 sampled out of an estimated total of 387 fishermen from 4 villages in the non FCD/I control area (Tables IX.3.6 and IX.3.7). The FCD/I sample of 120 respondents included 60 full time, 24 part time and 36 subsistence fishermen while the non-FCD/I sample of 40 respondents included 20 full time, 8 part time and 12 subsistence fishermen. The FCD/I impacts on the open water capture fisheries and on the fishing community have been summarised in Tables IX.3.8 and IX.3.9. The results of the questionnaire survey as obtained for both the FCD/I and Non-FCD/I areas in Kurigram, Ulipur and Lalmonirhat show adverse effects in the impacted project area than in the control area from the view point of the fish catches and the per capita income of the fishermen (Table IX.3.8). The total annual catch seems to have declined by as much as 82% in Ulipur with the minimum loss of 10% in Kurigram. The yearly average catch of a fishermen seems to have fallen by about 25 to 32% and the per capita annual income by about 10 to 33%. The daily average income of these poor fishermen hardly exceeds Tk. 14.00 as indicated here in the Table IX.3.8. The Table IX.3.9 data indicate a daily average income ranging from Tk. 12.4 to Tk. 22.0.

Table IX.3.9 depicts further the effects of FCD/I, interventions on the fishing community when their last week's, last month's and last year's income are compared. Comparatively lower average incomes in FCD/I areas for all three periods become apparent; but when the losses are computed to percentage, little difference is observed, the income losses ranging from only 4 to 10%. Nevertheless, the percentage loss in values of catch ranging from 10 to 77.5%, as indicated by Table IX.3.8, cannot be considered negligible.

The reasons for capture fishery losses may be attributed to the following :-

- Loss of formerly flooded habitats for major capture fishery species;

- Changes in hydrological regimes of remaining habitats

- Increased surface water extraction from existing habitats (Perennial beels, floodplains);

- Inhibition of breeding of species conditioned to breed and feed in floodplains and consequent loss of natural stock replishment;

- Limitation of nursing areas for the species having a riverine or estuarine breeding behaviour;

- Replacement of robust natural fisheries with more sensitive and expensive aquaculture;

- Blockage of fish migratory paths between beels and rivers thereby altering and diminishing the fish stock and species composition;

- Conversion of lotic (flowing) habitat into lentic (standing) habitat by embankment construction;

- Reduction in fisheries resource diversity and resilience;

- reclamation and utilization of perennial/low lying water bodies to create land for rice crop or for urbanization.

3.4.2 Impacts on Culture Fisheries

On culture fisheries in closed water bodies such as ponds and tanks, there is a potentially positive impact by effective flood control whereby protection against over flooding encourages regular restocking and improved culture methods, and where necessary, pond rehabilitation. However, from the many FCD/I schemes that have been established in Bangladesh, there is little evidence to suggest that the potential for increased aquaculture production has been realized in flood protected areas. The Chandpur Irrigation Project (CIP) is often quoted as an example of the benefits of increased aquaculture development following FCD/I. But this project is not a typical one, as there was a massive investment within the CIP involving the construction of the Rangpur Fish Hatchery which encouraged the expansion of pond aquaculture. The expected benefits did not occur in parts of the present project area because of the negative impact of rainwater flooding caused by inadequate drainage provision or because of frequent embankment breaches plus other factors of availability of good quality fish fry, fish food etc. etc mentioned earlier.

The impact of FCD/FCDI on pond culture fishery is negative unless a supplemental stocking program through increased hatchery production of fish seed is ensured as in the case the CIP Increasing withdrawals of ground water for irrigation will continue to lower the water table accelerating seepage of pond water. This could decrease the water levels to below the required minimum of one meter as required for fish production or would eliminate pond areas during the dry season.

3.5 Fisheries Development Activities

Fisheries development in the project area is supported by the Government (DOF) as well as by the Non-Government Organizations (NGOs).

3.5.1 Government Support

As stated earlier the project area includes two districts- Kurigram and Lalmonirhat. Each of the District Fisheries officers is supported by a District Extension Officer and a District Resource Survey Officer. In each Thana, the TFO (Thana fishery Officer) is assisted by an Assistant Fisheries Officer (AFO) and a Field Assistant. Of the 5 Thanas in the project area, Ulipur and Rajarhat, were found to be inadequately staffed, with some of the positions lying vacant.

Fisheries management, development and administration is primarily the responsibility of the Ministry of Fisheries & Livestock (MOFL) which operates through the Department of Fisheries (DOF), the Bangladesh Fisheries Development Corporation (BFDC) and the Fisheries Research Institute (FRI). The primary role of the DOF in the project area has been to support aquaculture through demonstration of ponds, supply of fish seed from the DOF hatcheries, nurseries and fish seed multiplication farms, extension of technical knowledge and technical know how and other supplies and services. Recently, inter-agency agreements have been developed for the DOF to implement the fisheries management policy in selected waters owned by the Bangladesh Water Development Board (BWDB). The objective is to improve the long term sustainability of open water capture fisheries through the introduction of a more effective management system which is designed to serve the interests of fishermen rather than entrepreneurs and lease holders.

Currently, the DOF has been implementing in the project area some of the important fisheries development activities, namely the Second Aquaculture Development Project, the Third Fisheries Project and the Project on Establishment of 13 Fish Seed Multiplication Farms including one at Kurigram. For the kind and the magnitude of fisheries development activities in the project areas, as elsewhere in Bangladesh, the DOF staff as provided for the five Thanas is indeed too inadequate. Each of the two District Fisheries Officers (DOFs) is supported by a Resource Survey officer and only with the recent implementation of the Third Fisheries Project, an Extension Officer. In each of the constituent Thanas, the TFU (Thana Fisheries Officer) is assisted by only an assistant Fisheries Officer and a Field Assistant. To add further, some of the positions in two of the five such Thanas were found lying vacant since long.
The BFDC is an autonomous organization engaged in improving the fishing industry and has been involved in the project area only in the transport and marketing of fish and the amount of fish transported and marketed is about 10 to 12 % as ascertained by interviewing the fish traders in the market. The FRI does not play any role presently in the project area but it can undertake some research projects on many different aspects of aquaculture and fisheries management. Other Government Organizations also participate in varying degrees in fisheries development activities in the project area. The Bangladesh Bank is the central agency for channelling institutional credit through the nationalised banks. the Bangladesh Agricultural Research Council (BARC) is responsible for coordinating any fisheries research work including the disease EUS carried out in the project area. The Ministry of Irrigation Water Development and Flood Control (MIWDFC) through its agency BWDB has already undertaken many small and large scale FCD/I projects most of which adversely affected fish populations and have altered long established aquatic ecosystems. The Ministry of Land (MOL) still controls many public water bodies including rivers and beels. The MOL has since been gradually transferring the management of a number of such Jalmahals to DOF under the New Fisheries Management Policy (NFMP).

3.5.2 Non Government Organizations (NGOs)

Of the many NGOs which operate in Bangladesh, quite a few contribute to the fisheries development in the project area. Many of them offer support to groups of poor for the development of small scale aquaculture through the provision of credit facilities together with extension services and training. The Grameen Bank has taken up the responsibility of running the Fish Seed Multiplication Farm (FSMF) of the DOF at Lalmonirhat since 1988. Ii consists of 10 ponds, 2 of which are used as nurseries, 4 for reaming and 4 for stocking of fish. It has the capacity to supply 1.5 to 2.0 million fish seed. There is also a small hatchery within the FSMF premises and it has fixed its next year's production target at 20 kg of fish spawn. The Rural Employment Sector Programme (RESP) II at Kurigram implemented by the Local Government Engineering Department (LGED) and Bangladesh Rural Development Board (BRDB) aims at improving the socio-economic status of the target group, especially the landless through three projects namely Institutional Support Project (ISP), Infrastructure Development Project (IDP) and Productive Employment Project (PEP). The fish culture activity report of the PEP for the period from 1987 to 1991 showed a spectacular benefit to 1,310 members belonging to 57 groups through a lease of 690 areas of water body (beels).

Rangpur and Dinajpur Rural Service (RDRS) is another NGO that has initiated in the project area fisheries activities early 1990. In has so far reclaimed 26 nos. of water bodies and has planned to reclaim in 1992 another 15 water bodies ranging in size from 40 to 100 decimal in Kurigram District. Both RDRS and PEP operate under the umbrella of the BRDB. Typical projects include assisting small groups of displaced fishermen to restore and operate formerly derelict fish ponds on long term leases, assisting other groups to operate Jalmahals by setting up their management systems and negotiating credit. BRDB is responsible for forming and supporting cooperatives of fishermen and fish farmers in the project area.

In fish harvesting operations, another NGO PROSHIKA has been planning to organize fishermen groups and provide support to them in procuring fishing gears and other fishing implements. Also the Bangladesh Rural Advancement Committee (BRAC) with its regional office at Rangpur and having been already staffed with a Fisheries Specialist has been planning to extend its activities to aquaculture development in the project area CARE (Cooperative for American Relief Everywhere) that has been working in Bangladesh since 1955 with the Government and Local Agencies on income generating and health improvement programmes comprises 6 projects of which, one is IFFW (Integrated Food For Work). Under this project, CARE is funding construction of a tank at Mouza-Thana village which is about 1/3 km away from the Chilmari Thana.

3.6 Summary and Conclusions on Fishery Impacts

The basic strategies for FCD/I development in the Kurigram South Unit include :

i) Flood Control works concentrating on heightening and re-shaping of 108 km embankment as well as bank protection at the intake site,

ii) Drainage improvement through desilting of the existing creeks, beels and khals, channel diversion of the Ratnai river and reconstruction of the existing regulators at Ratnai and Horichari

iii) Irrigation development by construction of canal headworks and main irrigations canal system.

The changes losses brought about by the existing FCD/I intervention on the capture fisheries and the fishering community have been outlined in subsection 3.4.1 and those on the culture fisheries in subsection 3.4.2.

The negative impacts on both the capture fisheries and the fishermen community appear to be moderate in the study area as indicated by the results of the questionnaire survey. These data did not show a severe decline in annual fish catches and even in the per capita annual income of the fishing community. Of course, the former fishing grounds in the beels were being destroyed by FCD embankments, blocking fish migration routes and in some cases by the atmost total drainage of the beel areas. FCD is unquestionably implicated in the decline in fish stocks because of the physical barriers to migrations, spawning, floodplain recruitment and reduction in areas of beels and other water bodies. Many water bodies which could hold water through the year and thus support breeding populations of resident fish species are drained or pumped dry to create land for another rice crop or for irrigation water instead of being managed for fish production on a sustainable basis.

FCD projects primarily have a negative impact on capture fisheries, though this may sometimes be offset, in an overall sense, by the production gains in culture fisheries made possible by reduced flooding. Current approaches envision replacing losses to natural fisheries in the project area with pond culture. The ample scope for increasing culture in ponds and large closed water bodies will not make up for the losses to natural fisheries. From the many FCD/I schemes that have been established in the project area these is little evidence to suggest that the potential for increased aquaculture production has been realized in flood protected area. The FAP#12 study report that a considerable number of ponds are often flooded. Anyway, on culture fisheries in close do water bodies such as ponds/tanks, there is a potentially positive impact by effective flood control whereby protection against overflooding encourages regular restocking and improved culture methods and where necessary, pond rehabilitation. The pond culture production in the project area is somewhat encouraging in the sense that the annual unit production surpasses the national average and that the average total annual income was found to be Tk. 16,000/ha which was close to Tk. 19,700/ha per year , as obtained by Davis et al. (1983) from their studies on 17 semi-intensively managed ponds.

4. Recommendations on Inland Fisheries Development

In a country where fish is the major source of animal protein, prevention and mitigation of fishery losses and enhancement of fish production should be ensured. The Government of Bangladesh (GOB) has, therefore, raised its allocation to the fisheries sector to Tk. 7,490 million for the Fourth Five Year Plan from Tk.4,000 million earmakcd for the Third Five Year Plan. These plans generally pledge priorities to aquaculture, artificial seed production, development of closed water fisheries, open water capture fisheries, marketing facilities as well as training, research and extension activities.

Since the implications of the KFCIP are towards the decline of the traditional open water fisheries in the project area presently contributing over 70% to the total inland fish catch from the project area, the present section will propose methods to increase production through aquaculture and refer to techniques for ensuring the continued productivity from capture fisheries of the project area.

4.1 Aquaculture

Flood control and drainage development offers scope for developing culture fisheries in ponds and stocking beels and flood plains to minimise the loss of fish production in these waters. FAP #12 studies indicated positive benefits to fish farming in most of the projects studied. The potential for farmed fish production is considerable and it is economically competitive will other land uses.

4.1.1 Pond culture.

The contribution of pond culture (as much as 30% to the total inland fish production) as against the national average 21% in the project area indicates that further development is possible and urgently needed. It has been noted that traditional extensive fish culture is being practised in the project are and 36% of the total number of ponds has been lying derelict. Thus there is scope for developing improved semi intensive and intensive culture systems in ponds of the project area to increase the proportion of productive ponds.

Flood embankments would also increase the scope for developing pond fisheries by minimizing the possibility of inundation of ponds and encouraging many of the pond owners to start fish farming. But this pond culture development is constrained by a general lack of low cost credit to finance pond construction on rehabilitation, lack of good quality fish seeds, fish feed and by inadequate technical Know how in several areas. The application of modern technology gearing up the fisheries extension services to revolutionalize this pond culture is, therefore, very urgently needed. Table IX.4.1 illustrates this application and shows that the loss to be sustained from open water capture fisheries due to FCD/I may well be compensated by pond culture. It is also heartening to note that DOF's project on Institutional Strengthening has already started gearing up its extension activities in the project area.

4.1.2 Paddy-cum-Fish Culture

Fish culture in Paddy fields has not gained popularity in Bangladesh; but the increased use of land for paddy cultivation makes this a potentially attractive proposition. It is an ideal method of land use. Now a days, millions of hectares of paddy fields are stocked with fish in different countries of the world. The paddy fields many be used for breeding, raising fry or fingerlings and also for raising fish to marketable size. If offers scope for the production not only of indigenous carps but also numerous other flood plain species and also for the production of carp fingerlings for pond stocking. The potential for deep water aman rice/fish forming in the North Central Region is now being investigated by BRRI. The practice of fry/fingerlings production in the paddy fields of the project area would help aquaculture saving **sealuable** on-growing areas.

Fish culture in paddy fields is of course not a new practice in Bangladesh. However, with the impact on the ecology in rice fields of new technology e.g. introduction of HYV rice varieties, increasing use of pesticides and fertilizer, flood control drainage and irrigation, there is a need to look a fresh at scope for fish culture in boro rice fields. The experience of CARE in Rangpur is relevant in this respect.

4.1.3 Pen and Cage Culture

Pen and cage culture although widely used throughout the world on both semi intensive and intensive levels is not yet an established practice in Bangladesh. Some success at stocking densities of upto 100 kg/m^3 has been achieved, although the results are not encouraging. The carp species, Labeo rohita (rohu fish) has proved to be the most promising one. Areas such as narrow rivers or khals, shallow rivers, irrigation canals and roadside canals can all be used for such purpose.

The economics of pen and cage culture depend upon the level of intensity envisaged. Whilst semi-intensive pen culture with little on no supplementary feeding is possible, cage farming depends on artificial feeding only, which incur much higher working costs but produces a considerably higher yield.

4.1.4 Fish Culture in Borrow Pits/Retarding Ponds

The project borrow pits are under utilized resource. These borrow pits may be used as nurseries for major carps and also for fish culture. The use of these borrow pits should be regulated by the project authority and those who gain from fish cultivation, for example, in the borrow pits could then bear some responsibility for operation & maintenance of the project.

4.1.5 Integrated Farming (Duck cum Fish Farming)

In addition to the aquaculture technologies discussed, another such technology that of integrated farming using fish ducks or chickens similar to rice/fish farming seems to be appropriate for the small scale farmers of the project are in a country like owner ours land is expensive and scarce for efficient utilization of the meagre resources and maximisation of production of diversified products from a minimum area. Work carried out in 9 ponds of 0.1 ha each on integrated duck cum fish farming by the Fisheries Research Institute, Mymensingh yielded promising results. The growth of different species of fish in integrated ponds was much higher as compared to the control ponds where ducks were not kept. The duck started laying eggs when they were 20 weeks old.

As we know the average carp culture production of 1,160 kg/ha/year has been recorded in a pond culture survey by FRSS in 1986 and other recent records show an yield of 1357 Kg/ha/year from ponds under traditional extensive methods. But it has been shown that recycling of poultry waste in fish ponds could give a fish production of as much as 4000 to 6000 kg per hectare per year without providing any supplementary feed to fish. In duck-fish-crop farming, the feed given to ducks produces not only duck meat or eggs; but also the undigested portion of the feed in their feces recycled in fish ponds, produces additional protein in the form of fish. At the same time, the pond embankment could be profitably used for cultivation of vegetables, cereals, fruits etc. thus giving diversified income base to the farmer. As observed by Jhingran and Sharma (1978), duck-cum- fish culture experiments conducted in India with 100 ducks per hectare, a fish yield of 4523 kg/ha year was obtained without the use of any supplementary feed to fish or fertilization of ponds with inorganic fertilizers. Wohlfarth (1978) reported a daily yield of 32 kg/ha (7600 kg/ha/240 days) of fish in ponds receiving only duck droppings. In Vietnam, raising 1000 to 2000 ducks/ha on ponds, increased the average fish yield to as much as 5000 kg/ha/year compared to 1,000 kg/ha/year without ducks, as found out by Delinando (1980).

In the FRI experimental ponds also, except for the excreta of ducks falling into the ponds directly from the duck houses, the fish were neither given any supplementary feed nor the ponds fertilized.

4.2 Fish Seed Supply

Central to the problems of raising yield per unit area is the supply of adequate fingerlings for use by the fish culturists. Currently, constraints to adequate seed supply lie in several areas :

- unquanlified suitable brood stock and hatchery facilities
- lack of nursery facilities
- lack of technical man power and extension services.
- If recommendations for increasing yield per unit area are followed, then the requirements for fry will dramatically increase.

4.3 Capture fisheries

The GOB Strategies for formulation and execution of policies for inland fisheries development would include:-

- biological management of fisheries;
- prevention of over fishing;
- artificial stocking;
- enforcement of fish and fish habitat conservation practises;
- development of selected preserved fish sanctuaries;
- development of appropriate low lying areas into permanent water bodies for fish cultivation;
- improvement of freshwater aquaculture in open water system;
- adequate **stem** of hatchling production and nursery rearing of fingerlings of suitable species;
- support for pen and other culture techniques in seasonal and perennial water bodies, etc.

The inland openwater fisheries of the project area should be developed through effective management and conservation measures of river the fisheries and flood plains. Massive artificial stocking of open water such as rivers, flood plains, beels etc. with fingerling should be done, and biological management and fish habitat conservation practices should be strictly observed. The Third Fisheries Project (TFP) of the DOF already in operation has been attempting to accelerate fish production in openwaters by releasing fingerlings of commercial importance.

4.3.1 Institutional Coordination

It is clear that the two principal causes of the capture fisheries decline namely FCD and illegal over fishing, both have the potential to do even more damage in future unless appropriate action is taken. Institutional coordination is essential for overcoming the negative effects of water control projects on fisheries. The GOB has already (August 1988) established a high level coordinating committee with the Minister, Planning as the Chairman, Member (Agriculture) and Member (Planning) of the Planning Commission and Secretariate of 7 Concerned Ministries as members with the Secretary MOFL as the member Secretary. Also a Memorandum of understanding (MOU) for fisheries development in the FCD/I areas has ultimately been signed by the Chairman, BWDB and the Director (DOF) on 14 February 1991.

The DOF and the MOFL should give urgent consideration to strengthening the fisheries inspectorate for enforcing the existing protective legislation with the aim of stopping the present wide spread and blatant use of illegal fishing methods with active cooperation of the law enforcing agencies. The MOFL and the Ministry of Environment & Forest should develop and implement a coordination programme for control of water pollution in relation to fisheries resources.

4.3.2 Biological Management and Conservation

Consideration should be given to the need to reduce fishing effort commensurate with the present low state of the fish stocks. Restrictive licensing, close seasons, further restrictions on fishing gear and net mesh sizes and the imposition of the stricter control on the collection of wild spawn and fry from the rivers should be strictly followed.

The New Fisheries management Policy (NFMP) has been formulated to achieves diversion of maximum benefits from fishery resources to the fishermen actually toiling in the fishing grounds as well as to ensure sustainability of the living aquatic resources. The public water bodies should, therefore, be leased only to the bonafide fishermen to ensure the Maximum sustainable yield (MDY)

4.3.3 Prevention and Mitigation of Fishery Losses

The loss of fish production in open waters due to FCD/I interventions (loss of nursery grounds or migration pathways) can be mitigated through artificial stocking of fingerlings. The DOF has a total of over 100 Fish Seed Multiplication Farms (FSMF). These include about 50 mini hatchery facilities. The project area, as already stated, has two of the FSMF, one of which, includes a hatchery. These with the increased availability of fry from private institutions will go a long way in meeting the local demand. The hatchlings alter hatching in the hatcheries available must be nursed in nurseries. For such nursery facilities, a number of strategies can be adopted. Some of these strategies, namely use of paddy fields use of cages have already been discussed others are :-

- nursery area built next to hatchery
- nursery area built into seasonal beel
- use of nursery areas by individual farmers a or cooperatives.
- Measures for prevention and mitigation of fishery losses can take the following forms (MPO, 1987) :-
- Trade off, in favour of fisheries production. For example, allocation of land for controlled flooding for fish production;

- Mitigation measures incorporated into the design of a water resources development project. For example, design water regulation structures to allow fish migration using fish migration habits and swimming ability as hydraulic design criteria;

- Mitigation measures incorporated into the operation of the project. For example, opening regulators and water control structures to allow fish to migrate into desired areas at the desired time.

- Mitigation through efforts external to the project. For example, construction of fish hatcheries, stocking of fingerlings creation and management of static water bodies.

Finally, the impact on the inland capture fisheries adversely affect large number of full time fishermen mostly landless, so the project should include specific mitigatory provisions to assist the affected fishing communities.

Table IX-1 Area of Each Constitent Upazila within the Project Boundary

Upazila	Total Area of the Upazila (ha)	Area within the Project (ha)	% Total Upazila Area within the project	Percentage of the Total Project Area
Chilmari	22,497	4,400	19.5	7.3
Kurigram	27,182	8,000	29.0	13.2
Rajarhat	19,359	15,200	78.5	25.2
Ulipur	45,849	20,500	45.0	33.9
Lalmonirhat	23,218	12,300	53.0	20.4
Total	138,105	60,400	-	100.0

Source: Small Area Atlas of Bangladesh:Rangpur District, and also JICA (December 1991) Inception Report:Feasibility Study on the Kurigram Irrigation and Flood Control Project-South Unit.

Table IX-2 Present State of Fish Demand and Fish Production in the Constituent Upazilas in the Project Area (The Figures in parentheses indicate the proportionate population and fish production)

Upazila	% Area of the Constituent Upazila	Population of Constituent Upazila	Annual Fish Demand in the PA	Annual Fish Production (MT)	Percentage contribution	Existing state: Deficit (-) Surplus (+)
Chilmari	19.5	89,102 (17,375)	182	551 (107)	19.8	(-) 75
Kurigram	29.0	175,945 (51,024)	536	342 (99)	17.4	(-) 437
Rajarhat	78.5	132,622 (104,108)	1,093	161 (126)	22.5	(-) 967
Ulipur	45.0	272,089 (122,440)	1,286	300 (135)	23.6	(-)1,151
Lalmonirhat	53.0	192,532 (102,042)	1,071	180 (95)	16.7	(-) 976
Total	-	862,290 (396,989)	4,168	1,534 (562)	100	(-)3,606

Note: Population data are taken from BBS (1985):Upazila statistics Vol.1, and the fish production data from the Upazila Fishery Officers of the Department of Fisheries (GOB) during field survey (Jan. 1992).
Fish demand calculations are based on the World average fish consumption level of 28.8 g/person/day ie. 10.5 kg/capita/year.

Table IX-3 Upazilawise Number and Area of Ponds Showing their Present Cultural Status 1/

Upazila	Upazila area (ha)	Number of ponds Cultured	Number of ponds Derelict	Number of ponds Total	Area of ponds (ha) Cultured	Area of ponds (ha) Derelict	Area of ponds (ha) Total	% of Upazila Area Covered by Ponds
Chilmari	22,497	200	50	250	27.0	6.5	33.5	0.1
	-	(39)	-	(49)	(05.3)	-	(6.5)	-
Kurigram	27,182	710	237	947	65.3	16.2	81.5	0.3
	-	(206)	-	(275)	(18.9)	-	(23.6)	-
Rajarhat	19,359	656	280	936	57.7	21.8	79.5	0.4
	-	(515)	-	(735)	(45.3)	-	(62.4)	-
Ulipur	45,849	1,098	894	1,992	96.4	49.6	146.0	0.3
	-	(494)	-	(896)	(43.4)	-	(65.7)	-
Lalmonirhat	23,218	779	500	1,279	127.0	68.0	195.0	0.8
	-	(413)	-	(678)	(67)	-	(103.4)	-
Total	38,105	3,443	961	5,404	373.4	162.1	535.5	-
	-	(1,667)	-	(2,633)	(179.9)	-	(261.6)	-
Average Size	-	-	-	-	0.10	0.08	0.09	
Percentage	-	64	36	100	70	30	100	0.4

Source : Qestionnaire Survey (January 1992)

Note: 1/ Figures in brackets indicate proportion of Upazila total within the project boundary.

Table IX-4 Pond Fisheries Resources and their Contributions to Fish Production in the Constituent Upazilas of the Project Area 2/

Upazila	Total area of Ponds Cultured (ha)	Proportionate Area of Such Ponds (ha)	Annual Fish Production from Such Ponds (MT)	Annual Proportionate Production (MT)	Unit Production Upazila part in the Project Area (kg/ha)
Chilmari	27.0	5.3	17.0	3.3	623
Kurigram	65.3	18.9	59.8	17.4	915
Rajarhat	57.7	45.3	50.0	39.3	865
Ulipur	96.4	43.4	90.9	41.0	945
Lalmonirhat	127.0	67.0	124.0	66.0	981
Total	373.4	179.9	341.7	167	4,329
Average production (kg/ha)		-	915	928	866
% Upazila Fish Production 2/		-	22	29.7	-

Source: District and Upazila Fisheries Officers of the DOF and the Questionnaire Survey (January 1992).

Remark: 2/ Total estimated Annual Fish Production from all the Constituent Upazilas being 1,534 tonnes, and the total proportionate production from the project area being 562 tonnes (Table IX-2).

Table IX-5 Input Cost and Net Production Value (NPV) of Pond Culture Fisheries in the Project Area

Upazial	Total Area Cultured (ha)	Total Annual Production (MT)	Annual Gross Production Value (GPV) Tk.000	Annual Total Input Cost Tk.000	Net Production Value (NPV) Tk.000
Chilmari	05.3	03.3	99	66	33
Kurigram	19.0	17.4	522	190	332
Rajarhat	45.3	39.3	1,179	434	745
Ulipur	43.4	41.0	1,230	436	794
Lalmonirhat	67.0	66.0	1,980	990	990
Total	180	167	5,010	2,116	2,894
Per ha (Tk.)			27,800	11,800	16,000

Source: Questionnaire Survey (January 1992)

Table IX-6 Capture Fisheries Resources and their Contributions to Fish Catch in the Constituent Upazilas of the Project Area (Figures in parentheses indicate proportion of Upazial total)

Upazila	Rivers_(A)			Flood Plains, Beels, Canals (B)			
	Water Area (ha)	Annual Production (MT)	Unit Production Kg/ha	Water Area (ha)	Annual Production (MT)	Unit Production Kg/ha	Total Annual Catch from Capture Fisheries (MT)
Chilmari	2,550	530	208	37.4	4.0	107	534 (104)
19.5%	(497)	(103)	-	(7)	(0.8)		
Kurigram	1,225	269	220	156.1	13.0	83	282 (82)
29%	(355)	(78)	-	(45)	(3.8)		
Rajarhat	474	103	217	100.9	8.0	79	111 (87)
78.5%	(372)	(81)	-	(79)	(6.3)		
Ulipur	907	202	223	83.0	7.0	84	209 (94)
45%	(408)	(91)	-	(37)	(3.2)		
Lalmonirhat	204	42	206	166.3	14.0	84	56 (30)
53%	(108)	(22)	-	(88)	(7.4)		
Total	5,360	1,146	-	544	46	-	1192
	(1,740)	(375)	-	(256)	(21.5)	-	(397)
Average Catch	-	-	214	-	-	84.6	202
(Kg/ha)	-	-	(216)	-	-	(83.9)	(199)
% Upazila Production		74.7 (A)			3.0 (B)		77.7
		(66.7)			(3.8)		(70.6)

Source: District and Upazila fisheries Officers (DOF) of Kurigram and Lalmonirhat District plus the Questionnaire Survey (January 1992)

Note: Average Catch from the Capture Fisheries as a whole is based on the total estimated water area of the entire Study Area (on 5904 ha) and that in the Project area (1996 ha)

Table IX-7 Information on Sample Size of Villages and Different Types of Fishermen in FCDI and Non-FCDI Areas (the Figures in brackets indicate estimated number of Fishermen)

Thana	Sample Village (No.)			Sampled Size of Different Types of Fishermen									Total
				Full Time			Part Time			Subsistence			
	FCDI	Non-FCDI	Total	FCDI	Non-FCDI	Total	FCDI	Non-FCDI	Total	FCDI	Non-FCDI	Total	
Kurigram	3	1	4	15	5	20	6	2	8	9	3	12	40
Ulipur	2	1	3	10	5	15	4	2	6	6	3	9	30
Chilmari	1	-	1	5	-	5	2	-	2	3	-	3	10
Rajarhat	4	-	4	20	-	20	8	-	8	12	-	12	40
Lalmonirhat	2	2	4	10	10	20	4	4	8	6	6	12	40
Total	12	4	16	60	20	80	24	8	32	36	12	48	160
				(534)	(111)	(645)	(589)	(81)	(670)	(1,425)	(195)	(1,620)	(2,935)

Table IX-8 Fishermen Household's involvement in Fishing Activities by Thanas in FCDI and Non FCDI Areas

Particular Household No.	Kurigram			Ulipur			Chilmari			Rajarhat			Lalmonirhat			Total
	FCD	Non-FCD	Total	FCD	Non-FCD	Total	FCD	Non-FCD	Total	FCD	Non-FCD	Total	FCD	Non-FCD	Total	
Total Sample	30	10	40	20	10	30	10	-	10	40	-	40	20	20	40	160
Full Tiem	90	60	150	49	15	64	22	-	22	317	-	317	56	36	92	645
Part Time	36	50	86	41	10	51	18	-	18	488	-	488	6	21	27	670
Subsistence	85	40	125	70	15	85	20	-	20	750	-	750	500	140	640	1,620
Total	211	150	361	160	40	200	60	-	60	1,555	-	1,555	562	197	759	2,935

Table IX-9 Effects of FCD I options on Fishermen's Ageerage Annual Fish Catch and Per Capita Income

	Kurigram			Ulipur			Chilmari			Rajarhat			Lalmonirhat			Total
	FCD	Non-FCD	% change	FCD	Non-FCD	% change	FCD	Non-FCD	% change	FCD	Non-FCD	% change	FCD	Non-FCD	% change	
Total Fishermen	201	150	351	160	40	200	60	-	-	1555	-	-	5.62	207	759	2,935
Fishermen Percentage of Village Population	11.82	15	13.0	22.86	10	18.18	7.5	-	-	27.06	-	-	5.62	4.14	5.13	-
Total Annual Catch (MT)	41.6	46.5	10.5	6.2	34.7	82.1	10.7	-		374.87	-	-	65.4	137.5	52.4	717.47
Total Value (Tk. 000)	1107	1232	10.1	254	1127	77.5	315	-	-	4,482	-	-	1,943	4,482	56.6	14,942
Yearly Average	0.21	0.31	32.2	0.15	0.22	31.8	0.18	-	-	2.42	-	-	0.24	0.23	25.0	0.31
Per CapitaAnnual Income (Tk. 000)	5.51	8.2	32.9	6.3	7.04	10.5	5.2	-	-	29.0	-	-	15.9	18.9	14.5	14.0

Table IX-10 Comperative Income and Employment of the Earning Members in Fishermen Families of the Study Area

Particulars	Number of Fishermen									
	FCDI					NON-FCDI				
	Full Time	Part Time	Subsis-tence	Total	Av. Income	Full Time	Part Time	Subsis-tence	Total	Av. Income
Total Numbers of Male Family Members	127	42	68	237	-	59	21	30	110	-
Total Numbers of Earning Members	106	30	41	177	-	1	10	19	60	-
Last Weeks Income Tk.	17,894	4,865	2,773	25,532	144.2	7,438	939	894	9,271	154.5
Last Month's Income Tk.	43,112	18,396	8,492	70,000	395.5	21,004	3,364	2,116	26,484	441.4
Last Year's Income Tk.	6,02,557	1,43,456	59,105	8,05,118	4548.7	2,46,884	36,893	1,895	2,85,672	4761.2
Av. Months Employed	12	10.58	7.97	12	9.5	9.33				

Table IX-11 Source of Alternatie Income of the Different Types of Fishermen FCDI and the Non FCDI areas

Income Source	Number of Fishermen										
	FCDI				NON-FCDI				Percentage		
	Full Time	Part Time	Subsis-tence	Total	Full Time	Part Time	Subsis tence	Total	Grand Total	FCDI N=120	NON-FCDI N=40
Agriculture	-	5	20	25	-	3	6	9	34	20.8	22.5
Daily Wage	-	14	5	19	-	3	2	5	24	15.8	12.5
Fish Marketing	2	-	-	2	1	-	-	1	3	1.7	2.5
Fish Processing	-	-	-	-	-	-	-	-	-	-	-
Fish Trap Making	10	-	-	10	5	1	-	6	16	8.3	15.0
Poultry/Livestock Raising	-	-	-	-	-	-	-	-	-	-	-
Small Trade	-	5	8	13	-	1	4	5	18	10.8	12.5
Service		-	3	3	-	-	-	-	3	2.5	-
Total										60.0	65.0

Table IX-12 Fish-Farm Budget Analysis from 1 acrea Farm (Rased on Average of Actucl Farm Observation 1989-90) of a Carp Polyculture Fish Pond

	Present without Project /1			Future with Project		
	Quantity	Unit cost	Total	Quantity	Unit cost	Total
I POND PREPARATION /2	-	-	-			
- Dewatering	-	-	-	100 m/d	Tk30	3,000
- Rotenne Renovation	-	-	-	-	-	700
- Quick lime Application	-	-	-	100 kg	Tk5	500
- Dipteryx Application	-	-	-	2.5 kg	Tk350	900
- Miscellaneous including cleaning cost as necessary		-	-	50 m/d	Tk30	1,800
SUB-TOTAL COST	-	-	-	-	-	6,600
II INPUTS						
- Inorganic Fertilizer /3	-	-	-	200 kg	Tk5	1,000
- Cowdung/Compost /4	1000 kg	Tk1	1,000	3600 kg	Tk1	3,600
- Fish Fry Fingerling /5	2000 kg	Tk1	2,000	3000 kg	Tk1.5	4,500
- Feed /6	100 kg	Tk3	300	300 kg	Tk4	1,200
- Imergency Labour	-	-	-	m/d	Tk50	1,500
- Maintenance /7	-	-	-	12 m/m	Tk1200	14,400
- Nets	2 kg	Tk200	400	2 kg	Tk200	400
- Other for harvesting/marketing /8	Tk24,000	5%	1,200	Tk136,000	5%	6,800
- Extension /9	-	-	-	-	-	-
SUB-TOTAL COST	-	-	4,900	-	-	33,400
TOTAL INPUTS COSTS	-	-	4,900	-	-	40,000
III OUTPUTS						
- Production of Fish /10						
Indian Carp	480 kg	Tk50	24,000	1,680	Tk60	100,000
Exotic Carp	-	-	-	720	Tk50	36,000
Total Gross Income (Production Value)	-	-	24,000	-	-	136,800
IV NET BENEFIT /11	-	-	19,100	-	-	96,800

1. In the Without Project case, the pond culturist is assumed to fish without investing in improvment.
2. Investment cost on pond construction and other aquaculture facilities not taken into cnsideration risk to stocking, predators and other competiors of fish are to be eradicated. Application of rotenone and quick lime will help achieve this goal. Dipteryx will kill the harmful aquatic inserts and crustaceans and will also promote development of rotifers to serve as food for the fish fry/fingerlings.
3. Urea and TSP will be used & 80kg/acre each and murate of potash will be used & 40 kg.
4. Cowdung/Compost to be used & 1200 kg/bigha.
5. Fingerlings not smaller than 10cm will be liberated.
6. Feed ration will be calculated as follows : 30% rice bran, 30% oil cake and 40% fish meal or 50% rice bran + 50% oil cake.
7. A guard to be in maintained on salaries of Tk1200/month & Tk40/day.
8. This is calculated on the basis of 5% of total sale value.
9. Extension staff to be employed & 600-700/ha and the salary to be paid by DOF.
10. Silver carp and common carp are fast grown and omnivorous these would be included in the species composition (30:70).
    - Recovery of 60% and 80% for the present and future case respectiely has been assumed.
    - Weight of 400g for the present and 1000g for the future situations hae been based in calculations.
11. Net benefit will be much less if the investment costs on ponds nurseris etc. are considered but after spreading this costs over the extent of projet life, the pond culture projet becomes viable.

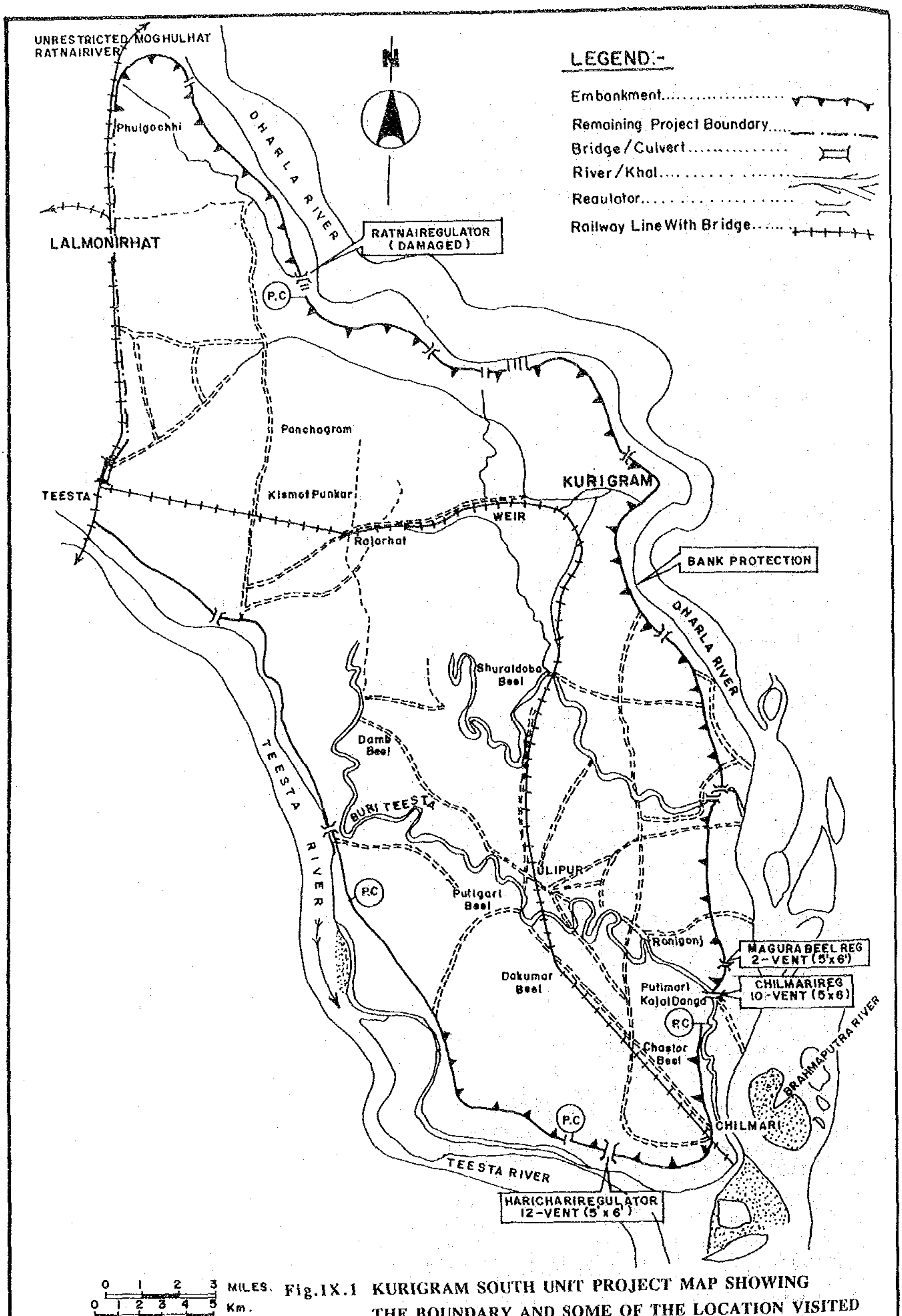

Fig.IX.1 KURIGRAM SOUTH UNIT PROJECT MAP SHOWING THE BOUNDARY AND SOME OF THE LOCATION VISITED

KURIGRAM SOUTH

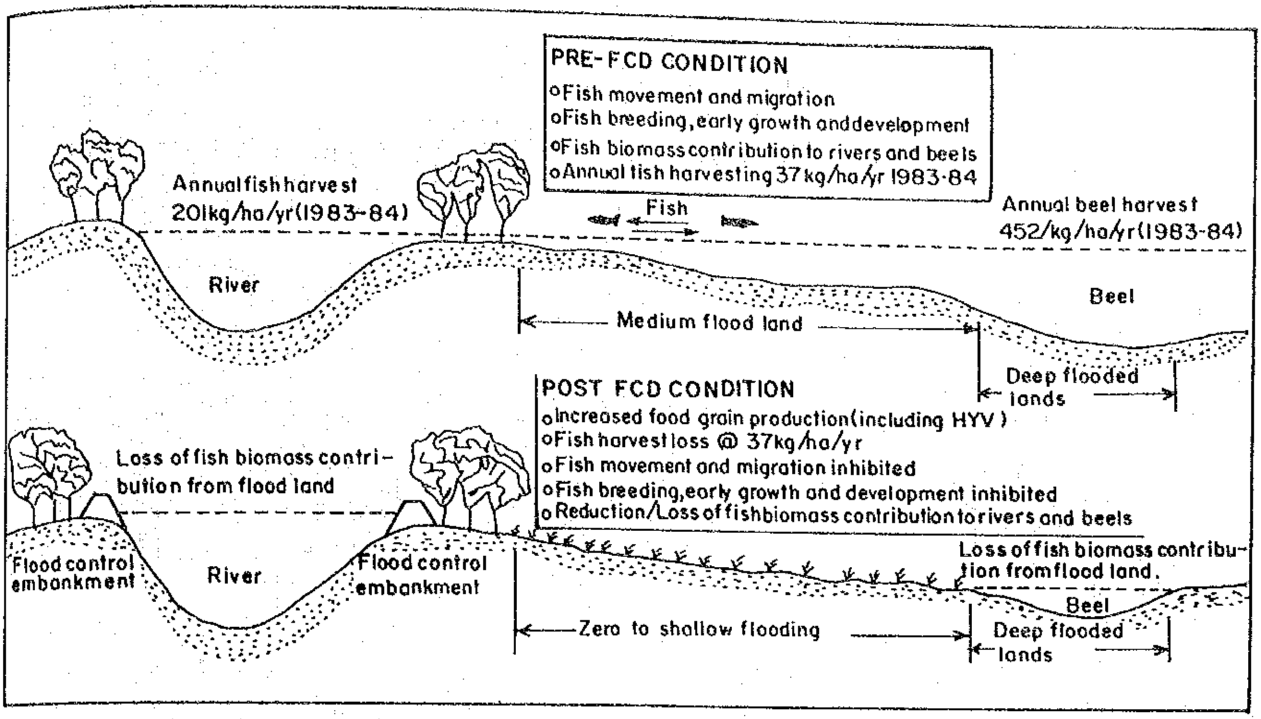

Fig.IX.2 ASCHEMATIC REPRESENTATION OF THE IMPACT OF FLOOD LAND REMOVAL ON FISHERIES THROUGH FLOOD CONTROL AND DRAINAGE PROJECTS IN BANGLADESH

A PRELIMINARY CHECK LIST OF THE FISH AND SHRIMP SPECIES FOUND IN THE STUDY AREA

(The 9 * asterish marked species are reported to be threatened)

A. FISH

	Taxon	Bengali Local Name		Kind of Habitat
I	ANABANTIDAE			
	1. Anabas testudineus	Koi,	-	Main Fresh Water Rivers also flood plains & beels
	2. Colisha Fasoiata	Khailsa, Khalisha	-	Main Fresh Water Rivers
II	BAGRIDAE			
*	3. Mystus aor	Aiir Aor, Guji	-	As above
	4. Mystus gulio	Nuna tengra, Gula tengra	-	Estuary Tidal Rivers
	5. Mystus tengara		-	Main freshwater rivers also flood plains
III	BELONIDAE			
	6. Xenentodon cancila	Kakila, Kaikka, Kakla	-	Flood Plains and Beels
IV	CENTROPOMIDAE			
	7. Chanda baculis	Phopho chanda	-	Main Fresh Water Rivers
	8. Chanda nama	Chanda	-	Main Fresh Water Rivers also flood plains a beel
	9. Chanda ranga	Lalchanda	-	As above
V	CHANNIDAE			
	10. Channa marulius	Gajal, Gojar	-	As above
*	11. Channa punotatus	Taki, lata	-	Main fresh water rivers also flood plains & beels
	12. Channa striatus	Shol, chena	-	As above
VI	CLARIDAE			
	13. Clarias batrachus	Magur, Jagur	-	Flood plains & Bells
VII	CLUPEIDAE			
	14. Corica soborna	Kanchki, subarna	-	Main fresh water rivers also flood planins & beels
*	15. Gadusia chapra	Kharica, chapila	-	As above
	16. Gonialosa manminna	Mookhchukka	-	As above
	17. Gilsa ilisha	Ilish, Ilisha	-	Estuary/tidal rivers, also main freshwater rivers
	18. Hilsa toli	Ilsh	-	As above
	19. Ilisha motius	Khor chona, pelna	-	Main fresh water rivers.
VIII	CYPRINIDAE			
	20. Amblypharyngodon microlepis	Mohula, Kagohi	-	As above also flood plains & beels
	21. Amblypharyngodon mola	Mola, Molongi	-	As above
	22. Catla catla	Catla, Katal	-	As above
	23. Cirrhina mrigala	Mirka, Mrigal	-	As above
	24. C. reba	Khorki bata raikhon	-	As above
	25. Danio devario	Banspati, chelbly	-	As above
	26. Labeo data	Bhangonobola, bata	-	As above
	27. Labeo calbasu	Kalbaus, Baus	-	As above
*	28. Labeo gonius	Gonia	-	As above
*	29. Labeo nandina	Nandil, Nandina	-	As above
	30. Labeo rohita	Rohu, Ruhit, Rui	-	Main fresh water rivers flood plains & beels

	Taxon	Bengali Local Name		Kind of Habitat
	31. Oxygaster bacaila	Chela, Katai	-	As above
	32. O. Phulo	Phul chela	-	As above
	33. Puntius sarana	Shorpunti, saral punti	-	As above also in ponds and canals
	34. P. sophore	Punti, Jati Punti	-	As above
	35. Rasbora daniconius	Darkina, Anjani	-	As above
IX	ENGRAULIDAE			
	36. Setipinna phasa	Phasa, Tel tempri	-	Estuary/tidal rivers
	37. Setipinna taty	Kanta Phaisa	-	As above
X	GOBIDAE			
	38. Glossogobius giuris	Bele, Bailla	-	Main fershwater rivers also tidal rivers
XI	HEMIRHAMPHIDAE			
	39. Hemirhamphus gaimardi	Ekthutya	-	Eshnary/tidal rivers also flood plains & beels
XII	HETEROPNEUSTIDAE			
	40. Heteropneustes fossilis	Shing, shinghi	-	Main freshwater rivers also flood plans & beels
XIII	MASTACEMBELIDAE			
*	41. Macrognathus aculeatus	Tarabaim, kata baim	-	Main freshwater rivers also flood plains & beels
	42. Mastacembelus armatus	Baim, Gonti	-	As above
	43. Mastacembelus pancalus	Gunohi, turi	-	As above
XIV	MEGALOPIDAE			
*	44. Notopterus chitala	Chital, Chiltal	-	Main freshwater rivers also floodplains & beels
	45 Notopterus notopterus	Phali, Phailya	-	As above
XV	MUGILIDAE			
	46. Rhinomugil corsula	Corsula Khailla	-	Extuary/Tidal rivers also main freshwater rivers
XVI	NANDIDAE			
	47. Nandus nands	Bheda, Meni	-	Main freshwaer rivers
XVII	SCHILBEIDAE			
	48. Ailiichthys panctata	Banspata, sutli	-	Main freshwater rivers also flood plains & beels
	49. Eutropiichtys vacha	Bacha, Bhacha	-	Estuary tidal rivers, main freshwater rivers, also rivers flood plains & beels
	50. Pangasius pangasius	Pangas, Pungwas	-	As above
	51. Silonia silondia	Shilong, Silond	-	As above
XVIII	SCIAENIDAE			
	52. Pama pama	Pama, Poa	-	Estuary/tidal riers
XIX	SILURIDAE			
	53. Wallago attu	Boal, Boali	-	Main freshwater rivers also flood plains & beels
*	54. Ompok pabda	Pabda, pabia	-	As above
	55. Ompok bimaculatus	Kanipabda, Boaipabda	-	As above
XX	TETRAODONTIDAE			
	56. Tetraodon cutcutia	Patka, Photka	-	Main freshwater rivers also flood plains & beels

B. SHRIMPS

	Taxon	Bengali Local Name		Kind of Habitat
XXI	PALAEMONIDAE			
	1. Macrobrachium dolichodactylus	Goda Chingree	-	Main freshwater rivers also flood plains & beels
	2. M. lamarrei	Gura ichha Kunchia ichha	-	As above
	3. M. malcolmsoni	Chatka ichha,	-	As above
	4. M. mirabilis	Latya ichha	-	As above
	5. M. rosenbergii	Golda Chingree	-	As above
	6. M. rudis	Shola ichiia	-	As above
	7. M.\villosimanus	Dimua ichha, Dimoala ichha	-	As above

APPENDIX - X

EROSION PROTECTION

FEASIBILITY STUDY ON

KURIGRAM IRRIGATION AND FLOOD CONTROL PROJECT (SOUTH UNIT)

APPENDIX - X EROSION PROTECTION

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APPENDIX-X EROSION PROTECTION

1. Introduction

1.1 Introduction

This report describes the background and present situation of the flood protection works surrounding the project area, protection works of the irrigation regulator and recommendations for the urgent protection works of the existing flood embankment.

1.2 Background of Flood Protection

The original town of Kurigram, the headquarter of the Kurigram Sub-division in the district of Rangpur, had been washed away and expired due to bank erosion of the Dharla river. A river bank revetment in a length of about one thousand meters was constructed in 1956-57 to protect the old town by brick mattress encased in wire-net. The lower part of the revetment was thereafter washed away completely. By the next effort, the eroded bank was successfully shifted away from the old town by short cutting of a neck of a meandering loop and by excavation of a diversion channel to the east of the old town. At Arazi-Palashbari, about one thousand meters long earth embankment was constructed on the upstream right bank of the old town. The existing town, known as the old town, was developed in the fringe of the original town, and when this was again threatened by the Dharla river, construction of a new township was started at Khalilpur in 1963. The Kurigram Flood Control and Irrigation Project including the north and south units was studied by a local consultant employed by WAPDA (former BWDB) in October 1971. A Report on Kurigram Town Protection Project was prepared by a local consultant employed by BWDB in August 1972. The old and new town were under the constant threat of erosion by the Dharla river in 1972. Thereafter, BWDB had constructed two groynes on the upstream right bank of Kurigram town. These consequences of successful protection works had resulted in the expansion of pourashava area on the eastern side up to the bank of the loop cut, and on the southern side forming the new town area.

After the independence of Bangladesh in the mid 1970's, some flood protection plans were prepared. A 108 km long flood protection embankment, located from the Moghalhat railway line to the Teesta railway line along the banks of Dharla, Brahmaputra and Teesta rivers, was constructed under World Food Program with financial assistance by CIDA during 1973/74 to 1983/84.

The widespread damage resulting from the exceptionally large floods in 1987 and 1988 once again focused attention on the need to protect major cities, towns and agricultural lands. The Government of Bangladesh undertook a comprehensive review of its flood policy. A number of studies were carried out with assistance from UNDP, France and Japan and finally proposed a major activity program known as Flood Action Plan (FAP) in June 1989.

In October 1991, an interim report on master plan for the Northwest Regional Study (FAP-2) was prepared by co-finance of JICA and United Kingdom, and a feasibility study for the Gaibandha area has been continued as of September 1992. In February 1992, Draft Final Report on Secondary Towns Integrated Flood Protection (FAP-9A) which included the flood protection plan of Kurigram town was prepared with financial assistance by Asian Development Bank.

In December 1991, Feasibility Study on this project known as the Kurigram Irrigation and Flood Control Project - South Unit was started by JICA. An Irrigation Regulator was conceived in an alternative plan during the interim study stage. Accordingly, a need for study on protection of the Irrigation Regulator from river bank erosion was envisaged. A result of study reported herein has been prepared in accordance with mutual understanding between BWDB and JICA within the minimum requirement to protect the Irrigation Regulator. In addition to the above, recommendation for the urgent protection works of the existing flood protection dikes has been presented herein in response to the request by BWDB in the meeting held on October 10, 1992.

1.3 Objectives on Erosion Protection

The existing flood embankment surrounding the project area was constructed along the Dharla, Brahmaputra and Teesta rivers by 1983/84 under FFW Program. The project area of the Kurigram Irrigation and Flood Control Project - South Unit has been protected to a certain satisfactory degree from floods in the Dharla, Brahmaputra and Teesta rivers due to existence of the flood embankment constructed by FFW. Upon these present conditions, objectives of this report was decided to be limited to[1];

(1) protection of the proposed Irrigation Regulator and

(2) recommendation for the urgent protection of the flood embankment against bank erosion.

2. Present Conditions in Flood Protection

2.1 Flood Risk

Northern part of the project area and Kurigram town are situated on relatively high land adjacent to rivers for both flood protection and ease of communication by water purposes. Except for central and southern part, the project area is relatively free from the risk of deep flooding either external or internal. The central and southern part which are situated in low-lying areas, depressions, old river channels and active khals, and adjacent to the major rivers, however, do suffer inundation from internal floods due to their restricted drainage systems including drainage channel and regulators. This could involve considerable loss of livestock, due to the risk of high water level inundating the area. The southern part of the project area which are surrounded by the existing flood embankment but not properly protected from internal floods, generally suffer from the internal floods in the low lying agricultural areas. Land development of the low lying flood plains will however accelerate in future to meet the increasing population pressure, despite the flood risk.

2.2 Flood Protection

The existing embankment was constructed in 1973-1984 to withstand the floods with return period of once in 50 years. The embankment is sufficient in height for the design water level and has successfully resisted against large external floods in recent years. Although there are some damaged portions, the embankment has been functioning properly despite its poor maintenance.

A portion of the embankment in a length of 9.5 km from a closure on the Old Dharla river (km 30.00) at upstream of Kurigram town to Km 39.50 is functioning as the flood

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[1] Rehabilitation of Kishorpur regulator is excluded in accordance with the Minutes of Meeting between the JICA Study Team and BWDB dated July 28, 1992.

protection embankment for Kurigram town. Although the Kurigram town is well above the normal annual flood level, the newly earmarked pourashava area contains several areas of low land. The area also contains some depressions associated with inundated channels formed by the river meanders, training works and loop cuttings.

These areas were used to be flooded before construction of the flood embankment along the right bank of Dharla river. At present, external flood cannot enter the Kurigram pourashava area due to existence of the flood embankment. Present conditions of the flood embankment from the closure point (km 30.00) up to Palashbari Regulator (km 33.60) is good, and is well maintained under FFW Program. A portion of the flood embankment from the Palashbari Regulator up to the RDRS road, however, was constructed using sandy soil, and requires repair in places. Since a majority of the crest of the flood embankment has been eroded by rain water due to improper sandy embankment material, periodical maintenance is required.

2.3 River Bank Erosion

River bank erosion puts the flood protection embankment at the risk of breaching and this is a major factor affecting the reliability of flood protection measure. The eroding sites were inspected by the Study Team during the site investigation in July and August 1992. Notable observation of the river bank erosion which invited failure of regulator or flood embankment as of August 1992 were :

1) Ratnai breach
2) Ratnai regulator and
3) Kishorpur breach

It was observed that although the Kishorpur regulator was not yet washed away as of early-August 1992, a groyne which was existed just upstream of the regulator and a flood embankment in a length of approximately 700 meters at just upstream of the said groyne have been washed away by local floods in the Teesta river. In the southeastern part of the project area at chilmari, although the flood embankment is located sufficiently far from the incident, erosion has placed roads and navigation infrastructure at risk of serious damage, and the river bank erosion was moving westward forcing the local people in evacuation of a ferry ghat.

(1) Ratnai breach

A closure embankment of the Ratnai river in the northeast of the project area was constructed without providing a drainage channel to short cut to the Dharla river. The closure embankment was washed away before 1992, and was causing internal flooding along the Ratnai river in an area surrounded by the flood embankment of the Dharla river.

(2) Ratnai regulator

The Ratnai regulator which was constructed for internal floods but not designed to release big floods from the Ratnai river was destroyed by floods from the Ratnai river which came into the regulator through the Ratnai breach.

(3) Joykumar breach

The flood embankment at Joykumar was constructed with the following appurtenant protection works;

One number of groyne
Set-back straight flood embankment
Revetment of the old embankment
Four numbers of X-bars, No.1-No.4

It was observed during a flood on August 6, 1992 that the groyne was effectively pushing the flood flow away from the river bank, diverting the river course toward the river center.

The old flood embankment at downstream of the X-bar No.4 was washed away for a length of about 1,300 m by 1991. A new set-back flood embankment was already constructed in 1992, and this new set-back flood embankment is sure to be capable of resisting against external floods.

(4) Mogolbasha breach

It was observed in August 1992 that the river current tendency is striking the flood embankment, and the flood embankment together with two numbers of X-bars which were there before had been washed away by 1991. A new set-back flood embankment was already constructed in 1992, and this new set-back flood embankment is sure to be capable of resisting against external floods. A school exists adjacent to the flood embankment at approximately 500 m upstream from the expired X-bars. The flood embankment has been eroded for a length of approximately 200 m. It seems that the flood embankment does not lasts long due to erosion.

(5) Kishorpur breach[12]

It was observed during a site inspection at the Kishorpur regulator on August 4, 1992 that a dominant river course has been shifted eastward tremendously compared with a topographic map in a scale of 1/15,840 prepared in 1963. It was informed by BWDB that the original river course of the Teesta river had been bifurcated and one of them running eastward was a small flow, but now this is attacking the Kishorpur area with approximately 60 % of the river current. On the day of the inspection, the Teesta river was attacking just upstream of the Kishorpur regulator directly and washed away a groyne which had been located just upstream of the regulator, and the flood embankment in a length of approximately 700 m just upstream of the expired groyne was also washed away. The erosion has been continued at the foundation of the regulator.

3. Erosion Protection Criteria

3.1 Planning Criteria

It is stated in the Interim Report on FAP-2 as follows;

"The flood protection levels for the existing schemes along the Teesta, Dharla and Brahmaputra rivers were planned to have protection level in 50-year to 100-year probability. In the tributaries of lower Atrai, flood protection works have been carried out or under implementation with protection level in 5-year to 20-year probabilities. In the study of FAP-2, a 20-year probable flood is determined to be used for the flood control planning taking into account that agricultural damage due to flood is dominant in the region". As seen in the above description, the flood embankment of the project area was constructed with a return period of once in 50-years to 100-years before implementation of the FAP-2 study, and it was used by the FAP-2 as the existing model. It is recognized that the Project is not

[12] BWDB is of the opinion that the urgent countermeasure will be undertaken by BWDB and no additional investigation by the Study Team will be required (Minutes of Meeting between the JICA Study Team and BWDB dated July 28, 1992).

necessary to re-plan the flood embankment which is functioning, more or less, in good condition.

The Study Team has decided to include erosion protection plan against some spots at which the bank erosion have been threatening the flood embankment in danger, in addition to the original Scope of Work to study erosion protection at the proposed Irrigation Regulator.

The proposed Irrigation Regulator on the Dharla river is located at about 5 Km downstream from the existing railway bridge in the Indian territory. It seems that the movement of river course meandering at the proposed Irrigation Regulator is not so much wide range compared with the Dharla river at downstream therefrom due to existence of the railway bridge which makes river course at fixed position with straight flow direction. A natural law water channel being formed by river erosion at downstream from the railway bridge including the area in front of the proposed Irrigation Regulator has been situated about 300 m far from the existing flood embankment on the high water channel at which the Irrigation Regulator will be constructed.

In consideration and on the basis of these natural environment, it is unlikely that the river course fluctuation reaches such a wide range that will invite destruction of the Irrigation Regulator. It seems that the location of the Irrigation Regulator is suitable and reasonable from the river erosion view point, and it will be the best location to provide the intake facilities with the lowest cost for erosion countermeasure.

Planning criteria of the erosion protection is determined as follows in consideration of the above conditions and on the basis of result of site inspections along the flood embankment conducted so far:

Erosion protection devices shall be provided at ;

(1) Irrigation Regulator and

(2) Mogolbasha which is only one place that is threatening the flood embankment in danger due to erosion.

3.2 Design Criteria

It is stated in the Interim Report on FAP-2 as follows ;

"To protect river banks from erosion, a combination of permeable and/or impermeable spur dike, groynes, revetment works and surfacing works is considered to be the most effective measures. Groynes with the following features are to be provided at the severe erosion sites mainly located in the Teesta and Dharla rivers.

Permeable and impermeable spur dikes, which are constructed mainly with earth and timber materials respectively, are to be designed to have similar dimensions with reference to the existing ones along the Teesta right bank.

Revetment works are to be provided with foot protection works by gabion mattress filled with concrete blocks".

It is stated in the Draft Final Report on FAP-9A as follows;

"In particular, for the flood and bank protection measures the use of locally available materials such as boulders, cement concrete blocks, bamboo piles etc, have been preferred wherever feasible, in preference to imported materials whether from outside the regional locality of the town or from abroad".

Although the existing study reports had determined the above design criteria, this chapter of the Project aims at protecting the river bank erosion only of which major conceivable structure is the revetment works. Since the Project does not require any groynes or river training devices, design criteria of only revetment works of the existing reports is referred to Design criteria in the FAP-2, however, states simply that "the revetment works are to be provided with foot protection works by gabion mattress filled with concrete blocks".

Design of the revetment works of the Project is, therefore, carried out in accordance with standard design being applied in local projects and practical availability of local materials. Riprap and gravel protection, gabions, or concrete or wooden frames filled with cobble stones or coarse gravels are often used adjacent to structures or in earth-surface canals and embankment where erosion may occur. Local conditions must be considered in determining the type of protection works to be provided.

It is considered for the Project that revetment of the river bank shall be designed as shown in a Fig.X.3.1. As shown in the figure, concrete blocks and foot protection shall be provided on the slope and riverbed, respectively. The foot protection for the Irrigation Regulator which can be constructed in dry condition shall be provided with timber piles. Brick mattress shall be provided beneath the concrete blocks on the slope. Although a local Khoa filter is planned in the design in consideration of availability of local material, geo-textile filters may be applied if local filter material is not available.

4 Erosion Protection Plan

4.1 Irrigation Regulator

The erosion protection of the Irrigation Regulator is planned for the approach channel and the flood protection embankment adjacent to the regulator.

The erosion protection for the approach channel is included to the design of the Irrigation Regulator discussed in the other section. Flood protection embankment at up- and down-stream of the Irrigation Regulator is to be protected by concrete block revetment works provided on the existing slope with foot protection as shown in Fig. X.4.1.

4.2 Mogolbasha Breach

The erosion protection for the Mogolbasha breach is planned at the flood embankment from the upstream end of the new set-back flood embankment to the upstream of a school in a total length of 700 m. The flood embankment is to be protected by the concrete block revetment works provided on the existing slope with foot protection as shown in Fig.X.4.2.

5. Construction Plan

The bank revetment works for the erosion protection at the Irrigation Regulator and Mogolbasha breach are planned to be constructed by manpower in consideration of availability of huge manpower in the region.

6 Cost Estimate

Cost estimate for the erosion protection works is carried out on the basis of official rates in "Schedules of Rates for Project-IV, BWDB, Rangpur" enforced in October 1989 and updated in December 1991.

Unit rates for the erosion protection works are summarized as follows:

(1) Sl. No.74. (iii) Concrete in foundation with mix-proportion at 1:3:6

2,154 Tk/m^3

Sl. No. 80. (a) Labour for the above works

164 Tk/m^3

Sum 2,318 Tk/m^3

(2) Sand cement blocks

Sl. No. 88 (b) Manufacturing and supplying sand-cement blocks (1:7)

1,756 Tk/m^3

Sl. No. 90 Labour for the above works

317 Tk/m^3

Sl. No. 92. (b) Labour for carrying, placing and dumping of S.C. blocks

36.5 Tk/m^3

Sum 2,110 Tk/m^3

(3) Brick Mattress

Sl. No.45 Laying brick mattress 15 cm thick encased in double layer of 12 SWG 10 cm mesh hexagonal wire netting including all materials and dressing of site

314 Tk/m^2

Sl. No.47 Labour for the above works

1,451 Tk/m^2

Sl. No. 62 Stripping of slope surface

36 Tk/m^2

Sum 1,801 Tk/m^2

(4) Khoa filter beneath the brick mattress or sand-cement blocks

Sl. No. 97 Supplying and spreading Khoa including breaking under brick mattress or sand-cement blocks

718 Tk/m^3

(5) Earth Work

Sl. No. 54 Manual excavation for foot protection

1,281 Tk/m^3

(6) Timber Pile

Supply and driving of a 150 mm dia and 3 m long timber piles

187 Th/m

Construction cost of the erosion protection works of the Irrigation Regulator and Mogolbasha breach are estimated in Bangladesh Taka as follows:

(1) Irrigation Regulator

Item	Unit	Q'ty	Unit Rate	Amount
Excavation	m^3	2,100	1,281	2,690,100
Foundation concrete	m^3	750	2,318	1,738,500
Sand-cement blocks	m^3	4,957	2,110	10,459,270
Brick mattress	m^2	7,776	1,765	13,724,640
Filter	m^3	1,166	718	837,188
Timber piles	m	1,206	187	225,522
Total				29,675,220

(2) Mogolbasha breach

Item	Unit	Q'ty	Unit Rate	Amount
Sand-cement blocks	m^3	4,554	2,110	9,608,940
Brick mattress	m^2	6,062	1,765	10,699,430
Filter	m^3	922	718	661,996
Total				20,970,366

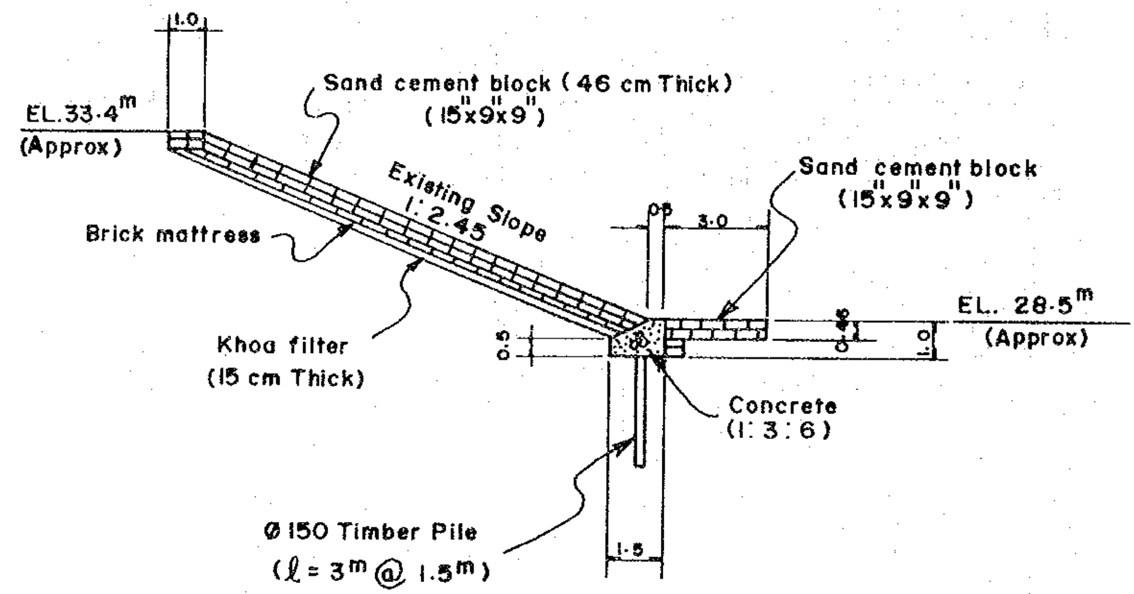


Fig. X.3.1 TYPICAL SECTION OF REVETMENT OF EMBANKMENT AT IRRIGATION REGULATOR

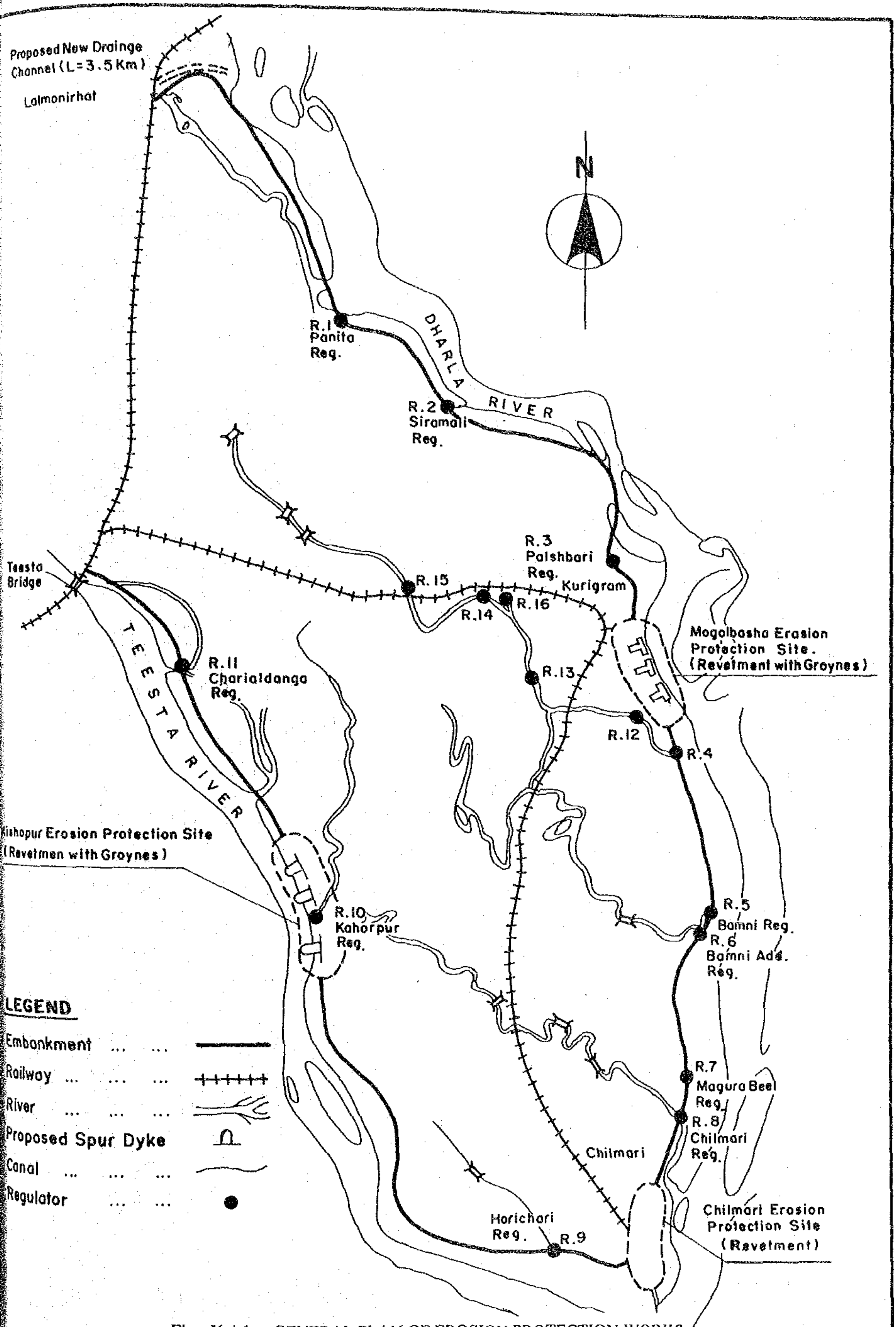
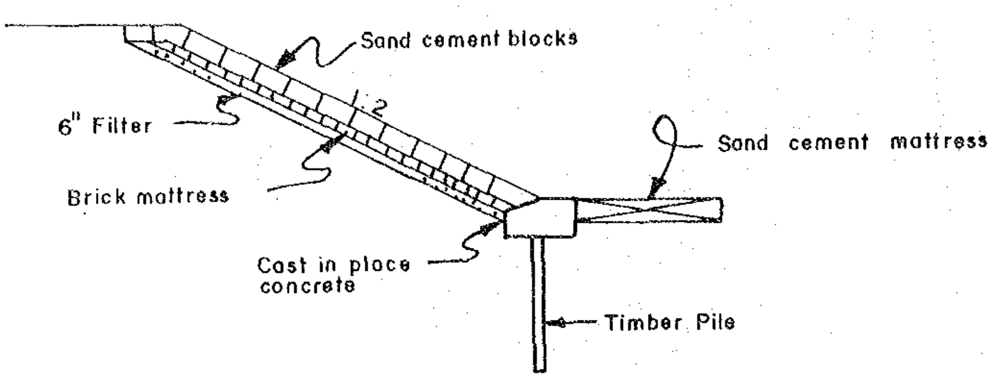
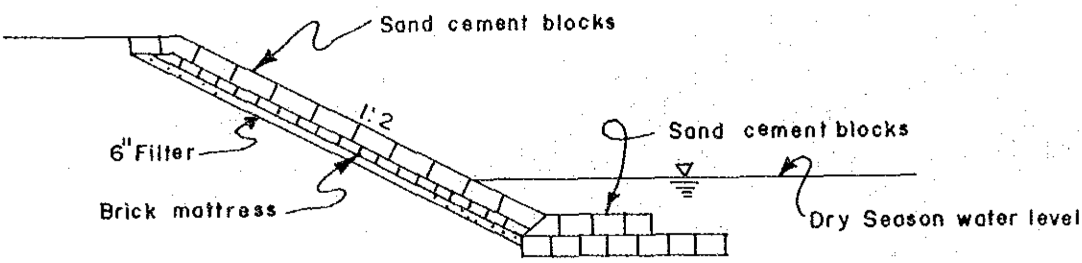


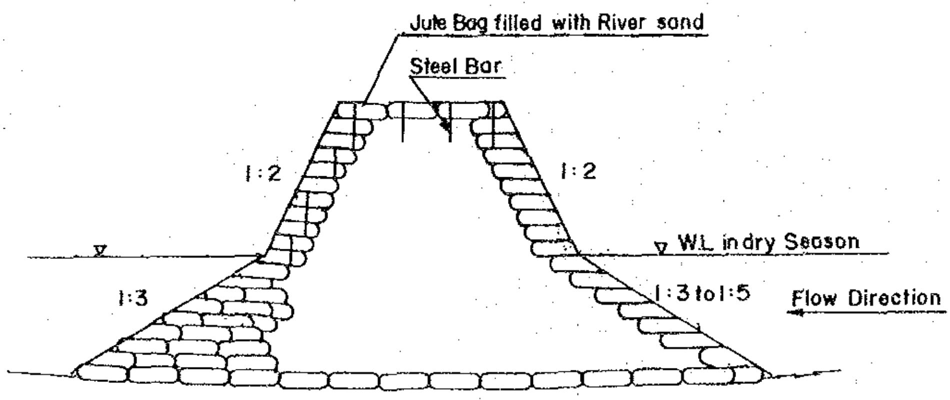
Fig. X.4.1 GENERAL PLAN OF EROSION PROTECTION WORKS

Type(A) Which will be applied for dry riverbed during Construction



Type(B) Which will be applied for Submerged riverbed during construction





Remark:

Riprap works by sand cement brocks shall be Provided at extream portion and upstream Site of groyae

Typical Sections of Groyne

Fig. X.4.2 TYPICAL SECTIONS OF EROSION PROTECTION WORKS AND GROYNE

APPENDIX - XI

IRRIGATION AND DRAINAGE

FEASIBILITY STUDY ON

KURIGRAM IRRIGATION AND FLOOD CONTROL PROJECT (SOUTH UNIT)

APPENDIX - XI IRRIGATION AND DRAINAGE

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1. Present Irrigation Condition

1.1 Flushing Irrigation

Along protection dike in front of the right bank of the Dharla river and the left bank of the Teesta river,some farmers groups have installed six pipe sluices for flushing irrigation for their farm lands which extend in the vicinity of foot of the dike. Their approximate location and diameter of pipe are as listed as follows:

Pipe Sluice	Cross Section	Location
No.1	600 mm in Dia	In between Silamari and Palashbari regulator
No2	600 mm in Dia	In between Malbanga and Bamni Regulator
No 3	600 mm in Dia	2 Km southward of Chilmari Regulator
No.4	600 mm in Dia	5 Km southward of Kishorpur regulator
No.5	600 mm in Dia	4 Km southward of Ghrialdanga Regulator
No.6	600 mm in Dia	1 Km southward of Ghrialdanga Regulator

In early stage,most of them might be provided with dual functions of irrigation and drainage, but now have completely lost their dual functions due to heavy sandbar formation in front of their inlets. It seems to be almost impossible for the farmers groups to rehabilitate and maintain these irrigation facilities. They will be surely abandoned and completely blocked with sand deposition and will be meaningless as an irrigation facility at this moment.

1.2 Low Lift Pump Irrigation

Low lift pump (so-called LLP) irrigation system is essential for dry season crops and widely extended all over the northwest region owing to low cost and easy operation.

(1) Water Sources and their Resources

Water sources for the LLP in and around the study area mainly consists of low-lying drainage canals (Khal) and swamps (Beel) in which limited runoff water are stagnated due to poor drainability at the end of the Monsoon season.

The water resources consumption for the LLP varies year by year due to rainfall fluctuation and operation of the existing regulators. Farmers around the beels and khals fully use the available water for supplementary irrigation for Boro and Rabi crops by means of the LLP during dry winter season,but this resources is unstable and undependable. There is no available data on this resources.

(2) Pumping Unit of LLP

The LLP is a diesel operated small centrifugal pump mounting 20 to 30 Hp with a rated capacity of 30 to 60 l/sec (about 1 to 2 cusec). The LLP is usually installed on bank of drainage canal or periphery of swamp. Irrigation water pumped up is discharged into earthen channel tentatively mouled by farmers.

(3) Coverage by Existing LLP

Based on the data collected in the relevant Thana Offices,the irrigation area covered by the existing LLP is roughly estimated as given below on the assumption that irrigation water resources for the existing LLp are fully obtainable from beels and khals.

$$Ai = f*q*Nt$$

where,

Ai	:	Possible irrigation area by LLP
f	:	Coefficient for mechanical life,
q	:	Average unit discharge of typical LLP
Nt	:	Number of LLPs in respective Thana.

The hectareage estimated above seems to be unreliable due to shortage of water resources in beels and khal during the dry winter season. In view of irrigation development plan in the study area,the irrigation area depending upon the LLPs would be ineffective and ignored.

1.3 Tubewell Irrigation

(1) Aquifer Condition

Aquifer condition in the Study area is divided into 3 formations, namely top aquitard layer, composite aquifer and main aquifer. The top aquitard layer consists of silty and clayey materials and appears mainly 0 to 6 m from ground surface. The composite aquifer consist of very fine to fine sand and appears at the depth of 3 to 21 m with the thickness of 9 to 15 m. The main aquifer consists of medium to coarse sand containing gravel layer. It appears at the depth of 12 to 18 m with the thickness of more than 40 m.

(2) Pumping Unit

STWs have been constructed by local method, mainly of locally manufactured components. It is usually 4 - 6 m deep and uses a centrifugal pump to lift groundwater by suction. The pump of the STW is located at the top of well at the ground surface and is driven by a 5 HP diesel engine with a normal discharge capacity of 14 l/sec. DTWs have been drilled with imported machinery, lined with imported casing and screen. The depth of DTWs and its screen length range from 50 to 70 m and 24 to 30 m, respectively. The DTW uses a turbine pump and most of wells are driven by 18 to 35 HP diesel engines with a normal discharge capacity of 57 l/sec.

(3) Planning Criteria and Existing Coverage

The existing tubewells have been installed in accordance with the following standard spacing rule :

DTW to DTW	762 m	2,500ft.
DTW to STW	549 m	1,800ft.
STW to STW	244 m	800 ft.

The number and actual irrigable areas of DTWs/STWs in the Study area were investigated during Phase-II period with assistance of Thana agricultural officers in the Thana concerned. The results are summarized as follows :

Thana	STW Installed (Nos.)	STW Irri.Area (ha/Well)	DTW Installed (Nos.)	DTW Operated(1992) (Nos.)	DTW Irri.Area (ha/Well)
Lalmonirhat	523	3.6	45	25	18.9
Rajarhat	850	4.0	64	55	21.6
Kurigram	339	4.2	30	16	16.6
Ulipur	969	4.1	128	120	19.4
Chilmari	139	4.2	40	20	15.7
Total/(Weighted Average)	2,820	(4.0)	292	236(19.4)	

All of the tubewells in the Study area are not always in operation, mainly due to mechanical troubles of pumps and/or institutional problem among the farmers in using the tubewells. Actual operation hours during 1992's irrigation season, from January to May, range from 8 to 10 hours a day. In case of the DTWs, annual operation hours reach to 521 hours on an average and 18 hours a day in the maximum. The area irrigated by STWs ranges from 3.6 to 4.2 ha with an average of 4.0 ha. The irrigated area by DTWs varies from 15.7 to 21.6 ha with an average of 19.4 ha against the planned command area of 14 to 50 ha.

Among the existing irrigated area of 9,800 ha, about 4,600 ha (47 % of the irrigated area) are covered by DTWs and the rest of 5,200 ha (remaining 53 %) are irrigated by STWs. The number of operational STWs is estimated at about 1,300 which are equivalent about 46 % of the existing installed number of STWs.

2. Irrigation Plan

2.1 Available Irrigation Water Resources

2.1.1 Dependable Surface Water Resources

The Hydrologist of the Team collects and arranges ten (10) day discharge records at the Kurigram Gauging Station (No.77) for 18 years from 1973 thru 1990 as shown in Table XI.2.1. After sorting the annual minimum discharge for 18 years,probability analysis is made by three (3) methods and the results are averaged ; Table XI.2.2 shows the probable drought discharge. The drought discharge with 10-year probability is averaged to be 49.41 m3/sec.

2.1.2 Potential Groundwater Resources

Based on the MPO's estimates, available recharge and unconstrained development potential for tubewells in the Study area can be calculated as follows (further details are given in Annex - IV):

Thana	Area (km2)	Available Recharge Volume (MCM)	Available Recharge Depth (mm)	Unconstrained Development Potential STW (0.5 csc) Volume (MCM)	STW (0.5 csc) Depth (mm)	DTW (2 csc) Volume (MCM)	DTW (2 csc) Depth (mm)
Lalmonirhat	120.7	47.07	390	47.44	393	49.85	413
Rajarhat	147.5	64.46	437	49.86	338	66.38	450
Kurigram	71.1	20.12	283	13.69	191	24.03	338
Ulipur	217.3	67.58	367	79.75	367	81.49	375
Chilmari	37.4	10.70	251	9.39	251	14.03	375
Study Area	594.0	209.93	353	200.13	337	235.78	397

2.2 Irrigation Water Requirement

2.2.1 Potential Evapotranspiration and Effective Rainfall

Potential evapotranspiration is estimated by Modified Penman on the basis of meteorological data at the Rangpur Station; effective rainfall is also estimated by FAO method based on potential evapotranspiration and rainfall data. Table XI.2.3 summarizes both the estimated evapotranspiration and effective rainfall. As shown in the Table,the annual evapotranspiration aggregates about 1,494 mm,while the annual effective rainfall, about 1,257 mm.

2.2.2 Crop Coefficient (Kc)

Crop coefficient for ten major crops is referred to FAO publications and data recommended by MPO The coefficient is estimated according to crop growing period by 10-day basis. Table XI.2.4 shows the crop coefficient applied for calculation of water requirement,making reference to the FAO and MPO publications.

2.2.3 Water Requirement by Crop

The Agronomist of the Team proposes ten major crops in cropping calendar. Water requirement by crop is estimated based on the evapotranspiration,the crop coefficient, and the effective rainfall. Table XI.2.5 shows the water requirement by crop,and the following is a summary of the annual figures of the table.

(Unit : mm)

Crop	ETc	Plant Requirement	Effective Rainfall	Crop.Requir't
Trans Aman	524	1,088	563	525
Trans.Aus	564	1,129	798	331
Trans.Boro	697	1,268	634	634
Local T Aman	627	1,244	892	352
Mustard	250.20		2.20	248
Pulse	315.40		8.60	306.80
Wheat,Potato	320.20		2.20	318.00
Onion	295.7		2.20	293.50

2.2.4 Irrigation Water Requirement

In accordance with the proposed cropping pattern by the agronomist and the estimated crop requirement above,seasonal irrigation water requirement is composed as shown in Table

XI.2.6. In the composite of the table,irrigation efficiencies are assumed as follows,making reference to the National Water Plan prepared by MPO:

(i)	Application Efficiency (Ea):	0.62
(ii)	Field Canal Efficiency (Eb):	0.80
(iii)	Conveyance Efficiency (Ec):	0.80
(iv)	Distribution Efficiency (Ed):	0.64
(v)	Project Efficiency (Ep):	0.40

As shown in the Table,annual diversion requirement in depth amounts to 2,206 mm,and the maximum unit diversion requirement is estimated to be 1.65 lit./sec/ha in the middle of March. Fig.XI.2.1 illustrates seasonal fluctuation of the diversion requirement thgether with ETo and rainfall distribution.

2.3 Delineation of Irrigation Area

Water resources development in the project area would be made firstly full exploitation of available surface water resources,and then,the shortage would be supplemented by ground water resources.

2.3.1 Irrigable Area Depending on Surface Water Resources

As mentioned in Section 2.1,the dependable water resources in the Dharla river is 49 m3/sec with 10-year return period. Following the MPO's recommendation,about 60 % of the drought discharge would be intaken for the irrigation development in the study area in consideration of navigation,fishery development,irrigation use,salt water intrusion,and environmental aspect in the lower basin. The drought discharge of 30 m3/sec would be therefore applied for delineation of the irrigable area by surface water resources.

The irrigable area of 18,180 ha by surface water resources is computed by dividing the available drought discharge (30 m3/sec) with the maximum unit diversion requirement (1.65 lit/sec/ha)

2.3.2 Irrigable Area Depending on Groundwater Resources

(1) Selection of Groundwater Exploitation Mode

Groundwater development will be made by private farmers' initiative in view of the government policy of shifting to privatization and successful performance of private sector on tubewell development in recent years. Although overall irrigation development plan will be prepared on the basis of conjunctive use of both surface water and groundwater resources, the installation of tubewells for the groundwater component will be made by the private farmers' initiative and will not be included as a project component.

Groundwater resources can be developed for irrigation through different modes such as HTW/DTW/STW to suit specific needs of the farmers. The Study area is endowed with ample groundwater resources and is recognized by WARPO (former MPO) as the suitable area for STW. The STW, small scaled, simple and low cost technology, is usually installed and operated by private farmers with various supporting services offered by the authorities concerned. In this view, the STW is tentatively selected to estimate an irrigable area by groundwater resources. Actual selection of development mode should be dependent upon the farmer's option. The proposed project will only demonstrate various modes of groundwater development to the farmers at a demonstration farm.

(2) Groundwater Dependent Area

Agricultural land which should be irrigated by groundwater is balanced at 13,530 ha, deducting the existing tubewell irrigation area of 9,800 ha, the proposed surface water irrigation area of 18,180 ha and the FAP-9A project area of 1,290 ha out of the total farmland area of 42,800 ha, as broken down below :

Items / Area	Classification of Project Area Northwest(ha)	Central(ha)	South(ha)	Total Area (ha)
(i) Farmland	10,340	26,290	6,170	42,800
(ii) Existing Irrigation Area				
1) by DTW	660	3,000	910	4,570
2) by STW	1,460	3,250	520	5,230
3) Total	2,120	6,250	1,430	9,800
(iii) Existing Rainfed Area,	8,220	20,040	4,740	33,000
(iv) Surface Irrigation Area	0	18,180	0	18,180
(v) Project area by FAP-9A	0	1,290	0	1,290
(vi) Groundwater Dependent Area (iii) - (iv) -(v)	8,220	570	4,740	13,530

Most of the central area will be irrigated by surface water irrigation system, and the remaining are of 570 ha will be irrigated by STWs with an additional recharge from seepage of surface irrigation water. Potential of STW development was therefore examined mainly for northwest and south areas as described hereunder :

(3) Assumptions for Estimation of Irrigable Area by STW

The following criteria is adopted for STW development :

i) Pumping Capacity of STW
A standard 0.5 csc (14.16 l/sec) centrifugal pump would be installed for the proposed STWs.

ii) Irrigation Period and Consumptive Use
Irrigation period is assumed from 2nd January to 1st May or 120 days a year. Total consumptive use during the dry season of 120 days is assumed to be 457 mm and the peak consumptive use is 5.67 mm per day in March.

iii) Operation Hours and Irrigation Efficiency
Operation hours of STWs are assumed at 10 hours/day according to the current operation. Irrigation efficiency is assumed to be 62% for application and 90% for distribution.

iv) Pumping Duty
Pumping duty is obtained from 10 hour operation a day, peak consumptive use of 5.67 mm, application efficiency of 0.62 and distribution efficiency of 0.90.: 5.67 / 0.62 / 0.90 x 10,000 x 24 / 10 / 86,400 = 2.823 l/sec/ha

v) Unit Irrigable Area by STW
Unit Irrigable Area per STW = Pumping Capacity / Pumping Duty : 14.16 / 2.831 = 5.0 ha / well

vi) <u>Allowable Spacing of DTW /STW</u>
The present spacing rule given by BADC is as follow:
for DTW : 760 m (2,500 ft)
for STW : 244 m (800 ft)

Thus, one DTW can be installed in every 58 ha (760 m x 760 m), and STW in every 6 ha (244 m x 244 m) in principle.

(4) Estimation of Irrigable Area by STW

Irrigable area by STW was estimated to be 7,940 ha in total under the assumptions mentioned above, including 570 ha in the central area as shown below :

Items / Area		Classification of Project Area Northwest	Central	South	Total Area (ha)
(i) Nos of Existing DTW / STW					
1) by DTW	(nos)	34	155	47	236
2) by STW	(nos)	365	813	130	1,308
(ii) Allowable Spacing					
1) DTW	(ha)	58	58	58	(58)
2) STW	(ha)	6	6	6	(6)
(iii) Catchment Area of Existing STW / DTW, (1) x (2)					
1) DTW	(ha)	1,970	8,990	2,730	13,690
2) STW	(ha)	2,190	4,880	780	7,850
3) Total	(ha)	4,160	13,870	3,510	21,540
(iv) Total Farmland	(ha)	10,340	26,290	6,170	42,800
(v) Remaining Catchment Area for Additional STW, (4) - (3)	(ha)	6,180	12,420	2,660	21,260
(vi) Proposed Nos. of STW, (5) / (2)	(nos)	1,030	114*	444	1,588
(vii) Unit Irrigable Area per STW	(ha)	5	5	5	(5)
(viii) Estimated Irrigable Area, (6) x ((7)	(ha)	5,150	570	2,220	7,940

* : Nos of STW required for irrigating 570 ha are given, because groundwater dependent area in the central area is limited and no shortage of groundwater supplies is expected.

(5) Justification of Proposed Groundwater Exploitation

Total pumping capacity should not exceed "available recharge" or "development potential" for STW in order to keep safe-yield of the groundwater. The estimated irrigable area by STW is smaller than the potential command area except South Area in view of development potential of groundwater as shown below.

Items / Area	Classification of Project Area Northwest	Central	South	Total Area (ha)
(1) Groundwater Dependent Area(ha)	8,220	570	4,740	13,530
(2) Remaining Catchment Area for Additional DTW(ha)	6,180	12,420	2,660	21,260
(3) Available Recharge (mm)	407	343	303	(353)
(4) Consumptive Use (mm)	457	457	457	(457)
(5) Potential Command Area* (ha) (2) x (3) / (4)	5,500	9,320	1,760	16,580
(6) Estimated Irrigable Area (ha)	5,150	570	2,220	7,940
(7) Balance, (5) - (6) (ha)	370	8,750	-460	8,640
(8) Proposed Irrigable Area (ha)	5,150	570	1,760	7,480

* :Potential command area (ha) = Potential catchment area for STW (ha) x Available Recharge (mm) / Consumptive use (mm)

In the South Tract, the potential command area by STW is calculated to be 1,760 ha which is smaller than the estimated irrgable area of 2,220 ha. It means that groundwater resources is rather limited in the South Tract to allow the present spacing rule of 800 feet (244 m). Therefore, irrigable area in the South Tract will be limited to 1,760 ha of the potential command area by STW in the maximum, which makes the proposed total irrigable area by STWs to be 7,480 ha.

The proposed irrigable area of 7,480 ha is thus estimated within the potential command area and considered to be appropriate in view of available groundwater recharge.

2.3.3 Delineation of Net Irrigation Area

The study area enclosed by flood protection dike would be divided into three tracts such as north-west,central and south in consideration of topographic and geographic conditions,existing drainage networks,and potentiality of groundwater resources.

From the viewpoints of low water level in the Dharla river, topographic condition in the polder,and available existing channels,the central tract would be only irrigable by the surface water resources. In the meantime,the northwest and south tracts would be irrigable only by the groundwater resources due to the topographic condition in the northwest tract and shortage of the existing channels in the south tract. The following is a summary table of the delineation of the irrigation area:

Name of Tract	Gross Area	Agricultural Land	Net Irr.Area	Rainfed Area
Northwest	14,460	10,340		
Central	34,480	26,290	18,180	8,110
South	8,180	6,170		
FAP-9A	2,280	-	-	-
Total	59,400	42,800	18,180	8,110

3 Proposed Irrigation Facilities

3.1 Comparative Study of Irrigation System

Out of nine (9) alternative plans which have been mentioned in the Interim Report,three (3) alternative plans (Alternative-4,6 and 9) are selected for comparative study. The concepts for each alternative are summarized as follows:

Alternative-4 : Tube well development in the north tract and a large scale surface irrigation development with the Dharla barrage in the central and south tract.

Alternative-6: Tube well development in the north tract and a large scale surface irrigation development with a pumping plant in the central and south tract.

Alternative-9: Large scale surface irrigation development with irrigation sluice and LLP,and tube well development in the remaining part.

3.1.1 Preliminary Layout of Each Alternative

(a) Alternative-4

This alternative plan envisages to irrigate the central and southern part of the area through a large scale canal system from a barrage constructed across the Dharla river and to develop minor irrigation system in the northern part depending on tube well development. The general layout of this alternative plan is shown in Fig.XI.3.1, and the general layout of the Dharla barrage is shown in Fig.XI.3.2. The main features of the layout are as follows:

Irrigation area

Gross area	59,400 ha
Net irrigation area	35,640 ha
by surface water resources	18,180 ha
by groundwater resources	7,480 ha

Dharla barrage (see Fig and Fig)

Design flood discharge (1/50)	7,080 m^3/sec
Design flood discharge for flood bypass(1/100):	11,200 m^3/sec
High water level (upstream)	29.70 m
High water level (downstream)	29.50 m
Dangerous water level (upstream)	30.20 m
Dangerous water level (downstream)	29.80 m
Design intake discharge	30.0 m^3/sec
Design intake water level	29.50 m
Width of barrage (between abutments)	689 m
Main gate (Tainter gate)	20mX5mX27 vent
Gate for undersluice (Tainter gate)	20mX5mX4 vents
Highway bridge	8.5 m in width
Fish ladder	3.0 m wide

Head Regulator

Design intake capacity	30 m^3/sec
Canal head	28.2 m
Intake gate	20mX5mX4 vents
Width of regulator	23.0 m

Irrigation Canal

Main canal	46 km
Secondary canal	67.3 km
Canal structures	
for main canal	89 nos
for secondary canal	463 nos

(b) Alternative-6

This alternative plan envisages to irrigate the central and southern part of the area through a large scale canal system facilitating power pumping plant,and to develop minor irrigation system in the northern part. The general layout of this alternative plan is illustrated in Fig.XI.3.3, and the general plan of Dharla pumping station is shown in Fig.XI.3.4. The main features of the layout are as follows:

Irrigation Area

Gross area	59,400 ha
Net irrigation area	35,460 ha
by surface water resources	18,180 ha
by groundwater resources	7,480 ha

Dharla Pumping Plant

Design pumping discharge	30.0 m3/sec
High water level	28.40 m
Intake water level	22.80 m
Suction water level	22.70 m
Design water level	28.02 m
Total pumping lift	5.4 m
Type of pump	Vertical mixed flow type
Bore of pump	1,800 mm
Nos of unit	4 nos
Power	Diesel engine of 1,200 HpX4 nos

Irrigation canal

Main canal	37.5 Km
Secondary canal	162.6 Km
Canal structures	
for main canal	72 nos
for secondary canal	302 nos

(c) Alternative-9

This alternative plan envisages to irrigate the central part of the area through a large scale canal system from the irrigation sluice on the Dharla river,and to develop minor irrigation system in the remaining part of the area. In this plan,the existing canals will be fully used as irrigation canal. Irrigation water will be lifted from the drainage canals to the fields by use of low lift (LLP). The general layout of this alternative plan is illustrated in Fig.XI.3.5, and general plan of Dharla irrigation sluice (regulator) is shown in Fig.XI.3.6. The main features of the plan are as follows:

Irrigation Area

Gross area	59,400 ha
Net irrigation area	35,460 ha
by surface water resources	18,180 ha
by groundwater resources	7,480 ha

Irrigation Sluice

Location	Bunka site
Design intake discharge	30.0 m3/sec
High water level	32.51 m
Intake water level(10-year probability)	27.15 m
Sluice gates	1.52mx1.83mx12 nos
Intake sluice	1.52mx1.83mx12 nos
Headrace (inlet channel)	
Length	265.0 m
Bottom width	100.0 - 25 m
Side slope	1 : 3.0
Longitudinal slope	1/10,000
Water depth	1.0 - 2.04 m

Irrigation Canal System

Existing canal and drainage channels will be fully used as irrigation canal with rehabilitation as follows:

Ratnai river	18.7 Km
Bamni river	33.3 Km
Buri Teesta river	54.8 Km
Minor drainage channels	77.1 Km
New construction of irrigation canal	37.5 Km
Total Length of Rehabilitation	220.5 Km

3.1.2 Preliminary Cost Estimate

The construction cost for each alternative paln is preliminarily estimated on the following assumptions;

(1) Unit costs for major construction works are based on the "schedule rate for project"prepared by BWDB as of January,1991. Prices of gates,however,are updated and revised on the basis of the price of the Teesta barrage project.

(2) Costs for pumping plants are based on the prevailing prices in Japan. Prices of DTW are based on the local estimates in Bangladesh.

(3) Indirect costs such as land acquisition costs and general administration costs are assumed to be 30 % of the total direct costs making reference to the feasibility study on the Kurigram North Unit.

(4) Physical contingency is assumed to be 10 % of the total direct costs. Price contingency is also assumed to be 20 % of the total sum of the direct costs and indirect costs including physical contingency.

Table XI.3.1 shows the construction costs for three alternative plans. The following is a comparative summary of the costs;

(Unit: Tk 1000)

Alternative Plan	Direct Cost	Administration Cost	Physical. Contingency	Price Contingency	Total
Alt-4	2,681,954	702,190	402,293	2,264,289	6,050,726
Alt-6	1,403,727	397,807	210,559	1,203,232	3,215,325
Alt-9	1,067,967	316,741	160,186	923,851	2,468,745

3.1.3 Preliminary Benefit Estimate

The project benefits for the alternative plans are estimated on a preliminary basis making reference to the feasibility study on the Kurigram North Unit. Only irrigation benefits are taken into account on the comparison from conservative side. Following assumption is made for the estimate.

(1) Future crop production level and cropping pattern proposed in the F/S on the Kurigram North Unit will represent the future conditions "with" the project. On the contrary,the present agricultural conditions in the South Unit will represent those under the future condition "without" the project.

(2) Economic prices of farm products and farm inputs are quoted from the "Guidelines for Project Assessment"prepared by FPCO (1991).

Three alternative plans are envisaged to irrigate same hectareage under the same cropping pattern and intensity. There is no difference at all among three alternative plans. The following is a summary of the estimated benefit.

Item	Unit	With Project	Without Project	Incremental Benefit
Total	(Tk.million)	1,040	530	509
Per Ha	(Tk / ha)	27,800	14,200	13,600
	(US $ / ha)	716	366	350

3.1.4 Economic Comparison of Development Alternatives

Economic comparison is made in terms of economic internal rate of return (EIRR),net present values (NPV),and benefit and cost ratio (B/C). In estimating these terms,the following assumption are made;

(1) The economic construction costs will be calculated by multiplying the financial construction costs after deducting the price contingency with a standard conversion factor of 0.82 recommended by FPCO.

(2) For estimating replacement cost for mechanical equipment,replacement interval is assumed to be 25 years for gates of the Dharla barrage,15 years for power pumping units,and 12 years for DTWs and LLPs. The cost and benefit for each alternative plan can be summarized as follows:

(Unit: Tk million)

Alternative	Economic C.	O&M Cost	Replacement Cost	Incremental Benefit
Alt-4	6,051	30	1,010	509
Alt-6	3,215	50	908	509
Alt-9	2,469	40	627	509

In accordance with flow of both cost and benefit,the economic terms are estimated as summarized below:

Alternative	EIRR (%)	NPV at 12% (Tk million)	B/C at 12%
Alt-4	10.9 %	- 212	0.902
Alt-6	18.0 %	711	1.445
Alt-9	27.6 %	1,273	2.230

The above table indicates that Alternative-9 (tube-well and irrigation sluice with LLPs) has the highest economic returns with the lowest investment. Alternative-9 would be therefore selected as the most promising plan for the development of the Kurigram South Unit.

3.2 General Layout of Irrigation Canal Networks

3.2.1 Layout of Irrigation Diagram

Following delineation of irrigation area previously mentioned, the limited area of 18,180 ha under the central tract would be irrigated depending on the surface water resources in the Dharla river by full use of the existing drainage channels. Irrigation diagram for the surface water supply is developed as illustrated in Fig.XI.3.7 on the basis of canal networks,independent command area,and the maximum unit diversion requirement. As shown in the diagram,all the tails of canals are connected to the existing nearest regulator.

3.2.2 General Layout of Irrigation Canal Networks and Related Structure

Following the existing drainage channels (khal)and swamps (beel),irrigation canal system is networked as schematically illustrated in Fig.XI.3.8. Most reach of the existing channels are extremely meandered, silted,and sometimes blocked. Such deteriorated channels would be so short-cut,desilted,and re-shaped as to get required conveyance capacity for irrigation and drainage.

The proposed irrigation system is composed of six (6) main channels as summarized below:

Channel	Channel Reach	Length(Km)
Main Channel:A	Ratnai R. - Kalua nadi - Irr. Canal - Bamni R	64.4
Main Channel:B	Deola Bil - Buri Teesta R	55.9
Main Channel:C	Upper Bamni River	35.9
Main Channel:D	Proposed New Channel	13.2
Main Channel:E	Proposed New Channel	10.0
Main Channel:F	Proposed New Channel	10.3
Total Channel Length		189.7

Major related structures consist of intake regulator,control regulator,check gate,railway crossing,and crossing bridge.

4 Present Condition of Floods and Drainage

4.1 Probable Water Level and Discharge

As compiled in ANNEX II (METEORO AND HYDROLOGICAL STUDY),data on water level was collected from six (6) gauging stations,such as Noonkawa,Chilmari,and Bahadurabad on the Brahmaputra river system,Taluk Simulbari and Kurigram on the Dharla river system,and Kaunia on the Teesta river system. Out of these data,the annual maximum water level of each station was picked out by years from 1960 through 1990 as listed in Table XI.4.1. Based on these data,the Hydrologist of the Team made a frequency analysis on the maximum flood water level by Gumbel-Chow method as recapitulated below:

Station	10-year	20-year	25-year	50-year	100-year
Noonkawa	28.127	28.475	28.583	28.923	29.260
Chilmari	24.594	24.835	24.911	25.145	35.377
Bahadurabad	20.219	20.432	20.499	20.708	20.915
Talk' mulbari	31.459	31.737	32.138	32.095	32.365
Kurigram	27.092	27.336	27.412	27.651	27.887
Kaunia	30.361	30.540	30.595	30.770	30.942

According to the data at the Kurigram (Dharla river) and Kaunia (Teesta river) stations,both flood disasters in 1987 and 1988 are nearly equivalent to that of 25-year return period in terms of flood water level.

In the meanwhile,flood flow (discharge) is converted from the water level data by rating curve which is provided by each gauging station. On the basis of the converted annual maximum discharge,the Hydrologist made a frequency analysis on the flood discharge at the Kurigram gauging station which is located nearly center of the study area. The following are the summary tables of the annual maximum flooding discharge from 1973 through 1990 and its probable flood discharge with a frequency

A) Annual Flood Discharge

Year	1973	'74	'75	'76	'77	'78	'79	'80	'81
Discharge(m3/s)	3563	4253	2976	2030	1913	1496	990	1640	1413
Year	1982	'83	'84	'85	'86	'87	'88	'89	'90
Discharge (m3/s)	2254	2080	1594	2363	1641	3377	4128	2147	2046

B) Probable Flood Discharge

Return Period	10-Year	20-Year	25-Year	50-Year
Discharge (m3/s)	3430	3965	4130	4628

In comparison with both tables above,the flood discharge of 4128 m3/sec in 1988 is of 25-year frequency flood equivalence; that of 3377 m3/sec in 1987, of about 10-year frequency flood equivalence.

4.2 Existing Flood Control Facilities

4.2.1 Flood Protection Dike

In order to protect the study area from overtopping of river flow,constructed are peripheral embankments of about 108 Km in total on the adjacent banks of the Brahmaputra,Teesta,and Dharla rivers The embankment has been aligned at a safe distance away from bank erosion by the rivers. The protection dike can be divided into three segments such as Brahmaputra right bank embankment,Teesta left bank embankment,and Dharla right bank embankment.

Brahmaputra Right Bank Embankment

BWDB constructed this embankment along the right bank of the Brahmaputra river from the confluence with the Dharla river to that with the Teesta river in the South Unit. The design flood profile of this embankment was determined by the frequency analysis of water level records at Nunkawa and Chilmari gauging stations. Five (5) ft freeboard were provided to 100-year flood profile to arrive at the crest profile of the embankment.

The embankment was provided with a crest width of 24 ft and side slope of 1 to 3.0 (vertical to horizontal) at riverside. The side slope at countryside varied between 1 to 3.0 to 1 to 4.0 depending upon stability requirement. Turfing was made on both slopes of the embankment to prevent the embankment from erosion.
Fig.XI.4.1 shows alignment of the constructed embankment,and Fig.XI.4.2 shows the typical cross section.

Teesta Left Bank Embankment

This embankment was constructed along the left bank of the Teesta river from the Kaunia bridge to the confluence with the Brahmaputra river near Chilmari.where the embankment joined to the Brahmaputra right bank embankment extending from the north.

Major part of the embankment along the Teesta river was under back-water influence of the Brahmaputra river. The design flood profile was therefore computed for the post embankment condition with 100-year probable discharge in the Teesta river and 100-year probable water level in the Brahmaputra river. The freeboard allowance varies from five (5) ft at the confluence to three (3) ft at the upstream end.

A crest width of 14 ft was provided with the embankment. Side slope of the embankment was designed with 1 to 3.0 vertical to horizontal.at the river side; the slope at the countryside was also designed with a range of 1 to 3.0 to 4.0 vertical to horizontal. Turfing also was provided on both slopes of the embankment to prevent the embankment from water and wind erosion. Fig.XI.4.1 shows the alignment of the embankment,and Fig.XI.4.2 shows the typical cross section.

Dharla Right Bank Embankment

BWDB constructed a marginal embankment along the left bank of the Dharla river from the railway embankment near Moghalhat to the confluence with the Brahmaputra river. Probable flood of 100-year return period at the Brahmaputra river confluence and that of 50-year return period at Taluksimulbari was applied for construction of the Dharla right bank embankment. The freeboard allowance varies from 5 ft at the Brahmaputra confluence to 3 ft at the upstream end.

The crest width and side slope of the embankment was constructed with completely same dimensions to that of the Teesta left bank embankment. Turfing was also provided on both slopes of the embankment for prevention of water and wind erosion. Fig.XI.4.1 shows the alignment of the embankment,and Fig.XI.4.2 shows the typical cross section. Fig.XI.4.2 illustrates the longitudinal section along the esisting flood protection dike.

4.2.2 Regulators

There exist eleven (11) regulators along the enclosed polder dike. Fig.XI.4.1 shows location of the existing regulators. The following is a summary of the dimension of the major eight (8) existing regulators.

Regulator	Size (BxH) (m x m)	No.of Vent	Hydraulic Area (m2)	Sill Level (m/PWD)	Remark
Chilmari	1.52x1.83	10	27.8	21.03	
Bamni	1.52x1.83	12	33.4	21.45	
Malbahanga	1.52x1.83	16	44.5	21.80	
Kurigram	1.52x1.83	2	5.6	22.85	Palashbari
Ratnai	1.52x1.83	8	22.3	25.38	
Harichari	1.52x1.83	12	33.4	20.12	
Kishorpur	1.52x1.83	12	33.4	22.77	
Gharialdanga	1.52x1.83	2	5.6	24.38	

Among the existing regulators,the Ratnai regulator has been washed away by recent floods,and both wingwalls of the Harichai regulator has been seriously eroded by river flow.

4.3 Runoff in Polder Dike

4.3.1 Rainfall

Seven (7) rainfall gauging stations have been operated in and around the study area for sufficient period for hydrological analysis. Table XI.4.2 shows annual rainfall data accumulated from the daily record collected from the seven stations. From Thiessen polygon analysis,the Hydrologist of the Team selects six (6) stations,and made a frequency analysis on the annual rainfall. The following is a summary of the annual rainfall frequency analysis.

Station	5-Year	10-Year	20-Year	25-Year	50-Year
Chilmari	2756	3123	3476	3587	3932
Kaunia	3000	3421	3827	3954	4350
Kurigram	2707	2986	3254	3389	3601
Lalmanirhat	3046	3423	3786	3900	4254
Sundarganj	2315	2583	2842	2922	3175
Ulipur	2619	2879	3129	3208	3452

In the light of the annual rainfall data in Table XI.4.2 and the probable rainfall in the table above,the annual rainfall of 3,173 mm in 1988 at the Kurigram station is nearly equivalent to 20-year frequency annual rainfall; that of 2,980 mm in 1987 at the same station,nearly equivalent to 10-year frequency annual rainfall.

4.3.2 Basic Design Year

From the frequency analysis for the flood water level and the flood discharge at the gauging station along the lower reach of the Dharla and Teesta rivers and the daily rainfall at the six (6) rainfall stations in the Kurigram polder ,the probable water level,discharge,and rainfall would be summarized as follows:

Record	Flood W.Level	Flood Discharge	Rainfall
1987	1/25 (96%)	1/10 (90%)	1/10 (90%)
1988	1/25 (96%)	1/25 (96%)	1/20 (95%)

In order to formulate drainage improvement for the Kurigram polder the year of 1987 would be selected in consideration of the table above and project economy.

4.3.3 Runoff

Runoff analyses would be made on the following condition and assumption:

i) Unit time for analysis: one (1) day
ii) Period of analyses : during the Monsoon season (May thru Oct during 1983 thru 1990)
iii) Rainfall record by drainage block

Drainage Block	Catchment (Km2)	Rainfall Station
Chilmari	80.8	Ulipur
Bamni	73.4	Ulipur
Malbasha	128.8	Kurigram
Palashbari	25.0	Kurigram
Harichari	81.6	Lalmonirhat
Ratnai	66.9	Chilmari
Kishorpur	85.0	Kaunia
Gharialdanga	19.9	Kaunia

iv) Runoff concentration time

a) Concentration Time : $Tc = Tg + 0.8\ Tr$
$L > 15$ Km, $Tg = 0.4 + 0.058\ L$
$L < 15$ Km, $Tg = 0.21\ L^{0.7}$

whereas,
Tc : Concentration time (hrs)
Tg : Lag time (hrs)
Tr : Unit analysis time (24 hrs)
L : Longest channel reach to outlet(Km)

Block	Channel Reach (Km)	Mean Velocity(m/s)	Concentration (hrs)
Chilmari	15.6	1.31	20.5
Bamni	16.8	1.37	20.6
Malbasha	21.6	1.65	20.9
Palashbari	6.0	.736	19.9
Harichari	15.6	1.31	20.5
Ratnai	10.8	1.11	20.3
Kishorpur	22.8	1.72	20.9
Gharialdanga	12.0	1.19	20.4

As shown above,concentration time in each block being less than the unit analyses time of one day or 24 hrs,it is unnecessary to reform hyetograph of rainfall by concentration time in order to get runoff hydrograph. The following procedure would be applied for estimating the hydrograph by deduction of rainfall losses:

i) 20 % of daily evaporation would be deducted
ii) 80 % of evapotranspiration would be deducted

iii) Daily percolation of 15 mm would be deducted
iv) Minus (-) runoff after deductions above would be regarded as zero runoff.

The percentage of i) and ii) is assumed according to vegetation ratio during the Monsoon period in the area. Fig.XI.4.3 illustrates the runoff hydrograph in the basic year (1987) in each drainage block

4.4 Drainage Calculation under Existing Condition

4.4.1 Continuous Equation

$$[\{Q_{i(t-1)} + Q_{i(t)}\}/2 - \{Q_{o(t-1)} + Q_{o(t)}\}/2]*t = S \text{ ,and}$$

$$S = V_t - V_{t-1},$$

whereas,

t	:	denote time (one day)
Q_i	:	inflow (runoff) discharge m^3/sec,
Q_o	:	outflow = $C*A*N*2g\sqrt{(Wl_i - Wl_o)}$,
C	:	flow coefficient (0.85),
A	:	sectional area of gate vent (1.52 m^2),
N	:	number of gate vent,
S	:	storage volume,
V_t, V_{t-1}	:	retained water volume,
Wl_i	:	internal water level,
Wl_o	:	external water level.

4.4.2 Calculation Procedure

i) The runoff in 1987 obtained in the previous section would be applied,
ii) The water level records in 1987 in the nearest gauging station would be applied as external water level,
iii) Effective runoff volume would be retained in the drainage block,and internal water level would be estimated by using H-A-V relation in each drainage block,as listed in Table XI.4.3 and illustrated in Fig.XI.4.4,
iv) Drainage discharge through regulator would be calculated by being compared with external and internal water levels,
v) Provided that internal water level is higher than external water level, some retained water would be drained through regulator,and lowering internal water level would be calculated by using retained volume and H-A-V relation.shown in Table XI.4.3.

4.4.3 Summary of Calculation

Computerized are the continuous equation and calculation procedure The outputs during 1987 are as illustrated in Fig.XI.4.5, and the following is a summary of the outputs.

Station (Km 2)	Rainfall (mm)	Max.Wlo (m)	Max.Wli (m)	Area (ha)	Inundation Depth(m)	Period(day)
Chilmari(80.8)	1,601	24.80	25.05	4,579	3.09	62
Bamni(73.4)	1,601	25.26	25.57	4,101	2.39	44
Malbhanga(128.8)	1,708	25.75	26.69	3,107	3.51	48
Palashbari(25.0)	1,708	27.45	27.17	1,461	3.38	68
Harichari(81.6)	1,797	25.07	24.80	6,339	2.84	89
Ratnai(66.9)	2,543	30.37	30.86	1,774	4.02	69
Kishorpur(85.0)	2,402	27.96	28.18	4,388	2.56	63
Gharialdanga(19.9)	2,402	29.58	29.78	1,530	2.94	111

4.4.4 Assessment of Existing Drainage Condition

(1) External water level
The water level in the Dharla,Brahmaputra,and Teesta rivers has maintained fairly higher than the ground level in the polder throughout almost the Monsoon season.

(2) Drainability in Polder
Flooding from the external rivers has been completely protected by the dike. Instead, internal runoff water is incapable of being drained by gravity due to the high external water level.

(3) Runoff control
There is no modernized drainage system. Runoff water from elevated area usually concentrates to low-lying area. Drainage condition in the polder is inequitable from tract to tract.

(4) Drainage networks
Drainage networks in the polder is quite poor and causes sporagical inundation. To attain more equitable drainage condition,the drainage networks should be improved.

(5) Substantial drainage improvement
As above mentioned,economic feasibility permitting,by-pumping drainage system should be envisaged for the substantial drainage improvement in the polder. Actually however,there is no possibility at all for introduction of the pumping system.from economic viewpoint.

5 Drainage Improvement Plan

5.1 Measures for Improvement

Two measures as mentioned below are applied for improvement plan :

i) increase of sluice capacity of the existing regulator,if effective,and
ii) increase of retention capacity of the existing beels and channels.

5.1.1 Increase of Sluice Capacity

The following is a summary table of the existing eight (8) regulators and their drainage capacities.

Regulator	Sill Level (m/PWD)	Sluice Area (m2)	Catchment (Km2)	Unit Sluice Capacity (m2/Km2)
Chilmari	21.03	27.8	80.8	0.34
Bamni	21.45	33.4	73.4	0.46
Malbahanga	21.80	44.5	128.8	0.35
Palashbari	22.85	5.6	25.0	0.22
Harichari	20.12	33.3	81.6	0.41
Ratnai	25.38	22.3	66.9	0.33
Kishorpur	22.77	33.3	85.0	0.39
Gharialdanga	24.38	5.6	19.9	0.28

As clarified above,unit sluice capacity of each regulator ranges from 0.22 m2/Km2 to 0.46 m2/Km2,averaging 0.35 m2/Km2. Simply judging from the unit sluice capacity, Palashbari and Garialdanga regulators are extremely small in comparison with their catchment area. Both regulators should be increased at least.

As well as the unit sluice capacity drainage capacity of regulator usually is affected with various factors,such as internal and external water level,runoff,topography,and gate sill. Further consideration should be therefore made in view of specific drainage capacity (m3/sec/Km2). The following is a table of the specific drainage capacity of the existing each regulator.

Regulator	Catchment Area (Km^2)	Max.Drained Discharge (m^3/sec)	Specific Drainage Capacity (m3/sec/Km^2)
Chilmari	80.8	110.7	1.4
Bamni	73.4	100.6	1.4
Malbhanga	128.8	196.0	1.5
Palashbari	25.0	23.0	0.9
Harichai	81.6	75.2	0.9
Ratnai	66.9	90.4	1.4
Kishorpur	85.0	82.8	1.0
Gharialdanga	19.9	16.0	0.8

As shown above,the specific drainage capacity of the existing regulators ranges from 0.8 m3/sec to 1.5 m3/sec,averaging about 1.1 m3/sec. The specific drainage capacity of the Parashbari,Harichai,Kishorpur,and Gharialdanga regulators are smaller than the average.

From the above two viewpoints,selected are the four (4) following regulators for the increase of the drainage capacity. The drainage capacity of the selected regulators is so increased as to upgrade the maximum level(1.5 m3/sec) of the capacity. The following is a summary of the increased capacity of the selected regulators.

Regulator	Exist Specific Capacity(m3/s/Km2)	Increased Ratio(%)	Exist No of Vent	Total No of Vent
Harichai	0.9	66	12	20
Palashbari	0.9	100	2	4
Kishorpur	1.0	100	12	24
Gharialdanga	0.8	100	2	4

5.1.2 Increase of Retention Capacity

Natural creeks and swamps would be excavated and re-shaped for the development of the main irrigation canal system. In addition,some swamps (beels) being further excavated for increase of retention capacity,the existing H-A and H-V curves would be revised taking the increased retention capacity by both excavation mentioned above for the calculation under the improvement condition. Table XI.4.3 and Fig.XI.4.4 indicate the H-A and H-V curves applied for the calculation of drainage improvement plan.

5.2 Calculation for Drainage Improvement

5.2.1 Summary of Calculation

Following the calculation procedures applied for the assessment of the existing drainage condition,the calculation for drainage improvement is made on condition of the increased vent of regulator in number and the revised H-A and H-V mentioned above. The calculation is made throughout the Monsoon season from May to October in 1987.

Fig.XI.4.5 illustrates the outcomes of the calculation by drainage basin. According to the comparison between the existing condition and the improved condition given in Table XI.5.1, the inundated area of about 1000 ha would be drained in total with this improvement plan; the improvement of four (4) regulators seems to be rather effective,but still insufficient.

5.2.2 Effect of Drainage Improvement

Drainage improvement would be so made as to equalize drainage condition in each drainage block on the basis of the specific drainage capacity of about 1.5 m3/sec/Km2.

The drainage condition in Harichari drainage block is not improved at all,wheras.the Bamni,Chilmari and Kishorpur drainage blocks have been considerably improved in terms of inundation area ; as far as inundation depth and period are concerned,no remarkable improvement has been expected in all the drainage blocks.

For the further substantial improvement of the drainage condition in the polder,necessity would be a mechanical improvement of regulator equipped with heavy sluice gates on the basis of further high specific drainage capacity. The following section mentions the possibility of the full drainage improvement plan.

5.2.3 Full drainage Improvement Plan

As above-mentioned,the proposed drainage improvement plan is insufficient due to low cost investment in view of the project economy. By way of trial,a full improvement plan is envisaged by full substitution of all the existing regulators with a large scaled and engine or motor driven regulators; each vent will be widened to 6.0 m and the existing number of vents will be unchanged, as listed below:

Regulator	Nos.of Vent	Improved Width(m)	Total Width of Vent(m)
Chilmari	13	6.0	78
Bamni	15	6.0	90
Malbhanga	16	6.0	96
Palashbari	2	6.0	12
Harichai	12	6.0	72
Ratnai	11	6.0	66
Kishorpur	12	6.0	72
Gharialdanga	2	6.0	12

Drainage calculation is also made under the full improvement condition mentioned above. Table XI.5.2 summarized the results of the calculation. Inundation area of about 3600 ha would be drained with implementation of this plan. Needless to estimate the cost, the plan is tremendously costly,and is infeasible economically.

Table XI.2.1 10-day Mean Discharge at Kurigram (No.77)

(Unit : m3/sec)

		Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1973	1st	113.0	148.7	395.7	511.1	760.0	360.4	384.5	281.8	199.1	165.9	155.8	135.7
	2nd	112.3	252.8	615.2	394.9	651.0	565.1	434.1	246.5	184.0	164.5	148.1	132.2
	3rd	135.1	240.4	725.3	529.5	426.8	479.9	353.1	221.8	173.7	162.9	140.6	135.1
	Mean	120.1	214.8	578.8	480.1	606.6	468.5	389.3	250.0	185.2	164.4	148.7	134.4
1974	1st	104.7	316.8	770.5	2,771.6	3,008.6	2,495.0	1,481.3	310.5	165.0	138.1	106.4	92.5
	2nd	167.5	674.9	691.1	1,867.1	1,063.5	2,170.9	806.1	233.6	166.3	126.0	100.0	86.0
	3rd	197.8	428.9	1,762.8	2,636.1	1,005.3	2,009.6	959.6	193.3	152.8	116.9	94.6	82.0
	Mean	156.7	472.1	1,074.8	2,431.8	1,670.3	2,225.2	1,078.4	245.8	161.1	126.7	100.7	86.7
1975	1st	94.4	96.0	191.4	1,356.1	1,695.8	1,380.3	1,146.6	338.5	182.0	145.2	128.4	108.3
	2nd	91.4	120.7	383.9	1,068.8	799.0	1,424.1	719.5	234.1	170.6	135.8	121.9	102.2
	3rd	100.6	139.3	1,004.2	2,112.0	991.6	1,183.6	499.8	197.2	156.4	127.9	113.1	94.9
	Mean	95.5	119.3	526.5	1,531.6	1,156.6	1,329.3	779.3	256.6	169.2	136.0	121.4	101.6
1976	1st	97.4	198.7	410.8	1,723.6	1,198.5	686.3	412.7	164.6	142.0	96.8	73.9	60.2
	2nd	93.5	260.7	978.7	1,494.4	1,213.7	561.0	272.5	155.4	120.5	88.4	68.3	55.9
	3rd	109.7	247.8	767.0	983.1	1,145.3	502.2	199.4	141.9	107.0	80.0	64.3	53.4
	Mean	100.2	236.1	718.8	1,386.9	1,184.5	583.1	291.8	154.0	122.7	88.1	69.2	56.4
1977	1st	78.5	201.1	574.4	768.5	822.0	1,057.7	837.5	249.9	138.6	107.9	116.8	99.1
	2nd	130.6	140.2	851.3	1,078.9	1,491.6	725.0	578.2	209.7	121.0	124.0	112.5	93.6
	3rd	138.5	237.7	836.7	1,235.5	1,600.3	781.7	312.4	161.6	107.3	122.4	106.2	86.3
	Mean	115.9	194.4	754.2	1,034.3	1,314.1	854.8	567.5	207.1	121.8	118.2	112.2	92.8
1978	1st	79.5	97.5	218.9	838.5	961.0	572.4	603.7	294.2	206.5	170.2	144.4	124.6
	2nd	72.8	112.8	373.1	1,069.3	713.2	869.6	500.6	255.7	190.7	158.9	142.4	116.3
	3rd	104.2	235.7	749.7	1,096.4	607.0	927.7	346.5	239.2	179.4	151.2	132.2	108.8
	Mean	85.5	151.5	447.2	1,004.5	755.5	789.9	479.2	263.0	191.8	159.8	140.2	116.3
1979	1st	94.7	119.8	96.3	380.4	624.6	849.3	643.6	241.1	202.3	143.2	111.2	109.9
	2nd	97.6	157.3	132.5	438.7	434.1	795.6	590.3	211.7	173.9	126.7	106.1	97.3
	3rd	102.6	134.4	171.3	792.8	720.7	441.8	322.8	190.5	157.8	117.0	103.6	96.5
	Mean	98.3	137.1	133.4	545.5	597.3	695.6	512.5	214.4	177.3	128.6	107.1	101.1
1980	1st	178.6	229.1	647.4	1,695.1	4,182.2	3,030.1	2,066.7	582.7	280.5	172.8	136.8	96.1
	2nd	157.0	325.9	1,900.2	3,382.7	6,268.7	2,910.2	1,126.4	415.5	231.4	157.1	124.3	93.4
	3rd	172.6	462.9	2,370.1	4,477.7	4,331.1	2,585.9	915.0	339.5	199.6	148.7	106.4	83.8
	Mean	169.4	343.3	1,639.2	3,226.8	4,908.1	2,842.1	1,354.7	445.9	235.9	159.2	123.7	90.9
1981	1st	53.1	77.1	138.1	995.5	1,029.3	1,034.5	457.5	188.9	135.6	114.0	94.9	85.7
	2nd	51.9	124.4	148.1	830.9	901.6	895.2	290.6	166.8	133.1	107.3	93.0	82.8
	3rd	70.7	113.5	282.4	1,052.5	1,072.0	550.8	224.2	151.1	122.2	100.0	88.2	90.4
	Mean	58.5	105.3	189.5	962.7	1,003.2	826.9	320.9	168.9	130.0	106.9	92.3	86.4
1982	1st	75.7	97.9	139.3	1,292.1	1,291.5	539.8	451.8	229.0	150.5	113.8	93.2	80.7
	2nd	78.4	114.4	376.4	1,798.7	516.1	988.3	301.4	179.9	134.0	104.1	87.9	75.2
	3rd	98.4	95.9	829.0	1,817.0	490.8	1,075.6	280.3	163.3	123.6	97.9	88.7	80.8
	Mean	84.2	102.5	448.2	1,641.7	757.2	867.9	342.4	190.7	135.6	105.0	90.0	79.0
1983	1st	85.5	161.8	339.7	1,314.1	981.0	995.4	701.8	240.0	149.4	119.1	-999.9	77.1
	2nd	77.7	225.2	469.6	-999.9	664.8	1,605.6	534.5	199.3	135.1	113.2	89.0	72.2
	3rd	79.4	256.9	826.6	-999.9	953.5	1,308.7	367.9	168.8	128.6	-999.9	76.2	68.4
	Mean	80.8	216.0	545.3	-999.9	869.2	1,303.2	529.4	202.7	137.4	-999.9	-999.9	72.4
1984	1st	44.7	78.2	419.6	688.1	759.9	641.6	419.7	256.0	167.1	133.2	97.4	85.3
	2nd	42.0	137.7	712.0	1,055.5	366.6	1,080.8	309.5	216.2	155.6	116.7	98.7	80.6
	3rd	52.4	374.8	593.9	1,038.7	471.6	813.0	408.2	188.3	144.7	102.3	90.7	78.0
	Mean	46.3	202.7	575.2	931.0	530.7	845.1	380.1	220.1	155.4	116.9	96.0	81.2
1985	1st	89.0	123.2	851.6	1,320.5	1,060.9	1,270.2	696.0	244.8	145.6	148.1	101.3	81.6
	2nd	79.6	177.1	574.5	1,545.0	680.5	947.8	520.5	198.8	140.3	124.1	92.2	77.5
	3rd	116.9	227.3	874.6	1,965.8	982.1	886.6	412.5	165.2	147.9	114.6	86.8	71.4
	Mean	95.2	177.5	766.9	1,621.9	910.2	1,034.9	538.8	202.9	144.7	128.5	93.9	76.7
1986	1st	105.3	192.6	228.4	1,000.7	1,173.5	1,038.8	657.8	200.2	124.8	87.9	72.3	73.8
	2nd	111.1	187.6	427.7	941.9	518.8	1,217.4	628.1	166.4	111.7	80.3	69.7	86.1
	3rd	126.8	179.7	699.7	999.9	803.3	787.0	328.8	150.9	99.5	73.1	68.4	83.2
	Mean	114.4	186.4	451.9	981.4	830.9	1,014.4	531.5	172.5	111.6	80.2	70.3	81.1
1987	1st	72.7	136.8	215.9	1,659.9	1,691.5	1,038.9	834.1	237.2	127.2	88.0	71.6	71.9
	2nd	65.0	137.7	369.3	1,170.2	2,312.7	1,006.1	367.8	182.0	109.1	84.3	68.1	71.8
	3rd	86.6	125.8	840.6	1,553.7	786.2	1,011.5	430.1	151.8	96.2	78.8	73.4	64.4
	Mean	74.8	133.2	475.2	1,464.2	1,570.6	1,018.8	540.3	190.3	110.4	83.6	70.9	69.2
1988	1st	52.7	85.6	335.5	1,486.7	1,061.3	2,343.0	660.0	135.6	99.4	78.2	67.8	61.8
	2nd	59.2	145.6	354.1	1,473.5	1,644.9	1,441.6	380.9	111.6	95.8	70.2	66.5	59.9
	3rd	97.6	291.0	672.3	1,615.4	3,218.4	746.1	209.0	100.2	89.6	70.0	74.2	59.5
	Mean	69.8	177.8	453.9	1,528.1	2,015.0	1,510.2	409.9	115.8	94.8	72.7	69.2	60.3
1989	1st	54.3	63.5	625.6	1,397.1	745.0	1,106.4	860.8	216.4	109.7	87.8	73.4	68.0
	2nd	52.6	68.3	963.9	1,568.5	815.5	1,155.0	521.9	160.2	100.3	81.8	73.0	66.1
	3rd	52.2	322.7	794.3	1,079.1	1,019.0	1,314.0	332.6	133.0	97.1	78.4	70.0	65.8
	Mean	53.0	157.0	794.6	1,339.6	865.0	1,191.8	564.0	169.9	102.2	82.5	72.3	66.6
1990	1st	77.2	189.3	887.2	1,180.2	1,205.3	967.6	1,400.7	276.3	140.9	107.8	70.8	54.0
	2nd	101.7	294.4	998.8	1,589.2	1,474.9	1,247.2	1,039.0	207.0	115.9	87.1	62.4	49.0
	3rd	128.0	325.5	1,341.8	1,611.6	1,307.3	1,414.6	453.7	168.2	97.1	76.4	56.3	48.3
	Mean	102.3	271.5	1,075.9	1,465.2	1,328.5	1,209.8	948.0	217.1	117.3	90.0	63.6	50.4

Table XI.2.2 Probability Analysis on Drought Discharge in the Dharla River

I. CALCULATION OF STATISTIC VALUE

i	Xi	LogXi	Xi/Xo	LogXi/Xo	(LogXi/Xo)	2Xi-Xm	(Xi-Xm)2
1	42.00	1.6232	0.6162	-0.21031	0.04423	-28.43	808
2	48.30	1.6839	0.7086	-0.14962	0.02238	-22.13	490
3	51.90	1.7152	0.7614	-0.11839	0.01402	-18.53	343
4	52.20	1.7177	0.7658	-0.11589	0.01343	-18.23	332
5	52.70	1.7218	0.7731	-0.11175	0.01249	-17.73	314
6	53.40	1.7275	0.7834	-0.10602	0.01124	-17.03	290
7	64.40	1.8089	0.9448	-0.02468	0.00061	-6.03	36
8	68.40	1.8351	1.0034	+0.00149	0.00000	-2.03	4
9	71.40	1.8537	1.0475	+0.02014	0.00041	+0.97	1
10	72.30	1.8591	1.0607	+0.02558	0.00065	+1.87	4
11	72.80	1.8621	1.0680	+0.02857	0.00082	+2.37	6
12	75.20	1.8762	1.1032	+0.04266	0.00182	+4.77	23
13	78.50	1.8949	1.1516	+0.06131	0.00376	+8.07	65
14	82.00	1.9138	1.2030	+0.08025	0.00644	+11.57	134
15	83.80	1.9232	1.2294	+0.08968	0.00804	+13.37	179
16	91.40	1.9609	1.3409	+0.12738	0.01623	+20.97	440
17	94.70	1.9764	1.3893	+0.14279	0.02039	+24.27	589
18	112.30	2.0504	1.6475	+0.21682	0.04701	+41.87	1753

MEAN VALUE OF Xi = 70.428
MEAN VALUE OF LOGXi = 68.165
STANDARD DEVIATION OF Xi = 17.968
STANDARD DEVIATION OF LogXi = 0.1115

II. ESTIMATE OF PROBABILITY

EQUATION FOR ESTIMATE
1) GUMBEL METHOD: X=dK+Xm
2) LOGARITHMIC NORMAL DISTRIBUTION METHOD: LogX=do.e+LogXo
3) MOMENT METHOD: LogX=do.e/SQR(2)*de+LogXo

RETURN PERIOD	GUMBEL	LOG.NORMAL	MOMENT
2	67.47	68.17	68.17
5	55.67	54.91	54.53
10	50.65	49.05	48.53
20	46.96	44.68	44.07
50	43.22	40.22	39.55
100	40.93	37.50	36.79

Table XI.2.3 ETo by Modified Penman and Effective Rainfall

A) Potential Evapotranspiration

Meteorological Station : Rnagpur

Month	Temperature (Centigrade)	Humidity (%)	Wind Speed (Km/day)	Sunshine (hrs)	Radiation (mm/day)	ETo by Penman (mm/day)	ETo by MPO (mm/day)
January	17.2	82	120	7.7	2.7	2.53	2.32
February	19.5	76	133	8	3.5	3.48	3.32
March	23.5	68	173	7.8	4.4	5.08	4.36
April	26.9	71	178	7.4	5.1	5.71	5.65
May	27.5	80	156	6.5	5.2	5.18	5.43
June	28.4	85	151	5.5	5.0	4.76	4.44
July	28.6	87	147	4.1	4.5	4.23	4.32
August	29.2	86	151	5.2	4.7	4.53	4.16
September	28.4	87	138	4.9	4.2	3.98	4.1
October	26.6	85	120	7.3	4.1	3.89	3.55
November	22.7	83	133	8.5	3.3	3.26	2.95
December	18.8	83	120	7.7	2.6	2.46	2.35
Annual	24.8	81	143	6.7	4.1	1493.64	1428.35

B) Effective Rainfall

Month	Potential ET		Rainfall		Effective Rainfall(mm/month)	
	(mm/day)	(mm/month)	(mm/month)		(mm/month)	(mm/day)
January	2.5	77.5	8.9		0.0	0.0
February	3.5	98.0	17.8		0.7	0.0
March	5.1	158.1	40.6		14.4	0.5
April	5.7	171.0	116.8		68.4	2.3
May	5.2	161.2	425.3		315.2	10.2
June	4.8	144.0	239.9		166.9	5.6
July	4.2	130.2	309.8		222.8	7.2
August	4.5	139.5	233.7		162.0	5.2
September	4.0	120.0	380.9		279.7	9.3
October	3.9	120.9	60.9		26.5	0.9
November	3.3	99.0	0.0		0.0	0.0
December	2.5	77.5	0.0		0.0	0.0
Annual		1,496.9	1,834.6		1,256.7	

Table XI.2.4 Crop Coefficients (Kc) for Major Crops for 10-Days Period

Major Crop	Crop Growing Period by 10-Day Basis													
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th`
i) Paddy HYV Aus	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.95	0.85				
LT. Aman	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.95	0.85		
HYV Aman	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	0.95	0.85			
HYV Boro	1.10	1.10	1.10	1.10	1.11	1.15	1.22	1.29	1.29	1.22	1.10	0.85		
ii) Upland Crop HYV Wheat	0.45	0.57	0.74	0.94	1.07	1.13	1.15	1.12	1.03	0.88	0.50			
Potato	0.40	0.50	0.85	1.09	1.15	1.15	1.12	1.05	0.80					
Pulses	0.46	0.61	0.85	1.04	1.10	1.11	1.10	1.01	7.00					
Mustard	0.46	0.65	0.92	1.13	1.15	1.15	1.12	1.03	0.80					
Onions	0.43	0.53	0.68	0.84	0.96	0.99	1.00	1.00	1.00	0.99	0.97	0.90	0.70	
Jute	0.40	0.45	0.50	0.60	0.75	0.95	1.08	1.14	1.15	1.15	1.15	1.15		

Source : MPO, Second Interim Report, Vol. VI

Table XI.2.5 Crop Water Requirement (1/5)

Crop : Transplant Aman   Transplanting Date : Aug. 01   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Jul.	1	0.10	1.20	0.53	0.3	1.8	2.6	0.68	1.95
	2	0.33	1.18	1.62	1.0	8.1	10.7	2.61	8.08
	3	0.78	1.13	3.78	2.3	8.1	14.2	5.54	8.66
Aug.	1	1.00	1.10	4.87	3.0	0.0	7.9	5.68	2.20
	2	1.00	1.10	4.97	3.0	0.0	8.0	4.50	3.48
	3	1.00	1.09	4.75	3.0	0.0	7.7	6.11	4.64
Sep.	1	1.00	1.08	4.51	3.0	0.0	7.5	8.92	0.00
	2	1.00	1.08	4.30	3.0	0.0	7.3	11.12	0.00
	3	1.00	1.08	4.27	3.0	0.0	7.3	7.71	0.00
Oct.	1	1.00	1.08	4.23	3.0	0.0	7.2	3.43	3.80
	2	1.00	1.08	4.20	3.0	0.0	7.2	0.00	7.20
	3	1.00	1.05	3.86	2.5	0.0	6.4	0.00	6.36
Nove.	1	1.00	0.99	3.44	1.8	0.0	5.2	0.00	5.19
	2	1.00	0.93	3.03	0.9	0.0	3.9	0.00	3.91
Total	(mm)			524	327	180	1,088	563	525

Crop : Transplanting Aus   Transplanting Date : May 01   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Apr.	1	0.10	1.20	0.67	0.3	1.8	2.8	0.11	2.66
	2	0.33	1.18	2.22	1.0	8.1	11.3	0.48	10.81
	3	0.78	1.13	4.88	2.3	8.1	15.3	3.48	11.83
May	1	1.00	1.10	5.89	3.0	0.0	8.9	8.77	0.13
	2	1.00	1.09	5.66	3.0	0.0	8.7	12.41	0.00
	3	1.00	1.07	5.40	3.0	0.0	8.4	10.13	0.00
Jun.	1	1.00	1.04	5.12	3.0	0.0	8.1	7.05	1.07
	2	1.00	1.03	4.90	3.0	0.0	7.9	4.36	3.54
	3	1.00	1.03	4.72	3.0	0.0	7.7	5.39	2.34
Jul.	1	1.00	1.03	4.54	3.0	0.0	7.5	6.81	0.73
	2	1.00	1.01	4.28	2.7	0.0	7.0	8.03	0.00
	3	1.00	0.96	4.15	2.0	0.0	6.1	7.15	0.00
Aug.	1	1.00	0.89	3.92	1.0	0.0	4.9	5.68	0.00
Total	(mm)			564	302	180	1,129	798	331

Crop : Transplanting Boro   Transplanting Date: March 20   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Feb.	3	0.10	1.20	0.48	0.3	1.8	2.6	0.02	2.56
Mar.	1	0.33	1.18	1.76	1.0	8.1	10.8	0.08	10.75
	2	0.78	1.13	4.52	2.3	8.1	14.9	0.29	14.65
	3	1.00	1.10	5.89	3.0	0.0	8.9	1.01	7.88
Apr.	1	1.00	1.11	6.15	3.0	0.0	9.2	1.11	8.04
	2	1.00	1.12	6.51	3.0	0.0	9.5	1.48	8.03
	3	1.00	1.14	6.38	3.0	0.0	9.4	4.49	4.89
May	1	1.00	1.15	6.16	3.0	0.0	9.2	8.77	0.39
	2	1.00	1.15	5.96	3.0	0.0	9.0	12.41	0.00
	3	1.00	1.15	5.80	3.0	0.0	8.8	10.13	0.00
Jun.	1	1.00	1.15	5.64	3.0	0.0	8.6	7.05	1.59
	2	1.00	1.12	5.32	2.5	0.0	7.8	4.36	3.45
	3	1.00	1.05	4.81	1.8	0.0	6.6	5.39	1.18
Jul.	1	1.00	0.98	4.33	0.9	0.0	5.2	6.81	0.00
Total	(mm)			697	327	180	1,268	634	634

Crop : Local Transplant Aman   Transplanting Date : June 10   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
May	2	0.10	1.20	0.62	0.3	1.8	2.7	1.24	1.48
	3	0.33	1.18	1.92	1.0	8.1	11.0	3.29	7.71
Jun.	1	0.78	1.13	4.27	2.3	8.1	14.7	5.46	9.24
	2	1.00	1.10	5.24	3.0	0.0	8.2	4.36	3.87
	3	1.00	1.10	5.04	3.0	0.0	8.0	5.39	2.66
Jul.	1	1.00	1.10	4.85	3.0	0.0	7.8	6.81	1.04
	2	1.00	1.10	4.65	3.0	0.0	7.7	8.03	0.00
	3	1.00	1.10	4.76	3.0	0.0	7.8	7.15	0.61
Aug.	1	1.00	1.10	4.87	3.0	0.0	7.9	5.68	2.20
	2	1.00	1.10	4.98	3.0	0.0	8.0	4.50	3.48
	3	1.00	1.10	4.78	3.0	0.0	7.8	6.11	1.67
Sep.	1	1.00	1.10	4.58	3.0	0.0	7.6	8.92	0.00
	2	1.00	1.08	4.28	2.5	0.0	6.8	11.12	0.00
	3	1.00	1.03	4.05	1.8	0.0	5.8	7.71	0.00
Oct.	1	1.00	0.98	3.82	0.9	0.0	4.7	3.43	1.27
Total	(mm)			627	357	180	1,244	892	352

Table XI.2.5 Crop Water Requirement (2/5)

Crop : Transplant Boro   Transplanting Date : Feb.10   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Jan.	2	0.10	1.20	0.30	0.3	1.8	2.4	0.00	2.40
	3	0.33	1.18	1.09	1.0	8.1	10.2	0.00	10.16
Feb.	1	0.78	1.13	2.76	2.3	8.1	13.2	0.01	13.17
	2	1.00	1.10	3.83	3.0	0.0	6.8	0.02	6.81
	3	1.00	1.10	4.41	3.0	0.0	7.4	0.17	7.24
Mar.	1	1.00	1.13	5.21	3.0	0.0	8.2	0.26	7.95
	2	1.00	1.19	6.14	3.0	0.0	9.1	0.38	8.76
	3	1.00	1.24	6.65	3.0	0.0	9.7	1.01	8.64
Apr.	1	1.00	1.27	7.07	3.0	0.0	10.1	1.11	8.96
	2	1.00	1.27	7.38	3.0	0.0	10.4	1.48	8.90
	3	1.00	1.27	7.11	3.0	0.0	10.1	4.49	5.62
May	1	1.00	1.27	6.80	3.0	0.0	9.8	8.77	1.04
	2	1.00	1.23	6.40	2.5	0.0	8.9	12.41	0.00
	3	1.00	1.17	5.87	1.8	0.0	7.6	10.13	0.00
Jun.	1	1.00	1.10	5.37	0.9	0.0	6.2	7.05	0.00
Total	(mm)			764	357	180	1,369	473	896

Crop : Transplanting Aman   Transplanting Date : Aug.10   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Jul.	2	0.10	1.20	0.51	0.3	1.8	2.6	0.80	1.80
	3	0.33	1.18	1.65	1.0	8.1	10.7	2.32	8.40
Aug.	1	0.78	1.13	3.86	2.3	8.1	14.3	4.40	9.89
	2	1.00	1.10	4.98	3.0	0.0	8.0	4.50	3.48
	3	1.00	1.10	4.77	3.0	0.0	7.8	6.11	1.67
Sep.	1	1.00	1.09	4.55	3.0	0.0	7.5	8.92	0.00
	2	1.00	1.08	4.31	3.0	0.0	7.3	11.12	0.00
	3	1.00	1.08	4.27	3.0	0.0	7.3	7.71	0.00
Oct.	1	1.00	1.08	4.23	3.0	0.0	7.2	3.43	3.80
	2	1.00	1.08	4.20	3.0	0.0	7.2	0.00	7.20
	3	1.00	1.08	3.97	3.0	0.0	7.0	0.00	6.97
Nov.	1	1.00	1.05	3.64	2.5	0.0	6.1	0.00	6.14
	2	1.00	0.99	3.23	1.8	0.0	5.0	0.00	4.98
	3	1.00	0.93	2.78	0.9	0.0	3.7	0.00	3.66
Total	(mm)			510	327	180	1,073	493	580

Crop : Transplanting Aus   Transplanting Date: Apr. 10   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Mar.	2	0.10	1.20	0.62	0.3	1.8	2.7	0.04	2.68
	3	0.33	1.18	2.05	1.0	8.1	11.1	0.33	10.79
Apr.	1	0.78	1.13	4.85	2.3	8.1	15.3	0.86	14.42
	2	1.00	1.10	6.39	3.0	0.0	9.4	1.48	7.91
	3	1.00	1.09	6.12	3.0	0.0	9.1	4.49	4.63
May	1	1.00	1.07	5.74	3.0	0.0	8.7	8.77	0.00
	2	1.00	1.04	5.41	3.0	0.0	8.4	12.41	0.00
	3	1.00	1.03	5.19	3.0	0.0	8.2	10.13	0.00
Jun.	1	1.00	1.03	5.05	3.0	0.0	8.0	7.05	1.00
	2	1.00	1.03	4.90	3.0	0.0	7.9	4.36	3.54
	3	1.00	1.01	4.64	2.7	0.0	7.3	5.39	1.95
Jul.	1	1.00	0.96	4.22	2.0	0.0	6.2	6.81	0.00
	2	1.00	0.89	3.75	1.0	0.0	4.7	8.03	0.00
Total	(mm)			589	302	180	1,171	701	469

Crop : Transplant Boro   Transplanting Date : Apr. 01   Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Mar.	1	0.10	1.20	0.55	0.3	1.8	2.7	0.03	2.63
	2	0.33	1.18	1.98	1.0	8.1	11.1	0.12	10.93
	3	0.78	1.13	4.67	2.3	8.1	15.1	0.78	14.31
Apr.	1	1.00	1.10	6.12	3.0	0.0	9.1	1.11	8.01
	2	1.00	1.10	6.39	3.0	0.0	9.4	1.48	7.91
	3	1.00	1.13	6.32	3.0	0.0	9.3	4.49	4.83
May	1	1.00	1.19	6.35	3.0	0.0	9.3	8.77	0.58
	2	1.00	1.24	6.43	3.0	0.0	9.4	12.41	0.00
	3	1.00	1.27	6.40	3.0	0.0	9.4	10.13	0.00
Jun.	1	1.00	1.27	6.22	3.0	0.0	9.2	7.05	2.18
	2	1.00	1.27	6.05	3.0	0.0	9.0	4.36	4.68
	3	1.00	1.27	5.82	3.0	0.0	8.8	5.39	3.44
Jul.	1	1.00	1.23	5.44	2.5	0.0	7.9	6.81	1.14
	2	1.00	1.17	4.93	1.8	0.0	6.7	8.03	0.00
	3	1.00	1.10	4.74	0.9	0.0	5.6	7.15	0.00
Total	(mm)			784	357	180	1,387	781	606

Table XI.2.5 Crop Water Requirement (3/5)

Crop : HYV.Boro Transplanting Date : Mar. 01 Unit : mm/day

Month	10 day	Area	Kc	ETc	Percolation	Land.Prepa	Plant Req	E.Rainfall	Irrig. Requirement
Feb.	1	0.10	1.20	0.38	0.3	1.8	2.5	0.00	2.48
	2	0.33	1.18	1.33	1.0	8.1	10.4	0.01	10.40
	3	0.78	1.13	3.50	2.3	8.1	13.9	0.14	13.79
Mar.	1	1.00	1.10	5.07	3.0	0.0	8.1	0.26	7.81
	2	1.00	1.10	5.70	3.0	0.0	8.7	0.38	8.32
	3	1.00	1.13	6.04	3.0	0.0	9.0	1.01	8.03
Apr.	1	1.00	1.19	6.60	3.0	0.0	9.6	1.11	8.48
	2	1.00	1.24	7.21	3.0	0.0	10.2	1.48	7.73
	3	1.00	1.27	7.11	3.0	0.0	10.1	4.49	5.62
May	1	1.00	1.27	6.80	3.0	0.0	9.8	8.77	1.04
	2	1.00	1.27	6.58	3.0	0.0	9.6	12.41	0.00
	3	1.00	1.27	6.40	3.0	0.0	9.4	10.13	0.00
Jun.	1	1.00	1.23	6.05	2.5	0.0	8.6	7.05	1.51
	2	1.00	1.17	5.55	1.8	0.0	7.3	4.36	2.93
	3	1.00	1.10	5.02	0.9	0.0	5.9	5.39	0.51
Total	(mm)			793	357	180	1,366	570	796